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The conference covers a wide range of topics related to traffic and transport engineering, with the aim of representing the importance of all modes of traffic and transport, especially the importance of improving these industries, and their compliance to the most significant principles nowadays, sustainable development and transport efficiency. ICTTE Belgrade 2018 gathers researchers, scientists and engineers whose fields of interest are traffic and transport engineering, and should provide them a good platform for discussion, interactions and exchange of information and ideas. ICTTE Proceedings have been indexed within CPCI - Conference Proceedings Citation Index, a Web of Science™ Core Collection database.

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PREFACE - ICTTE Belgrade 2018
Transportation Impact of Industry 4.0...

Ladies and gentlemen, distinguished guests and speakers, dear colleagues and readers,

Traditionally, ICTTE 2018 becomes an event which took place to highlight the remarkable contribution which transportation makes in so many areas of our lives.

A glance through the list of papers and presentations planned for the next two days reveals the amazing diversity of provided research from the universities and laboratories from 30 countries worldwide.

Nowadays, transport has had a profound impact on the way we live and the ICTTE 2018 is pleased to have been a partner in the growth of new technologies, mobility and digitalization era.

Our key role is to make transportation science and technology available to human wellbeing.

Conferences such as this provide a valuable opportunity for research scientists, industry specialists and decision-makers to share experiences.

I am grateful to the many experts who have come to share their knowledge and face challenges in implementation of Industry 4.0.

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CONTENTS

MULTIMODAL TRANSPORT AND LOGISTICS RESEARCH

POSTAL TRAFFIC AND LOGISTIC SERVICES

PPP, ROADS PLANNING, DESIGN AND CONSTRUCTION ISSUES

TRANSPORT INFRASTRUCTURE AND INTELLIGENT TRANSPORT SYSTEMS

TRANSPORT MODELING AND DECISION MAKING

MULTI-STATIC PRIMARY SURVEILLANCE RADAR DATA SIMULATION

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Abstract: The 21st century brings new trends in Non-cooperative Surveillance technologies. One of them is the Multi-Static Primary Surveillance Radar (MSPSR) technology, which is being widely discussed and just about to be operationally released. ANSPs have a real interest in MSPSR technology as it can be one of the possible solutions to the increasing pressure on the continued operation of existing Primary Surveillance Radars (PSRs). From an ANSP's perspective it is not possible to rely just on the cooperative technologies. There is a need to have at least one non-cooperative back up system due to multiple reasons, such as transponder failures or non-cooperative aircraft. MSPSR can bring 3D surveillance, better precision, coverage in mountainous areas and wind-mill regions, detection of UAV and more. This all leads to importance of evaluation and testing of this technology. As it is very difficult to obtain an MSPSR recording for general scientific community, EUROCONTROL in cooperation with University of Zilina (Air Transport Department) did their research based on current interoperability of Surveillance Analysis Support System for ATC-Centres (SASS-C) tool with MSPSR data and its data simulation. The simulation of the pure MSPSR non cooperative data is based on modification of a WAM recording. Such a recording then can be used for the future analysis. The guide is a partial outcome of the research done on the independent non-cooperative sensors in EUROCONTROL.

Keywords: multistatic, independent, non-cooperative, multilateration, MSPSR.

1. Introduction

The overall topic of Multi-Static Primary Surveillance Radar (MSPSR) is subject to discussions at EUROCONTROL. There is a lot of effort spent on proper documentation and regulation of independent non-cooperative sensors as they show better performance than classical Primary Surveillance Radar (PSR). The new ASTERIX category 15 is right now under development to support Independent non-cooperative sensors (INCS) deployment. The ERA company announced their plan to deploy the first operational MSPSR system in 2018. The approach of EUROCONTROL to this situation was to check the interoperability of their current software equipment with the MSPSR system. As internal analysis of SASS-C compatibility with MSPSR systems that took place in 2017 has shown, the SASS-C is fully capable of handling the MSPSR sensor data. The overall subject of research was held by University of ZILINA in cooperation with EUROCONTROL. As the partial outcome of the research we would like to share the means of simulating MSPSR data in terms of SASS-C software. The simulated data can be used for performance comparison with other technologies or scientific data analysis (Alia et al., 2014). The topic of this article is quite new and unique. Therefore, there are very few scientific publications related to MSPSR subject. We would like to enforce and encourage air navigation services providers (ANSP) and research labs to support the future concept of INCS, providing them with a powerful simulation tool. As EUROCONTROL is the owner of the SASS-C system, we cannot share all sensitive information and principles. The purpose of the article is to share and discuss gathered knowledge with the scientific community.

1.1. SASS-C Brief Description

SASS-C is a surveillance analysis tool that allows verification of surveillance infrastructure performance based on opportunity traffic in a multi-sensor environment. SASS-C is being currently re-engineered into four distinct suites, interoperable through common interfaces. TRES is one of the four suites integrated into the modular architecture of SASS-C V8 (Besada et al., 2008).
TRES has three main roles:

- to reconstruct reference trajectories from opportunity traffic surveillance target reports (OTR),
- to assess ATC surveillance infrastructure performance vs. EUROCONTROL standards (CMP),
- to enable computer-aided identification and investigation of problems of an ATC system (CAI).

1.2. Software Tools for Analysis

The first version of IRIS was developed in 2008 and the development of the version 2 is based upon IRIS v1 development. IRIS is a surveillance data acquisition tool based on SASS-C v6.6 IOSS and RaSta. IRIS is meant to import and record surveillance data by any means supported by SASS-C v6.6 into the Sass-C DataBase (SCDB). After

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the run of IRIS, SASS-C V8 TRES is able to perform reconstruction (OTR module) and analysis (CoMParator - CMP) (Besada et al., 2008)

1.3. MSPSR Principle of Operation

MSPSR refers to a sparse network of transmitters (Tx) and either a single receiver (Rx) or a network of receiver ground stations using static (i.e. non-rotating) antennas. These units receive signals reflected from the aircraft and prepare them for onward transmission to the centralized processing unit. The signal received defines an ellipsoid of constant bistatic range on which the target lies. The location of the transmitter and the receiver are the two loci of the ellipsoid. In the CPU an intersection point of a number of ellipsoids (at least three) is calculated, and this represents the 3-D position of the reflecting target. These systems may use transmitters of opportunity like radio and television broadcast stations, mobile telephone base stations or dedicated transmitters specially deployed to avoid relying on third party illuminators [Kubiková, et al., 2014]. The signal received via the reflected path is cross correlated with the direct signal from the transmitters in order to locate the position of the target reflecting the signals. (ICAO Doc 9924)

2. Methodology

The main condition for simulation of MSPSR data is to choose a proper alternative (existing) data/technology. The chosen technology must be suitable for a future modification to MSPSR final format. This kind of data had to be based on the technologies working on the same geometrical and technical principles as the analyzed MSPSR sensor. For this purpose WAM technology has been chosen as the best available alternative data source (Stevens et al., 2014). So the main condition for the successful simulation of MSPSR data is to use a scenario containing WAM recordings. All further made tests and outcomes of this guide are based on modified WAM data. The main reason for choice of WAM as a data source for this experiment is an analogy in the principles of determination of position by MSPSR and WAM systems. Considering similar geometrical principles of both analyzed technologies, existing WAM data can be modified to any kind of required format where MSPSR data need to be simulated. All systems are using the principle of multilateration for accurate determining of target position (Kubecek and Sterba, 1996). The only difference between those two systems is in the capability of reading information from the received signals. WAM is using cooperative messages (transponder replies) in Mode A/C and S to determine the callsign, barometric altitude, Mode A code and other data provided by the transponder. A WAM position update message can in general contain all this information received from different type of messages. MSPSR on the other hand works as a non-cooperative sensor. Therefore, WAM data can approximate data which could be potentially received from an MSPSR, when the cooperative information is removed (exactly which items should to be removed is described further in this article in the chapter 3). It is important to keep in mind that the mentioned technologies are using completely different technical aspects, signals and principles used for receiving and transmitting the signals. The only common is the geometrical approach of measuring of position. The calculation of the position itself is affected by exactly the same bias and noise principal errors caused by the same geometry (Kubiš and Novák, 2011), (Žáčik and Novák, 2016).

3. MSPSR Simulation Guide

Overall simulation done based on SASS-C VERIF tool should be designed as follows:

3.1. Step 1 –SASS-C VERIF Tool Installation

The first important step is to install the appropriate version of SASS-C VERIF tool and to clarify which version. For the purpose of this analysis we used SASS-C VERIF version: V8.0.E.6.3 (BUILD 1784). This was the most current version of VERIF software supported by SASS-C at the time of writing of this article. The same results of the expertise should be expected in case of using all higher versions based on V8.0.

3.2. Step 2 –WAM Data Record

One of the main requirements for this MSPSR simulation is to import a dataset consisting of WAM data and sensors as it was described and explained in the methodology section above.

3.3. Step 3 – Beginning of the Analysis and Data Modification

This is the most important part of the expertise that must to be followed as it is described below in this document for successful simulation of MSPSR data based on WAM record (Arlery et al., 2015).

It is important to follow exact approach step by step as it is described in this part of the guide, otherwise obtained results may not be relevant. The approach of the experiment is described systematically for the future reproduction as follows:

1. Start IRIS in your “job” folder, which must consist of WAM systems. Then wait until IRIS action will be finished. There are not special requirements for settings in this part.

2. Modify IRIS through a MySQL command which will remove all cooperative information from WAM database. The MySQL command will therefore modify all cooperative (such as identification) and not relevant data from the SD_MLAT table where all the WAM data is stored. Data further needed for the purpose of she simulation you can find in the Table 1 (Garcia, et al., 2014). All other data which are not mentioned in the table have to be removed. Complete list of data available from WAM systems (that are stored in the SD_MLAT table) can be found in the "EUROCONTROL Specification for Surveillance Data Exchange all-purpose structured EUROCONTROL surveillance information exchange" (ASTERIX) Part 14 Category 20 Multilateration Target Reports" (Cabalkova et al., 2014).
Important note: The MySQL command described in the Appendix no 1. needs to be executed BEFORE running of OTR action

Table 1
Items Needed for MSPSR Data Simulation

Data items to keep	Status
DS_ID	Mandatory
REC_NUM	Mandatory
REC_TIME_POSIX	Mandatory
REC_TIME_MS	Mandatory
REPORT_TYPE	Mandatory
TOD	Mandatory
POS_LAT_DEG	Mandatory
POS_LONG_DEG	Mandatory
POS_DOP_X POS_DOP_Y POS_DOP_XY POS_STD_DEV_X_M POS_STD_DEV_Y_M POS_STD_DEV_CORRELATION_COEFF	Recommended Possible to set to null value, but those parameters have significant impact to RRT. In case of removing of this parameter RRT works only for few tracks. Because of bias filtering many plots are skipped. In case of removing of this POS items, it is necessary to set BIASes manually to get relevant results.

Source: Author/ SASS-C

The evaluation of the impact for all items contained in the ASTERIX part 14 cat 20 has been based on their definition provided in the EUROCONTROL documents: "EUROCONTROL Specification for Surveillance Data Exchange ASTERIX Part 14 Category 20 Multilateration Target Reports", "SCDB External Interface Requirement Specification" and "Technical specification for WAM system". The presence of each item in the simulated database has been properly discussed with SASS-C experts. Afterwards the impact of each item modification was properly tested in the first phase of the experiment (Arlery et al., 2015). The outcome of this simulation is the table of reduced data items as it is described in the Table 1.
All items summarized in the Table 1 represent just pure geometrical data of the detected targets. This represents a basic database of MSPSR data. If only data as described in the Table 1, are used, we can confidently clarify that original WAM sensors behave as MSPSR technology in the modified scenario (Cabalkova and Plsek, 2016).

3. In case that only "Mandatory" data from SD_MLAT table are used, it is need to pre-set the SASS-C accuracy and noise limits manually. You can find them in the "Data sources" table. This action has to be done for all defined WAM sensors before running OTR action. Here it is important to mention that removing position accuracy items (POS) has significant negative impact on OTR/ RRT reconstruction (Smith et al., 2006). (RRT - Reference Reconstructed Trajectory) In case that both, "Mandatory" and "Recommended data" are used, there is no required change of default accuracy and noise limits. They will be given by the system itself and the accuracy of RRT result will be significantly better in comparison with scenario where "Recommended data" are not used for reconstruction. For both possible solutions it is important to configure the OTR parameters to ensure that only WAM sensors (which should be already modified in this step) will be used for OTR reconstruction to get desired results. Other sensors should to be kept only for BIAS estimation to improve result accuracy (Chernyak 2009), (Bugaj, 2012).
Run OTR action. Be aware that running of OTR on the modified dataset can take very long to execute. Due to high processor load you should expect more than two hours OTR processing, depending on the amount of data fed and the available computing power. It is not possible to run more than one OTR at the same time, because the previous one will be automatically corrupt with an error code 137 (Conversano, 2011). Graphical examples of different results achieved in case of scenario with not modified data compared to scenario where data has been modified to contain only "Recommended" items as it is described in this document you can see in the figure no. 1 – 2 .

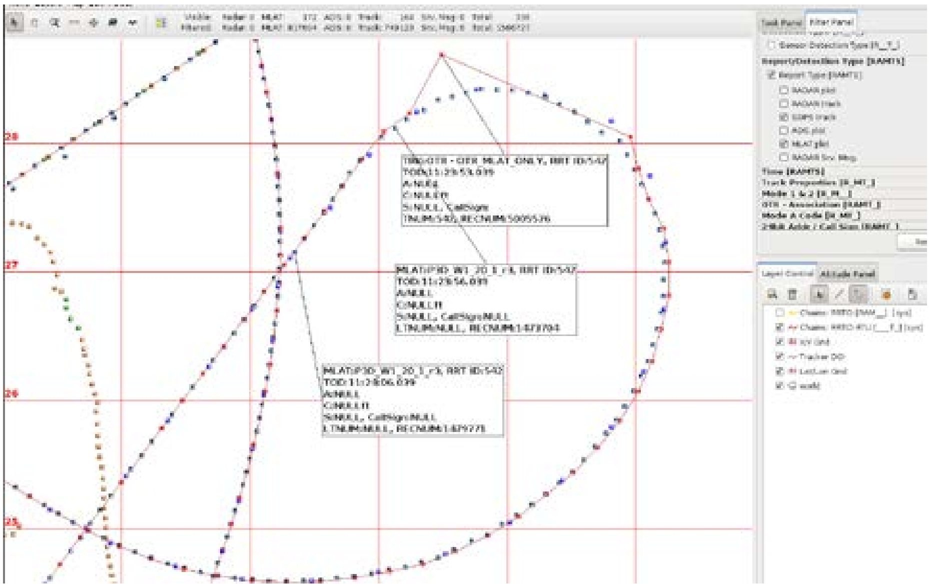

Fig. 1.
RRT Example from Simulated MSPSR Scenario
Source: Author/ SASS-C

In the figure no. 1 you can see an example of tracks on the SASS-C display after the data modification has been done. As you can see OTR chaining is working without problems. On the labels you can observe that all identity data has been removed but all plots are properly chained. This data represents simulated MSPSR data based just on the geometry retrieved from WAM detection. As detail parameter analysis has shown us, chaining observed in the SASS-C is working perfectly. In this case "Recommended" items have been kept as it is described in this document. As you will see in the next figure, the air situation displayed here is almost the same as in the case where data is not modified.
Although in some very rare cases OTR associating was not working because of crucial modifications of the dataset. This problem was observed just in very few cases (less than 2%) and it could cause uncertainties in some specific situations. Until the date of the writing there is no explanation for this rare phenomenon but this problem will be subject of the deeper analysis in the future.

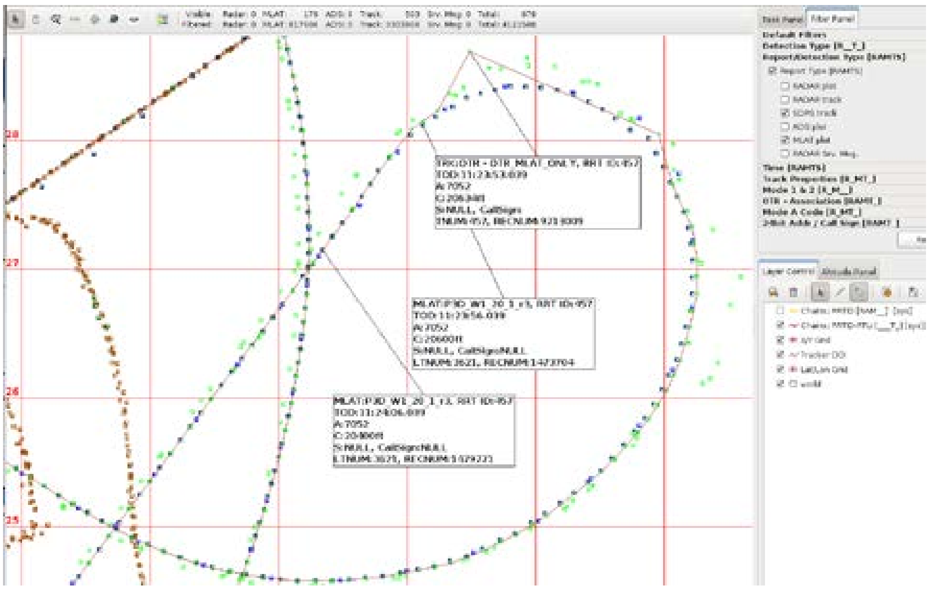

Fig. 2.
RRT Example from not Modified WAM Scenario
Source: Author/ SASS-C

In the figure no. 2 you can see the same airspace situation as it is displayed by OTR in the figure 1 although without modification. It means all contributing devices take part on the detection during this test. As you can see all identity information and all others parameters are visible on each label. OTR chaining is based on pure WAM data obtained from the sensors. That includes contributing data from secondary radars, Mode S and ADS-B (automatic dependent surveillance – broadcast). In comparison with modified scenario there is no difference in the functionality of OTR which means that OTR is working in the same way for both scenarios. Therefore OTR algorithm is able to handle data

based on pure geometry and to chain all plots generated by all targets even if identity of the target is unknown. It means that the modified MSPSR record is still valid and can be processed by any verification or simulation software which was previously configured to handle WAM data.
According to OTR data verification procedure and results obtained from the deeper analysis of simulated MSPSR data we can confirm the simulated data as consistent and valid. According to asterix items used for MSPSR data we can also confirm that only non cooperative geometrical data was used. The same data would be possibly available through any kind of MSPSR record in line with new ASTERIX category 15 designed for INCS. If we will consider that in the previous test the same record was used, we can compare the numbers of total tracks in both tests.

4. Summary

As you can see in the figures, the simulation of MSPSR data based on WAM record is possible just by simple modification of the core data. As SASS-C analysis confirmed, OTR reconstruction of the track is possible even without cooperative and identification data. The test shows that SASS-C is capable to work with pure geometry data as it is summarized in Table 1 which is something that has never been tested before. The same data items/ geometrical information as it was used for this analysis would be possible to obtain from MSPSR technologies [Garcia et al., 2014]. SASS-C verify the complexity and validity of each dataset before its proceeding. If the data set is not valid or some important information is missing, OTR algorithm cannot be successfully executed. In the majority of cases, OTR results obtained from the analysis either based on data modification to MSPSR or based on the original MLAT data, are exactly the same. The only difference was observed in the amount of tracks generated by OTR. Although in few cases OTR algorithm is not working as it is supposed and system is not able to chain the existing plots (Leonardi et al., 2009). There is no clear explanation to why this phenomenon occurs but we have received better results with manual preset of the accuracy thresholds as an emergency solution. The general assumption is: too strict automatic pre-set of the filters results in filtering of data which do not match sufficient requirements defined for MLAT plots (Matousek and Ochodnicky, 2006). Now we are in the phase of designing new MSPSR ASTERIX category which would allow SASS-C to set up all filters and thresholds for the given category, without user interaction with the system (Kalasova et al., 2015). This solution could prevent problems with OTR filtering in case that our assumption is correct.

5. Conclusion

According to the outcomes of the experiment we can confidently clarify that SASS-C is well prepared for MSPSR technologies and is capable to handle that kind of data. The first intent was to start the development of the algorithm compatible with MSPSR directly. There was no assumption that SASS-C or any other software could be able to handle data without identity information because the algorithms were never meant for this purpose .
But as an analysis show us, the amount of reconstructed RRT samples which has been achieved in this experiment for simulated MSPSR sensors (based on SD_MLAT modifications) has been nearly the same as was achieved in case of not modified MLAT data.
The comparison of the results you can see in the figures 1-2 in this article. The only condition to achieve exactly the same results is to use all accuracy items from SD_MLAT table (POS parameters). Otherwise the user interaction and input of the filters is required to achieve the relevant results. All outcomes are demonstrated in the figures in this article, together with verified guide for simulation of MSPSR and pure data that can be used by all SASS-C users for the future simulations and analysis. The main reason for this analysis is that proper ASTERIX category for MSPSR data is not designed yet and the design itself is a topic of many discussions nowadays. Although, new technologies are already deployed and prepared for testing (some of them ready to work in operational conditions). This guide provides a great advantage to test operational functionality and behavior of simulated MSPSR and sensors based on analysis of simulated data before its deployment. The guideline can be used in the same way for SASS-C Prediction tool where you can design a whole virtual network with all desired sensors and evaluate its functionality and predicted accuracy (Zacik, 2017). New categories will be officially implemented to both SASS-C tools as soon as the ASTERIX categories will be designed and officially issued. The complete detailed documentation of the experiment is a property of EUROCONTROL and can be required by all the SASS-C users.

Appendix A. MySQL command used to modify SD_MLAT data

UPDATE SD_MLAT SET SAC = NULL , SIC = NULL, FLIGHT_LEVEL_V = NULL , MODE2_V = NULL , MODE2_G = NULL , MODE2_SMO = NULL, MODE2_CODE = NULL, MODE1_V = NULL, MODE1_G = NULL , MODE1_SMO = NULL, MODE1_CODE = NULL, MODE3A_V = NULL, MODE3A_G = NULL, MODE3A_SMO = NULL, MODE3A_CODE = NULL, FLIGHT_LEVEL_V = NULL, FLIGHT_LEVEL_G = NULL, FLIGHT_LEVEL_FT = NULL, TARGET_ADDR = NULL, ACAS_COMM_CAPABILITY = NULL, ACAS_FLIGHT_STATUS = NULL, ACAS_MODES_SERVICE = NULL, ACAS_ALT_CAPABILITY_FT = NULL, ACAS_AIRCRAFT_IDENTIFICATION = NULL, ACAS_BDS_1_A = NULL, ACAS_BDS_1_B = NULL, SPI = NULL, RDP_CHAIN = NULL, DISPLAY_STATE = NULL, TRD_SSR = NULL, TRD_MS = NULL, TRD_HF = NULL, TRD_VDL4 = NULL, TRD_UAT = NULL, TRD_DME = NULL, CAT = NULL, RAW_MSG = NULL, POS_LOCAL_X_NM = NULL, POS_LOCAL_Y_NM = NULL, VELOCITY_VX_MS = NULL,

VELOCITY_VY_MS = NULL, ACCEL_AX_MS2 = NULL, ACCEL_AY_MS2 = NULL, GROUND_BIT = NULL, GEO_AREA_MASK = NULL, POS_SYS_X_NM = NULL, POS_SYS_Y_NM = NULL, POS_LOCAL_X_NM_CALC = NULL, POS_LOCAL_Y_NM_CALC = NULL, POS_LAT_DEG_CALC = NULL, POS_LONG_DEG_CALC = NULL, MAS_TRACK_NUM = NULL, ALT_GEO_FT = NULL, TRACK_CLIMB_DESC_MODE = NULL, TRACK_MANOEUVRE_HORI = NULL, TRACK_GHOST_TARGET = NULL, SIMULATED_TARGET = NULL, TEST_TARGET = NULL, CALLSIGN = NULL, MODES_MB_DATA = NULL, POS_SMOOTHED = NULL, POS_STD_DEV_LAT_DEG = NULL, POS_STD_DEV_LONG_DEG = NULL, POS_STD_DEV_LATLONG_DEG = NULL, POS_STD_DEV_LAT_M = NULL , POS_STD_DEV_LONG_M = NULL , POS_STD_DEV_LATLONG_CORR_COEFF = NULL , GEO_ALT_STD_DEV_FT = NULL , GEO_ALT_STD_DEV_M = NULL , HEIGHT_3D_FT = NULL, POS_DOP_XY_CORRELATION_COEFF = NULL, TRACK_NUM = NULL, LINE_ID = NULL, MSG_FMT = NULL, TRACK_COASTED = NULL, POS_SMOOTHED = NULL, TRACK_CONFIRMED = NULL, TRACK_END = NULL, TOD_CALCULATED = NULL

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EFFECTS OF UNWANTED TRACKING BOXES IN A REMOTE TOWER CONTROL ENVIRONMENT

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Abstract: In the field of air transport operations, "Remote Tower" is a fast-growing concept offering more cost-efficient Air Traffic Services (ATS), mainly for small aerodromes with low traffic volumes. It primarily relies on camera sensors at the aerodrome, producing a video stream, which is relayed to an ATS facility situated independent from the real Tower, where it is usually displayed on a video panorama, in order to replace the direct out-of-the-Tower-window view. This offers the opportunity to provide ATS to more than one airport from a centralized ATS facility, also called Remote Tower Center. By such a center, the critical resource "Air Traffic Control Officer" (ATCO) can be utilized much more cost-efficiently since the ATCO can now control multiple low density aerodromes, sequentially or even simultaneously. To maintain or even increase the ATCO's situational awareness, augmentation features are introduced, such as automated tracking of the traffic the ATCO is responsible for. However, a tracking function is never reliable by 100% and with reference to the signal detection theory, gains and losses are to be expected. This paper investigates the minimum performance parameter of a tracking function in a Remote Tower environment to gain ATCO's acceptance and positive effects on her/his situational awareness and workload. In a human-in-the-loop real time simulation, seven ATCOs performed a realistic traffic scenario. The study was conducted at Remote Tower laboratory at DLR in Braunschweig. By four test conditions the performance of the visual tracking was varied by the number of unwanted tracking boxes: (1) no visual tracking (baseline), (2) low, (3) medium, and (4) high. The findings show that ATCOs very much appreciate visual tracking augmentations. ATCOs can more easily detect critical traffic situation, which increases their situational awareness and safety. Further on, acceptance is rather high and workload on a moderate level and both parameters behave rather robustly, even when the number of unwanted tracking boxes increases.

Keywords: remote tower, tracking, signal detection theory.

1. Introduction and Background

"Remote Tower" is a concept allowing air traffic control officers (ATCOs) to provide control to an airport remotely, independent of their conventional control Tower position. All information the ATCO usually needs to perform her/his job is relayed to a controller working position (CWP) that can be hundred kilometres away from the actual airport. Preferably, several other small airports are connected to such a location that would then be called a Remote Tower control center (RTC). Since particularly small airports due to very occasional traffic suffer cost-efficiency. Thus, a RTC has the advantage to provide more cost-efficient air traffic control (ATC). Out of a pool of available ATCOs, the allocation of ATCOs to airports can be conducted much more efficiently; the ATCOs work at the airports where the traffic happens. With more complex traffic, one, two or more ATCOs provide ATC to one airport but also one ATCO can be in charge of one, two or more very less frequented airports. Core of such a RTC and particularly for each CWP is the camera sensors based on visual presentation of the conventional out-of-the-Tower-window view, usually presented through a panorama video wall. Such a video view of the outside world offers another advantage: Additional ATC relevant information can be superimposed, or augmented, on the real scenery. Information, related to weather or wind for instance, or even flight plan or track data are usually available head down only. With Remote Tower, apart from the head-up outside view, this visual information can now be spatially and timely linked to the video scenery. Hence, head-down times are reduced and the ATCO can capture all relevant ATC information with one gaze. One of the most promising augmentation features is the tracking and indication of surrounding traffic.
Such an automatic tracking function reads out the camera sensor information, associates groups of image pixels with real world objects by image processing, detects moving objects, tracks them and provides an object indication, e.g., a box capturing the moving object (EUROCAE, 2018). If the aerodrome is equipped with additional surveillance sensors, like approach or surface radar, the quality of the tracking function can be further improved with that information. Particularly in far distance when neither ATCOs nor camera sensors are able to detect and track traffic, the radar captures the traffic and track information can be indicated on the video panorama. When the aircraft comes closer also the camera sensors would capture the aircraft and camera and radar track information are to be fused to provide again one single track. Radar and camera sensors complement each other very well, because radar has a much higher coverage range (up to 25 miles) than cameras. Cameras on the other side provide much better spatial accuracy and a much higher update rate. That is, even when provided with a low update rate and low position accuracy, ATCOs know right in advance about traffic in far distance. When the ATCO becomes in charge of traffic in closer vicinity, cameras provide more accurate position information. Another advantage of a tracking function is the labelling function. As soon as the position and identification of an aircraft or vehicle is known to the system, label information stemming from cooperative radar or flight plan information can be linked to the object. Call sign information, aircraft type, altitude, speed or destination information could be provided by a label attached to the object.

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In the past, such automated tracking functions were investigated in several national and European research projects with concordant results: Tracking information is very much appreciated by the ATCOs. In the project "Advanced Remote Tower" (ART) of the 6th European Framework Program (Van Schaik et al., 2016a&b) and with the SESAR project P06.09.03 (SESAR, 2014a) ATCOs in an active shadow mode setting were presented tracking information captured from an aerodrome 100km away from their ATCO working position under test. Within the ART project, ATCOs complained about some quality issues, e.g., jumping tracking information, but the majority of the ATCOs appreciated tracking information. In the SESAR project 06.09.03, ATCOs' opinions resulted in an over-average acceptance score of 4.03 on a Likert scale from 1 "strongly disagree" to 5 "strongly agree". Also subjective "trust" and "situation awareness" (SA) measurements scored over-average high. Regarding safety, the ATCOs admitted that "Remote Tower environment can have features that a local tower does not have, including the addition of technical enablers such as tracking overlays". In SESAR project 06.08.04 (SESAR; 2014b), tracking and labelling information was investigated in a multiple Remote Tower setting. In a real time simulation, ATCOs worked a very heavy traffic scenario with 30 movements per hour via a single airport (baseline condition) and the same traffic scenario spread over two airports on a multiple Remote Tower CWP (treatment factor) via two factor levels, with and without automated tracking function. In accordance to SESAR (2014a), the tracking was appreciated as 'nice to have', but was, contrary to SESAR (2014a) results, hardly been used. The authors explained this effect by the high traffic load that led ATCOs to work head down predominately to get ATC relevant information and to operate the electronic flight strips. Papenfuss & Möhlenbrink (2016) tested 12 ATCOs in a simulated Remote Tower environment with automated tracking and assessed their eye-point of regards. By the means of tracking, head-down times could be significantly reduced. ATCOs also regarded the tracking functionality as helpful, particularly in critical situations.

Even when past results could show that augmented tracking information are much appreciated by the ATCOs to increase their SA, there is also a risk that ATCOs get distracted by tracked objects that are not of interest to the ATCO or that the tracking function misses to track an object that is of interest to the ATCO. Both effects decrease the ATCO's SA, can cause additional workload and even safety risks. Wickens (2002) describes these effects in its signal detection theory (SDT). Core of the SDT is a "signal", which is to be detected, can be present or absent when it is detected. If the signal is really present, the SDT speaks of a "hit"; if it is absent, the SDT names it "false alarm". Present signals that are not detected are "misses" (1-p(hit)). The SDT result pattern can be applied for our automated tracking function (see Fig. 1).

	Object of interest	Object not of interest
Object tracked	Wanted → overtrust? → learnt carelessness	Unwanted → negative influence on acceptance, workload or Situation awareness?
Object not tracked	Missed → Safety critical?	Correct Rejection

Fig. 1.
Result Pattern of the Automated Tracking Function and its Associated Effects with Respect to the Signal Detection Theory

To minimise negative (amber colour in Fig 1) and maximise positive effects (green colour in Fig 1) the tracking function must be tuned in an optimal way. It must be sensible enough to keep the "missed" on a low level but also sensitive enough to keep the "unwanted" on an operationally reasonable level (see also Friedman-Berg, 2008). In a nutshell, the minimum performance of the tracking function must be high enough to gain operational benefits. Past research could show that the tracking function can provide operational benefit in a Remote Tower context but the quality of the tracking function has never been varied in an experimental setting to gain knowledge about the minimum operational performance. For the future, this knowledge would help to better tune the function to the local operational needs, to support the standardisation process and to reduce the implementation time. The research question of this study therefore reads: What is the minimum acceptable operational performance of a tracking function in a Remote Tower Control context to provide positive effects on SA and workload.

2. Experimental Design

2.1. Participants

Seven male ATCOs between 29 and 62 years (M = 42.1, SD = 12.8) took part in the experiment. Except of one they all held an active ATC license and work or worked for various air navigation service providers (Austrocontrol, LFV, AVINOR, NATS and ROMATSA). ATCOs were directly invited by an invitation letter and they supported the study voluntarily and without any monetary compensation. All ATCOs and pseudo-ATCOs were familiar with the Remote Tower concept. The written and spoken language was English.

2.2. Experimental Platform

The experimental study was carried out at the Apron Tower Simulator at the Remote Tower laboratory at DLR Braunschweig between 15th and 31st of May 2017. A 45 minutes lasting traffic scenario at the Braunschweig-Wolfsburg airport (EDVE) was prepared to be used in a real time simulation. EDVE is a controlled regional airport with class D control zone (CTR), 2200 feet altitude. The simulated scenario reflected typical day-to-day traffic with 17 total movements (15 VFR and two IFR movements), amongst them two aircraft performing right-hand traffic patterns, four arrivals, seven departures and four CTR crossers. Furthermore, two abnormal traffic events were induced, a maintenance car, which crossed the runway during a simultaneous departure event without waiting for an ATC clearance and one CTR crosser was flying through the CTR from north to south without receive/transmit radio communication (R/T) and without a clearance. Visibility was CAVOK without any clouds. Wind was calm, 260 degrees, five knots and runway 26 was in use. All communication was done via one radio channel and also VFR communication was done in English, because of the international ATCO test sample. Each ATCO controlled the traffic alone, no coordination with apron control or approach control was needed. In- and outbound traffic called directly before entering CTR (VFR), or IFR, when established on final 10 miles out, respectively, outbound traffic requested start-up or taxi. The traffic was operated by two blip pilots, one responsible for arrivals and crossers, one for departures and traffic patterns. The ATCOs was provided with 200 degrees northwards out-of-the-window view and a 360 degrees pan-tilt zoom camera (PTZ). The CWP should simulate a very basic Remote Tower equipage, therefore they were neither provided with 360 degrees panorama nor with approach or surface radar. Head down, they were provided with a tower flight data processing system to operate the flight strips, a space mouse to operate the PTZ, a communication display and an information data processing system (IDVS), providing visibility, wind and QNH information. The automated tracking function was realised with cyan-coloured boxes. There were "wanted" and "unwanted" boxes (see also Fig. 2).

Fig. 2.
Experimental Set Up of the Remote Tower CWP with "wanted" and "unwanted" Tracking Boxes (two left boxes are "unwanted", the right hand box, capturing the departing aircraft is "wanted"

2.3. Test Variables and Test Procedures

The reliability of automated tracking function is related to the relation of "wanted" to "missed" boxes and the amount of "unwanted" boxes. To keep the experimental design efficient and manageable, the relation of "wanted" to "missed" boxes was kept stable. On the other hand, the amount of "unwanted" boxes was varied over the test conditions. Because a perfect 100% "hits" system is very unlikely in an operational environment, the "wanted" hits were fixed on a reasonable value: 15 out of 17 movements were permanently tracked while two out of 17 movements were permanently untracked, which resulted in a 88% hit rate. This hit rate perfectly corresponds to a recommendation of ATCOs out of the international EUROCAE working group WG-100 (EUROCAE, 2018) who proposed a minimum "hit" performance of 85%. What is "wanted" to be tracked is also dependent on the local operational needs, but for this experiment, it was assumed that all aircraft and vehicles on the movement area and in the vicinity of the airport shall be "wanted" targets to be tracked. The amount of “unwanted” boxes instead was selected as the independent variable (IV-A) and was varied over three factor levels A1, A2 & A3. A fourth test condition worked as a baseline condition (BL) in which the automated tracking function was switched off. The appearance of the “unwanted” boxes were varied over four dominant operational locations (runway, taxiway, traffic pattern and final approach area) and over their dwell time, the time the “unwanted” boxes lasted until they disappeared by themselves (2, 5, 30 seconds). The amount of them was varied over the factor levels A1, A2 & A3, whereas A1 should represent a very reasonable and acceptable amount of “unwanted” boxes, A2 should represent a medium amount and A3 a very annoyable amount of “unwanted” boxes. The right choice of the amount of “unwanted” boxes was very important to avoid bottom and ceiling effects in order to be able to judge about the minimum acceptable performance of “unwanted” boxes in the end. In a pre-trial with a Norwegian AVINOR ATCO the amount of “unwanted” boxes was optimally tuned to meet this prerequisite. Table 1 represents the final setting of the amount of “unwanted” boxes.

Table 1
Independent Variable A and its Variation over the amount of “Unwanted” Boxes in the 45 min lasting traffic scenario

Location →	Runway				Taxiway				Final Approach				Traffic Pattern			
Dwell time ↓	**BL**	**A1**	**A2**	**A3**	**BL**	**A1**	**A2**	**A3**	**BL**	**A1**	**A2**	**A3**	**BL**	**A1**	**A2**	**A3**
30 sec	0	0	0	7	0	0	7	14	0	0	0	7	0	0	0	7
5 sec	0	0	7	14	0	7	14	28	0	7	7	14	0	7	7	14
2 sec	0	14	28	42	0	14	28	42	0	14	28	42	0	70	140	210

All test conditions (Baseline, A1, A2, A3) were run with the same traffic scenario to allow a final deduction on the IV-A “amount of unwanted boxes” with respect to measured effects on the dependent variables: Acceptance, SA and workload. To avoid ATCOs’ recognition and training effects caused by a fourfold repetition of the traffic scenario, the aircraft’s call signs were varied over the four different test conditions. The timing of the intruders (runway crossing vehicle and CTR crosser) and the two “missed” boxed movements were alternated as well. The sequence of the test conditions was randomized over the seven ATCOs to eliminate systematically learning or fatigue effects.
The procedure of the study was structured in three parts. The briefing and training phase represented the part in which ATCOs provided demographical date, were informed about the data protection procedure and prepared for the actual experiment. Secondly, the experimental phase corresponded to the conduction of four successive test runs and the third part dealt with completion of the post-run questionnaire and a final debriefing phase. The ATCOs were kept unaware of the actual test condition. During the experimental phase, the ATCOs’ workload, SA and acceptance were assessed. Workload was subjectively measured by I.S.A., a 5-point Likert scale, which popped up every 5 min at the IDVS requesting the ATCO to assess her/his current workload by pressing a button reaching from 1 “under-utilised” until 5 “excessive” (SESAR, 2012). At the same time, the ATCO was requested to subjectively judge about her/his acceptance of the tracking function by the statement: “During the past five minutes I found the tracking boxes: 1 = „Disturbing“, 2 = „Not of interest“, and 3 = „Helpful“”. Moreover, SA and workload were assessed every nine minutes by the SARA-T online questionnaire (Kraemer & Süß, 2015). Regarding the abnormal events, the experimenter noted if the intruders were recognised by the ATCO and how they dealt with them. During the debriefing phase, the ATCOs were asked to fill in standard questionnaires with respect to SA (SASHA), workload (AIM) and Acceptance (SATI), a test battery developed by EUROCONTROL in its project “Solutions for Human-Automation Partnerships in European ATM” (SHAPE) (Dehn, 2008). Further on, the ATCOs provided answers to several closed statements regarding SA, workload and acceptance and were given the chance to provide additional comments and remarks which they eventually had in mind after a full day of testing the automated tracking function.

3. Results

In order to get reasonable result with an acceptable external validity, a sample size of experts was aimed for. A potential drawback with expert sample sizes is the availability of experts. By consequent, the sample size often lacks a reasonable size to apply parametric inference statistics with an acceptable internal validity. The analysis therefore focussed on the descriptive analysis of the results and when appropriate, non-parametric inference statistics like the Friedman or binomial test were applied.
Regarding workload, neither mid-run ISA and SARA-T nor the post run AIM provided significant results by a Friedman test and also the mean values do not draw an easily interpretable pattern. In general, workload is rather under-average and rather unaffected of the treatment (compare Fig. 3).

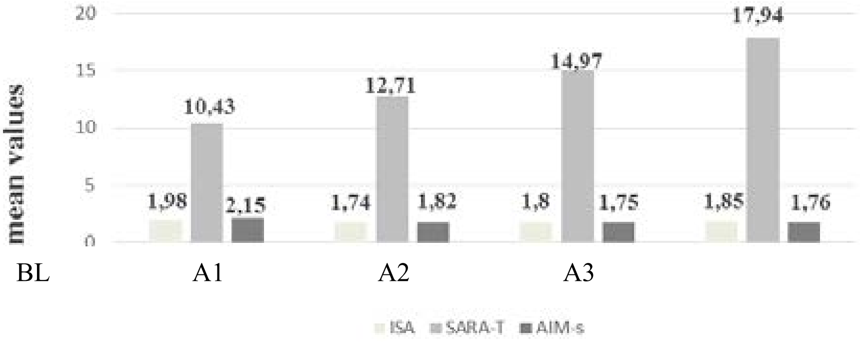

Fig. 3.
Mean values of the Workload measurement metrics ISA, SARA-T and AIM

A similar result was obtained with respect to SA measurements. Neither the mid-run SARA-T nor the post-run SASHA provided a significant result pattern. For SASHA following mean values (M) and standard deviation (SD) were measured: BL = 4.48/.98; A1 = 4.74/.78; A2 = 4.83/.77 and A3 = 4.93/.71. With SARA-T it was measured BL = 4.39/1.89; A1 = 3.47/.76; A2 = 4.51/2.52 and A3 = 4.65/2.96.
According the ATCOs' acceptance, the mid-run assessment via a three-point Likert scale with 1 = „Disturbing", 2 = „Not of interest", and 3 = „Helpful", revealed an overall over-average acceptance but without any significant deviation between the test conditions: A1 = 2.84/.2; A2 = 2.86/.2 and A3 = 2.8/.24 ($\chi^2(2) = .353$, $p = .838$). Same pattern with the SATI post run questionnaire: A1 = 4.29/1.27; A2 = 4.14/.77 and A3 = 3.60/1.07. Actually, acceptance decreases with higher amount of "unwanted" boxes but not significantly. Post-run the ATCOs were also asked: "The experienced wanted, missed and unwanted Boxes had an acceptable rate to help me increasing my situational awareness." and "I experienced unwanted boxes (nuisance boxes) but they popped up in an acceptable amount that did not prevent me from working in a safe and efficient manner" to be answered on a 6 point Likert scale from 1 "strongly disagree" to 6 "strongly agree". Both statements were answered over-average positive and after having conducted a binominal test, A1 and A2 with the first question, and A1 with the second question, became significant ($p = .016$) (see Fig 4).

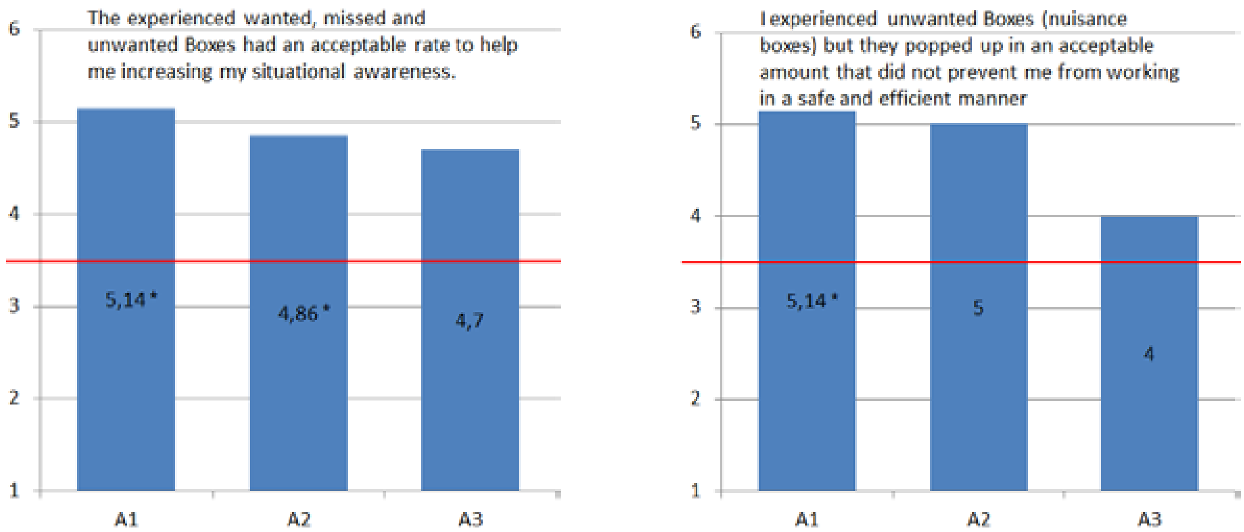

Fig. 4.
Post-run Questions regarding acceptance assessment
Rem.: An asterisk symbol marks a significant over-average value tested by a binominal test with p = .016.

With respect to the two abnormal events: The CTR crosser was not recognised at all it in the BL condition but four of seven ATCOs spotted it in the tracking conditions. Similar results were gained with the vehicle crossing the runway without clearance, which in the BL conditions was seen by four out of seven ATCOs but in the tracking conditions was seen by all ATCOs.
After performing all test runs, the ATCOs were asked 11 further general statements to the automatic tracking function to be answered on a 6-point Likert scale from 1 "strongly disagree" to 6 "strongly agree". Fig 5 shows the mean values and when marked with an asterisk became significant by a binominal test with $p = .016$.

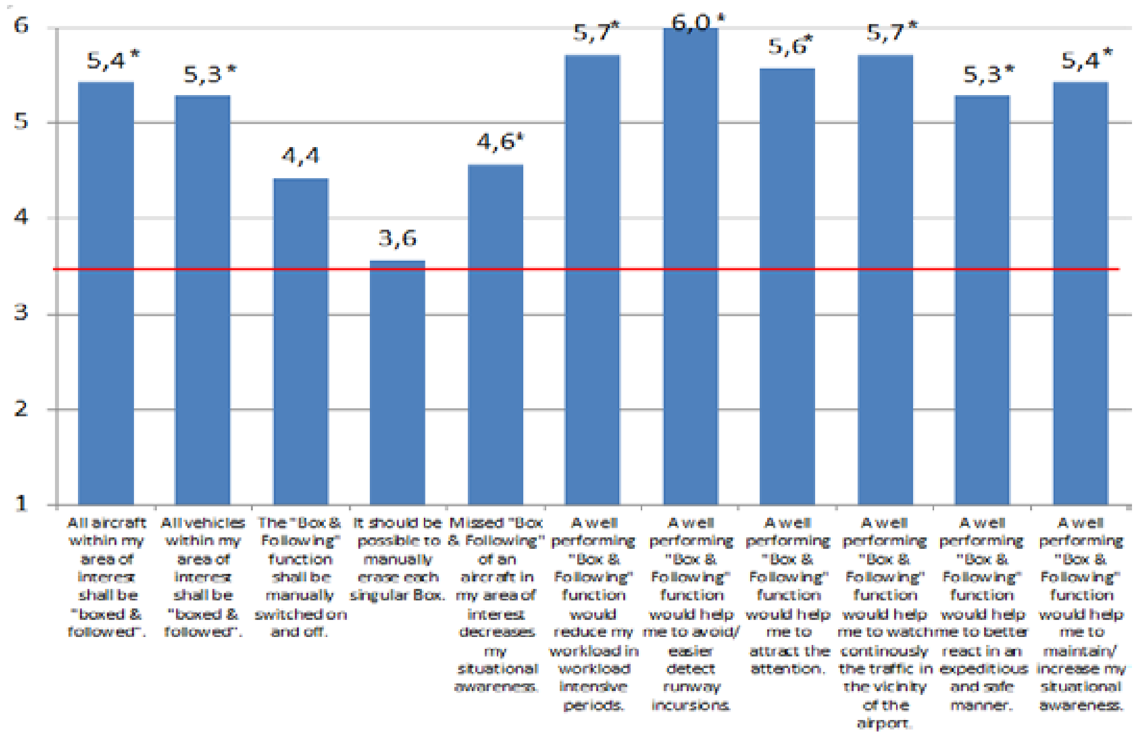

Fig. 5.
Post-trial Questions regarding 11 general Statements to the Automatic Tracking Function
Rem.: An asterisk symbol marks a significant over-average value tested by a binominal test with p = .016.

4. Discussion

The experimental study aimed to get to the bottom of the minimum quality threshold of an automatic tracking function in a remote Tower context. It fixed the relation of "hits" and "missed" with 88% and varied the amount of "unwanted" tracking boxes on three factor levels. Even when the ATCOs recognised performance differences in the amount of "unwanted" tracking boxes and significantly preferred the lower amount of "unwanted" boxes (see Fig. 4), the mid- and post-run standardised measurement tools were not sensitive enough to reveal any significant differences with SA and workload. Instead, a dominant ceiling effect was observed: ATCOs felt permanently confident regarding SA and workload independent of the treatment "amount of unwanted tracking boxes". They appreciated the "wanted" boxes and behaved more or less unaffected from the disturbing "unwanted" boxes.
This result pattern can be explained by three considerations: Firstly, the traffic scenario was challenging but manageable for the ATCOs and in their subjective perception they must have had a proper SA and workload in order to manage such a challenging scenario. This phenomenon is quite well known with ATCO expert samples (Badke-Schaub et al., 2012). That is why the experimental design also focussed on the objective SA measurements, like the SARA-T SA metrics, but unfortunately with the same ceiling effect. Most probably, the SARA-T operational mid-run questions were too easy or not affected by the amount of "unwanted" boxes. Secondly, "What the eye does not see, the heart does not grieve over" is a very good proverb to describe the situation when an aircraft crossed the CTR without a clearance. Even when visible by some pixels in the panorama view, in the BL condition nobody of the seven ATCOs spotted the crosser. The crosser kept unnoticed by them and they did not deal with it, that is, neither workload nor SA was affected, because they did not know that they missed something. By contrast, they detected the crosser through the "wanted" box in the tracking conditions, which surprised them and they were thinking that they have missed an initial call or a clearance. Then they had additional workload by trying to contact the crosser via R/T without any response and to provide traffic information to the traffic in the vicinity to warn of the intruder. All those actions helped to avoid potential safety critical risks but negatively affected ATCOs' subjectively perceived SA and workload. Third consideration why SA and workload remained rather unaffected by the amount of "unwanted" boxes refers to the ATCOs' comments that they could easily distinguish "wanted" from "unwanted" boxes. Particularly large boxes without any contents, stationary boxes or boxes appearing in non-critical areas like on buildings, on the greens or apron could easily been falsified by the ATCOs or even remained unnoticed by them. Critical are "unwanted" boxes with a similar appearance like the "wanted" boxes, .e.g., a moving box appearing in the final approach area with size and vector speed similar to a real target. But those "unwanted" boxes could not be created by the simulation facility.
Further comments from ATCOs presume that they used the tracking function like a non-cooperative surface movement radar (SMR). An SMR provides the ATCO with yellow-coloured pixel swarms on a 2D birds view airport surveillance detection (ASDE) equipment display. The radar cannot distinguish between "wanted" or "unwanted" pixel swarms, it simply shows everything that provides a shadow through the radar beam. The ATCOs do not use such an ASDE as a control tool but as an additional means to verify aircraft or vehicle positions seen through the out-of-the-window view

or provided by pilot reports. Over the time, using an ASDE ATCOs become very efficient in distinguishing between operational relevant aircraft/vehicle shadows or "unwanted" shadows induced by light masts, buildings, grass, snow banks, Tarmac reflections or flocks of birds. Having these considerations in mind that a tracking function is not used as a control tool and that many "unwanted" tracking boxes, after a certain adaption time, can easily be falsified by the ATCO and thus are not that much disturbing, one could think about increasing the sensibility of the tracking function to get "hit" rates of up to 95% or 99% on the costs of higher amounts of "unwanted" tracking boxes. This consideration is also supported by item 5 (Fig. 5) by which the ATCOs uniformly state that "missed" tracking boxes may decrease their SA.
Other results refer to the improved recognition of intruders like CTR or runway incursions. With the tracking function intruders are easier to detect and thus the tracking function significantly contributes to safety (see also Fig. 5 item 7, 8 and 9). Referring to the statement whether the entire tracking function or single boxes should be able to switch off manually, ambivalent results were gained Instead agreement was gained referring the statement what is to be tracked: ATCOs want to have tracked all aircraft and vehicles in their area of interest but not on the apron area when the objects are visible anyway (Fig. 5).

5. Conclusions and Outlook

In accordance to existing studies (see Section 1) this experimental study could also show that an automated tracking function in a Remote Tower environment is very much appreciated by the ATCOs and that they significantly admit its positive contribution to situation awareness and safety. Further on, the tracking function seem to be rather robust against "unwanted" tracking boxes and probably more focus could be laid on the increase of the sensibility in terms of getting higher percentage rates with the "wanted" tracking boxes. Furthermore, defining a quantitatively expressed minimum performance value for "unwanted" tracking boxes seems to be very difficult. This study varied "unwanted" tracking boxes in dwell time and location but there are more attributes, such as size of the tracking box, or if they are stationary or moving. Most probably, each implementation of a tracking function must be repeatedly tuned in line to the local operational needs and accepted by the local ATCOs. Future studies should focus on a bigger sample size and more realistic "unwanted" tracking boxes to provide further empirical evidence to these conclusions.

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METHODOLOGICAL APPROACH TO FATIGUE RISK MITIGATION IN FLIGHT OPERATIONS

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Abstract: Paper presents methodology of fatigue risk management through assessment methods and tools and applicative mitigation measures. The research has been targeted towards objectification of the crew fatigue on the sample of flight operations and results interpretation of referent indicators measuring. The crew fatigue is measured using Complex Reactionmeter Drenovac (CRD) device, which records the results of tests solved by pilots in various work conditions. The results are converted in several key indicators, and fatigue is derived from obtained indicators' values. The analysis of the obtained results is conducted using the One Way ANOVA (Analysis of Variance) method by software Statistica 10. Furthermore, the safety risk assessment is conducted for obtained results, which shows the level of risk implicated by crew fatigue. As a conclusion, the recommendations are given for fatigue risk mitigation related to concrete research sample.

Keywords: air transport, fatigue, risk assessment, safety management system, fatigue measurement, analysis methods.

1. Introduction

Fatigue affects various cognitive abilities such as alertness, memory, getting around in space, learning, problem solving, decision making, and more. Besides the restrictions expressed in flight time limitations, a very important role in reducing fatigue risk has a Fatigue Risk Management System (FRMS) that presupposes some method for fatigue quantification.

This paper presents a part of the research carried out in the air carrier and is concerned with finding answer to the question: "Does the individual self-assessment of the current "energy status", which is based on a verbal "self-assessment scale of energy level", comply with objective indicators of "mental efficiency status" measured in the chronometric psychological test (CRD 422).

2. Objectification of the Crew Fatigue

Most commonly used methods for objectification of the crew fatigue are:

- Subjective fatigue scales (Samn Perelli fatigue scale, Karolinska Sleepiness Scale);
- Psychomotor vigilance test (PVT);
- Actigraphy;
- Predictive models (biomathematical algorithms usually use applications like SAFE);
- Sleep diaries.

Subjective objectification of fatigue is also commonly found in fatigue reports and fatigue reporting that are used as main data collection tool. Predictive models can be found in modern crew management software applications and they can warn crew planners on fatigue risk (usually warning messages and colour schemes – from green as no risk to red – high fatigue risk). Other objective methods are used in fatigue studies for specific cases when required by airline (e.g. for certain type of flight operation of an airline) (Steiner et al, 2012).

This paper describes study of fatigue objectification using CRD instruments. The analysis of the obtained results is conducted using the methods of Multi-Criteria Decision Making (MCDM) and Analytic Hierarchy Process (AHP).

The research is aimed to find correlation between cognitive, psychomotor and functional mental disorders, measured with electronic tests of the CRD series and workload parameters of flight crew (pilots). Personal assessments on current state of fatigue (subjective scales) were used. The aim of the research is to identify and quantify elements that affect the risk of fatigue.

3. Description of Research, Measuring Equipment and Methodology

For the purpose of a study, an electronic CRD system of standardized chronometric cognitive tests is used. CRD series have been used in various researches and studies since 1969. Instruments, methodology, measuring parameters and other information are well explained and documented in university book (Drenovac, 2009).

Measurements were made with four male pilots of an average age of 42 years (+/- two years), who are professional airline pilots for the last 11 years (standard deviation 4.7 years) and average 6.305 flight hours (standard deviation of 2.532 hours flight) (Steiner et al, 2018).

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The pilots were familiar with the method (process and dynamics of the study) and the metering CRD equipment and tests to be used. Firstly, pilots had training for 10 iterations and in single iteration they did five CRD tests on four different CRD instruments (Steiner et al, 2018).
Those testing aimed to prevent the effect of learning how to better do tests in a later measurement because the main objective was to measure the drop of mental potential due to fatigue (Steiner et al, 2018).
Measurements, during which pilots did full tests (five different CRD tests) and fill subjective survey, were done before flight duty period and after flight duty period. Tests were done in improvised "CRD laboratory", a room on International Airport Zagreb, where pilots had done check-in and check-out (pre-flight and post-flight duty).

Fig. 1.
CRD laboratory
Source: Prepared by authors

The subject of measurement of the CRD 422 test is an operational thinking with tasks of work coordination, i.e. hand and leg work combinations depending on the emitted sound level or the sound intensity level.
The signal-command system of the CRD 422 includes, along with the main signal-command board, the connecting elements: headphones (speakers) and pedals. In different tasks, one of two predetermined (high or low) signals is emitted. At high volume, at the same time, it is necessary to press with the left hand, the large key in the left corner of the control panel and, at the same time, press the right foot, the right foot pedal. After hearing low sound, it is required to respond at the same time by pressing the right hand of the large key in the right-hand corner of the control panel and the left foot of the left foot pedal (Steiner et al, 2018). The reason for choosing this test for study presentation is the complexity of co-ordination of hand and foot work, and complex mental processing - operational thinking.
A set of variables obtained by chronometric measurement on the CRD 422 test, which have been analysed in this study are:

- UKT - mental processing speed (total test time);
- MinT - mental processing speed (the shortest time to solve the test tasks);
- MaxT - mental processing speed (the longest time to solve the test tasks);
- UB - total ballast, an indicator of individual stability as a dynamic attribute of mental processing;
- SB - initial ballast (fluctuation of task solving time in the first half of the test);
- ZB - final ballast (fluctuation of task solving time in the second half of the test);
- ZB/SB - the ratio of the final and the initial ballast, greater than 1 means a slowdown in the test solving time, i.e. fatigue;
- BrPog - the number of errors made on the test, the indicator of attention and concentration while solving the tests.

UKT, MinT, MaxT, UB, SB and ZB are time indicators (milli-seconds), and BrPog is an integer that indicates the number of errors. All chronometric data are transposed into the standard statistical scale (T value).
Since chronometric data are distributed asymmetrically, normalization of their distribution is necessary in order to apply statistical methods that assume normal distribution in the analytics. The second reason for the transposition of the original results in milli-seconds into the standard statistical scale (T-value) is to eliminate the individual differences between the pilots and the different sizes of the metric values.
The T-value transposition is made in such a way that the individual results of each pilot on the test are first converted to the standard z value according to the formula z score = (original value – average of the original value) / (standard deviation of the original value). Then z values are transposed into T values by the formula T score = 50 + 10 * z.

The reason for using the T value is that z values also have negative values, which is a drawback for graphic analysis of results (graphs), while T values usually range in the range of 20 to 80, where value 50 denotes the arithmetic mean. By transposing into the standard statistical scale in T values, the same average for each pilot is reached and is 50 in T values, eliminating individual differences.

After the original values in milli-seconds for the UKT, MinT, MaxT, UB, SB and ZB variables were transposed into the standard T value, a further statistical processing was started. It should therefore be taken into account that the shorter time of outlined variables means greater efficiency of mental processing and vice versa, which means that the lower T value of the result represents greater efficiency of mental processing and vice versa.

The dependent variables of BrPog and ZB/SB are further expressed in the original values, where a smaller number of errors indicate higher accuracy of mental processing, and the ratio ZB/SB indicates acceleration or deceleration in mental processing when solving the test - if ZB is greater than SB then it means slowing down, if ratio is greater than 1.

An independent variable represents a subjective result of „self-assessment scale of energy level". Subjective self-assessment scale of energy level contains ranking from 1 to 10, shown in Table 1, where the status rating is the worst for 1 and states: „I'm completely exhausted, unable to do the least effort“, while the status rating of 10 is the best and states: „I feel great energy for which there are no imperceptible obstacles“.

Table 1

Self-assessment scale of energy status

Rate	Description of energy status
1	I am completely exhausted; unable to do the least effort.
2	I'm terribly tired; incapable of any activity.
3	I am very tired; without energy; immobile.
4	I'm pretty tired; apathetic; wishing a good night sleep.
5	I do not have enough energy; I get tired easily.
6	I feel quite fresh.
7	I'm fresh and I have a lot of energy.
8	I have a lot of energy; I feel the need for action.
9	I have great energy and a strong need for action
10	I feel great energy for which there are no imperceptible obstacles.

Source: (Drenovac, 2011)

4. Results

There were altogether 227 reviews of self-assessments of energy level status, ranging from status 5, which states: „I do not have enough energy; I get tired easily“ up to status 8 that states: „I have a lot of energy; I feel the need for action“. The response rate of self-assessment of energy level is shown in Table 2.

Table 2

Response frequency of energy level self-assessment

Self-assessment	Description	N
5	I do not have enough energy; I get tired easily.	30
6	I feel quite fresh.	98
7	I'm fresh and I have a lot of energy.	74
8	I have a lot of energy; I feel the need for action.	25
	Total	**227**

Source: Prepared by authors

In the statistical analysis, the ANOVA procedures of Statistics 10 were used to test the significance of differences in CRD variables between the variables of independent variables, i.e. the self-assessment of energy level. The results of that analysis are shown in the Table 3 and in the graphs 1 and 2.

Table 3

One-way ANOVA variance analysis – Differences in "mental processing efficiency" on CRD 422 among self-assessment categories of „current energy status“

Energy rate	Category 5	Category 6	Category 7	Category 8	F	p
UKT 422 average	55.208	50.866	47.677	46.951	5,317357	0,001476 **
MinT 422 average	51.383	50.305	49.562	48.057	0,576179	0,631230
MaxT 422 average	55.079	49.750	48.601	48.834	3,266034	0,022186 *
UB 422	56.142	50.767	47.387	47.364	6,633782	0,000260 **

Energy rate average	Category 5	Category 6	Category 7	Category 8	F	p
SB 422 average	53.988	50.734	48.038	48.208	3,036948	0,029969 *
ZB 422 average	56.686	50.545	47.434	47.389	7,257021	0,000115 **
BrPog 422 average	1.6667	1.8776	2.7568	4.1600	4,684491	0,003408 **
ZB/SB 422 average	1,482319	1,353771	1,354691	1,492949	1,101157	0,349516

Source: Prepared by authors, Statistica 10
** statistical significance at the level 0,05*
*** statistical significance at the promile level*

The variance analysis showed statistically significant differences in mental efficiency at the risk level less than 0.05 for MaxT and SB variables, and at the risk level in promiles for the variables UKT, UB, ZB and BrPog. In all these variables, except for BrPog, statistically significant weaker mental efficiency was shown in the Category 5 of self-assessment of energy level, in comparison with other self-assessment categories. A statistically significant difference was not found in test variables 422: MinT and ZB/SB.
Additionally, the post-hoc analysis (Table 4) more precisely shows how undesirable self-assessment of category 5, which states: „I do not have enough energy; I get tired easily“, significantly differentiates the efficiency of mental processing in more favourable categories of self-assessment such as Category 6 which states: „I feel quite fresh“; or Category 7: „I'm fresh and I have a lot of energy“ or Category 8: „I have a lot of energy; I feel the need for action“.

Table 4
Post-hoc analysis UKT, Fisher LSD test

UKT average	55.208	50.866	47.677	46.951
Self-assessment	**5**	**6**	**7**	**8**
I do not have enough energy; I get tired easily.		0,034057	0,000443	0,002016
I feel quite fresh.	0,034057		0,034903	0,074694
I'm fresh and I have a lot of energy.	0,000443	0,034903		0,748150
I have a lot of energy; I feel the need for action.	0,002016	0,074694	0,748150	

Source: Prepared by authors, Statistica 10

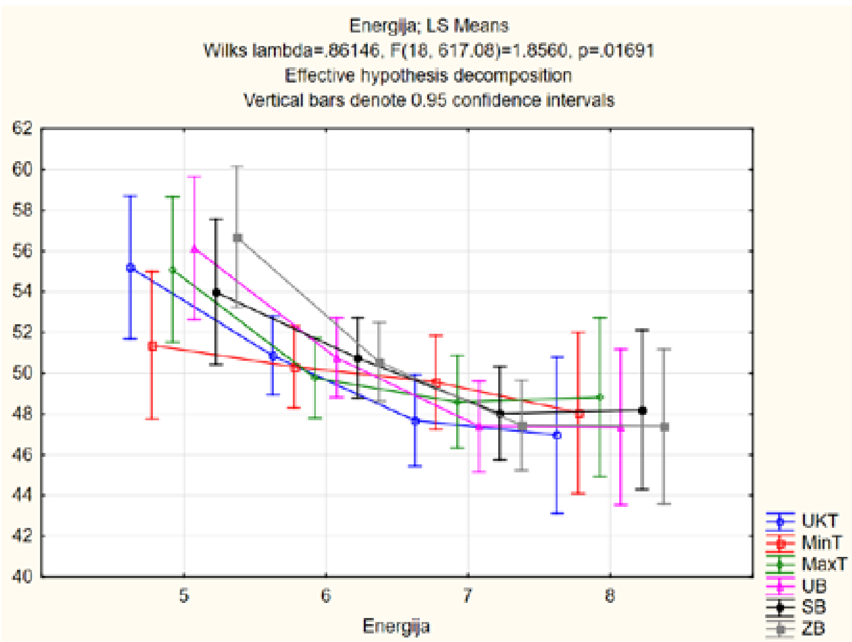

Fig. 2.
One-way ANOVA analysis of dependent variables UKT, MinT, MaxT, UB, SB and ZB and the category variables of self-assessment of energy level
Source: Prepared by authors, Statistica 10

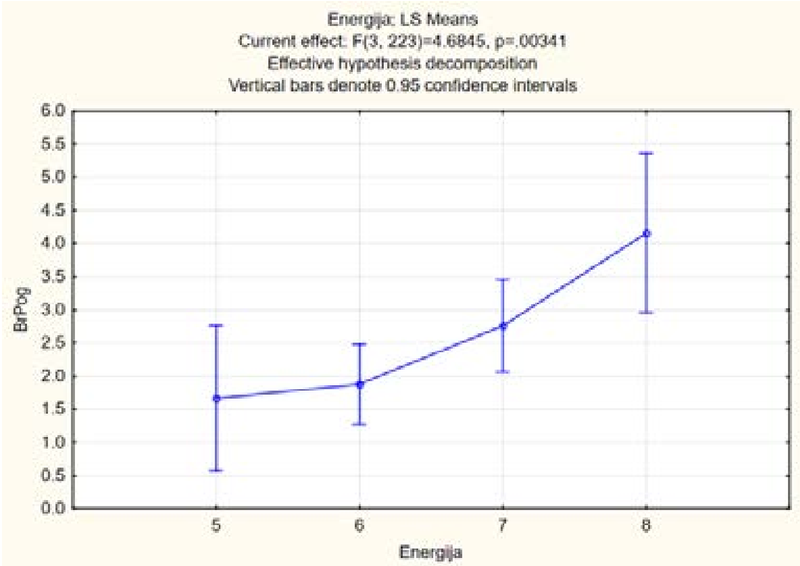

Fig. 3.
One-way ANOVA analysis of dependent BrPog variables and the category variables of self-assessment of energy level
Source: Prepared by authors, Statistica 10

From the Figure 2, it is noted that the mental speed and stability of the mental processing of the pilots (expressed in UKT, MaxT, UB, SB and ZB) is lower than the self-assessment of energy level. However, this is not the case with the attention indicator (number of errors), i.e. the concentration of the pilot was worse as the energy rating was higher (Figure 3).

5. Fatigue Risk Management and Related Safety Risk Assessment

Fatigue Risk Management System (FRMS) is "a data-driven means of continuously monitoring and maintaining fatigue related safety risks, based upon scientific principles and knowledge as well as operational experience that aim to ensure relevant personnel are performing at adequate levels of alertness" (IATA; ICAO; IFALPA, 2015).
Information and reports' data related to crew alertness are routinely collected and analysed by the means of an effective FRMS. FRMS helps to control the risk associated with fatigue. FRMS can be established as a standalone system or as a part of the Safety Management System (SMS).
FRMS aims to ensure that flight crew members and cabin crew are sufficiently careful to work at a satisfactory level of performance. The principles and processes from the Safety Management System (SMS) are applied to manage the specific risks associated with the crew member's fatigue. Like SMS, FRMS seeks to achieve a realistic balance between safety, productivity and costs (IATA; ICAO; IFALPA, 2015). It seeks to proactively identify opportunities to improve operational processes and reduce risk, as well as to recognize disadvantages after adverse events. The structure of the FRMS is modelled on the SMS basic framework. Basic activities are Safety Risk Management and Safety Assurance. These basic activities are governed by FRMS policy and supported by FRMS promotion processes.
SMS and FRMS rely on the concept of an effective reporting culture, where staff are trained and are constantly encouraged to report any dangers (hazards) whenever recognized at the work environment (Steiner et al, 2012).
The FRMS's goals are to "manage, monitor and mitigate the effects of fatigue to improve flight crew members' alertness and reduce performance errors" as well as to balance safety and productivity (Starr, 2017).
The use of SMS to manage fatigue is fundamental. Fatigue is recognized as aviation hazard and as such, it creates risks, for which is essential to maintain the solid SMS. Because of this, basic SMS elements should be established (Steiner et al, 2018).
Incorporation of an FRMS works in parallel with the elements of the Safety Risk Management component of the organization's SMS. Further, the FRMS supports the Safety Assurance component of SMS by providing, among other things, performance monitoring and a system of employees' reporting. Finally, Safety Promotion component of SMS, needs to establish safety as a core value with a sustained Safety Culture (Starr, 2017).

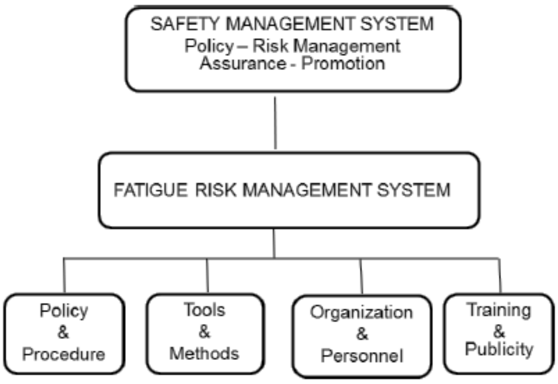

Fig. 4.
SMS and FRMS
Source: (Starr, 2017)

Safety Risk Management (SRM) is used to identify hazards, analyse identified hazards, conduct the safety risk assessment using the ICAO Doc 9859 tools (safety risk matrix), and to propose the risk mitigation measures in order to reduce, mitigate or eliminate risk.
The objective of safety risk management is to assess the risks associated with identified hazards and develop and implement effective and appropriate mitigations. Safety risk management is therefore a key component of the safety management process.
Fatigue is identified hazard to safety of air transport operations. Due to this fact, Fatigue Hazard is analysed and recognized as potential danger to safety of air operations.
Next step of SRM is Safety Risk Assessment. In order to obtain the risk level, it is necessary to evaluate Risk Probability (Table 5), i.e. how often does the fatigue occur; and it is necessary to evaluate Risk Severity (Table 6), i.e. what could be severity of such fatigue risk occurrence.

Table 5
Risk probability of the fatigue hazard

Likelihood	**Meaning**	**Value**
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	4
Remote	Unlikely to occur, but possible (has occurred rarely)	3
Improbable	Very unlikely to occur (not known to have occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Source: ICAO, 2018

Table 6
Risk severity of the fatigue hazard

Severity	**Meaning**	**Value**
Catastrophic	▪ Equipment destroyed ▪ Multiple deaths	A
Hazardous	▪ A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely ▪ Serious injury ▪ Major equipment damage	B
Major	▪ A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency ▪ Serious incident ▪ Injury to persons	C
Minor	▪ Nuisance ▪ Operating limitations ▪ Use of emergency procedures ▪ Minor incident	D
Negligible	▪ Little consequences	E

Source: ICAO, 2018

Once the Risk Probability and Risk Severity are defined, the Risk Level is obtained from the Safety Risk Assessment Matrix (Table 7), and by obtaining the Risk Level, the Tolerability (Acceptability) Area of the risk can be determined.

Table 7
Risk severity of the fatigue hazard

Risk probability		**Risk severity**				
		Catastrophic **A**	Hazardous **B**	Major **C**	Minor **D**	Negligible **E**
Frequent	**5**	**5A**	**5B**	**5C**	**5B**	**5A**
Occasional	**4**	**4A**	**4B**	**4C**	**4D**	**4E**
Remote	**3**	**3A**	**3B**	**3C**	**3D**	**3E**
Improbable	**2**	**2A**	**2B**	**2C**	**2D**	**2E**
Extremely improbable	**1**	**1A**	**1B**	**1C**	**1D**	**1E**

Source: ICAO, 2018

The margins of fatigue risk belong to the Tolerable Area, and appropriate actions need to be conducted accordingly, as described in Figure 5.

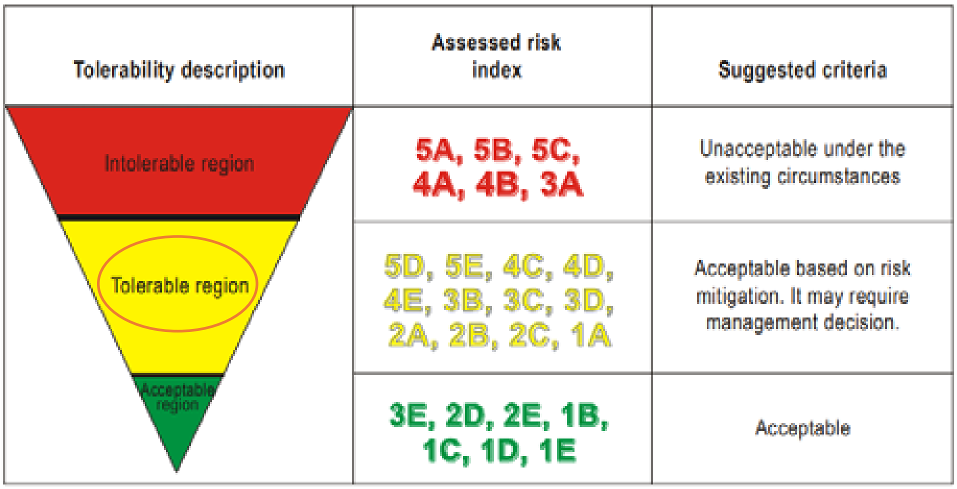

Fig. 5.
Tolerability of the Risks
Source: ICAO, 2018

Considering what the Fatigue Hazard represents, it is mandatory to ensure Risk Mitigation measures in order to reduce risk level to the acceptable. Therefore, further research, to explore and define appropriate mitigation measures to reduce fatigue risk levels to the acceptable, should be conducted.

6. Conclusion

According to the results presented in this study, it can be argued that the objective indicators of mental efficacy determined by chronometric testing on the CRD 422 test agree with the individual self-assessment determined on the verbal "self-assessment scale of energy level". That is indicated by the significance of the differences (ANOVA analysis procedures) at the risk level less than 0.05%, or at the risk level in promiles.
The exception was the BrPog variable, which is the indicator of attention when solving tasks in the CRD 422 test for which a statistically significant difference in risk level was observed, but the (paradoxically) concentration of attention was lower as self-assessment was more favourable. This finding needs to be furtherly explored.
Fatigue affects various cognitive abilities such as alertness, memory, getting around in space, learning, problem solving, decision making, and more. Fatigue Risk Management System (FRMS) and Safety Management System (SMS) have very important role in reducing fatigue risks and should be used as a tool to determine and manage fatigue hazards.

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MODEL OF THE OPERATION PROCESS OF AIRCRAFT IN THE TRANSPORT SYSTEM

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Abstract: Correct operation of technical facilities ensures uninterrupted performance of tasks. Therefore, reliable description of operation process is an important issue that enables proper control of its processes, as well as to ensure and maintain required operation level. In this case, appropriate mathematical methods and tools are applied, which provide important knowledge, not only to persons responsible for carrying out orders, but also to the logistical component responsible for securing them. In many situations, the processes of mathematical analysis of the operation process are hampered by traditional method of processing and recording documentation. Modern systems that enable to obtain accurate and multidimensional information on the activities carried out by technical facilities are implemented in companies gradually, sometimes even not at all. Although such traditional records seem to be an obstacle to use forecasting mathematical tools, this article presents a mathematical description of aircraft operations based on such information. ARIMA model was proposed, which allowed not only for short-term forecasting of future flights, but also for current evaluation of operations, possibility to control and coordinate flight schedules, especially in terms of maintenance and repairs. Such information enabled to improve implementation process of performed tasks, including sustainable use of human and technical resources.

Keywords: forecasting, aircraft, ARIMA model, transport means.

1. Introduction

The world of science and technology, among many different areas, also focuses on development and improvement of the theory and practice of creating, exploiting and eliminating of technical objects, thus creating three basic branches of knowledge dealing with the science and technology of technical objects exploitation, presented in Fig. 1 (Będkowski and Dąbrowski, 2000).

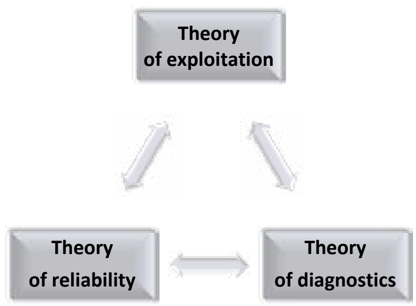

Fig. 1.
Pillars of science on exploitation
Source: Adapted from (Będkowski and Dąbrowski, 2000)

An aim of the exploitation theory is to define such conditions of using technical objects, which will ensure their highest efficiency in the safest and least cost way (theory of use) and will allow to maintain, and if necessary to restore the lost properties during operation (theory of operation) as optimally as possible. However, the theory of reliability refers to period of designing and manufacturing technical objects by defining the principles of creating constructional and functional structures, as well as operating procedures ensuring their best performance. The theory of diagnostics, in turn, concerns the process of controlling exploitation of technical objects. Therefore, it requires knowledge of their condition and deals with identifying the most accurate, cheapest and safest way to obtain information on the technical condition of objects (Będkowski and Dąbrowski, 2000). Methods of diagnostic tests enable to recognize the object state on the basis of available observation results of its operation and the existing interactions between object and its surroundings. On this basis, maintenance and repair intervals are defined. Timetables for restoration works of the object must take into account the uninterrupted performance of necessary tasks (Woropay, 1996) to ensure that there are no delays and that the remaining objects are operational.

Knowledge concerning diagnostics of the condition of possessed technical objects is particularly important in systems requiring sudden, unexpected interventions. Such a system is, for example, the armed forces, and in particular their air component. Ensuring the safety of flights is the most important issue, and therefore it is necessary to respect the established maintenance intervals throughout the entire service life. Furthermore, these processes require a certain amount of time and their implementation excludes the aircraft from operation. This may affect the readiness of the entire base and efficiency of assigned tasks. That is why it is so important to take into account, in the process of command, all the factors that may interfere with proper functioning of the base. Nevertheless, the specific nature of

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armed forces means that most of taken decisions are based on the knowledge and experience of commanders, as well as on laws and regulations governing the operation of the army. Existing modern technologies on the civil market for identification, collection and representation of data, which may be a support in the management of the fleet, are being introduced gradually in the army. Difficulty of their implementation results mainly from the size of the army, which is formed by many military units, differing in location, tasks, equipment, and the level of computerization. Moreover, there is still functioning traditional (non-digital) way of document flow and archiving, which makes it difficult to use not only the latest technological achievements, but also mathematical methods and tools based on the data obtained from this system. Standardization and digitization of such a system requires huge financial expenses and a long period of implementation. At the same time, priority projects must also be carried out, related to preparing soldiers to conduct combat activities, which requires not only permanent training, but also modernization of possessed resources, improvement of their condition or exchange for new ones. However, products and services used in civil activities that enable to identify, locate and monitor transport means would be for commanders not only support of everyday operations, and guarantee more efficient and effective resource management, but would also provide reliable data and forecasts on their basis. So far, both due to the specificity of the army and mentioned traditional method of documentation processing, the use of mathematical forecasting tools in the army has been negligible. However, the present study attempts to predict the activities carried out by aircraft on the basis of currently possible to obtain available data. Based on empirical data from two years of operation, a method for describing aircraft operating states based on the ARIMA model has been proposed and is presented in the article. It enables to assess the readiness of military facilities and ultimately to analyze the areas, in which they can be improved.

2. Introduction to ARIMA Model

The evolution in time of any object with properties described mathematically by a set of one-dimensional random variables $X(t)$ with values $x(t)$ randomly dependent on physical (continuous) or discrete (e.g. calendar) time t is called the time series. Otherwise, it is a sequence of information in chronological order. Analysis of time series enables to determine the nature of studied phenomenon, to find (if any) deterministic element and to present the analyzed process as a function of random and deterministic elements. This enables to forecast future values of time series (Bielińska, 2007).

Among the models used to describe real stochastic processes, the ARMA stationary series (Autoregressive Moving Average Model) and ARIMA non-stationary series (Autoregressive Integrated Moving Average Model) take a special position. These are models based on the autocorrelation phenomenon, developed by integration of the autoregressive model (AR) and moving average model (MA) (Bielińska, 2007; Czyżycki, Klóska, 2011).

The ARMA model assumes that the value of forecasted variable at time *t* depends on its past values and on differences between its past real values and the values obtained from the model – forecast errors. The form of ARMA model is as follows (1) (Dittmann, Szabela-Pasierbińska, Dittmann, Szpulak, 2011; Sokołowski, 2016):

$$y_t = \alpha_0 + \alpha_1\, y_{t-1} + \alpha_2\, y_{t-2} + \ldots + \alpha_p\, y_{t-p} + \varepsilon_t\, \beta_0 + \varepsilon_t - \beta_1\, \varepsilon_{t-1} - -\beta_2\, y_{t-2} - \ldots - \beta_q \varepsilon_{t-q} \quad (1)$$

Determination of the ARMA model is used to determine three parameters: autoregressive parameter (p), differential order (d) and moving average parameter (q). Since the classic ARMA models can only be used for stationary series, it is necessary to analyze this state. The most common cause of non-stationary is the existence of a trend or seasonal variations, which can be eliminated by applying logarithmic or differential transformations, thereby leading the series into stationary. Then we are talking about the ARIMA model. The use of a letter *i* means that the studied time series has been differentiated. Non-stationary caused by seasonal variations is eliminated by seasonal differentiation. This is the SARIMA model (Seasonal ARIMA), which allows for modelling of seasonal data. It is constructed by supplementing the ARIMA model with element resulting from the seasonality of analyzed process, taking into account P – seasonal delays row of AR type, Q – seasonal delays row of MA type, D – seasonal differentiation component

3. Characteristics of the Research Object

In the process of operating an aircraft, it is essential to plan the operations process in such undisturbed way so that orders could be executed smoothly, flight safety could be ensured and the maintenance process could be properly scheduled. Therefore, commanders should be provided with reliable information concerning planned flights in order to ensure the continuity of tasks and proper use of resources. The possibility of forecasting may ensure excellent support for military scenarios.

The study was carried out on flights by military aircraft. The documentation was available, which is a reflection of the exploitation year, and on its basis the possible technical conditions were identified, in which the analyzed objects are located. The article presents analysis of the exploitation state – performance of task, which is the flight. Collected data was divided into three groups, due to great variability, which precludes the estimation of reliable forecasts. In this way was created:

- short flights, lasting up to 30 minutes, these were flights characterized by the highest frequency,
- average flights, lasting from 30 and 60 minutes, also with a high intensity level,

- long flights – above an hours, which intensity was lower in comparison to short and average flights.

Results of study for a group of short flights are presented in the following section. The first step was a visual inspection of studied series, presented in Fig. 2. Individual observations are noticeable, definitely distant from others, which suggest that these are untypical observations. This is confirmed by the box plot in Fig. 3.

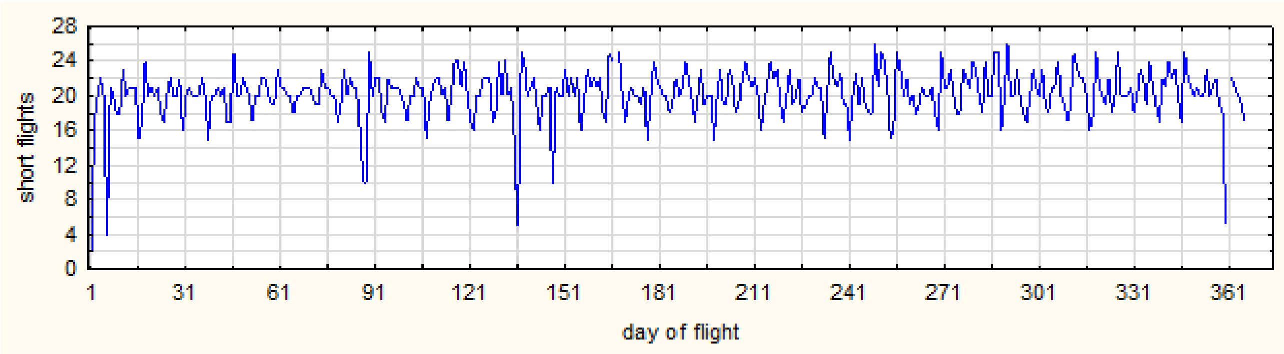

Fig. 2.
Diagram of studied time series
Source: own study

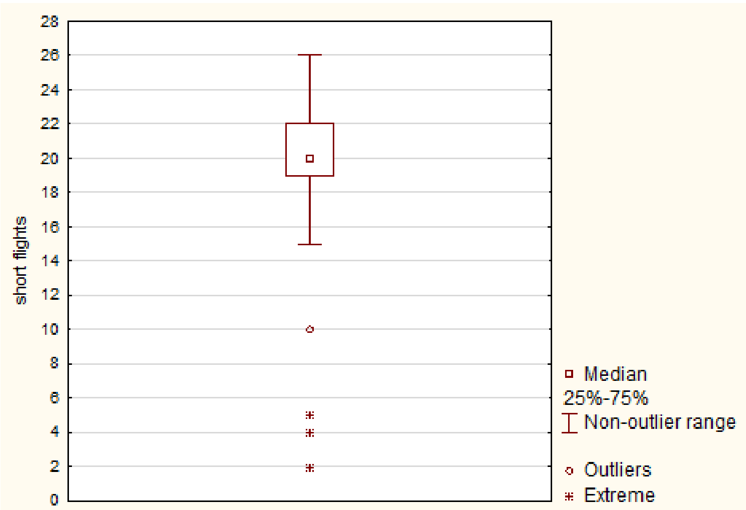

Fig. 3.
Box plot of studied series
Source: own study

A detailed analysis of disturbing observations showed that they concern national and church holidays, when the activity of base and the number of performed tasks is negligible. In the scale of the whole process, there were 6 observations on: 1.01 (the New Year), 6.01 (Epiphany), 27-28.03 (Easter), 15.05 (Pentecost), and lack of observations on the following dates: 15.06 (Corpus Christi) and 25-26.12 (Christmas Day). It was decided that these observations would be unusual and would be replaced with a median, which would result in the following process (Fig. 4):

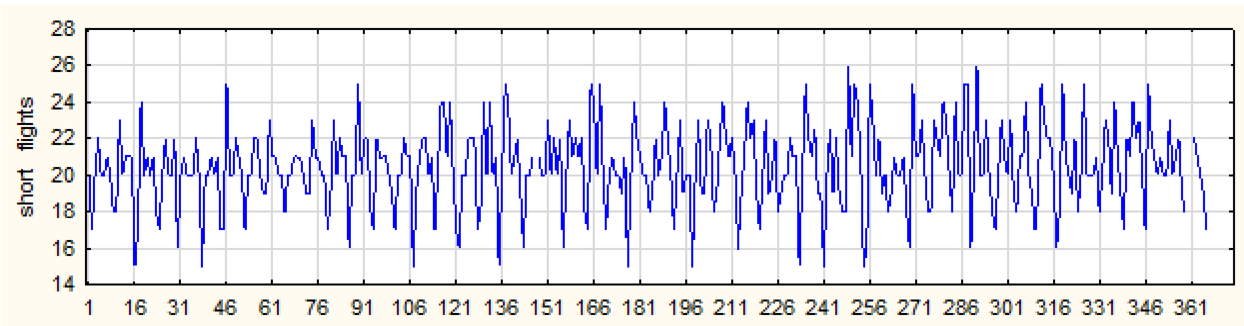

Fig. 4.
Diagram of transformed time series
Source: own study

Analysis of empirical distributions of the duration of analyzed exploitation state is necessary not only to correct doubtful observations, but also to avoid analytical uselessness of the model, which may be caused by e.g. multimodality of distributions.

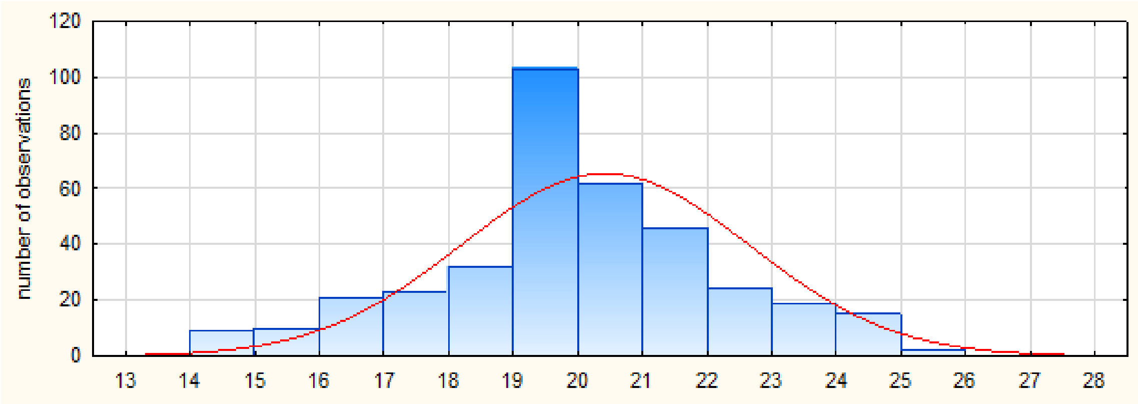

Fig. 5.
Histogram of studied series
Source: own study

The distribution is not normal, but fulfils the criterion of mono-modality (Fig. 5). Moreover, it does not show a noticeable upward or downward trend (Fig. 4) and therefore there is no basis for assuming the existence of a trend. However, a certain seasonality of the process is noticeable on enlarged diagram (Fig. 6).

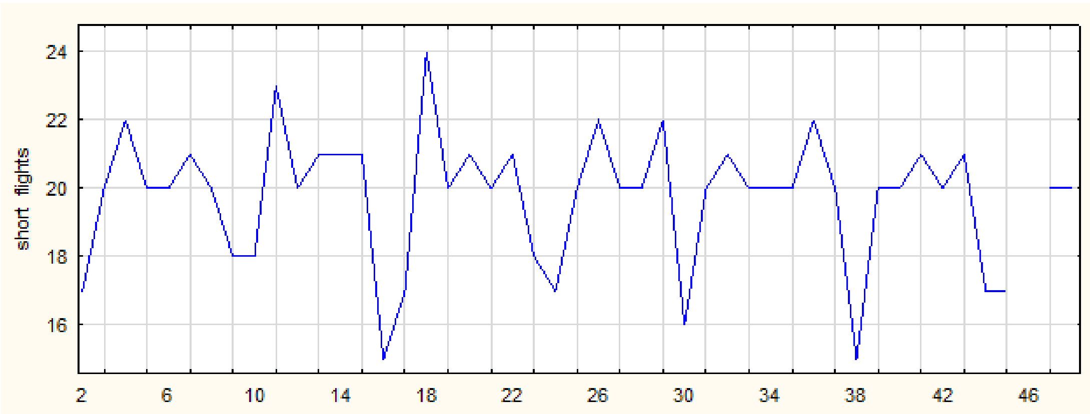

Fig. 6.
Approximate diagram of time series
Source: own study

It turns out that the intensity of performed tasks is much lower on Saturdays and Sundays in comparison to remaining weekdays, while the majority of tasks are performed on Mondays, as confirmed by the categorized box plot (Fig. 7).

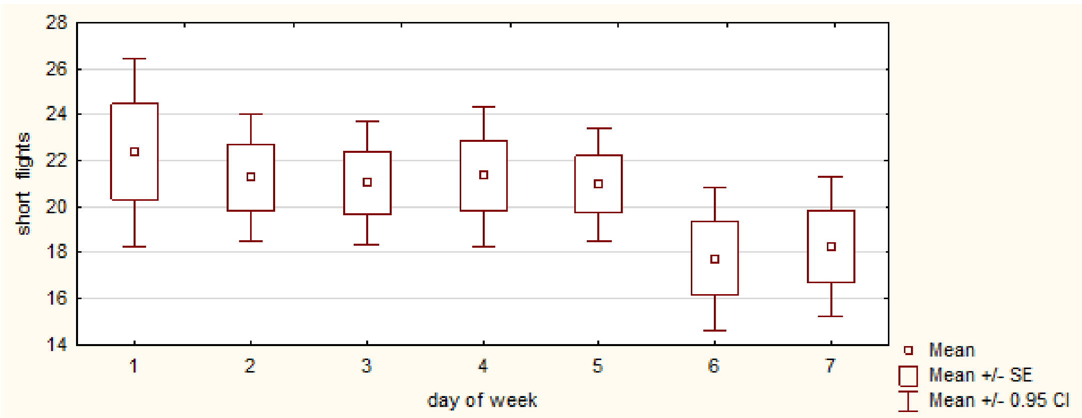

Fig. 7.
Box plot of studied series according to weekdays
Source: own study

The seasonality of process causes that the studied series is not stationary, and due to the fact that ARIMA methods can only be applied to stationary series or led to stationary series, it is necessary to achieve at least stationary in a wider sense (invariability during the first and second moment) (Dittmann, *et al.,* 2011; Sokołowski, 2016). The autocorrelation function ACF (Fig. 8) and partial autocorrelation function PACF (Fig. 9) is helpful in the assessment of stationarity, as well as in model construction.

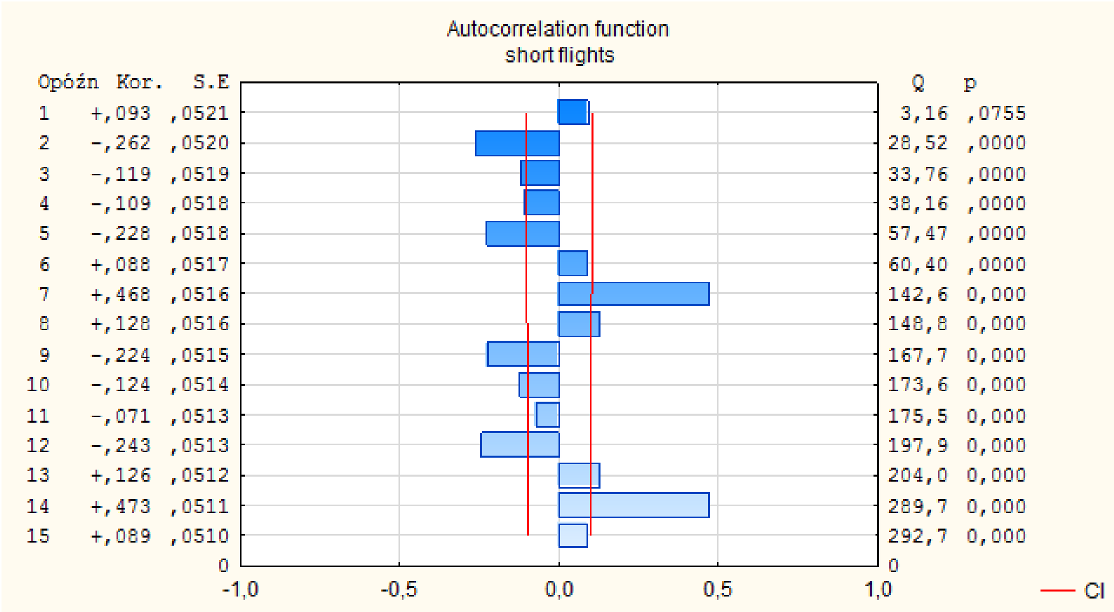

Fig. 8.
Autocorrelation function diagram of studied series
Source: own study

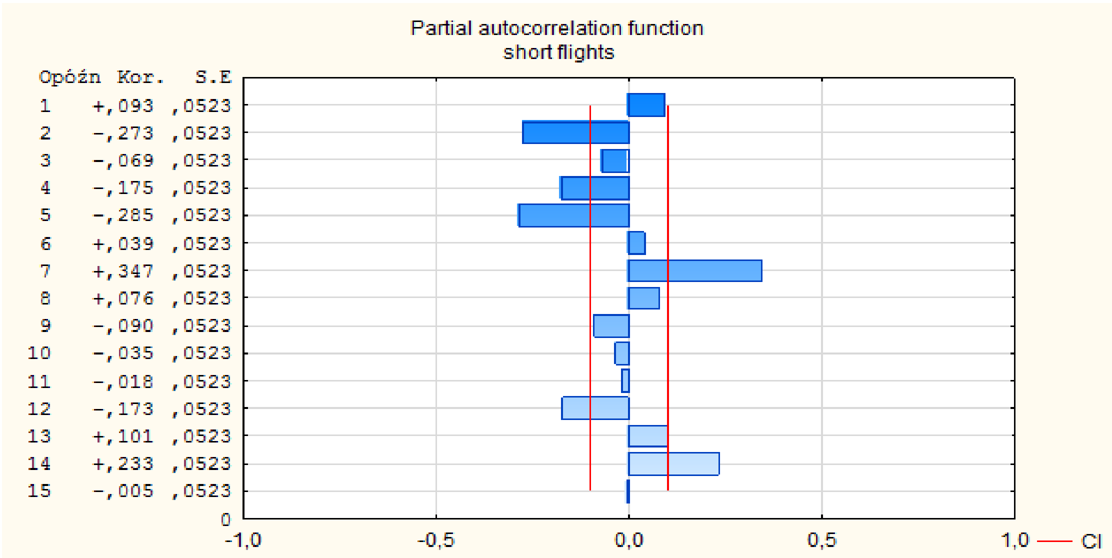

Fig. 9.
Partial autocorrelation function diagram of studied series
Source: own study

Diagram of partial autocorrelation function PACF suggests that it should not be the autocorrelation process. However, the autocorrelation function ACF decreases for most of delays, taking a form of fading sinusoid, which confirms that the process is not stationary (Bielińska, 2007). In the first place, the non-seasonal differentiation was conducted and the autocorrelation function was re-studied (Fig. 10).

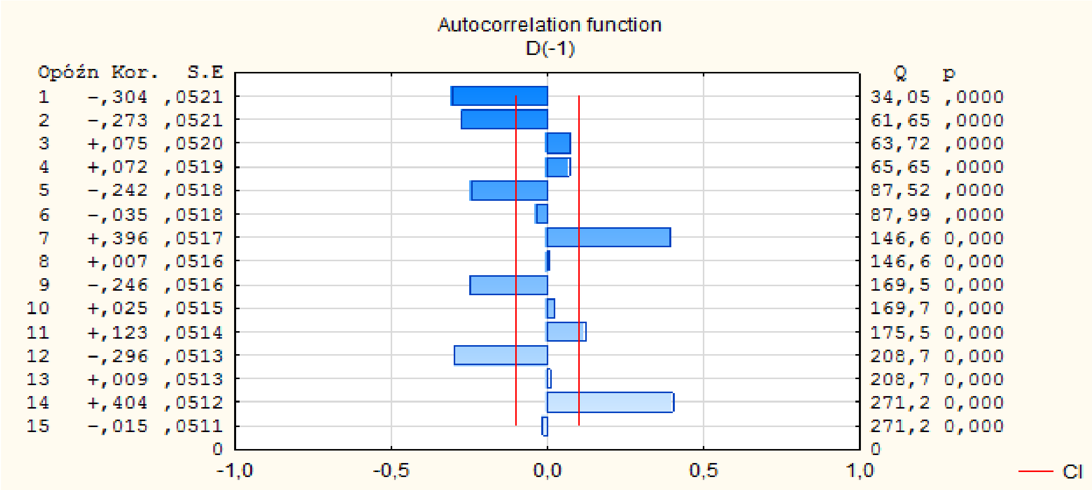

Fig. 10.
Diagram of autocorrelation function with non-seasonal delay d=1
Source: own study

Most of significant values of the autocorrelation function disappeared, but there also remained significant values for the first two delays. There is also a clear correlation for delay 7 and its multiplication, which suggests the need to carry out the process of seasonal differentiation with a delay equal to 7. Finally, it was decided to estimate the ARIMA model with the testing down method, assuming initially that it is a moving average process with the parameter $q = 2$. To stabilize the variance, the series was also logarithmed. In order to take into account seasonal variations resulting from lower intensity of flights, on weekend days the series were subject to seasonal variation with a delay of 7 and the seasonal moving average Q was estimated. Due to an ambiguous course of autocorrelation function, the model with autoregressive parameter was also tested. Selected estimation results are presented in Table 1 (statistically significant parameters are underlined). To estimate the models, a time series shorter by the last five observations was used, which was retained as a test series for the analysis of forecast.

Table 1
Summary of estimation results

		SARIMA model (1.1.2)(0.0.1)	SARIMA model (0.1.2)(0.1.1)	SARIMA model (0.1.2)(0.1.1)	SARIMA model (0.1.2)(0.0.1)	ARIMA model (1.1.1)(0.1.0)
Transformation		ln(x), d(1)	ln(x), d(1), D(7)	ln(x), d(2), D(7)	ln(x), d(1)	ln(x), d(1), D(1)
Constant						0.00021
Parameters	p(1)	-0.4368				-0.2568
	q(1)	0.43928	0.67174	-0.0686	0.90482	0.94920
	q(2)	0.55359	0.32813	0.91346	0.09033	
	Qs(1)	-0.3323	0.60453	0.89515	-0.3360	
	D		7	7		7
MS		0.01055	0.00884	0.00732	0.01065	0.02293
Residuals		significant residuals autocorrelations exist	significant residuals autocorrelations exist	no significant residuals autocorrelations exist	significant residuals autocorrelations exist	significant residuals autocorrelations exist

Source: own study

The evaluation of proposed models first comes down to checking whether the estimated parameters are statistically significantly different from zero, as the insignificant parameter informs that the variable does not affect fitting the model and can be omitted from it. In listed models only in SARIMA model (0.1.2)(0.0.1) and ARIMA (0.1.2)(0.0.1) model, one parameter is statistically insignificant. Therefore, it was necessary to use different measures. These can be different information criteria or the value of mean error MS, but it is particularly important to diagnose the distribution of residuals, which in a properly constructed model should be characterized by randomness and symmetry. Therefore the stationary and normality of their distribution should be investigated. Again, the autocorrelation functions and partial autocorrelation functions were used for this purpose. It turned out that only for SARIMA (0.1.2)(0.1.1) model the correlograms met the above assumptions. The diagrams of ACF and PACF functions presented below (Fig. 11 and Fig. 12) show the lack of statistically significant autocorrelations and partial autocorrelations, whereas the normality graph (Fig. 13) does not differ significantly from normal distribution and enables to consider the model residues as a white noise process.

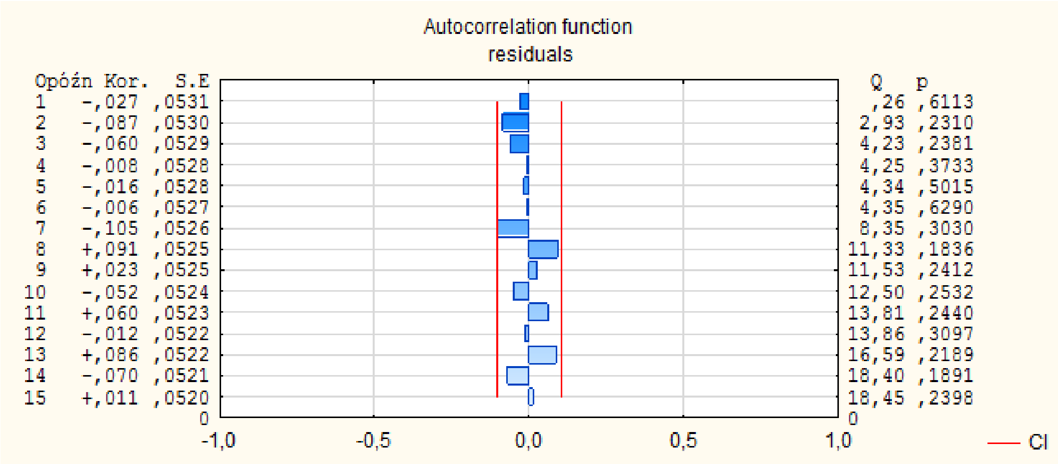

Fig. 11.
Autocorrelation function diagram of model residues
Source: own study

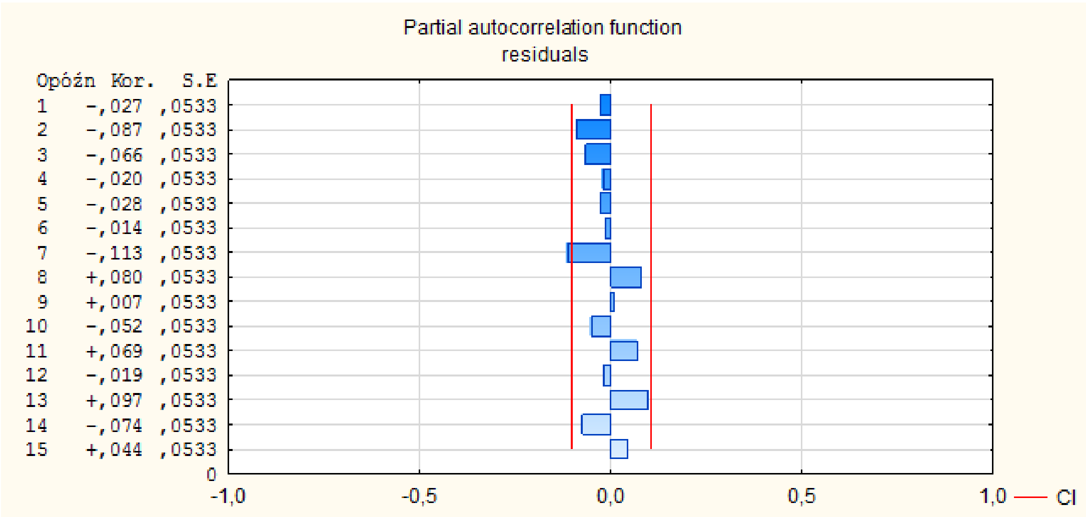

Fig. 12.
Partial autocorrelation function diagram of model residues
Source: own study

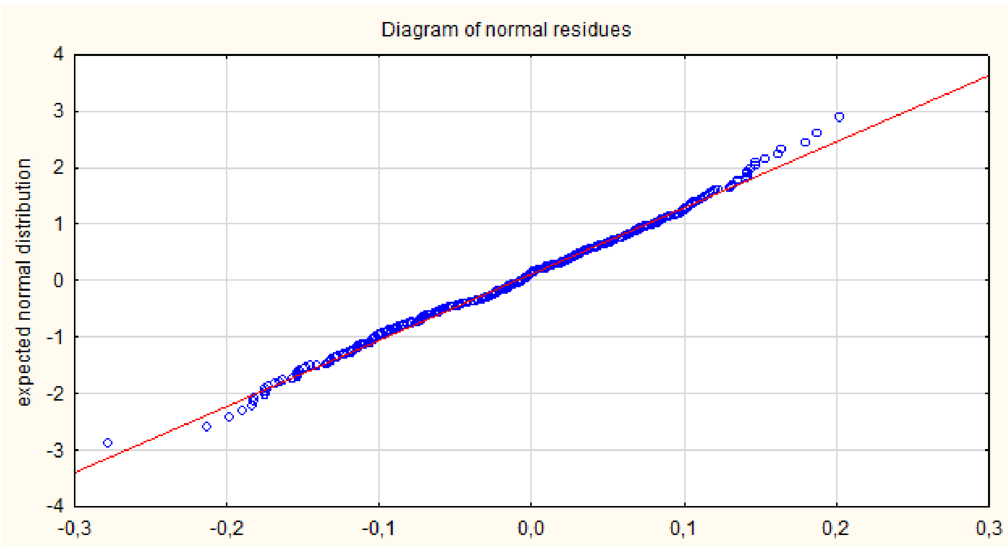

Fig. 13.
Diagram of normal residues
Source: own study

Positive verification of the model enabled to determine the forecast (Fig. 14) and assess it on the basis of known observations, which were retained as test observations that along with a relative error in the forecast were presented in Table 2.

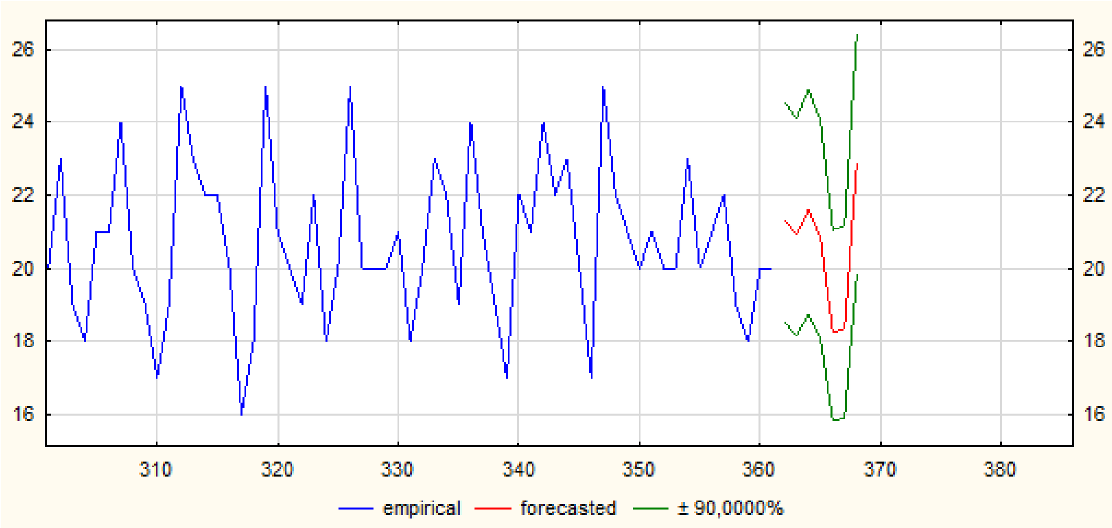

Fig. 14.
Diagram of studied series and forecasts
Source: own study

Table 2
Verification of obtained forecast

Date	Number of observations	Forecast	Empirical data	Mean standard error Ψ [%]
2017-12-27	367	18,27851	21	-1,5932
2017-12-28	368	22,75831	21	0,3604
2017-12-29	369	21,03319	22	1,80208
2017-12-30	370	21,00812	21	0,70824
2017-12-31	371	21,37311	17	-7,3903
2018-01-01	372	20,94401		
2018-01-02	373	17,88985		
2018-01-03	374	18,40636		
2018-01-04	375	22,57938		
2018-01-05	376	21,18032		

Source: own study

The obtained results of forecasting errors are small, which is particularly satisfactory as the test observations concerned the end of the year, which could cause significant errors. The biggest forecasting error concerns 31.12.2017, but it is New Year’s Eve, a day preceding the day off, i.e. the New Year. Therefore, the exploitation intensity was lower, which caused the forecast to be overestimated. An approximate diagram of analyzed time series, taking into account test observations and forecasts, is presented in Fig. 15.

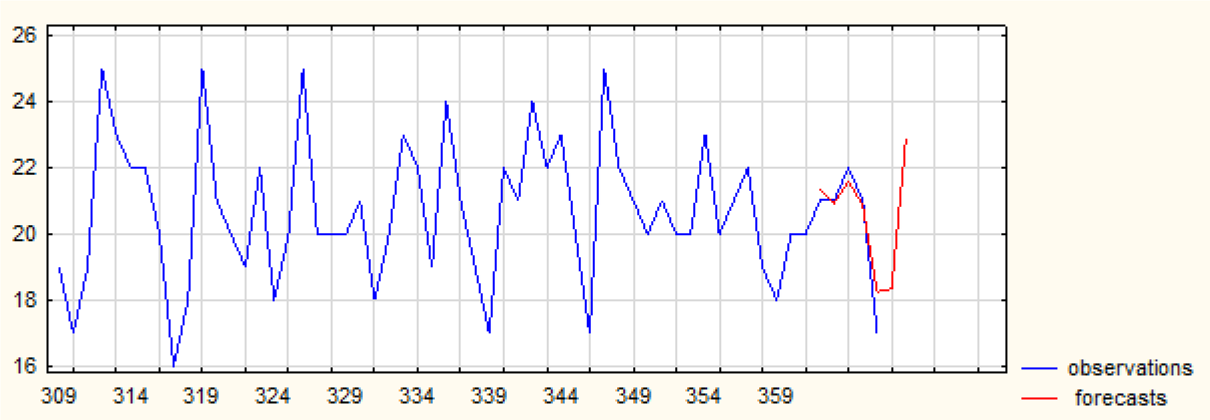

Fig. 15.
Approximate diagram of studied series and forecasts
Source: own study

Of course, each forecast requires constant monitoring and verification, and its task is only to support management processes, and not to provide ready-made answers. Conducted analysis showed that current methods of data acquisition, processing and archiving – used by the armed forces – allow for creation of reliable models, which can be used in decision-making processes concerning military exploitation systems. The combination of commander's experience and mathematical methods can turn out to be a very effective approach.

3. Conclusions

The article presents an example of practical use of the ARIMA model for forecasting military exploitation systems. Using the time-series analysis, based on the dependence of studied characteristic (variable) from the time, led to conclusions concerning the dynamics of studied phenomenon in the near future. Short-term forecasts are important not only in the process of managing a company, but also in command, in the military environment. They allow for proper delegation of tasks, ensure necessary forces and resources to carry them out, as well as more accurate decisions associated with preparation to carry out potential orders.
Conducted study enabled to predict the demand for flights with a high degree of probability. This allows the commander to plan tasks more precisely for his subordinate staff, to manage his aircraft, and as a result with great credibility to determine the readiness of system, which is managed.

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SLOT ALLOCATION PROCESS AS A TOOL FOR OPTIMAL USE OF AIRPORT CAPACITIES

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Abstract: The air traffic system is characterized by insufficient infrastructure capacity, particularly on the congested airports. Slot allocation process is an operational approach that is used to maximize the utilization of available airport infrastructure. The purpose of the aerodrome slots allocation is to optimize airport operations, develop an optimal airlines flight schedule and ensure the introduction of new airlines. The current slots allocation process in the European Union, which is based on the IATA guidelines, is not optimal and requires improvements. In addition is presented the slot allocation method based on the IATA guidelines. The paper presents a slot allocation processes at European Union airports and shows Dubrovnik airport case study.

Keywords: airport capacities, slot allocation, airlines, Dubrovnik airport.

1. Introduction

Due to global air traffic growth and insufficient airport infrastructure development the number of congested airports is increasing. Consequently, there are significant delays at arrivals and departures at airports, resulting in lower service quality and penalties for air carriers. In order to reduce the delays caused by insufficient capacity, airport slots were introduced.
The International Air Transport Association (IATA) in collaboration with air carriers, airports and air traffic industry experts, has developed a set of procedures whose main goal is to provide guidance for the implementation of slot allocation process at the congested airports.
The slots allocation process at airports can performed on the primary and secondary mode. The primary slot allocation at European airports is administrative process defined in the EU Slot Regulation 95/93, based on the global aerodrome slot allocation principles prescribed in the IATA Worldwide Slot Guidelines (IATA, 2017). According to the regulation, the primary allocation applies historical criteria for the use of airport slots held by air carriers present on the market for a longer period. Air carriers entering the market can access only the remaining available capacities. Secondary slots allocation implies the process of exchange and slots trading between air carriers (Zografos et al., 2017).

2. Airport Slot Allocation

Slots are permits for carrying out aircraft operations when traffic demand is higher than the available airport capacity (Kalligiannis, 2010). An air carrier who cannot perform operations within the slot time, or if it does not intend to use it, is obliged to return that slot to the airport for reallocating to other air carriers. Definition of slot use proves that airport slots are not and cannot be the property of air carriers.
Slot allocation is a planning tool to ensure that the available slots are efficiently used at the coordinated airports where infrastructure capacity does not meet air traffic demand. At such airports, a slot coordinator shall be designated to allocate aerodrome slots to air carriers. Also, the purpose of slot allocation is the transparent, non-discriminatory and optimal use of aerodrome capacities as well as the efficient and optimal use of the slots allocating process (Butcher, 2017). Aerodrome slots are allocated twice a year, for the summer and winter season. Today's slots allocation system is based on the historical rights. Historical rights have carriers who fulfilled the condition defined by the *Use it or lose it* rule (IATA, 2017). The current slot allocation system, based on historical rights, does not allow optimal flight schedules for new air carriers.
There are 73 airports in Europe partially or fully coordinated and slot allocations are based on IATA guidelines (De Wit and Burghouwt, 2008).
The slot allocation process in Europe is based on the airport coordinating parameters such as: capacity of the runway, passenger terminal and other infrastructure components. At heavily congested US airports, additional negotiations should be carried out to allow the use of appropriate gate, check-in counters, baggage handling and other important parameters. Aerodrome slots allocation may also relate to other operational or environmental criteria that affect the available capacity.
The airports are categorized, regard to the traffic level they are exposed and airport capacities according to the IATA, into three categories (IATA, 2017):

- Level 1 - non-coordinated airports;
- Level 2 - schedule facilitated airports;
- Level 3 - coordinated airports.

Level 1 airports represent airports where currently available infrastructure meets the traffic demand at all times of the year.

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Level 2 airports are those airports where there are potential for traffic congestion at certain time periods. Excessive congestion over a given period may adversely affect the regular operations at the airport.
Level 3 airports are those where service providers have not sufficiently developed airport capacities or where the government has set conditions that preclude the fulfillment of traffic demand. At these airports, the slot coordinator must be appointed to allocate aerodrome slots to air carriers (IATA, 2017).

3. Slot Allocation Rules

The primary criteria for initial slots allocation is based on the historical rights and coordinators should allocate airport slots according to the next priority order (IATA, 2017):

- Operations performed on a regular basis;
- Non- regular („Ad Hoc ") operations;
- Other operations.

When historical slots and changes of historical slots are allocated, the coordinator establishes a slot pool that includes historically allocated, non-allocated and new created aerodrome slots (IATA, 2017). In the initial allocation phase, 50% of the slots in the pool must be allocated to new air carierrs. An exception is the case where the requirements of new air carriers on the market are less than 50% of the total requirements of all carriers at a particular airport (IATA, 2017).
When a slot can not be allocated using the primary allocation criteria, additional factors are considered, such as: time of operation, type of operation and market, competition, the airport working hours, passenger and other user requirements, local guidelines and regulations, frequency of operations etc.

4. Historical Slots and *Use it or lose it* Rule

The principle of slot allocation at the EU airports is based on the slot historical rigths (IATA, 2017). Historical slots are series of slots that have the advantage for the next equivalent flight season. "Historic precedence applies to a series of slots that was operated at least 80% of the time during the period allocated in the previous equivalent season" (IATA, 2017). Coordinators are obliged to inform the carriers in advance if there is a risk that this condition will not be fulfilled. This criterion is called the *Use it or lose it* rule. If the condition of 80% of the slot allocation is not met, the slots will be returned to the slot pool after the end of the allocation period.

4.1. Justified Non-utilization of Slots

Slots which are not used will be considered as realised if the non-utilization is justified for any of the following reasons (IATA, 2017):

- Interruption of air traffic services because *force majeur* (closing an airport or part of the airspace because of the bad weather conditions…);
- Actions taken to harm and sabotage the normal provision of air carrier services such as strikes.

4.2. Intentional Misuse of Slots

At the level 3 airport slots must be allocated to each carrier before starting operations. The following actions are considered to be misusing slots (IATA, 2017):

- keeping allocated slots for which, the carrier has no intent to use, transfer, exchange or use for shared operations ("Slot Babysitting");
- keeping allocated slots to reduce airport capacity for a certain period to other carriers;
- requiring new slot allocation that the carrier does not intend to use;
- requiring slot allocation with the aim of gaining greater priority for future slots.

5. Slot Allocation Process at the Dubrovnik Airport

Dubrovnik Airport (DA) is an international airport. According to the passenger traffic data is the third Croatian airport with 2.3 million passengers in 2017 (Dubrovnik Airport, 2018). Based on the IATA methodology, the DA is categorized as level 2 airport. According to the IATA guidelines, the DA is obliged to use the term "Authorized Time" instead of the term „Slot"(in further text is mainly used term slot).
The available airport capacities are particularly congested in June, July, August and September with approximately 400,000 passengers in 2017. Daily peak periods were on Thursdays, Saturdays and Sundays with approximately 21,000 passengers (Dubrovnik Airport, 2018). During the summer season 95% of the annual traffic is realised, and in the winter season remaining 5%. The busiest month in 2017 at the DA was July with 442,122 passengers while the minimum passengers were handled in January, 19,329 (ratio about 23:1).
The number of aircraft operations also shows a large degree of inequality: in the busiest month, August, 3,524 operations, and at least busy month in January, 264 operations (ratio about 13.5:1).

The number of operations on the DA on an annual basis for the period 2010-2017 is shown in Table 1. The total number of operations in the table includes commercial and general aviation (Dubrovnik Airport, 2018).

Table 1
Number of operations on the Dubrovnik airport from 2010 to 2017

Year	Number of operations	Increase/decrease in %
2010	15,539	-
2011	16,050	+ 3.29%
2012	16,216	+1.03%
2013	16,126	- 0.56%
2014	16,492	+2.27%
2015	16,852	+2.18%
2016	19,244	+14.19%
2017	21,496	+11.71%

Source: (Dubrovnik Airport, 2018)

Continued growth in passenger traffic, rising tourist demand as well as the unstable political situation in reciptive tourist destinations in North Africa and the Middle East has resulted with expanding growth in traffic at Dubrovnik Airport and other coastal airports in Croatia. By construction of a new additional passenger terminal in 2017 enabled DA to increase the number of available slots (Fig. 1).

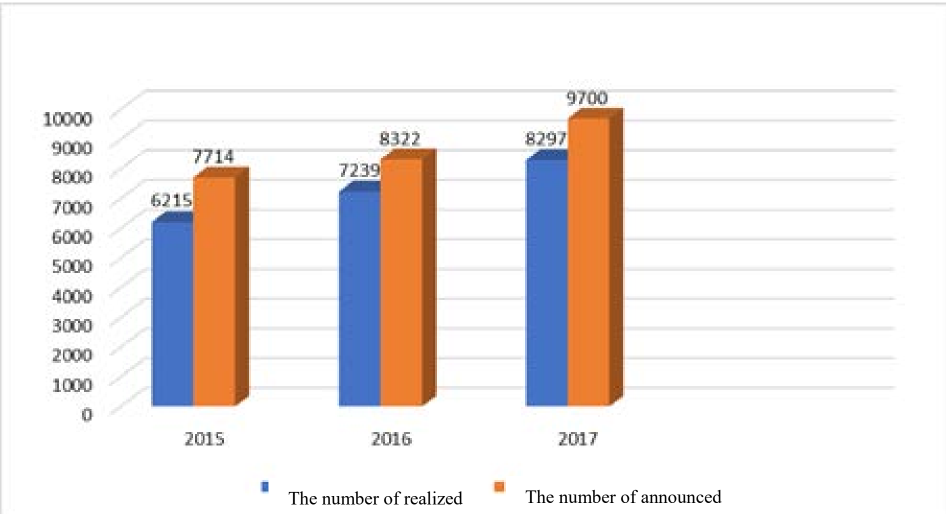

Fig. 1.
The number of realized and announced slots at DA in the period 2015-2017
Source: (Dubrovnik Airport, 2017)

Based on graph 1, the growth of allocated and realised slots in the period from 2015 to 2017 was significant. The main reasons for not realizing allocated slots are:

- less passengers in pre-season and post-season;
- the capacity fulfillment in peak season;
- other reasons such as canceling airline operations due to low ticket sales, excessive carrier's competition and bankruptcy of certain air carriers.

Regarding to slot capacity the problems of the DA are:

- the impact of the project realization on the airport capacity (during passenger terminal construction);
- non-optimal computer system for slots allocation;
- other problems such as human factors, procedures and standards.

5.1. The Impact of Slots Allocation

Airport infrastructure capacity depends on the capacity of a particular subsystem: runway with taxiways, apron, passenger terminal (check-in counters, security check, gates) etc. (WWACG, 2018).
Airports are characterized by certain limitations regarding the available capacity, and the mentioned limits are called co-ordinating parameters. According to the IATA WSG manual, the co-ordinate parameters are defined as technical, operational and environmental limits at the airport.
Coordination parameter depends on the airport type and can be categorized into four main groups (WWACG, 2018):

- environmental;
- Air Traffic Control;
- apron and runway;
- passenger terminal.

5.1.1. Enviromental Parameters

The environmental parameters that influence declared airport capacity are: maximum number of aircraft operations, noise limits, prohibition of night operations, reducing the maximum number of aircraft operations etc. (WWACG, 2018).
Limitations on the aircraft operations over a given period are introduced due to the impact of the airport's operation on the environment and population living in the vicinity of airport. Aircraft operations at the DA is determined by the declared runway and taxiways capacity of seven arrivals and seven departures per hour or 14 mixed operations hourly.
The maximum number of aircraft movements is limited by working time. During the summer working hours of the airport are from 04:00 to 21:00 UTC, and in winter from 05:00 to 21:00 UTC. Operations can be performed out of the working hours only if an agreement is made with the Flight Scheduling Coordinator and Traffic Dispatcher.

5.1.2. Runway Capacity

The maximum runway capacity at the DA is 43 aircraft operations (Republic Croatia, 2018) significantly higher than the declared capacity, 14 operations. The reason is that the maximum capacity is planned with the reconstruction and extension of a current maneuvering area.
Coordinating parameter of the current runway capacity at DA is not a limiting factor for slot allocation process.

5.1.3. Capacity of the Aircraft Parking Positions at the Apron

The DA apron consists of commercial aircraft and general aviation apron. Total surface area is approximately 110,000 m² (Republic Croatia, 2018). At the apron for commercial air carriers there are 19 fixed parking positions, mainly for airplane ICAO code letter C (Republic Croatia, 2018). Alternatively, there are also three superimposed positions for wide-body airplanes ICAO code letter E. The capacity of apron based on two configurations is shown in Table 2.

Table 2
Apron capacity of two basic configurations at the DA

ICAO code letter	Configuration 1	Configuration 2
C	12	4
D	7	7
E	0	3
Total number of parking positions	19	14

Source: (Republic Croatia, 2018)

Table 2 shows that the DA does not have the capability to handle aircraft code letter F. The current capacity of DA apron is sufficient to meet the high traffic demand even in the peak period. The DA's maximum number of commercial airplanes on the apron at any time may not exceeds 10 aircraft according to DA standard operation procedures.

5.1.4. Passenger Terminal Capacities

Up to 2017 the passenger terminal capacity has been limited aiport capacity component, the most critical co-ordination parameter was the capacity of the passenger security check. If one X-ray machine can screen approximately 200 hand baggage per hour, i.e it is possible to carry out a security check for 1,600 passengers per hour using all eight X-ray devices installed in the new passenger terminal "C" (Republic Croatia, 2018).

In 2017, a new additional passenger terminal was opened, and passenger terminal capacity increased from 2 to 3.5 million passengers a year (table 3).

Table 3
Passenger terminal capacities before and after opening of terminal "C"

Passenger terminal capacities in 2016	Passenger terminal capacities in 2017
17 passenger and baggage check-in counters	34 passengers and baggage check-in counters
10 gateways (8 international and 2 domestical)	16 gateways (14 international and 2 domestical)
4 X-ray devices for hand baggage	8 X-ray devices for hand baggage
3 metal detector doors for security check	6 metal detector doors for security check

2 passenger boarding bridges	4 passenger boarding bridges
8 arrival passeport control counters	8 arrival passeport control counters
3 departure passeport control counters	3 departure passeport control counters
3 carousels for reclaim	4 carousels for reclaim
Terminal capacity 2 million passengers yearly	Terminal capacity 3,5 million passengers yearly

Source: (Author)

Table 4 shows the number of aircraft movements and the number of passengers during the relevant peak hour on the DA in 2011 and 2016, as well as forecasts for year 2022 and 2032 (Republic Croatia, 2018).

Table 4
The total number of passengers and aircraft operations during the relevant peak hour on the DA in 2011 and 2016 and forecasts for year 2022 and 2032

Year	Aircraft operation in the relevant peak hour	Number of passengers in the relevant peak hour
2011	7	978
2016	9	1,315
2022	13	1,920
2032	20	2,916

Source: (Republic Croatia, 2018)

After the construction of a new passenger building in 2017, the capacity of the apron and the passenger terminal is more harmonized, and the capacity of the passenger terminal satisfies the capacities of the apron as well as runway and taxiways.

5.3. Process and Basic Principles of Slot Allocation at the Dubrovnik Airport

For slot allocation process Dubrovnik Airport is using computer software *Timetable* (Fig. 2). This software is a part of NIKO AS DCS system, main software system at the Dubrovnik Airport.

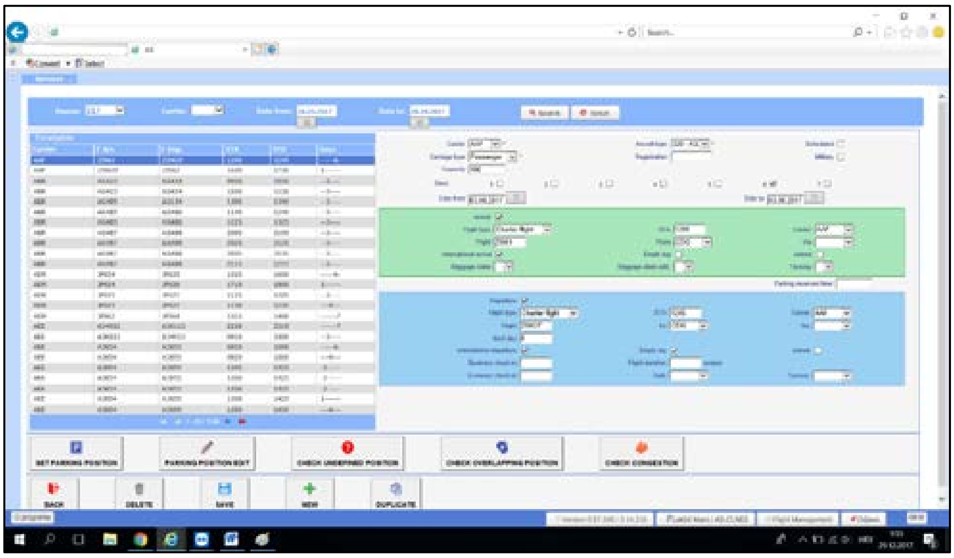

Fig. 2.
Timetable application in computer program NIKO.AS.DCS
Source: (Dubrovnik Airport, 2017)

Timetable supports flight and slot data imputs. This software supports overview of slots allocations on monthly, weekly, daily, and hourly base so that the Flight Scheduling Coordinator could track the capacities and adjust slots to meet the declared capacity.
Timetable is the main database of the Departure Control System (DCS). The *Timetable* records all the flights that air carriers announce and assigns authorized time to the carriers. The software consists of three main parts: basic data, arrival and departure flights data.
The basic data contain information about air carrier, the period in which flights are planning to be realized, the type and capacity of the aircraft, arrival and departure flight numbers, arrival and departure airport. An air carrier must provide certain flight data such as: flight type (regular, charter or general aviation), required time of arrival and departure etc. All the data are shown in Figure 2.

The *Timetable* software is associated with all applications within DCS and is used as a basic database for various DA systems and subsystems and is also used for traffic statistics, traffic forecasts and analytical purposes. Timetable displays all the slots on a specific day and automatically assigns parking positions.
The DA does not apply directly the concept of historical slot rights because airport is classified as a scheduled facilitated airport level 2. All planned operations in flight seasons are agreed between the flight schedules manager and the air carriers based on a voluntary agreement. The Flight Scheduling Manager considers the slots time which are assigned to regular carriers from the previous season and, by prior arrangement with the carrier, allocates the same time for the new flight season. Thus, the flight schedule manager gives a certain advantage to carriers who have been operating on DA for many years.
New carriers can operate in almost all periods except in specific peak periods due to the DA declared runway capacity. Such periods in 2017 were in the morning of Thursday, Saturday and Sunday at the peak summer season when the capacity of the runway was congested.

6. Conclusion

In recent years, global demand for air transport has grown at an annual rate of roughly 6%, and the available capacities at the most congested airports in the Europe and the world have not followed the growth trend. Lack of capacity is caused by lack of investment in airport infrastructure. Therefore, an aerodrome slots and authorized time systems has been introduced to ensure that aircraft operations are planned in accordance with the airport capacity to avoid delays.
The slot allocation system in the EU is based on the historical rights i.e. air carriers must satisfy the *Use it or Lose it* rule. This rule requires that the allocated slots has been used at a minimum of 80% during the period they are allocated. Advantage of historical rights during the slot allocation process is extremely favorable to the dominant air carriers, and the vast majority of slots on congested airports are used by dominant carriers. Thus, new carriers receive slots outside peak times resulting with nonoptimal flight time.
At the Dubrovnik Airport, the declared capacity of 14 aircraft operations per hour is mainly sufficient for current traffic demand. On the level 2 airport, the scheduling of authorized time is performed by the flight schedule manager. *Timetable* computer program is used for this proposed and represents an integral part of the NIKO.AS airport main software system at the Dubrovnik airport.
The number of aircraft operations are growing continuously at DA, but certain number of planned operations were cancelled. Reasons for canceling a number of announced operations were less passengers/tourists in pre and post season, congestion in peak hours of certain days in the summer and bankruptcy of certain carriers such as the Monarch Air who operated with significant number of flights at the DA.
DA coordinating parameters, runway and apron capacity mainly satisfying traffic demand. The new passenger terminal "C" significantly increased the capacity of the passenger terminal, which was early the main cause for the introduction of authorized times. By increasing capacity, congestion has been reduced in peak periods, especially for passenger and baggage check-in and passenger and hand baggage security check. The capacity of the check-in counters is doubled as well as the capacity of the security check units. The DA is currently meeting all the criteria for providing services to passengers at "C" level according to IATA recommendations.
Coordination parameters, whose capacities may be critical, especially during peak periods, are the capacities of passports and identity documents control counters on the arrivals and departures. After completion of the reconstruction of the runway and the construction of additional taxiway, it is reasonable to expect the DA carry out capacity analysis and to define a new declared capacity which will be greater than the current one.
The existing authorized times at DA airports gives satisfactory results and enables optimum capacity utilization. Certain corrections should be made primarily relate to the administrative constraints present at the level 2 airports. Future improvements should relate to redefining the administrative process of historical rights. The above rule is applied informally at the level 2 airports and the formalization of the mentioned rule should be established.

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EUROPEAN AIR TRANSPORT MARKET UNDER INFLUENCE OF COOPERATIVE ARRANGEMENTS

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Abstract: European air transport plays a vital role in the European economy. Liberalization of European air transport market combined with the ever-increasing permeation of Internet in the booking systems brought airlines into unenviable position. European full service carriers, as well as flag carriers, are highly exposed to competition from low cost carriers on short haul markets. On the long-haul markets they are exposed to competition from the Gulf airlines, including Turkey. These threats caused further airline industry consolidations that were various and multiple. Consolidation can be recognized in alliances, mergers and take-overs, but also bankruptcies of financially weak airlines. The paper provides an overview of European air transport market in the last decade considering various modes of cooperative arrangements and business models.

Keywords: European air transport, full service carriers, low cost carriers, alliances.

1. Introduction

Until the EU Third package of liberalization measures in 1993, EU routes were monopolized by EU so called flag carriers such as Air France, British Airways, Lufthansa, KLM and so on. After the removal of restrictions on market entry, capacity, frequency and pricing, and a removal of cabotage rights in 1997, new players exploited the opportunity and entered the European market in the second half of 1990s'. These new players were low-cost carriers (LCCs) which competed full service carriers (and flag carriers) in short-haul market, and Gulf carriers which competed full service carriers in long-haul markets. According to Vidović, Steiner and Škurla Babić (2004: 2) LCCs are airlines that provide transportation at lower price while eliminating many services that full service carriers provide, such as free in-flight service and extra baggage. They operate short-haul flights from secondary airports and provide no service onboard, having one type of aircraft in fleet (Ryanair and easyJet). A term "Gulf carriers" is used for airlines based in a country alongside Persian Gulf, but mostly used for these three: Etihad Airways (founded in 2003, based in Abu Dhabi), Emirates Airline (founded in 1985, based in Dubai) and Qatar Airways (founded in 1993, based in Doha). These three airlines have expanded aggressively and are creating an increasingly global network (Dresner et al, 2015: 31) and compete head-to-head with European, Asian and American carriers in international markets.
Over the last 30 years a series of consolidations and bankruptcies in European (and global) air transport market began to occur. Liberalization, while providing market access to new players, has led to a wave of numerous mergers and take-overs (or acquisitions) of full service carriers, and their formation into global alliances around the globe. For the most part, mergers and take-overs are quite similar - two previously separate firms are combined into a single legal entity. A merger is a result of a mutual decision of two companies to consolidate and to become one entity. Merger is often described as a decision made by two "equals". On the other hand, a take-over is a purchase of a smaller company by a larger one. A take-over can produce the same benefits as a merger, but it does not necessarily have to be a mutual decision of the two companies in question. Thereunto, full service carriers began to form alliances to broaden their networks. Over the years many alliances have emerged, and many have failed, but three most prominent alliances were forged in the late '90s and still exist: Star Alliance, SkyTeam and oneworld. The purpose of the paper is an overview of European air transport market in the last decade in terms of different cooperative arrangements of full service carriers.

2. Mergers and Take-Overs in Europe 2008 – 2017

During the era of flag carriers, bankruptcies and take-overs were rare in the European air transport market. However, they've become more often and have had a significant impact on the market function and competition.
Following the global financial crisis in 2008, air transport market went through significant consolidations. In the US, Delta Air Lines merged with Northwest Airlines in 2008, United Airlines merged with Continental Airlines in 2010, Southwest Airlines and Air Train Airways merged in 2011 and in 2013 American Airlines merged with US airways. Accordingly, several mergers (Table 1) occurred in Europe in the last decade.
Popularity of mergers and take-overs has increased due to liberalization, globalization and technological development. Mergers have become a popular practice in aviation, since the "key concept of merger is that a company can extend its business and create shareholders' value by purchasing another company" (Hsu and Flouris, 2017).

Table 1
Mergers, take-overs and bankruptcies of chosen air carriers in Europe from 2008 to the end of 2017

Year	Airline	Mergers, take-overs or bankruptcies
2008	KLM	Take-over of Martinair
2009	Lufthansa	Take-over of Germanwings Take-over of Brussels Airlines

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Year	Airline	Mergers, take-overs or bankruptcies
		Take-over of British Midlands Take-over of Austrian Airlines
	SAS	SAS Norge, SAS Sweden, SAS Denmark and SAS International merged into SAS Scandinavian Airlines
	Alitalia	Joint venture with Air France-KLM group and Delta Airlines
2010	Lufthansa	Take-over of Eurowings
2011	IAG	Merger of British Airways and Iberia into IAG
	British Airways	Integration of British Midlands into BA
2012	airberlin	Etihad acquired 29,21% share in Air Berlin share hold
	Malev	Bankruptcy – ceased operation
	Air Serbia	Etihad acquired 49% share in Air Serbia share hold
2013	Darwin Airline	Etihad acquired 33% share in Darwin Airline share hold
	Alitalia	Etihad acquired 49% share in Alitalia share hold
2014	Germanwings	Merged fully into Eurowings (Lufthansa Group)
2015	Air Lituanica	Bankruptcy – ceased operation
	Estonian Air	Bankruptcy – ceased operation
	Nordica	Formed after bankruptcy of Estonian Air as Estonian flag carrier
	Darwin Airline	Etihad sold its stake to Adria Airways
2017	Monarch Airlines	Bankruptcy - ceased operation
	airberlin	Bankruptcy after Etihad pulled financing – ceased operations
	Alitalia	Bankruptcy after Etihad pulled financing – continue to operate due to governmental loan
	Darwin Airline	Bankruptcy – ceased operation

Source: gathered by the authors

The major benefit of mergers is cost rationalization (Vasigh, Fleming & Tacker, 2016: 16). Since the airline industry exhibits large economies of scale, merged airlines can spread their high fixed costs over a greater network. While some see mergers as solely positive outcome, European Commission is concerned that a change towards a more concentrated market might reduce competition. Following that concern, in 2004 Council Regulation (EC) no. 139/04 on control of concentrations between undertakings (EU Merger Regulation, 2004) was adopted. This EC Merger Regulation gives the European Commission authority to make decisions regarding potential mergers and take-overs. When two or more airlines (of which one is an EU carrier) decide to merge they need to notify the European Commission (Nemeth and Niemeier, 2012: 45). If the merger leads to a dominant position on a given EU route, the Commission introduces remedies or prohibits the merger. Remedies are simply conditions under which a merger could be approved, such as:

- surrender of slots at congested airports;
- interlining and codeshares obligations;
- open frequent flyer programs;
- freezing or reducing frequencies;
- price reduction mechanism;
- sale of assets.

Lufthansa and KLM were one of the first airlines faced with European Commission new rules. In only few years Lufthansa has finalized five mergers, as seen in Table 1. Lufthansa took over Austrian Airlines in 2009. Two airlines had many overlapping routes. Origin/points of destination impacted by the merger were: Vienna-Stuttgart, Vienna - Cologne/Bonn, Vienna-Frankfurt, Vienna-Munich and Vienna-Brussels. The Commission concluded that Lufthansa is to make available slots at Vienna and/or Frankfurt and/or Munich and/or Cologne/Bonn and/or Stuttgart and/or Brussels (COMP/M. 5440, 2009) to allow one or more prospective new entrant(s) to operate a new or additional competitive air service on the following identified city pairs. Just like in the Lufthansa-Austrian case, European Commission decided that in the case of British Airways and Iberia merger, British had to give up their slots on Heathrow and Gatwick routes to competitors, but only if the competitors have already exhausted their slot portfolio (COMP/39.596-BA/AA/IB, 2010). From this, and other decisions of European Commission regarding merger control, it can be seen that in the most cases where an airline gains full control of the other airline, the most common remedy is surrender of slots at congested airports.

There is an interesting pattern seen in a Table 1, regarding bankruptcies of European carriers, linked with the Gulf carrier Etihad Airways and its pulling out of financing of their insolvent equity partners, such as Darwin Airline, airberlin and Alitalia. Etihad Airways' equity partner network at the beginning of 2017 included airberlin, Air Serbia, Air Seychelles, Alitalia, Jet Airways, Virgin Australia and Etihad Regional, and represented the world's seventh largest global grouping of airlines. However, since the CEO who designed a plan to gain proxy presence of Etihad Group in different countries, obtaining stakes in different airlines has left the Etihad, Etihad has changed its business plan and stopped financing their risky investments, airberlin and Alitalia. This decision weakened further airberlin and Alitalia, causing airberlin to completely cease operations and Alitalia to file for bankruptcy, continuing to operate but relying on Italy government support.

3. Global Airline Alliance

According to (Ohmae, 1989) "Companies are just beginning to learn what nations have always known: in a complex, uncertain world filled with dangerous opponents, it is best not to go alone". Evans (2001: 229) defined the concept of a strategic alliance as "a particular horizontal form of inter-organizational relationship in which two or more organizations collaborate, without the formation of a separate independent organization, in order to achieve one or more common strategic objectives".

The basic strategy of every airline is to weaken competition on certain routes and to gain market share, so it is no wonder that alliances were formed. Since the deregulation and liberalization on both sides of the Atlantic have impacted the airline market, full service carriers developed a strategy to form global alliances which will expand their global network and provide them comparative advantage versus low cost carriers. The first truly global alliance is Star Alliance. It was formed in 1997 between United, Lufthansa, SAS, Air Canada and Thai Airways. Shortly after formation of other alliances followed:

- oneworld alliance in 1998 was formed between American, British Airways, Qantas and Cathay Pacific,
- Qualiflyer in 1998 included Swissair, Sabena, Turkish Airlines, Air Liberte and TAP Portugal,
- SkyTeam in 1999 formed between Delta, Air France and Aeromexico.

However, Qualiflyer alliance was dissolved in 2001 after Swissair demise, and ultimately in 2002 when it was bought by the Lufthansa group and incorporated into Star Alliance.

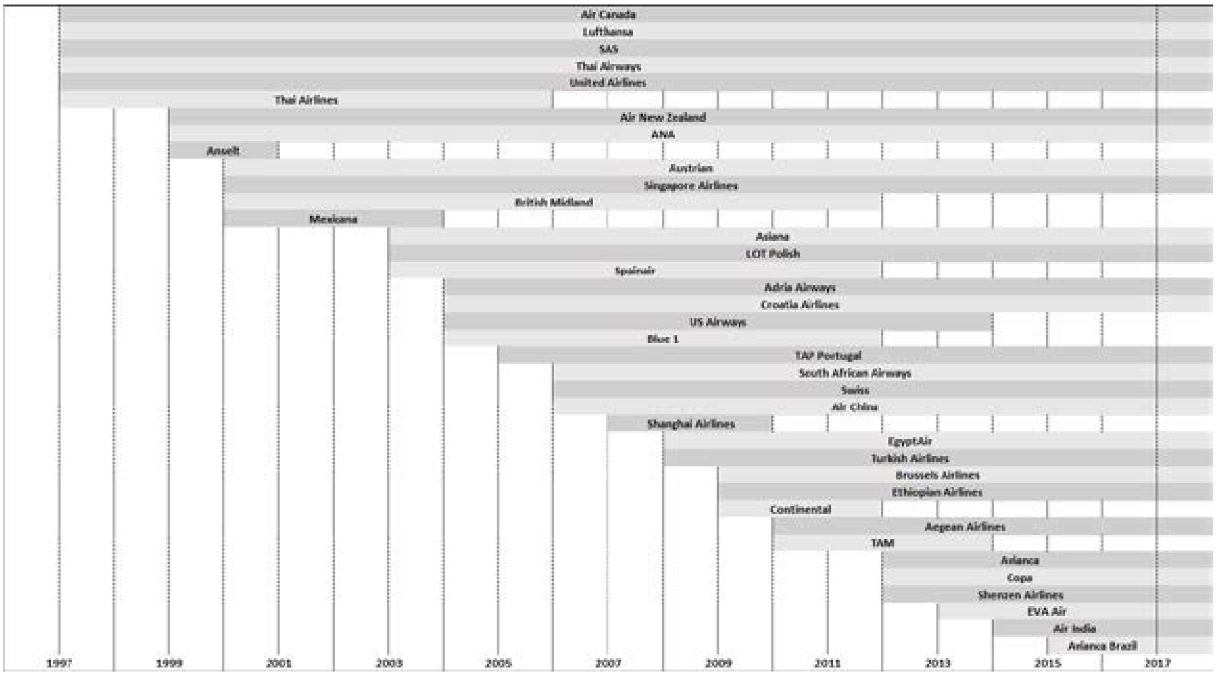

Fig. 1.
Timeline of member airlines participation in Star Alliance
Source: Airline Business Airline Alliance Survey, September 2017

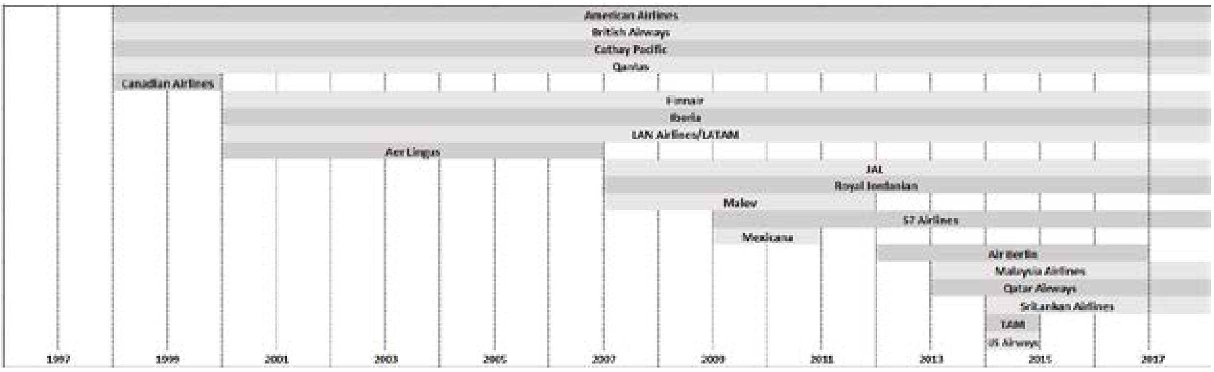

Fig. 2.
Timeline of member airlines participation in SkyTeam
Source: Airline Business Airline Alliance Survey, September 2017

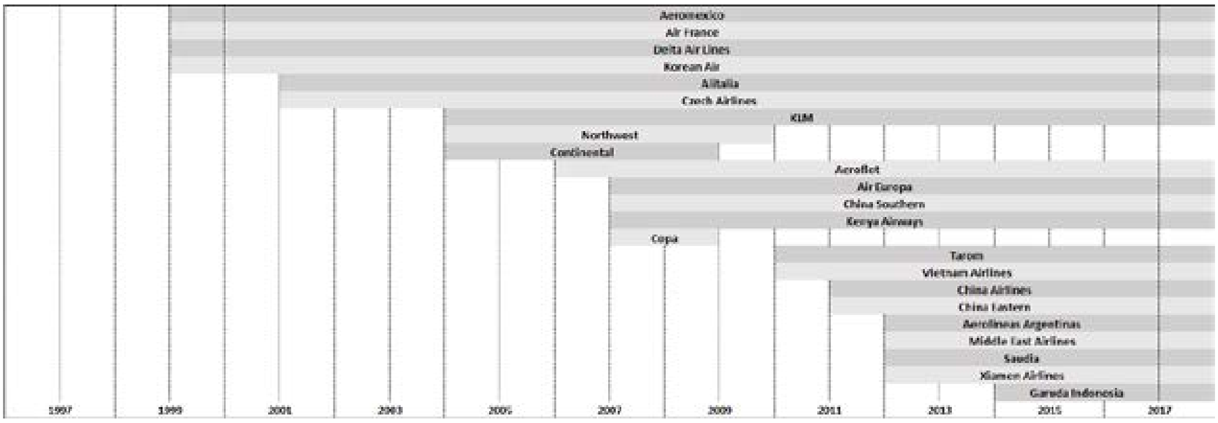

Fig. 3.
Timeline of member airlines participation in oneworld
Source: Airline Business Airline Alliance Survey, September 2017

The three existing global alliances have expanded over the course of two decades, which can be seen in Fig. 1, 2 and 3. They provide geographical coverage to all areas of the world. Expansion and optimization of alliance members route network provides greater flight options to passengers. Combined, these three alliances hold 56.9% (Table 2) of share in total nonstop scheduled capacity offered in year 2017. Dominantly full service carriers are members of global alliances, with an exception of Qatar Airways, Gulf carrier that became a member of SkyTeam in 2013.

Table 2
Alliance statistics

Column1	Star Alliance	SkyTeam	oneworld
Member airlines	28	20	14*
Revenue ($ bn)	181	147	134
Countries Served	191	177	157
Destinations served	1218	1065	978
Share in scheduled capacity offered	22.7%	18.3%	15.9%

Source: Airline Business Airline Alliance Survey, September 2017
**since Air Berlin ceased operations in late 2017, it is no longer part of oneworld alliance*

4. Development of Full Service Carriers

The business model of full service carriers is under increasing pressure, on short-haul as well as on long-haul market. According to (Eurocontrol Seven-Year Forecast, 2018) LCCs accounted for over 31% (versus 26% in year 2013) of the European flights in 2017. Figure 4 shows the comparison of total share of European flights per market segment shows in 2017. Even though full service carriers do own a significant market share in 2017, the comparison indicates a negative trend in full service carriers market share in regards to LCCs in the total supply of intra-EU flights. It is presumed that due to the stagnation in growth in European market (mostly UK and Ireland), some LCCs will develop a new strategy, and increase route range, which will generate a so-called hybrid LCCs (Burghouwt et al., 2015). This occurrence might provoke the cannibalization of full service carriers.
According to the same report (Eurocontrol Seven Year Forecast, 2018) on the extra-EU market, first partner is USA, which was a number one destination from European countries, and the second was Russian federation. However, the third one was The United Arab Emirates with 164 daily departures on average and an increase of 1.2% compared with 2016. The growth of Gulf carriers is increasing due to their massive network and their hubs that provide passengers great connectivity to beyond markets (Australia, North and South America, Africa and Asia).

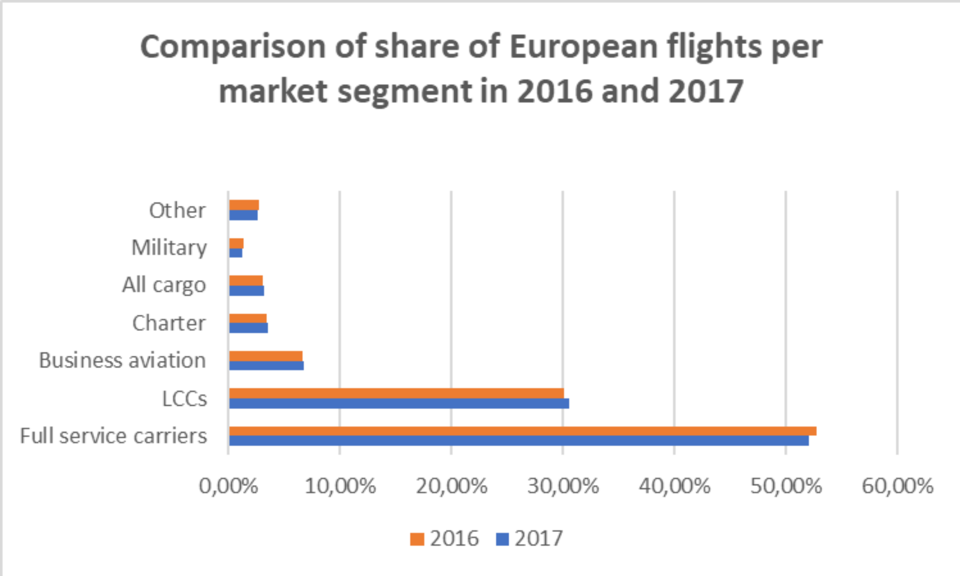

Fig. 4.
Comparison of share in European flights per market segment in 2016 and 2017
Source: Eurocontrol Seven-Year Forecast, February 2018

The effects of anti-monopolization due to rise of new players on the market, as well as merger control regulations have pushed full service further to consolidation. The increase of mergers in European market, with the increase of number of alliance members, show that full service carriers are looking for an optimal collaborative arrangement to remain on the market, preferably gaining more market share and financial gain. It is evident that full service carriers will be increasingly exposed to their opponents (LCCs and Gulf carriers). Therefore, further industry consolidation might be expected, along with continuity of bankruptcies of financially week airlines, but also the optimization of hub-networks. Idea of integration of LCCs into global alliances so that they could be feeders to full service carriers network is no longer just an idea: Vueling (Spanish LCC) started to optimize their schedule to contribute to Iberia financial results (Burghouwt et al., 2015).
The invasion of Gulf carriers into market that was previously dominated by Europe an US full service carriers has raised the concerns on "fair competition". Various mechanisms are being considered currently on a global scale (since it is a global issue) to address the issue of "fair competition". One of them is to include "fair competition" clauses that will be formulated by European Commission, E States or ICAO in international agreements on air transport, and the other could be requesting more transparency on the financials of the carrier in question before granting any traffic rights.

5. Conclusion

There are numerous factors that effect the consolidation of full service carriers and entire European air transport market. All of them are derived from the liberalization of air transport market (regionally and globally). In the past 30-year period the regulative framework has changed and adapted countlessly to the needs of the market. However, regulatory framework to be differed takes time. At the same time, all the airlines on ne global market looks for a cooperative arrangement that is the best option to their prosperity. Most of the major players participate in many forms of cooperative arrangement, pulling even smaller players into their networks: via mergers or full take-overs, or via forming alliances global networks. This overview of European air transport market gives a sense of whet are the threats to a full service carriers business model, and gives a input to a further more detailed research of efficiency of merger control remedies in European air transport market, as well as the impact of global alliances on specific route networks (extra-EU routes operated by European full service carriers and their alliance partners vs. Gulf service carriers).

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DISPATCH RELIABILITY FROM ASPECT OF AIRCRAFT MASS AND BALANCE

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Abstract: Dispatch reliability is an important factor in aircraft operation. If the aircraft is not available in required moment, even for a short period, it can have a great effect on the airline which can lead to bad reputation – losing the slot, canceling the flight, delays. Mass and balance is a critical part in aircraft operation, and since all airlines tend to maximize the payload while remaining within defined limits, this task can sometimes lead to a delay. There are many parameters which can influence mass and balance process, and some aircraft are more convenient than the other. Parameters observed were MAC limits, load accessibility, cooling surfaces, lock positions, etc. Also, statistical values are included, which were measured in live operation. TOPSIS method was used to rank the aircraft, while importance of parameters was given by a group of experienced experts in the field, which directly influenced the weights of criteria, defined by Delphi method. Both wide body and narrow body aircraft were included in the research, and they were finally ranked by the dispatch reliability from aspect of mass and balance.

Keywords: Dispatch reliability, mass and balance, TOPSIS.

1. Introduction

Dispatch reliability prediction methods present an important step in delay prevention (Bineid et al., 2003) on both short haul and long haul flights. Delay codes are attached to aircraft systems in order to define and prevent leading causes for the delays. Performance parameters are taken into account, and the findings could be applied to aircraft in conceptual phase.

Dispatch reliability has increased due to new maintenance models („on condition“) as it is stated in the "BAC One-Eleven = reliability" (1974). Carriers tend to maximize dispatch reliability, and each aspect leading to the aircraft not being reliable at the scheduled time of departure, should be properly analyzed.

Load factor and aircraft utilization have a high effect on the operational efficiency (McLean, 2006). It is concluded that high loading factor can lower operational efficiency.

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method can be used to analyze aircraft operational parameters (Čokorilo et al., 2010), and select optimal aircraft for regional air travel realization. Four regional aircraft types were taken into consideration, which were further evaluated by operational and technological criteria. Results were used to define the aircraft fleet.

TOPSIS method was used (Moazami et al., 2016) to analyze maintenance and repair system of Antonov 74 aircraft. They used access ratio, quality and efficiency ratio for evaluating repair systems. Conclusion was that intervals between inspections are crucial when choosing the right maintenance model, hence the proper inspection defined the best model.

Ranking of the aircraft safety when landing on a carrier was done using Fuzzy Multi-Attribute Group Decision Making (FMAGDM) (Wu et al., 2016). Landing routes were evaluated and simulated under a number of conditions.

TOPSIS was used method to evaluate anti-submarine aircraft maneuverability (Yang et al., 2014), in order to select the best aircraft for the task. Aircraft performance indicators were used as criteria by which the alternatives (aircraft) were analyzed.

The best aircraft for air combat were selected using TOPSIS method (Wang et al., 2008), by measuring the aircraft performance. TOPSIS was used to provide crisp performance value, and to provide the ranking of the aircraft. Also, fuzzy AHP method was combined with the TOPSIS.

Each aircraft has performance values and indicators which define its suitability for a certain task. Wide body aircraft are used for long-haul flights and high payload values, narrow body aircraft are usually used for short haul flights, combat military aircraft have a high maneuverability due to requirements of the task, etc. One of the aspects of aircraft operation is dispatch reliability. If the mass and balance task is difficult, it is best to select optimal aircraft for the operation. As it has been shown, TOPSIS method is convenient for selecting the aircraft for certain task, when different performance indicators are considered. This research, in a same way offers the insight into important criteria from the aspect of mass and balance reliability, and uses TOPSIS to evaluate the most reliable aircraft from the mass and balance reliability aspect. Further, this reliability can be considered as one of the many factors for the airlines, when selecting the best aircraft for the task.

2. Selecting the Criteria

There are many specific aspects that affect the mass and balance, and the preparation of loading instruction report. Predicted payload, special and dangerous goods limitations, cargo compatibility, aircraft performance and route conditions, as well as predicted fuel and zero fuel mass. At the moment of issuing a loading instruction report, many values are predicted and not definite (number of passengers, baggage mass, fuel values). However, during the certain phases, these numbers become final (check in closure – number of passengers, baggage mass; captain fuel message –

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fuel figures). When these numbers become final, some modification has to be done in order to have a proper loading and remain within the limits for the loadsheet.
This means that aircraft parameters which offer flexibility and quick modification in the case of loading change are very important factors affecting the dispatch reliability at the given moment (Scheduled time of departure – STD).
Also, possibility to create loading instruction report without many limitations (cooling surfaces, reachability, large MAC envelope values), can help avoid problems and last-minute changes to the loading.
Some of the parameters can't be easily measured, and statistical values can indicate dispatch reliability.
Considering all these parameters following indicators are used as criteria for analyses of dispatch reliability from aspect of mass and balance:

where
Ps – represents probability that the aircraft will not be usable (out of trim or overweight) based on statistical analyses of the sample (values 0-1)
MACmin – percentage of the mean aerodynamic cord usable for weight and balance at minimum values for ZFM, TOM, LM (mean value of the three; values 0-1)
MACmax - percentage of the mean aerodynamic cord usable for weight and balance at maximum values for ZFM, TOM, LM (mean value of the three; values 0-1)
MACnormal - percentage of the mean aerodynamic cord usable for weight and balance at middle values for ZFM, TOM, LM (mean value of the three; values 0-1)
Combining the statistical values with MAC values creates a most important indicator for mass and balance reliability. MAC envelope is an area in which the position of aircraft center of gravity (CG) at ZFM, TOM and LM should be, in order to have an aircraft within defined limits. The higher the MAC value and lower the *Ps*, it is more probable that the aircraft would be in defined limits. This combination of statistical probability that the aircraft would be within given limits, and the area (MAC envelope) is defined as dispatch MAC factor.
Dispatch MAC factor *DMF* for *i* type of aircraft is then calculated as:

$$DMF_i = (1 - Ps_i) \cdot \frac{MACmin_i + MACmax_i + MACnormal_i}{3}$$

Table 1
Dispatch MAC Factor Values For Selected Aircraft

Aircraft type	A319	A320	A321	A330	A350	B747
DMF	0.1256	0.138603	0.0929	0.121629	0.137926	0.149296

However, CG position being within the defined limits isn't the only condition by which the aircraft dispatch reliability is measured. Aircraft could be within the limits with the high *DMF*, but still not provide proper cooling for perishable goods, or a good locking position for the pallet or ULD. Also, total mass can be within MAC, but at certain position can still cause overweight due to floor capacity limit. This capacity, combined with a given volume on that position results in compartment capacity.
When considering the mass and balance reliability, there are other quantity and quality indicators, such as:
Cs – cooling surface in the holds (number of holds with cooling available divided by total number of holds, values 0-1), very important for handling perishable goods;
Rs – reachable surface (number of doors divided by number of holds, values 0-1);
Us - usable surface (number of positions divided by number of positions available for use – for example B747 aircraft has container positions without hooks);
Cc – compartment capacity, (capacity measured for each position – when exceeded, it would be overloaded).

Table 2
Quantity/Quality Indicators by Aircraft Type

i/j	*DMF*	*Cs*	*Rs*	*Us*	*Cc*
A319	0.1256	0.4	0.6	1	1045
A320	0.138603	0.375	0.375	1	1045
A321	0.0929	0.3	0.3	1	1013
A330	0.121629	0.625	0.1765	1	1587
A350	0.137926	0.6	0.15	1	1588
B747	0.149296	0.75	0.1875	0.4375	1000
Wj	1	0.3	0.63	0.37	0.67

The importance of each factor is given as a weight W_j. These weights are calculated using Delphi method based on evaluation of group of experts in the area. Group consisted of nine experts, six were Centralized Load Control (CLC) agents, two were shift Coordinators, and one was Operations manager.

2. Multi-Criteria Analyses Using TOPSIS Method

TOPSIS was defined as a method (Hwang, 1981) which ranks alternatives according to the distance from ideal and anti-ideal solution. Best alternative is the one which is farthest from anti-ideal and closest to the ideal solution. In that way, all the positive and negative sides of alternatives are observed and included into the final ranking.
TOPSIS method was used to rank the aircraft according to dispatch reliability. Aircraft type is defined as an alternative A_i, while indicators are considered as a criteria k_j. Each value presented in table 1 given for indicator j and aircraft i, is presented as x_{ij}.
First step is normalizing the table by using the following expression:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_i^2}}$$

Also, weights need to be normalized, using the following expression:

$$W_j' = \frac{W_i}{\sum W_j}$$

Normalized table is shown (table 3).

Table 3
Normalized Indicators by Aircraft Type

i/j	*DMF*	*Cs*	*Rs*	*Us*	*Cc*
A319	0.40	0.31	0.73	0.44	0.34
A320	0.44	0.29	0.45	0.44	0.34
A321	0.29	0.23	0.36	0.44	0.33
A330	0.39	0.48	0.21	0.44	0.52
A350	0.44	0.46	0.18	0.44	0.52
B747	0.47	0.57	0.23	0.19	0.33
Wj’	0.34	0.10	0.21	0.12	0.22

Next step is weighing the table, and defining the criteria type by min/max. Weighing of the table is done by using the following expression:

$$V_{ij} = r_{ij} \cdot W_j'$$

Weighed table is shown below (table 4):

Table 4
Weighed Indicators by Aircraft Type

i/j	*DMF*	*Cs*	*Rs*	*Us*	*Cc*
A319	0.13	0.03	0.16	0.05	0.08
A320	0.15	0.03	0.10	0.05	0.08
A321	0.10	0.02	0.08	0.05	0.07
A330	0.13	0.05	0.05	0.05	0.12
A350	0.15	0.05	0.04	0.05	0.12
B747	0.16	0.06	0.05	0.02	0.07
Wj’	0.34	0.10	0.21	0.12	0.22
max/min	max	max	max	max	max

Next step is forming ideal (A^+) and anti-ideal (A^-) solution. This is done as:

$$A^+ = \left\{\left(\max_i V_{ij}\,; j \in K'\right) \vee \left(\min_i V_{ij}\,; j \in K''\right)\right\} = \{V_1^+, V_2^+, \dots, V_j^+, \dots, V_n^+\}, \qquad i = 1, \dots, m$$

$$A^- = \left\{\left(\min_i V_{ij}\,; j \in K'\right) \vee \left(\max_i V_{ij}\,; j \in K''\right)\right\} = \{V_1^-, V_2^-, \ldots, V_j^-, \ldots, V_n^-\}, \qquad i = 1, \ldots, m$$

$K' \subseteq K \rightarrow K'$ related to max type of criteria
$K'' \subseteq K \rightarrow K''$ related to min type of criteria

Ideal solution is: A^+ = (0.16; 0.06; 0.16; 0.05; 0.12)
Anti-ideal solution is: A^- = (0.20; 0.02; 0.11; 0.04; 0.03; 0.05)

Next step is consisted of measuring the distance of each alternative (aircraft type) form the ideal (S_i^+) and anti-ideal (S_i^-) solution and calculating aggregated distance (C_i) from these solutions. This is calculated as:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^+\right)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2}$$

$$C_i = \frac{S_i^-}{S_i^- + S_i^+}$$

$$0 \le C_i \le 1$$

If the $C_i = 0$, solution is anti-ideal, and if the $C_i = 1$, solution is ideal.
The complete distance and ranking is shown in the table below (table 5):

Table 5
Ranking of Aircraft Types

Aircraft type	A319	A320	A321	A330	A350	B747
C_i	0.697071	0.515169	0.304956	0.36871	0.390016	0.37058
Rank	1	2	6	5	3	4

Conclusion

When considering all aspects of aircraft being out of balance and/or overweight, and also the possibility of resolving such issue (accessibility of holds – door access, switching the load position – special loads on cooling positions, etc.), A319 has proven to be the most reliable, and the least likely cause of delay 31 (aircraft documentation late – loadsheet issued late due to mass and balance problem). This is caused by high compartment capacity, easy access to the load, high ratio of usable surface, and overall flexibility in resolving out of trim situations. As expected, wide body aircraft have a significantly lower ranking, due to low flexibility of solving out of trim issues (special equipment used for loading, difficult access in ULD aircraft, etc.). Also, important factor when considering the wide body aircraft is high amount of cargo, special cargo, and dangerous goods transported by these aircraft. When special load is considered, cooling surface is an important factor (B747 has a high number of holds with the cooling). Also, MAC envelope and statistics are included in DMF, which is considered as the most important criteria. A350 is the most reliable wide body aircraft, which is due to high number of compartments, high capacity, excellent envelope and fuel index influence on TOM and LAM indexes. The proposed methodology can be used by the airline when selecting aircraft for specific task, especially challenging from the aspect of mass and balance. These tasks are directly linked to maximum payload uplift, which can be difficult when aircraft performance factors are limited (high temperature, low pressure, high altitude airport, obstacles and short runway, contaminated runway, etc.). Good selection of the aircraft, helps in having the maximum payload uplift, reduced number of delays and carriage of special goods requiring cooling, ventilation or controlled temperature.

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BIRD STRIKE RISK ASSESSMENT AT THE MILWAUKEE'S GENERAL MITCHELL INTERNATIONAL AIRPORT

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Abstract: Airports have been recognized as a critical spot when it comes to bird strike risk. Most birds fly at less than 300 m above the ground (Kazda and Caves, 2007). Therefore, flight phases that involve aircrafts low altitude such as take-off and landing are the most endangered. Considering that each area has its own specific elements that may attract birds, whenever it is feasible it is highly recommended to consider all particularities of specific airport region when analyzing the bird strike risk. This paper will analyze bird strike occurrences at Milwaukee's General Mitchell International airport. The focus of this study will be the number of confirmed cases of damage to an aircraft by a wildlife strike, and the number of cases where residue and bird remains was visually confirmed on an aircraft following a strike. Other cases where only remains of wildlife were found with no report of a strike, reported strikes but without aircraft damage or visual confirmation of residues, and other examples, will be displayed to show the complexity of the topic of wildlife strikes at an airport. Consequence of bird strike varies and depend on numerous elements. Some of them such as aircraft type, and part of the aircraft that suffered the impact will be analyzed as well. Data from the years 2013 to December 16, 2016 are used for this analysis.

Keywords: bird strike risk, wildlife hazard, airport, air traffic safety.

1. Introduction

Increasing air traffic volume and populations of many bird species put pressure on all aviation stakeholders to participate in bird strike risk mitigation process. The bird strike risk in aviation requires a comprehensive approach and a detailed analyze of historical data (Nešić and Čokorilo, 2018). Proper reporting of wildlife strikes will determine quality and accuracy of data which will be used for the risk evaluation and in the process of making decision which prevention measures will be applied. The bird species are often poorly identified, and a lot of other valuable data, such as weather details, are frequently missing from bird strike reports. In addition, bird strikes that did not cause any damage were often not reported (Nikolajeff, 2014). Beside flight crew other subjects may submit bird strike report to aviation authorities like technical staff engaged on maintenance and airworthiness related tasks, air traffic controllers, airport or aircraft handling employees (Nešić and Čokorilo, 2017). The most important is that all parties in aviation should be involved in this problematic thus each wildlife strike shall be timely reported. Per International Bird Strike Committee (IBSC) Standard 6 bird/wildlife occurrences are divided in 3 categories: confirmed strikes, unconfirmed strikes and serious incidents. According to (IBSC, 2006) previously mentioned categories are defined as follows.
Confirmed strikes:

- Any reported collision between a bird or other wildlife and an aircraft for which evidence in the form of a carcass, remains or damage to the aircraft is found;
- Any bird/wildlife found dead on an airfield where there is no other obvious cause of death.

Unconfirmed strikes:

- Any reported collision between a bird or other wildlife and an aircraft for which no physical evidence is found.

Serious incidents:

- Incidents where the presence of birds/wildlife on or around the airfield has any effect on a flight whether or not evidence of a strike can be found.

The wildlife hazard may have multiple impacts, of course, the most important is effect on flight safety. According to Federal Aviation Administration (FAA) wildlife strikes have killed more than 262 people worldwide and destroyed over 247 aircraft since 1988. In most cases wildlife strike won't affect flight safety. During the decade of 1999-2008 in total 71 accidents occurred due to a bird strike. Of these only 6 led to fatal injuries (EASA, 2009). Bird strike effect on flight depend on many factors like bird's mass, flight phase, which part of the aircraft suffered the impact and so on. The aircraft parts most likely to be damaged are the nose, radome, fuselage and the wing (EASA, 2008). Beside safety effect wildlife strikes also generate additional costs to aviation industry. Reported bird strikes have increased more than six-fold from 1990 to 2013 and cost an estimated $625 million annually to civil aviation in the United States (Koros and Hale, 2016). In conditions of difficult economy terms and high competition additional bird strike costs are undesirable and airlines can't afford expensive repairs, delays, cancelations and airplane withdrawal. Besides, there is whole other group of costs which amount is almost impossible to estimate, that costs are costs of lost demand, passengers' dissatisfaction, influence on company reputation and modal split (Nešić *et al.,* 2016).

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2. Airport's Area and Wildlife Hazard

FAA announced that in the period from 1990 to 2015, 169,856 wildlife strikes were reported (166,276 in USA and 3,580 strikes by United States registered aircraft in foreign countries). In 2015, birds were involved in 95.8 percent of the reported strikes, terrestrial mammals in 1.6 percent, bats in 2.3 percent and reptiles in 0.3 percent. In commercial air transport, bird strikes usually take place during departures and approaches below 500 feet (Dolbeer, 2006). Using various sources of information (ICAO, UK CAA, EURBASE) it can be derived that most of the bird strikes occur below 2500 feet (90%-93%), and the majority occurs at altitudes below 200 feet (64%-75% depending on data source) (EASA, 2009). When it comes to wildlife hazard focus should be on the airport's area where most likely bird strike will occur. Airports should conduct an inventory of bird attracting sites within the International Civil Aviation Organization (ICAO) defined 13km bird circle, paying particular attention to sites close to the airfield and the approach and departure corridors (IBSC, 2006).

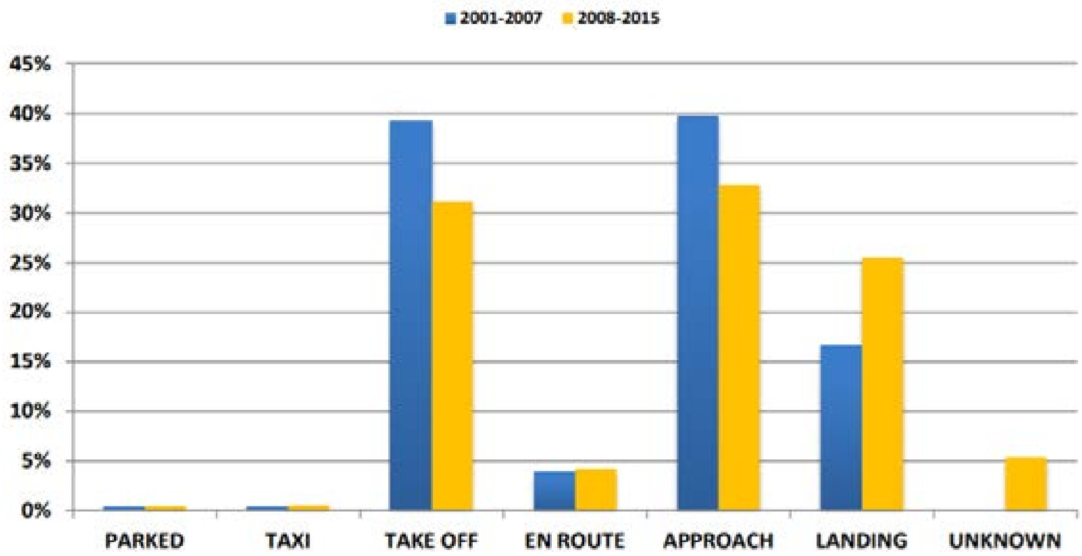

Fig. 1.
Percentage of Reported Strikes Based on Flight Phase where Collision had Occurred
Source: (ICAO, 2017)

2.1. Airport Areas with Higher Bird Strike Risk

Beside birds other animal species may affect airport operations and cause aircraft damage, the most common are deer and coyote. This type of collisions may occur at different airport maneuvering surfaces. The crucial is the fact that focusing on airport maneuvering areas and airport complex is not enough. Hazardous wildlife attractants in the airport vicinity could be any element that provides food, water and shelter for the birds. Therefore, aquatic areas, agricultural fields and forests are very risky when it comes to bird strike risk. The previously mentioned areas are usually very large which makes wildlife management and bird strike prevention highly complex. Second type of airport risky areas are characterized by containing highly attractive elements to birds but occupy significantly smaller area comparing to first category. This are fields with freshly excavated lend, sewage or landfill areas. Sometimes certain area could temporary become very attractive to birds and those cases require immediate short-term actions to remove elements that attract birds which means that presence of temporary activities on the airport must be included in the analysis. The most common case that requires temporary actions is land excavation which is leading to insect presence on the surface (Nešić *et al.,* 2016).

Per (Kazda and Caves, 2007) special attention must be paid to the maintenance of the areas covered by grass and it is best if the grass height is kept around 20 cm or more. If the grass is higher than 20 cm, the view of the birds is limited, and they cannot move easily in the grass. Airport regulation and wildlife management responsibilities are largely matters of federal law, which governs classification, certification, federal grant funding, and operation of airports and which prescribes actions airport operators must take to evaluate and respond to wildlife hazards at airports (Rillstone and Dineen, 2013). Wildlife management plan should be developed based on previously conducted risk assessment for the specific airport. In cases where wildlife risk is low, and no corrective actions are required airport authorities should continue with area monitoring in case of unexpected changes.

3. Milwaukee's General Mitchell International (MKE) Airport

Milwaukee's General Mitchell International (MKE) airport is in the city of Milwaukee, state of Wisconsin. The airport is located in 5 miles (8 km) south downtown Milwaukee. MKE airport is classified as a medium hub commercial service airport and it is the largest airport in Wisconsin with 2,386 acres. As General Mitchell International Airport published there are five runways at, ranging in size from 10,000 feet long (a little less than two miles) and 200 feet wide, to the shortest runway of 3,500 feet long (about two-thirds of a mile long). For the year 2017 the airport had 112,169 aircraft operations, an average of 307 per day (FAA, 2018). According to Milwaukee County for 2017, 6.9 million passengers traveled through Mitchell International, an increase of 164,772 from 2016. MKE serves commercial service airlines, cargo aircraft, private and business aviation, and the Wisconsin Air National Guard. It is owned and operated by Milwaukee County, and is the largest airport in the state of Wisconsin. Also, MKE airport has a helipad which is located on the south side of the airport property.

Fig. 2.
Milwaukee's General Mitchell International (MKE) Airport

3.1. Safety Management System and Wildlife Management at the General Mitchell International Airport

Safety management processes identify hazards with the potential to adversely affect safety. These processes also provide effective and objective mechanisms to assess the risk presented by hazards and implement ways to eliminate these hazards or mitigate the risks associated with them (ICAO, 2013). General Mitchell International Airport (MKE) officially announced that a Safety Management System (SMS) has been developed. An integral part of the SMS is reliance on participation of all parties to improve safety practices at every level. MKE officials emphasized that all staff, tenants, and contractors are responsible to report hazardous conditions, accidents, incidents, or unsafe actions. No matter what role employee have at the airport, they all play an integral part in maintaining MKE's Safety Management System. As they said, *"If hazards are not reported, they cannot be corrected"*. Also, for this purpose SMS Portal has been developed, it allows all staff, tenants, and contractors to report safety hazard to the Airport Program Safety Manager. The Airport Operations department is the responsible airport authority tasked with the safety, security, and maintenance of airport facilities and the airfield.

In order to conduct successful wildlife management along with proper data collecting it is necessary to duly analyze collected data. Wildlife management often requires numerous preventive and corrective measures, but feedback of the applied measures efficiency sometimes can be omitted. A survey of 38 airports in the Canada has shown that over 75% of airports kept strike records, but less than 7% used them to measure the outcomes of countermeasure implementation (Hesse *et al.,* 2010). The FAA requires airport sponsors to maintain a safe operating environment, which means they must conduct a Wildlife Hazard Assessment (WHA) and prepare a Wildlife Hazard Management Plan (WHMP) if it is needed. Numerous actions can be taken to reduce wildlife presence in the airport areas. Risk mitigation actions that will be taken depend on airport's risk category. At the General Mitchell International airport the task of wildlife management is a responsibility of the Operations department. General Mitchell International airport Operations department works in accordance with federal recommendations, guidance and regulations of airport operations. The Airport Operations staff responsible for wildlife management at MKE airport receive a training on this topic 12 months.

3.2. Particularities of the General Mitchell International Airport's Area

Water rich areas are characterized by specific wildlife species that pose special hazards to air traffic. Birds that settle aquatic areas like loons, grebes, albatrosses, pelicans, cormorants, waterfowl, herons, egrets, rails shorebirds, gulls, tems, and kingfishers were responsible for 48% of reported strikes that involved known species and 67% of damaging strikes, 1990-1999 (Cleary *et al.,* 2000).

FAA classifies state of Wisconsin into the Great Lakes region together with Illinois, Indiana, Michigan, Minnesota, North Dakota, Ohio and South Dakota. Generally, aquatic areas are considered as areas with higher wildlife activity, especially during seasonal months. For the airports in the Great Lakes region (FAA, 2015) recommends reviewing their wildlife hazard management plan (WHMP) every 12 consecutive months or in cases: an air carrier aircraft experiences multiple strikes, an air carrier experiences substantial damage from striking wildlife, an air carrier aircraft experiences an engine ingestion of wildlife. Specific of Mitchell International airport area is that beside closeness of Lake Michigan there is also a military presence.

Fig. 3.
Milwaukee's General Mitchell International Airport is Located in the Vicinity of the Lake Michigan

Military aircrafts are especially affected by wildlife hazard due to low flight levels and possibility of bird ingestion on the aircraft with only one engine. Research of wildlife strikes in military aviation is very complex because these data are often classified. Nowadays, more and more military organizations becoming aware of wildlife hazard importance and have started sharing wildlife strake data. General Mitchell International airport is another airport with military flight activities within a restricted area. The 128th Wisconsin Air National Guard (ANG) Air Refueling Squadron Base, located on the eastern edge of the airport, maintains and operates the KC-135 aircraft. Fighter aircraft in-flight refueling activities are coordinated and monitored by the Tactical Control Flight Facility (MKE, 2017).

Fig. 4.
The 128th Air Refuelling Wing (128 ARW) Stationed at General Mitchell International Airport

4. Bird Strike Data Analysis at Milwaukee's General Mitchell International Airport Based on Historical Data

The data that is used in the paper is a collection of all entries that have been filed under "Wildlife Strike." Per the requirements by the Operations department, any report of a bird or animal strike, findings of wildlife residue, and pilot reporting of a wildlife strike through the Federal Aviation Administration's wildlife strike system are logged, an entry of Wildlife Strike must be completed. Wildlife strike reports are filed and completed by the Airport Operations

Manager, Assistant Manager, or Airport Operations Coordinator. The data used in this study has been collected from Airport Operations Department logbook system. The data was sorted manually and noted as to the findings of the logbook entry. The entries were classified into six categories of a pilot report (PIREP) (Table 1).

Table 1
The Six Categories of a Pilot Report (PIREP)

PIREP category	Description
PIREP - Negative Findings	A report of a bird strike by a pilot, where the end-result was no findings of any bird remains and/or damage to an aircraft. This is often the case when an aircraft on take-off reports a bird strike, no bird remains are found, and no reports of aircraft damage to the airport authority.
PIREP - Only Remains Found	A report of a bird strike by a pilot, often after departure, where bird remains are found, but no other information regarding damage to the aircraft.
No PIREP - Only Remains Found	A case where bird remains are found on the runway by the airport authority/inspector, and no report of a bird strike by a pilot.
PIREP - Damage Seen	Visual confirmation of damage to an aircraft by the airport authority and/or pilot after a bird strike.
PIREP - Remains on aircraft, no physical damage	Visual confirmation by the pilot and/or airport authority of bird remains on an aircraft, such as blood, or feathers, but no physical damage or indication of a repair being needed.
PIREP - Remains found, no damage to aircraft	A confirmed bird strike by a pilot, and the retrieval of bird remains on the runway by the airport authority, however no damage to the aircraft or any remains found on the aircraft after inspection by the pilot and/or airport authority.

The risk assessment process relies on reported bird strikes so reporting this kind of events in a selective way may significantly impact results (Nešić and Čokorilo, 2017). For the purposes of this study, only written confirmation by the logbook entry author of confirmed damage or residue of wildlife remains on the aircraft will be acknowledged as confirmed cases where damage was done to the aircraft, or there was a risk of damage. Due to inconsistencies in the reporting methods, many entries, for the accuracy of this study, were not classified in either group. The reason for the omission of these entries is, by the wording of the entry, there could be no confirmation of damage to an aircraft, or if visible remains were observed on the aircraft.

Historical bird strike data for the General Mitchell International airport for the period from the 2013 to 2016 have been classified based on the PIREP category (Table 2). According to these data at MKE airport there were 8 cases of damage to an aircraft by bird strike and 22 cases of residue found on the aircraft following a bird strike. There were 28 cases of confirmed bird strikes with remains found by the airport authority, but no damage to the aircraft. There were 39 cases of a report of a strike, but no findings of remains or damage. There were also 14 cases of a report of a strike with remains found, but no inspection of the aircraft to determine damage. Finally, there were 186 cases of bird remains found by the airport authority with no report of a strike. For the cases of aircraft damage and remains found on the aircraft, the findings were individually displayed using Microsoft Excel. The date, type of aircraft, and area struck were noted.

Table 2
Bird Strike Data at the MKE Airport Classified Based on the PIREP Category for the Period from the 2013 to 2016

PIREP category	Year				Totals
	2013	2014	2015	2016	
PIREP - Negative Findings	13	10	9	7	39
PIREP - Only Remains Found	1	3	8	2	14
No PIREP - Only Remains Found	32	39	46	69	186
PIREP – Physical damage Seen	4	3	1	0	8
PIREP - Remains on aircraft No physical damage	1	10	2	9	22

PIREP - Remains found No damage to aircraft	7	9	7	5	28
Total bird strikes	58	74	73	92	

Analyses shows that for the observed sample of wildlife strikes the most common aircraft type is Boeing 737, followed by Airbus A310. This data needs to be taken with caution due to the fact that B737 and A310 are extremely popular aircraft types in civil aviation.

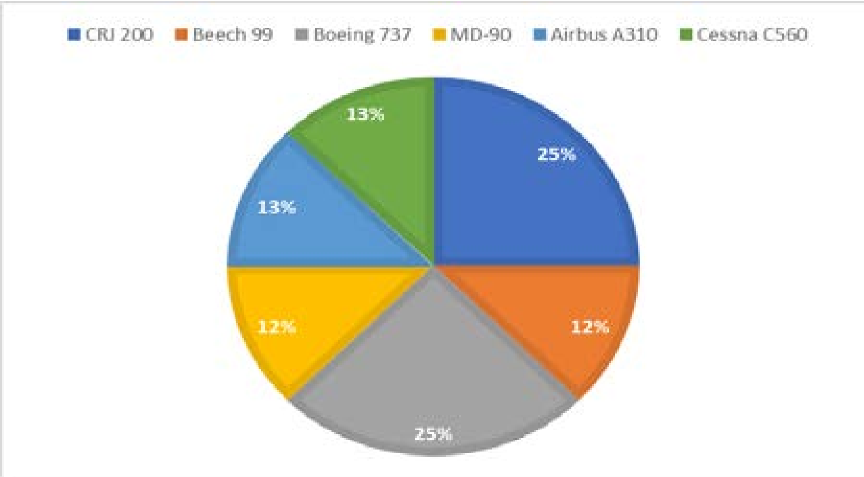

Fig. 5.
The Aircraft Type in Cases when Bird Strike at MKE Airport Caused Aircraft's Damage for the Period from the 2013 to 2016

4.1. PIREP - Physical Damage of the Aircraft has been Detected

In case of bird strike at the General Mitchell International airport following actions have been taken:

- Airport operations staff collects bird remains;
- Flight information and aircraft information is collected;
- If aircraft is at gate, it is inspected for damage;
- Pilots are interviewed;
- Any damage is photographed;
- All information need to be entered into logbook;
- Identifying location of strike on the airport's map;
- Discussing how strike happened based on pilot interview.

Wildlife-aircraft collision sometimes means collision with entire flock of birds in which aircraft would suffer multiple impacts. These cases are particularly dangerous because different parts of aircraft may be damaged and cause multiple failures. The most famous case of such kind is the flight 1549 when collision with flock of f Canada geese caused shut down of both engines. Consequently, the crew was forced to land at the surface of the Hudson river. Study of bird strike occurrences at MKE airport showed that windshield was the most vulnerable part of the aircraft (Fig. 6). This is expected due to exposed position of the windshield and the weaker material comparing to other parts of the aircraft.

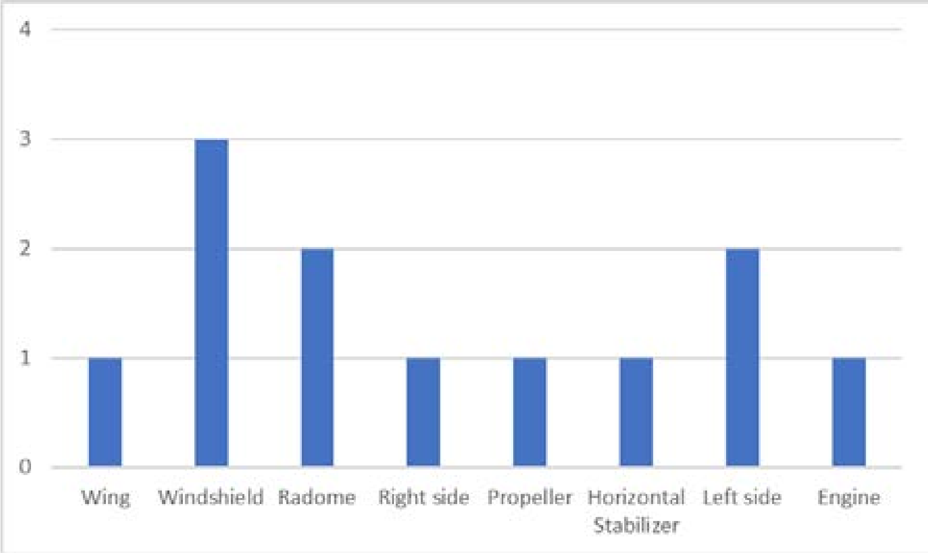

Fig. 6.
The Part of the Aircraft which Suffered the Damage after Bird Strike at MKE Airport for the Period from the 2013 to 2016

Wildlife strikes that caused aircraft damage for this dataset have been emphasized for each year for the period from the 2013 to 2016 (Fig.7).

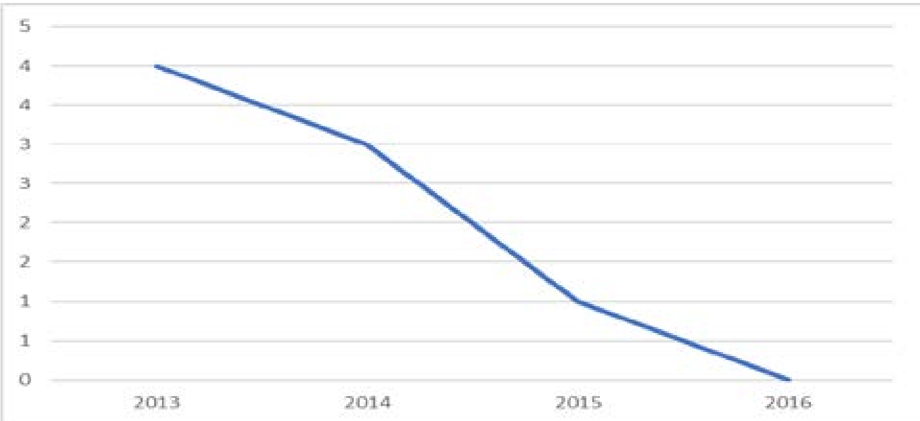

Fig. 7.
The Number of Bird Strikes that Cause the Aircraft's Damage at MKE Airport for the Period from the 2013 to 2016

4.2. PIREP - Remains on Aircraft have been Detected but without Physical Damage to the Aircraft

The study analyses wildlife strikes which caused the aircraft damage and the cases of strikes without damage separately. Per the above research methods, from January 1, 2013 to December 16, 2016 8 cases of bird strikes that caused the damage to the aircraft have been identified. In this chapter 22 cases of bird strike where residue was found on the aircraft but without a damage have been analyzed. For the second bird strike dataset same research methodology was used and the given results are displayed based on various criteria such as type of the aircraft that participated in the collision, part of the aircraft that suffered the impact, the number of bird strikes cases for specific dataset for each year in the given period.

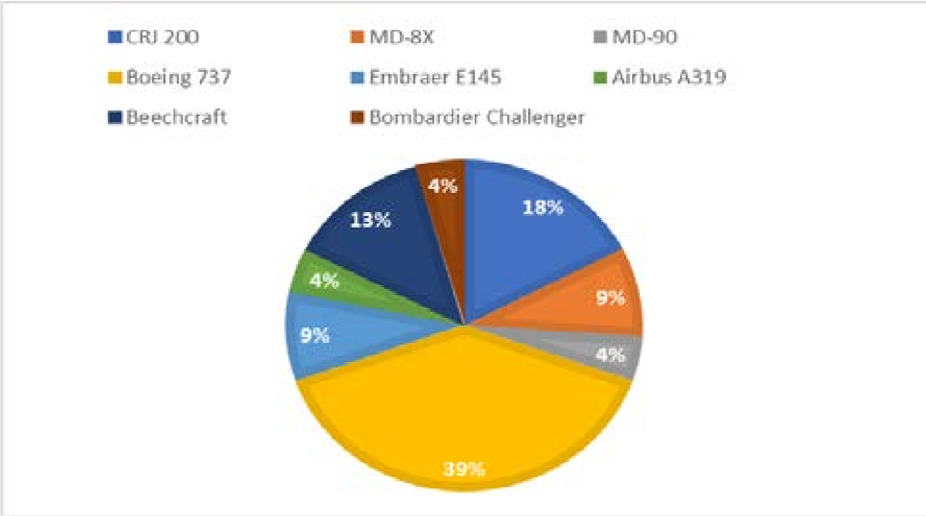

Fig. 8.
The Aircraft Type in Cases where After Bird Strike Remains were found on the Aircraft but Without Physical Damage, for the Period from the 2013 to 2016

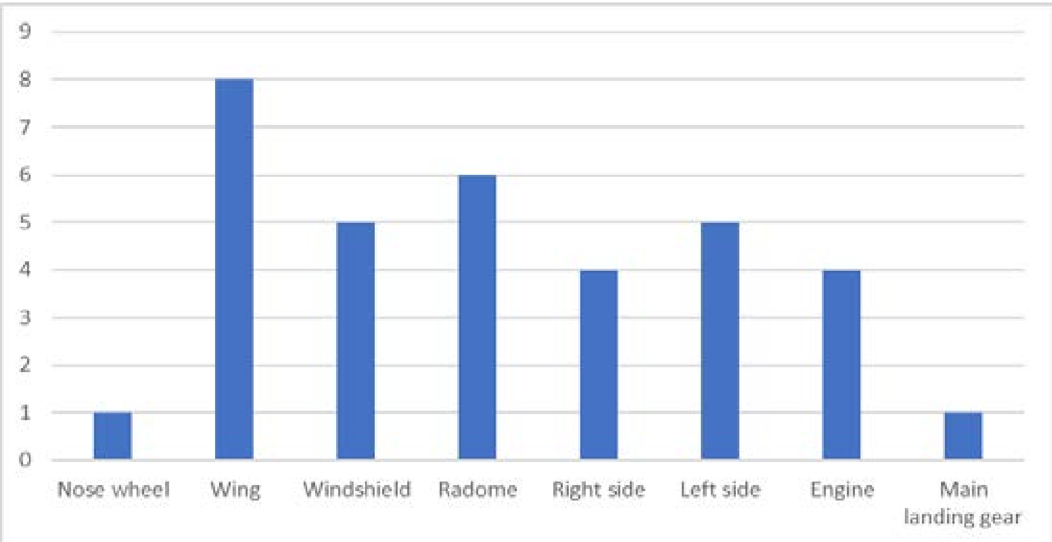

Fig. 9.
The Part of the Aircraft which Suffered the impact after Bird Strike at MKE Airport - Cases where Remains were Found on the Aircraft but without Physical Damage, for the Period from the 2013 to 2016

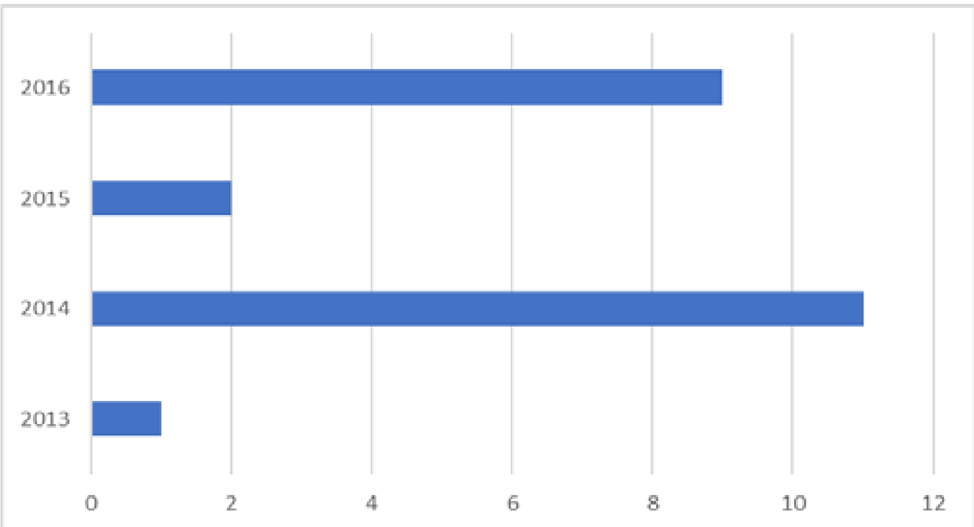

Fig. 10.
Yearly Distribution of Bird Strikes at MKE Airport for Cases when Remains were found on the Aircraft but without Physical Damage, for the Period from the 2013 to 2016

5. Conclusion

For the years 2008 to 2015, the 97 751 wildlife strikes were reported to ICAO by 91 States. Wildlife strikes are also affecting military aviation. At least 283 military aircraft from the 32 countries were destroyed or damaged beyond repair in 1950-99 as a result of bird strikes or during maneuvers to avoid birds. For the United States minimum number of military aircrafts that have been lost due to bird strike in this period is 62 (Richardson and West, 2000). Wildlife hazard concerns all parties in the aviation: airlines, airports, military organizations and aviation authorities. Complexity of the problematic requires comprehensive approach and constant improvement. First step is valid and detailed occurrences reporting. Failure to report bird intrusion leads to an underestimation of the true risk, while the false alarms may lead to blindfold management efforts (Ning and Chen, 2014). General Mitchell International airport operates in accordance with FAA regulations and recommendations regarding wildlife management. Closeness to the Lake Michigan and presence of 128th Wisconsin Air National Guard makes MKE airport more exposed to wildlife hazard. Collected wildlife strike data for the MKE airport showed bird strike data for each PIREP category. It is shown that the number of bird strikes that caused the aircraft's damage at MKE airport for the period from the 2013 to 2016 was constantly decreasing. Same trend hasn't been established when it comes to cases with detected residue but without physical damage.

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MULTIAGENT MODELLING OF INDIVIDUAL TRANSPORT BEHAVIOUR IN THE OSTRAVA CITY

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Abstract: Current computational technologies enable to model transport conditions on the base of stochastic simulation of individual movements. This approach emphasizes a behavioural aspect in the modelling and recommendation to build models by aggregation from individual characteristics and needs. The aim of the paper is to present results of evaluation of individual car transport modelling in the Ostrava city using multiagent simulations (MAS) implemented in the AnyLogic software. The individual mobility patterns are derived from results of the questionnaire survey in Ostrava using the Day Recognition Method following age and gender structure. The residencies of agents are represented by 264 median centres of urban zones. Destinations are location of 2141 important employers, shops, and sport facilities. The random trips were generated according to expected temporal distribution of transport requests for 5 typical scenarios. The external OSM server implements car and pedestrian transport including Open Source Routing Machine (OSRM) for searching routes. Appropriate destinations are randomly selected according to the type of targets, their capacities, distances and the transport mode applying the gravity principle. AnyLogic implements the transport movements based on parameters delivered from the OSM server, visualizes and records all trips into a database log. Further statistical processing of data recorded from more than 0.5 million trips enables to evaluate the transport situation using indicators like average distances, time and the share of pedestrian mode. The results show relatively heterogeneous employer's accessibility with significant differences between urban centres and peripheries as well as strong variations in peripheries. It indicates important local differences in road network and employer's distribution. The results are useful to better understand commuter's needs, for targeted development of road infrastructure, for modelling traffic frequencies in each road segments and for predictive modelling of conditions after completion of the city road network.

Keywords: multiagent modelling, simulation, urban mobility, transport, commuting, Ostrava, AnyLogic.

1. Introduction

Current computational technologies enable to model transport conditions on the base of stochastic simulation of individual movements. This approach emphasizes a behavioural aspect in the modelling and recommendation to build models by aggregation from individual characteristics and needs.

Today data capture about human movement is technically simple using various individual sensors and tools of providers mainly communication and transport services. It includes GNSS logs for cars, bikes or persons (Liao et al. 2007, Kostak et al., 2017), cellphone aggregated CDR data (Yim, 2003; Tranos, Nijkamp, 2015), social networks and user-generated contents (Lee et al., 2013; Hawelka et al., 2014; Kocich, Horák, 2016), Wifi logs (Fratasi, Della Rosa, 2017; Krejcar, 2006), contactless cards in the public transport (Houée, Barbier, 2008) and different combinations (Brida et al., 2014). The common issues of such data are limited availability (limited in time and participants), cost, big data phenomena (Beyer, Laney 2012; Bello-Orgaz et al., 2016), missing reasoning and privacy protection binded with processing of individual personal movement and behaviour. Often such data describes only selected user's category (customers of only one provider, users of registered contactless cards and not all travellers etc.) which create a bias.

Contrary we can utilise a soft data obtained from i.e. questionnaires. The advantage is better understanding the behaviour of each respondent (if detail questions about the purpose, frequency, patterns and influences are included). Unfortunately, due to the privacy protection, lack of time and lack of willingness to provide details we usually obtain a rough picture of human movement patterns without precise time and distance measurements, accurate location of origins and destinations etc.

Disadvantages of both data groups (hard and soft data) can be overcome by joining these data (Klous et al., 2017; Kimijima, Nagai, 2017; Šveda, Madajová, 2015) and integrate them to models of human behaviour which reflects our existing knowledge. Such models can generate simulated artificial data which enable us to precisely answer our questions about movement conditions, to significantly improve our pattern analysis (González et al., 2008; Burian et al., 2018) and understanding the pulse of the city (Batty, 2010).

Such models can be developed in multiagent simulations (MAS). Simulation models based on MAS enable to solve problems and utilize tools depending on time, previous knowledge and also not clear relationships between model elements and their non-linear behaviour. The model retains the system states in loosely coupled autonomous systems called agents (Wooldridge, 2009). Agents in the modelling environment pose certain location which can be changed during modelling according to their properties (Benenson, Torrens, 2004). The agent often knows what his state is and its following activity depends on this state. MA models support simultaneous modelling for different levels of abstraction (Marceau, Benenson, 2011). It enables to represent individual persons as well as to provide aggregation of result for the whole class of agents, or all population of agents, or other logic entities.

Such models are well fitted and broadly utilised also for transport modelling like commuting to work or daily travel behaviour of population (Tilahun, Levinson 2013; Čertický et al., 2015).

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The paper is organized as follows: first, the pilot city and data sources are explained. Further, AnyLogic SW is described with focus on GIS capabilities and how to utilize them for transport mobility modelling. A special chapter is dedicated to description of external services required for routing and target selection. Next, details about model implementation in AnyLogic are provided. The final chapter provides results of modelling and discuss the accessibility evaluation for residents.

2. Methodology

2.1. Pilot City

The Ostrava city (290 thousands of inhabitants, 214 km^2, fig.1) is characteristic by its heterogeneous and non-concentric urbanisation (Kovář, 2009; Igor et al., 2012), where densely urbanised settlements are separated by large non-residential parts like industrial and technological complexes (i.e.ArcelorMittal Ostrava, BorsodChem MCHZ), or by a coarse rural settlement, forest and agricultural fields, mining waste dumps etc.

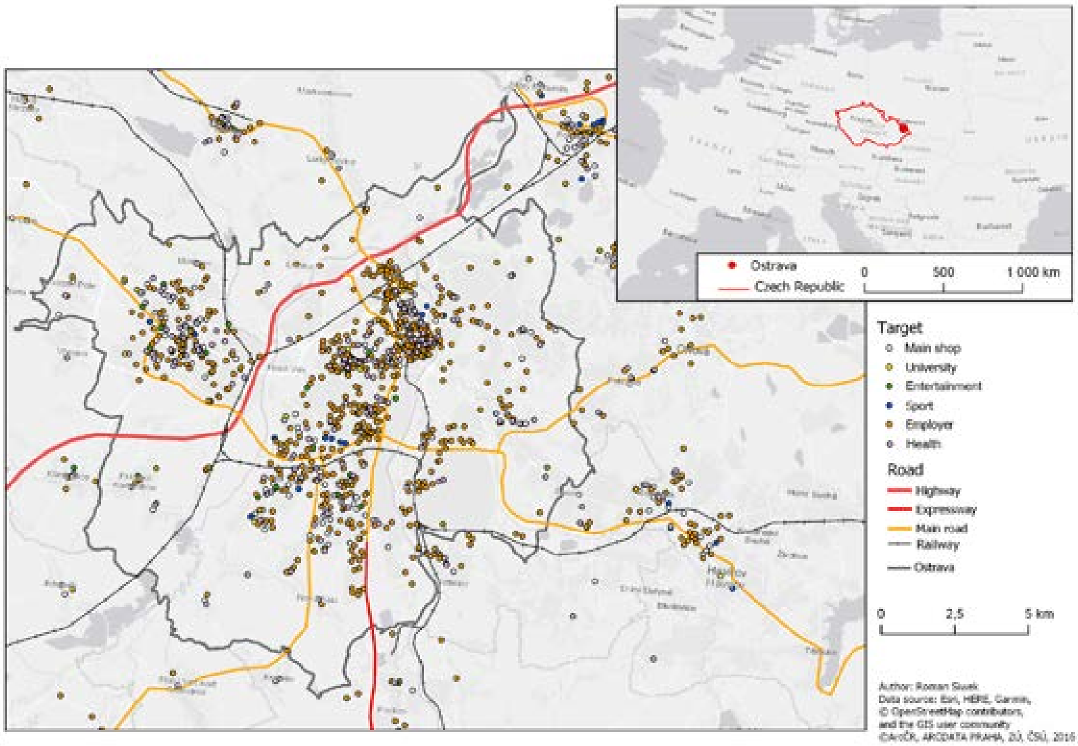

Fig. 1.
Pilot city
Source: own map

2.2. Type and Distribution of Activities

The individual person's mobility is modelled using the scenarios of activities which is planned to perform the given day. Our modelling is currently focused only to residents for whom the start from home and the return to home are anticipated. Each activity can be performed on different places. Different transport modes and their combination can be used for movements but currently in our simulations only car and pedestrian transport modes are available.
Type of activities, their frequencies, usual time and their chaining into the sequence of activities (the scenario), were derived from results of the questionnaire survey in Ostrava between September 22 and 26, 2014 using the Day Recognition Method following age, gender, economical status, educational and locational structure. Altogether 534 questionnaires were collected (Burian et al., 2018). The results document also type of targets, distance and time of travelling, used transport mode etc.
The modelling and its results are focused on the most frequent group of respondents which are full-time workers (employees). The distribution of probabilities of various scenarios for employee is summarised in fig. 2.
The **residencies** of agents are represented by 264 median centres of buildings in urban zones. Potential **destinations** are locations of 2141 employers, shops, educational, health and sport facilities (point features in fig. 1). Each destination is attributed by its capacity (estimated number of employees, shopping area etc.) and time restrictions (working hours, opening hours etc.) to identify time interval when the destination acts as a target.

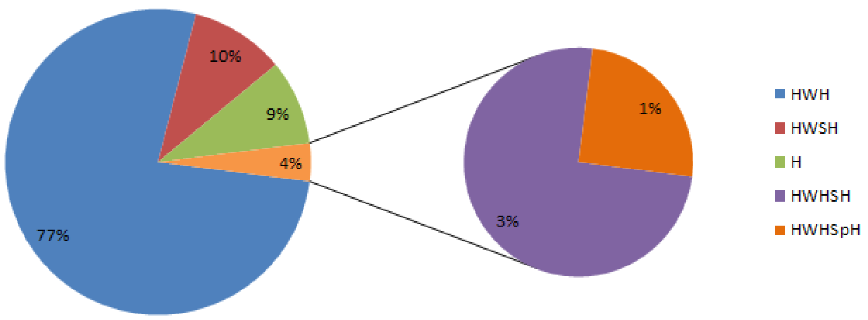

Fig. 2
Probability of scenarios for employee (H home, W work, S shopping, Sp sport)
Source: questionnaires in Ostrava, September 2014

2.3. AnyLogic

For model development the software AnyLogic version 7.3.5 was selected. AnyLogic is a simulation software enabling the design of various types of models like supply chain models, management and marketing, optimisation of manufacturing and storing complexes, including logistic chains and transportation (Grigoryev 2015, Janosikova et al., 2017). The software includes specific libraries for modelling different transport environment and mobility types like Rail Library, Pedestrian Library or Road Traffic Library.

Relatively new (since 7.0 version) (Churkov, Borshchev, 2015) are **GIS capabilities** in AnyLogic. The obligatory component for any GIS related model is the map window offering several map projections (e.g. Cartesian, Mercator).

There are several possibilities implementing agents' movement in this window. Movement functions play an important role for mobility modelling not only for visualisation. The first option is to mark out the whole route. The second option is to use Route Provider function which is more flexible. It enables agents to select own route based on communication with the external server. The type of transport and the corresponding algorithm have to be selected. It is possible to use own (map) server or the route optimisation is performed by AnyLogic based on imported data. Testing of both possibilities discovered issues of the second variant in the case of large data volume (even the graph calculation was failed for the countrywide road networks). Thus we decided to use external map server to provide routing.

2.4.External Services for Agents

The model anticipates a rational choice of the transport mode between car and pedestrian transports. Thus it is necessary to provide parallel route optimisation for car and pedestrian modes to select the favourite mode according to results. For both cases the external Open Source Routing Machine (OSRM) for fast graph searching in road or other networks was utilised. The important step for installation is the selection of the appropriate profile for the network. The profile is a script written in LUA language which describes various network situations. It comprises also information about appropriate setting of values for edges and nodes in the graph, mainly average velocities for each type of road, identification of one-way roads, quantified preferences for every type of roads, penalty for turning and for delay on lights. The script is used to create the graph and not for every searching of the path. Three standard profiles (cars, walking and biking) are available but it is possible to create your own profile (GitHub 2017).

2.5. Model Implementation

AnyLogic performs the transport movements based on parameters delivered from the OSRM server, visualizes routes and records all trips into a database log.

Three classes of agents are implemented: Employee, Destination, and Home. The obligatory backend element of any AnyLogic model is the **Modelling time** where the time unit (one minute in our model) has to be set up. The Modelling time launches all triggers for scenario selection which are regularly repeated at the beginning of the new day. It is also utilised for the selection of destinations or selection of temporal duration of activities.

The **Destination** and **Home** are created from database records by the script in the Main agent before the start of modelling.

The required number of **Employee Agents** is generated during the creation of Home Agents representing population of employees in the given urban zone. They obtain appropriate attributes as parameters; some of them are generated by probability functions.

The behaviour of the Human Agents is driven by scenarios and the agent selects every day only one of the possible scenario for execution. The scenarios were constructed on the base of the survey results – frequency of various activities and their sequences master the probability of scenario implementation.

The model implementation of scenarios contains definitions of various agent's state, the transitions between them, and decision taking i.e. which target and optimal transport mode to select.

Scenarios consist of various states of agents in disjunctive branches of the model (fig. 3). Every scenario possess certain probability of implementation (derived from the survey results) transformed into the corresponding interval of values from uniform distribution from which a random selection is made.
The starting time and duration time are also randomly selected from the probability distribution based on travel diaries. The similar approach is applied to decide when to leave the activity – after randomly selected duration from the probability distribution of duration from the diaries of the corresponding group of respondents.
The decision nodes, placed between each two following states, assure the model's stability and provide the possibility to return the agent home what is necessary in cases when no target for following activity is available. It may happen especially due to time restrictions applied on targets when no „open" targets is available for the given activity in the requested time.
Every scenario ends returning the agent home. The current selection is one of five scenarios (fig. 3). One of them is to stay at home (due to i.e. home office, sick day, and holiday). Scenarios of HWHSH and HWHSpH share the same beginning and they are not fully separated in the diagram.

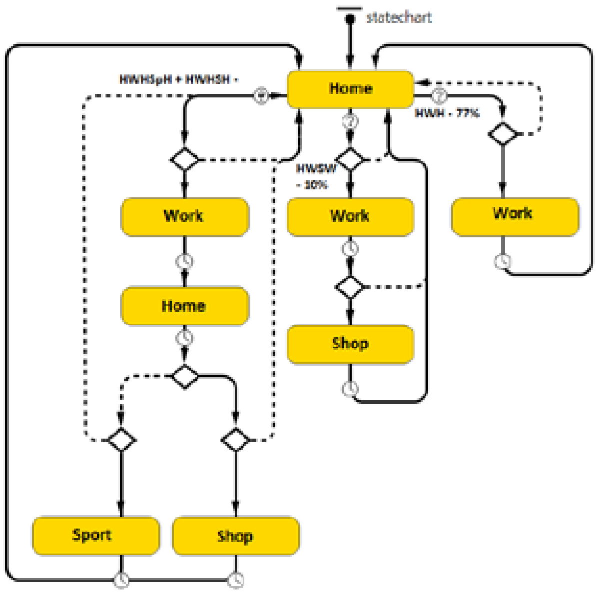

Fig. 3.
Diagram of possible scenarios for Employee Agents in AnyLogic
Source: own scheme

The target for the given activity is selected when the Modellin time matches the time simulated for this activity. The appropriate target is randomly selected according to the type of target, its capacity, distance and the transport mode applying the gravity principle (Horák et al. 2014). The gravity values are calculated for all considered transport mode and all relevant "open" targets. This calculation takes into account also personal preferences of the agent (currently economic type, age, education) and the weight of the target (expressed usually by some capacity assessment like number of employees, shopping area etc.). Higher gravity value indicates better transport mode for the given target. Values are recorded with the transport mode for all relevant targets. Finally the gravity values are normalised, ordered and used for the proportional selection of the target. It means the target with the highest gravity value is not always selected but the normalised gravity value is used as a probability of the target selection to be the goal.
Further, for the selected target (goal) the travel distance and travel time for better transport mode from OSRM server are found. Next, the agent is moved from the origin to the destination along the route provided by the Route Provider for the given transport mode and using the time delivered by the OSRM server.
The model was used for the **accessibility evaluation for employees**. To reach the balanced evaluation we use the same number of simulations in each urban zone. The model launches 10 agents in every urban zone every day and repeat simulations for 50 days, thus we collected 500 simulations for every urban zone. Further statistical processing of data recorded from more than 0.5 million random trips enables to evaluate the transport situation using indicators like average distances, time and the share of pedestrian mode.

3. Results and Discussion

The evaluation of accessibility based on results of the multiple agent simulations utilises selected parameters of the executed movements. We have focused on the share of the pedestrian mode (the rate between the usage of pedestrian and car modes), transport time and transport distance which were calculated as an average from all individual trips.
The first obligatory step is to exclude records of not completed executed scenarios. The ratio of prematurely terminated scenarios represents also one of the useful indicators of accessibility.

The modal split (fig. 4) shows the places where employers (and shops and sport facilities) are accessible on such high level that pedestrian mode is significantly utilised. It corresponds to the premise of higher walking in the centre (Haybatollahi et al., 2015). Except of the centre, such places are located in Poruba (western part), in the southern part of the city and in the surroundings of the ArcelorMittal Ostrava (SE). In these places the destinations are very well accessible and possess the highest evaluation.

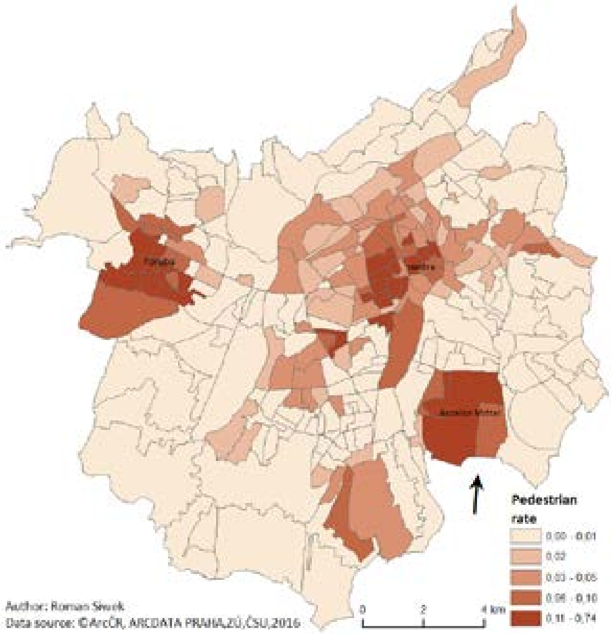

Fig. 4.
The average share of the pedestrian mode from all agent movements
Source: own calculation

The next figure (fig. 5) shows similar inverse patterns. The average travel distances are the smallest in Poruba and the city centre and it shows good accessibility for these centres of population. To the opposite the third most inhabited centre, Ostrava-south, clearly shows worse conditions mainly due to the shortage of large employers in this city part. The second important observation is the pattern is more continual than those for pedestrian share. It indicates relatively sharp switching between usage of pedestrian and car modes and a potential to relax this condition to better reflect differences in individual preferences for pedestrian/car mode. High average distances point out places with bad accessibility conditions. Some of them is relatively close (measured by the Euclidean distance) to places with minimal distances (Hošťálkovice, Lhotka, Paseky near Bartovice etc.). Such abnormal increase of average distance is usually caused by geographical barriers issued in high deviality of routes. While Hošťálkovice and Lhotka are separated from the rest of Ostrava by Odra and Opava rivers, Paseky lies in the shadow of the large fenced industrial area of AccelorMittal.

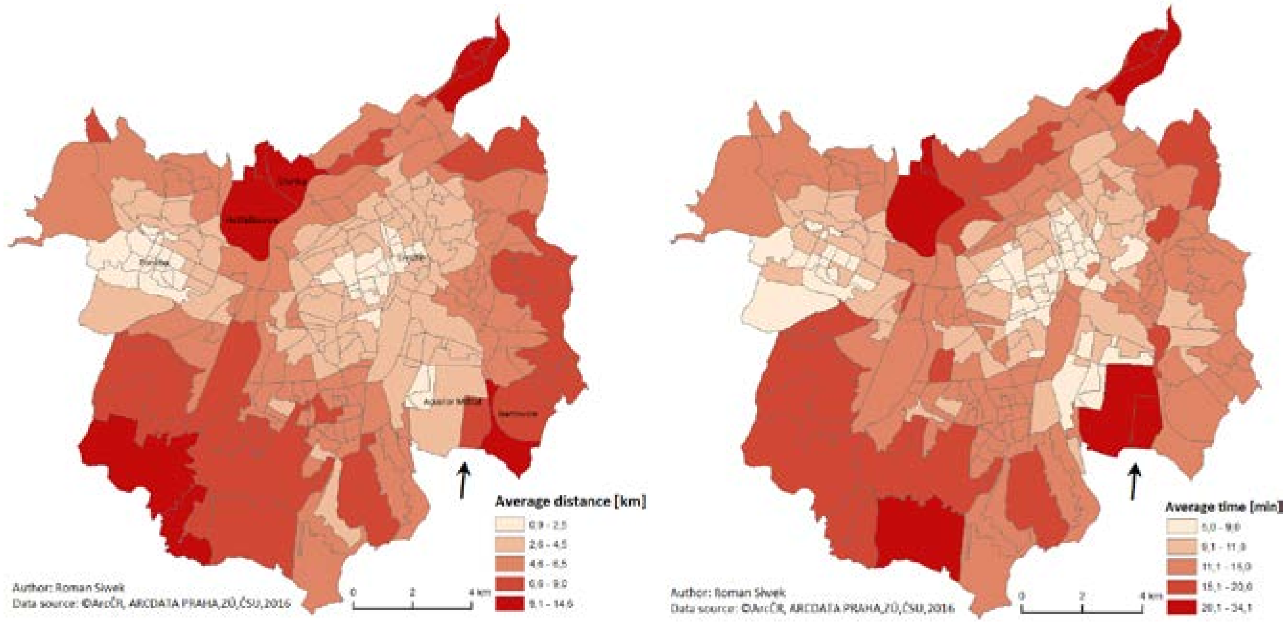

Fig. 5.

Average distances (left) and average travel time (right) of all movements of Employee Agents using car or pedestrian modes
Source: own calculation

The next figure (fig. 5 right) portrays the average travel time. Comparing with the left figure we can see some differences. More fragmented and less continual central parts of settlements shows the internal differences of accessibility caused by the different street/road infrastructure. Some urban zones in SW and SE indicate relatively well temporal accessibility despite of larger average distances. The reason is better developed road infrastructure in the southern part of the city which enables quick movements even for longer distances.
In fig. 6 we can see a bivariate choropleth map where the mean and variability can be study together. It is clear that some urban zones with low average movements are burden with high variation of the accessibility (blue colours in the figure) which are well assessed only for limited number of destinations. The worst conditions are coloured by dark red – in such places (Polanka, outer part of Radvanice on E) practically all movements are very long and the resident has no choice to shorten it. The pink violet shade is quite frequent in the territory, mainly for marginal parts, and it indicates urban zones with large but variable distances which give an opportunity to satisfy the part of requirements in short distances.

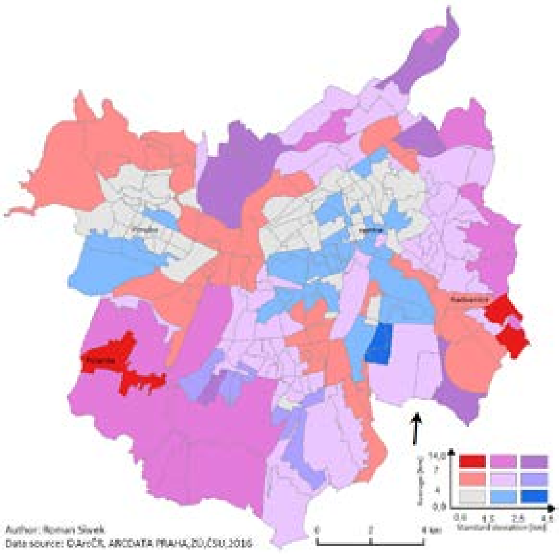

Fig. 6.
Bivariate choropleth maps of the mean and standard deviation for distances of agent's movements
Source: own calculation

4. Conclusion

The MAS was developed using the most frequent scenarios, probability distribution and gravity modelling based on travel diaries. MAS utilizes external OSRM servers which provide car and pedestrian network services including optimal routing and cost evaluation.
The results show relatively heterogeneous employer's accessibility with significant differences between urban centres and peripheries as well as strong variations in peripheries. It indicates important local differences in road network and employer's distribution. The results are useful to better understand commuter's needs, for targeted development of road infrastructure, for modelling traffic frequencies in each road segments and for predictive modelling of conditions after changes in the city road network.
The accessibility evaluation is not the only possibility how to utilise such simulations. We can model the dynamic population in arbitrary spatial and temporal steps (to aggregate locations of agents by i.e. one-minute interval) and create series of kernel density estimations of expected dynamic population during the day. Such results are valuable to identify accumulation of travellers and provide reasoning of existing congestions, to model loading of any parts of road/street network or for predictive modelling of traffic distribution in the case of road network planned changes. Except of transport application also other domains like emergency planning and risk management would utilise modelling the dynamic population in the territory to plan appropriate measures.
The weak point of these models is their validation. We have no appropriate data to validate results of the modelling. We intend to use the remotely sensed data (including hyperspectral data) to detect cars and compare the modelling results with real intensities on roads. In future we plan to implement also an external server for the public transport mode to cover all significant transport modes.

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INTERMODAL AIR-RAIL TRIPS - BAGGAGE DROP OF INSIDE THE TRAIN

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Abstract: Supported through the increasingly extended high-speed railway network in Europe, there are a wide range of considerations for replacing intra-European air traffic to a large extent with the railway. In short-haul traffic, the railway can thereby replace the whole of air traffic as well as play an essential role in feeder traffic on medium- and long-haul flights. In order to create a corresponding demand, the railway must be highly attractive and operate within the framework of an overall airport-feeder system. The following essay deals, from the point of view of travellers, with the basics that should produce a corresponding attractiveness and thus acceptance.

Keywords: AIRail cooperation, intermodal transport, baggage handling.

1. Introduction

In order to reach the EU international community of nations demand for a limitation in temperature rise by 2050 in the EU, greenhouse gas emissions in the transport sector must be lowered by at least 60% compared with 1990 and around 70% compared with 2008. By 2030 a reduction of about 20% below the level of 2008 is required.1 Taking into account the assumption that mobility will continue to increase and as a result the volume of traffic will increase, a reduction in greenhouse gases can only be achieved by an increased use of environmental- and resource-conserving modes of transport. For this purpose, the European Commission has defined ten objectives for the transport sector in a White Paper titled "Roadmap to a Single European Transport Area - Towards a Competitively Oriented and Resource-Conserving Transport System". One of these objectives targets long-haul passenger traffic and proposes the following measures:

- Completion of a European high-speed railway network by 2050;
- Tripling the length of the existing network by 2030 and maintenance of a dense rail network in all member states;
- By 2050 the majority of passenger transport over middle distances should be allotted to the railway.

In order to be able to meet these objectives as much as possible, one feasible approach is to shift to the train (ultra) short-haul flights, which usually have a feeder function to medium- and long-haul flights. In this regard, there are a variety of cooperation possibilities between the aviation and railway sectors.

Parallel to this, the political objectives in the field of air traffic are formulated in “FlightPath 2050” published by the European Commission in 2011.3 In this strategy paper, in addition to societal objectives (for 90% of EU citizens a door-to-door four hour connection should be possible by 2050), environmental protection measures are also formulated (reduction of emissions despite projected growth in the aviation industry). This is a subject of discussion by European industrial leadership who also demand preservation of the already very high safety level in Europe despite the increase in air traffic. These objectives are currently being processed and implemented within the framework of European research programmes (such as JTI CleanSky - fuel efficiency and noise reduction and SESAR - "common" European airspace)

2. Intermodal Cooperation Concepts Between Train and Aircraft

A good transport connection is an important attractive feature for airports. At present, around 130 of all airports worldwide have rail connections, with further railway connections being planned. Originally, rail connection played only a limited role, which mostly involved only local transport and primarily connected city centres and the surrounding areas with airports. It has only been in the past few years that concepts have been implemented to connect city centres to airports, which have made rapid connections possible (e.g. Heathrow Express in London), and in some cases also connections providing service functions such as check-in or luggage check-in (e.g. the CAT in Vienna).

With the advent of high-speed rail transport, new opportunities for trains were created with regard to their competitive relationship to aircraft. The shorter travel times allowed the train to compete directly with aircraft at distances between 350 km and 750 km. From this competition situation, cooperation comprised of a combined offer between train and aircraft also developed to some extent. A distinction is made in the literature between the following forms of the relationship between train and aircraft:

2.1. Competition, Cooperation and Integration

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The two points "cooperation" and "integration" are the forms of intermodal traffic between train and aircraft which are relevant for airport connections. Different forms of cooperation between railway companies (RCs) and airlines are being developed, which are intended to provide passenger-aligned services. This can include, for example, the area of luggage transport, check-in, ticketing, information and security services. Depending on the degree of cooperation, the offers may be classified as follows:

- **low:** This type of cooperation is intended to provide travellers with a fast and congestion-free arrival to or departure from the airport. This includes, for example, the sale of train tickets by the airline (e.g. Rail&Fly - Germany).
- **moderate:** This form of integration usually involves codeshare agreements between the RC and the airline. In addition to the train number, the respective train is assigned its own flight number and is distributed by both parties. The advantage for the traveller is that in case of late arrivals, the necessary measures such as rebooking are carried out by the airline or the RC (e.g. tgvair - France).
- **high:** A higher form of integration in addition to the aforementioned points also includes luggage transport or separate areas in the train for business- and first-class passengers (e.g. AIRail - Germany, up to 2007).

Table 1

Measuring results provides an overview of the forms of cooperation and the respective characteristics

Level of cooperation	Type	Example	Participating companies	Range of services
low	Interlining-agreement	Rail&Fly	DB with 70+ airlines on 5000+ routes	Sale of tickets
moderate	Codeshare-agreement	tgvair	SNCF with 10+ airlines	Assignment of own train- and flight number; ev. Integration of IT-systems
high	Joint-Venture	AIRail	Lufthansa with DB between Frankfurt – Cologne and Frankfurt - Stuttgart	Coordination of luggage transport (up to 2007) and other service features; separate areas and catering service in the train

There are different cooperation models between airline and railway operators worldwide. In the following, four concrete examples are described in more detail, each of which have a different degree of cooperation.

Table 2

A comparison of the included service features of the described models

Intermodal offer	Train ticket sales by airlines	Codeshare - agreement (own flight number for train)	Check-in at departure train station	Luggage check-in at departure train station	Guarantee in case of late arrival	Separate area in the train and catering
Rail&Fly (DB)	●					
Fly Rail Baggage und Check-in at the train station (SBB)			●	●		
tgvair (SNCF)		●	●*		●	
AIRail (DB)		●	●	○**	●	●

*Note: *just for a view airlines; **service was offered till 2007.*

3. Influence of Luggage on the Choice of Transport Mode

The transport of luggage is an essential decision-making criterion for the choice of transport mode. Despite increasing costs in the area of motor vehicle traffic or increasing traffic problems, the auto still enjoys unwavering popularity, with feeder traffic to the airport as well, above all due to luggage transport when travelling. The reason is that compared to all other elasticities, elasticity with luggage is highly valued (see Table 3).

Table 3

Travel elasticity in Austrian holiday travel traffic – comparison

Luggage	0.685
Mobility to destination	0.655
Travel cost	0.630
Transfer	0.469
Travel time	0.386

Source: (Rüger, 2005)

The thereto by comparison lower cost and travel time elasticity presupposes that changes in travel cost whether these are: cost increases for passenger-car traffic, cost reductions for train traffic as well as alterations in travel time, prolongation with passenger-car traffic or expediting measures with public transport; in all cases of travel in which luggage is transported, these have a correspondingly lower effect than measures relating to luggage transport.
Thus, for example, for 82% of winter holidaymakers travelling by auto in Austria, travel luggage is a major reason for the choice of the auto during holiday travel, whereas for only 55% the cost and for 40% the travel time have a decisive influence.24 These findings apply analogously in feeder traffic to airports.
In the case of air travel, the luggage for example, strongly influences the choice of transport mode for arrival at the airport. Above all in the case of transport of larger and heavier pieces of luggage, airport taxi services or private autos are chosen depending on the distance to the airport. The train is then preferred if little or no luggage is taken. Conversely, travellers in intermodal traffic (rail- air-traffic) are prepared to pay the most for luggage transport services compared to all other services.

4. Wishes for Airport Feeder Trains

In the research projects “Gepäcklos” and "TerminalAufSchiene", among other things, the wishes and needs of AlRail passengers for appropriate feeder trains were compiled separately.

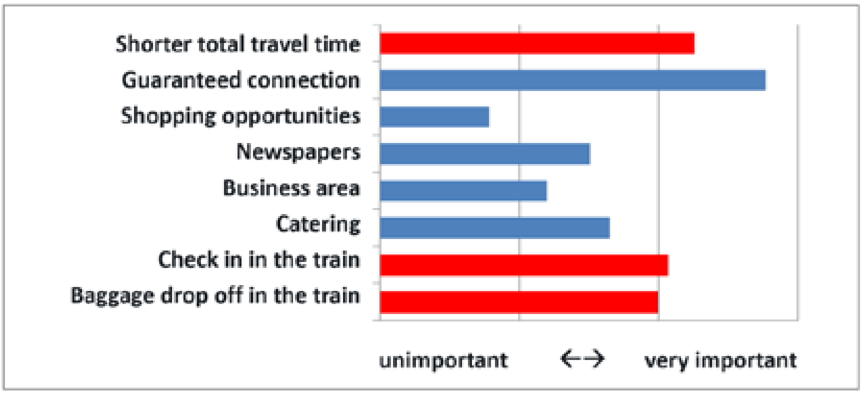

Fig. 1.
Importance of diverse product features for airport feeder trains
Source: (Albl, 2015)

In addition to the connection guarantee in the sense of assurance of connections or travel alternatives, which are offered in the above-mentioned cooperation and integration systems, above all the factors: "short travel time", "check-in on the train" and "luggage check-in on the train" play an important role in regard to the attractiveness and increased choice of the train in feeder traffic to airports. All three criteria are evaluated on average as "rather important", with an average score of 2.9 to 3.3 on a scale from 1 (not important) to 4 (very important) (see Figure 1) (Albl, 2015).
For approx. 70% of travellers arriving at the airport, the possibilities for handing over luggage and at the same time checking in on the train are important (for 40% of them even "very" important) and would therefore be a significant reason for the decision to choose the train as a mode of transport to the airport. For over 80% of travellers the shorter travel time is correspondingly important (see Figure 2).

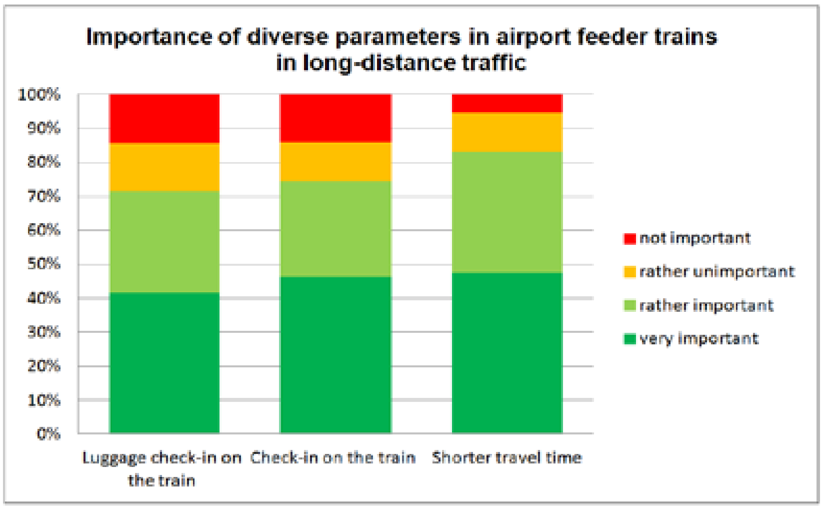

Fig. 2.
Importance of luggage drop off and check-in on the train
Source: (Albl, 2015)

For a short travel time, in addition to high travel speed and short stop-over time, an efficiently used travel time is also important. This can be achieved by relocating activities at the airport (e.g. check-in and luggage check-in) to the train. For this, an appropriate interior design in an airport feeder train is necessary. With regard to check-in service, it must be taken into account that through the use of new media, the classic check-in at the counter is being increasingly replaced by web check-in or mobile check-in. It is to be assumed that check-in at the counter is predominantly used in connection with luggage check-in. However, the possibility of check-in on the train is rated as similarly important to the possibility of luggage check-in on the train.

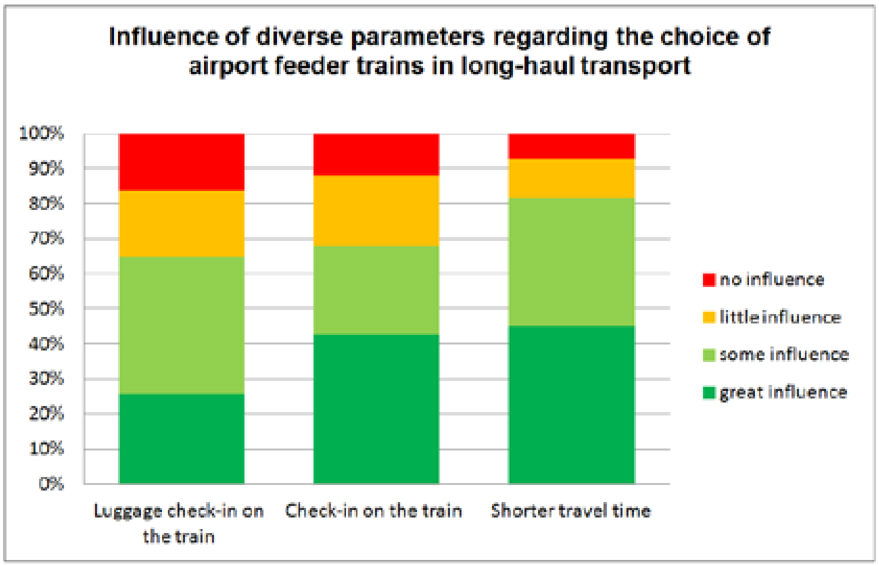

Fig. 3.
Influence of diverse criteria on the choice of transport mode for airport feeder traffic
Source: (Albl, 2015)

Regarding the influencing criteria: whether in the future appropriate airport feeder trains in long-haul transport will be chosen, 65% of travellers indicate that the possibility of luggage check-in on the train would have an influence on behaviour in the choice of transport mode. For more than 25% this possibility would have a great influence. In terms of travel time, over 80% of travellers say that a shorter travel time would have an influence on the future choice of the transport mode for arrival to flights and for 45% travel time for arrival would have a large influence (see Figure 3). It is important to take into account that travel time for arrival is not the only travel time to the airport, but is to be considered as a whole-time requirement for door-to-door mobility.

5. Conclusion

The studies show that there is a great interest among air travellers in using the train for arrival to the airport. Attractive service features tailored to air travellers are essential for the acceptance of the train. These include: on the one hand,

already known services and in many cases services that have already been implemented by many providers in the area of "connection guarantees". On the other hand, it is clear that above all luggage transport has a major influence on the choice of the transport mode, also in terms of airport arrival behaviour. In this area, there are to date few or no suitable service concepts that ensure the attractiveness of the train to a sufficient degree. At the same time, it is clear that from today's point of view, effective innovative concepts such as luggage check-in during train travel to the airport would create corresponding interest and acceptance by air travellers and would have a deciding influence on the choice of transport mode.
If the aim is to transfer a large part of intra-European short-haul air-feeder traffic as well as the airport-feeder traffic overall to the train, it is essential to develop innovative service concepts that are from the traveller's point of view, highly attractive and go beyond what is offered today.

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PLANNING OF RAIL FREIGHT UNIT TRAIN OPERATION IN THE LIBERALIZED ENVIRONMENT – INSTRUMENT FOR DYNAMIC ASSIGNMENT OF PATHS ON RAILWAY NETWORK

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Abstract: Reliability, speed and accuracy of transport according to customer needs is an essential aspect that affects the competitiveness of rail freight transportation. All resources used for planning, assuring and realization of individual transport are limited. The basis is that all operations must be planned, because it is the best way, how to provide service as required by customers with the least possible use of the capacity of the resources and also does not overload them. This paper considers the problem of improving short-term train path planning and operation path management that the ad hoc assignment of train path to the definite trainset operating under real-time information and automated assigning system. The proposed instrument performs dynamic assignment of ad hoc request for train running to appropriate train path through a fast and efficient solution procedure based on the assigning algorithm. The instrument reduce time for path assignment and enable to dispatchers use more time on solving real-time operational problems caused by disruptions. The procedure has been tested on real-life data from one of the major railroads in Central Europe.

Keywords: rail freight transport, planning, path assignment, train operating company, infrastructure manager.

1. Introduction

Railway transport is a dynamic system. The train operating company (TOC) must fill the conditions on the goods transport market. On the other hand, the TOC must satisfy the customers demand as much as possible. Creation of the train path is based on the customer requirements.

Unfortunately, the assignation of train path is an elemental limitation in the planning of freight train running. This is done by the fact that train path creation and assignment is not in the TOC competence, but infrastructure manager. Moreover, there is a long-term plan of assigned capacities of train paths being created one year before the timetable regular construction. This plan is needed to be abided as much as possible, because the train paths were already paid by TOC. There is a high potential of risk for TOC, that it won´t be possible to get another train path (the ad hoc train path) due to quality reasons or no capacity available. Last but not least the ad hoc train paths are more expensive than regularly constructed train path, what affects the final price.

This document is focused on problem of ad hoc straight unit trains. In the past, this problem was not being solved much, for example due to prioritizing of operational problems with the shipments. Customer´s requirements is not always possible to provide by trains from the regular timetable or train formation diagram. There are various influencing factors, like for example the arrival of the ship, technology of production, etc. Some of shipments are organized only few times per year, so it´s not possible to create the train path in regular construction for them. Also there are shipments, which are being organized without future plan, so it´s impossible to predict the real organization time. In some destinations, there is not possible to create the paths for regular timetable construction due to loss of orders, what again causes increased demand for ad-hoc paths.

As already mentioned, the current trend is customer oriented behaviour, where the train path plan is being adjusted based on the customer wish. There is a risk, that if the train paths were ordered as regular ones, it might cause sanctions for operator due to non-used/refused capacity, or wasting of the other capacities. All the cases of transport demand, which is not possible to be solved by regular trains, are planned ad hoc, as mentioned below:

- Unit trains, not mentioned in regular timetable;
- Unit trains, mentioned in regular timetable, with ride planned per demand;
- Late regular trains;
- Trains, which are operating delivery of shipments above the regular timetable and train formation diagram. (Internal document ČD Cargo, 2013).

In first and last mentioned case, the planning process works like below. First, client has to create order of transport, resp. ad hoc train. This kind of order client has to send current time before the estimated/demanded departure of train. After that order is being handled via system for long-term trace planning. If it´s not possible to handle the ad hoc order in the current scope, the order is returned back to the client and he is offered another operative solution. The order of ad hoc train has to include the starting and final destination details, sender and final recipient data, information about all transport operators, who will handle the shipment, borders crossing stations of the path, also information about length and weight of the train, goods, estimated time of handing/departure/arrival of shipment and moreover important

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characteristics about shipment (for example dangerous goods). Ad hoc trains are being aligned in order of importance after the regular trains (Internal document ČD Cargo, 2013).
The aim of this document is to find the algorithm for ad hoc path assignation. The algorithm will be used in the operational planning for satisfying of customer demands or internal parts of TOC's.
Every train, which is not using the year regular timetable or any other timetable, is ad hoc train. A train which for example is using another timetable is a regular train whose timetable is scheduled 14 days before the drive, and in this period there is no other change of the timetable or planned capacities.

2. Problem Definition

The rail cargo operator, who provides wide network of current wagon load and also unit trains, which are connected via system, has in the environment of liberalised market take care about ordering of train paths and their using. In time of renaissance of rail transport is not possible to apply process, used in the past, when ad hoc trains were being handled only by experience and knowledge of dispatchers. It is necessary to find systematic and efficient solution for using of ordered, but useless paths. It is necessary to minimize infrastructure costs for TOC.

3. Analysis of Railway Infrastructure Charge

The railway infrastructure managers must deal with several factors that affect the assignment of the train route capacity. Those factors are:

- overload of the key infrastructure segments;
- global increasing amount of trains in the whole system;
- growing amount of passenger trains in the peak times;
- decreasing stability of the rail transport sector;
- increasing length of the transport lines, which causes higher variance of train paths;
- requirement for a more precise cost division of the provided services.

Some railway infrastructure managers have decided to change the system for calculating the transport infrastructure using cost. They have also decided to introduce a system with incentives and sanctions for regular using, or not using of the ordered services. (SŽDC, 2016) Those steps have a direct impact on the TOC's. The cost of the train running in the Czech Republic contains two basic parts. The calculation formula is:

$$C_c = C_{pk} + C_{pd} \tag{1}$$

Cpk is a cost of assignment of capacity (train paths assignment);
Cpd is a cost of using the infrastructure.

The price of assignment of capacity is calculated by the formula:

$$C_{pk} = K_1 + K_2 \cdot L + K_3 \cdot D \tag{2}$$

K_1 is a price of proceeding and assigning of train path and assigning of infrastructure capacity;
K_2 is a price of train route compilation;
K_3 is a price related with the day of assignment of train path;
L is a length of train path;
D is an amount of days which the train path is assigned.

The price depends on the submission time of the application, resp. on the length of time between the submission and the time of the train running. Despite the fact, that the core of this paper are ad hoc trains, it is necessary to calculate with non-used train paths planned regularly. (SŽDC, 2016) It is no doubt that is a necessary solve all tree infrastructure tariff parts.
The second part is a price of using railway network. The price Cpd is calculated:

$$C_{pd} = L \cdot Z \cdot K \cdot P_X \cdot S_1 \cdot S_2 \tag{3}$$

Cpd is a cost of using the infrastructure;
L is a length of train path;
Z is basic price;
K is coefficient of the railway line category of the (regional, mainline);
Px is product factor (train categories);
S1 and S2 are specific factors (weight, ETCS (European Train Control System) equipped vehicle);
In case of S2 factor fulfilling by the train, the carrier gets 10 % discount from the Cpd.

If the train path will not be used, the infrastructure manager charge penalty for non-usage. This penalty is charged by the formula:

$$F = T \cdot L \tag{4}$$

F is penalty for non-used infrastructure;
T is a sanction index (the level on this sanction is depend on the individual line and their using);
Larger TOC uses planning tool for planning and ordering of train paths use. This system usually allows to edit own train paths, modelling of the train runs and impact of modelled steps (Oltis Group, 2017d);
In the process of train path planning is necessary to use data stored in databases – for example data about infrastructure, another trains, lockouts, goods flows, locomotives, etc. Thanks to the link in the system is possible to deal with every feature. The results can be tested immediately. The program can calculate financial cost deviations from proposed technology (Oltis Group, 2017b).

Table 1
Inputs and Outputs of the information system for freight train operating company

Inputs	Outputs
Data about railway network	Freight transport timetable
Data about trains and locomotives	Matrix of relation for train formation
Archive data about goods flows	Data for managing of marshalling yards
Lockout plans	Plan of the freight trains composition
	The lockout orders
	Orders for the Infrastructure Manager System

Source: Authors with (Oltis Group, 2017b)

In context of the operational work planning for unit trains, the result are trains paths. These train paths are edited by the capability of the transport infrastructure capacity. The infrastructure capacity is ordered by the infrastructure manager system. (Oltis Group, 2017d) The result is complex background data from rail timetable for other systems used by another TOC's and infrastructure manager.
System approach methods and logic methods (analysis and synthesis) have been used for fulfilling the main objective of the paper. System approach in management tries to achieve application of functional analysis concept and application of general systems theory in management. It is characterized by complex view of objective reality that is assessed as a multi-dimensional organized unit. The contribution of this approach is based on inner relations management system analysis, in acceptance of importance of both mutual influences of inner factors and interaction of the system with its environment. (Habr, 1972)

4. Discussion

In this chapter algorithm **for assigning the train path to the railway infrastructure** is described. This algorithm chooses the most appropriate path between available paths (ordered paths in regular timetable) or between available paths and ad hoc (new) path. The algorithm could be used in the short time planning and operative control of train running. The algorithm completes the totally missing element in the planning of freight railway transport and assignment (and management) of infrastructure capacity (especially in the Czech Republic).
The input data for algorithm are:

- ordered paths of individual freight trains;
- time possibilities of available train drivers, their work plan;
- available path offered by the infrastructure manager;
- routing of freight wagons;
- customer´s demand.

In the everyday railway traffic, the algorithm has to be connected with usually used information systems for TOC's and infrastructure manager. During the test, done by authors, the algorithm worked with sample data.
During the whole process of checking capacity of railway infrastructure, the algorithm works with the paths database, which contains paths ordered by the TOC and available ad hoc paths. At the end of the process demands on paths are placed into relevant databases.
The algorithm in the TOC's information systems structure and infrastructure manager information systems structure is on the figure 1.

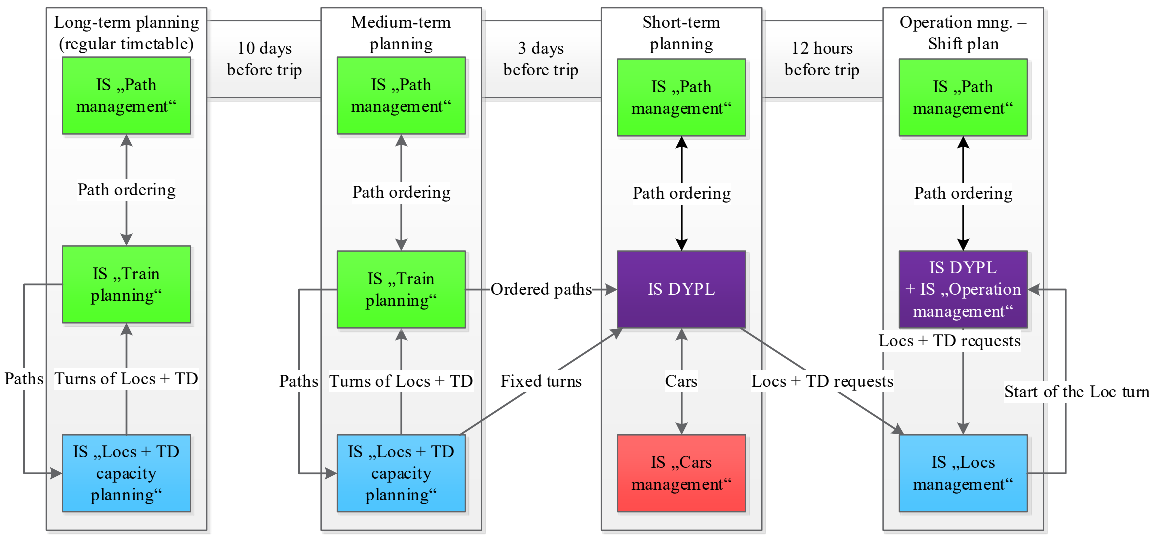

Fig. 1.
Structure of information systems used for train operation planning
Source: authors

The aim of the algorithm is to lay principles for further research on the management optimization of available resources whose are planned in the long term. Those resources have to be listed with the real facts that occur at any time between the entry of the train request into the TOC's planning systems and the output which is a scheduled train in the infrastructure manager's operational control system. For each individual train path, the algorithm will provide basic capability possibilities, then planning of infrastructure capacities and assignment of specific capacities on the railway infrastructure. For example, if there will be a request to secure ad-hoc path from starting point A to a destination B (over a period of more than 1 month), a departure at x and an arrival at x + t, the system will find solution for that situation based on predetermined criteria. The all of new incoming transport requirements will take in account the options that will be defined from the previous planned shipment including in the timetable.
The purpose function *f (x) = min*
Due to the fact, that pattern we are interested in is composed of variable parts, there will be a new pattern, which will work in the same time like a minimization function.

$$C_{c\ opt} = K_1 + K_3 \cdot D + L \cdot Z \cdot K \cdot P_X \cdot S_1 \cdot S_2 + T \cdot L \tag{4}$$

where:
K_1 is a price of proceed and assign of train path and assign of infrastructure capacity;
K_3 is a price related with the day of assignment of train path;
D is a number of path using days;
P_x is product factor (train categories);
Z is a basic price;
K is coefficient reflecting the category of railway line (regional, mainline);
L is a length of train path;
T is a penalty for non-used infrastructure;
S_1 and S_2 are specific factors (weight, ETCS equipped vehicle).

Limitations:
Analyse of requirement on the transport services and available infrastructure capacity. The requirements like system inputs are variable by the character and location of origin. The proposed deal with the three basic types of input requirement (figure 2).

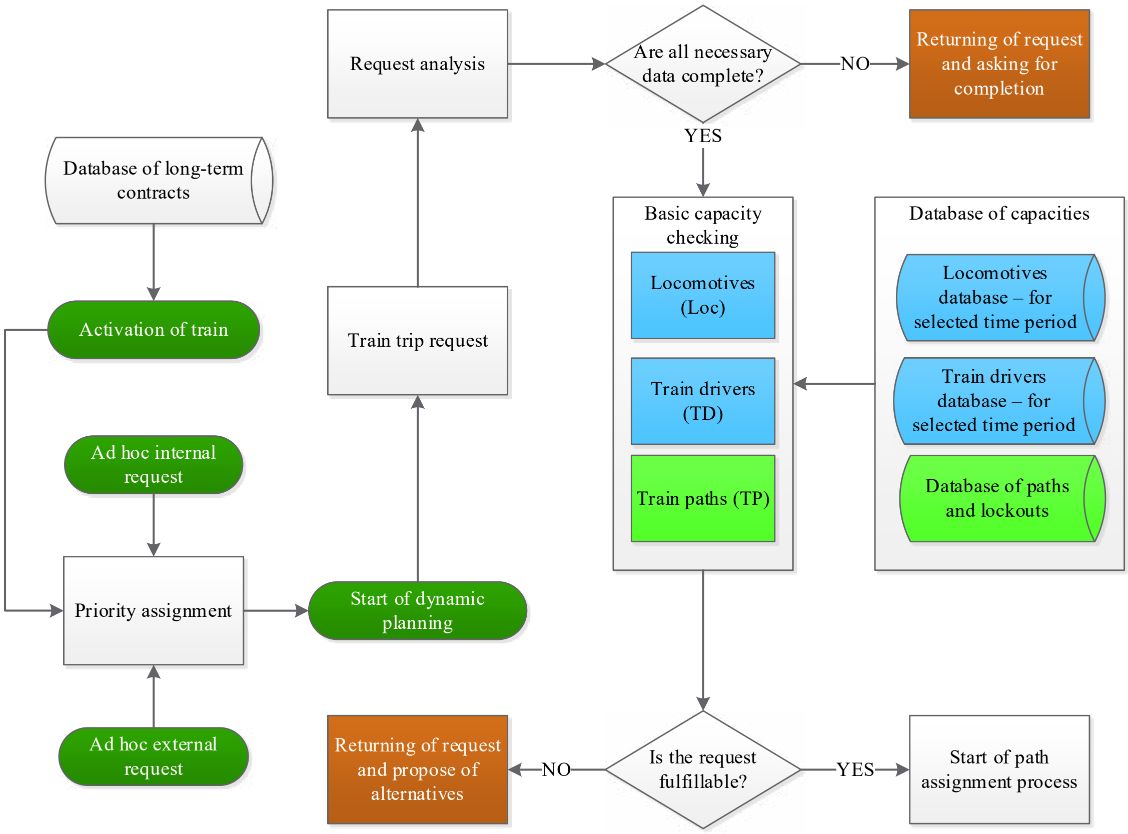

Fig. 2.
Scheme of request analysis and inputs
Source: authors

The first is a requirement that should be the most occurring. That requirement is a train running based on long-term plan (the regular timetable request) with unchanging dispositions and a simple assignment of already scheduled capacities to the given train path. After activation of the long-term requirement (assuming that it is a long-term contract and customer will inform on time, when it will be proceeded), the algorithm is entered in the system. This category also includes regular (daily or almost daily) trains. The creation of train run according to the optimally planned capacities has a direct link to the quantification and assignment of the real costs to a solution for the individual specific business. The assignment of cost will be made on the outputs from the current TOC's operational management information system or another information system.
The second requirement is internal. It could be e.g. the requirement to transport empty wagons to the loading station or the requirement of the TOC's train run for their own use.
The third requirement is a random one-time or random repeated request for transport services (ad-hoc train request).
Individual requests gain assigned priority based on customer information. Priority assignment is not the goal of this paper. On the other hand, it is necessary to present it here, as they will be determined by the customers and by their requirement of transport importance and by train categories.
Between important factors for priority determination belong:

- international train path on the rail freight corridor (RFC);
- another international train path;
- customer requirement on the Just in Time carriage;
- train paths ensure carriage of single load wagons service.

RFC are currently pushing carriers to improve the accuracy of trains running on freight corridors. In specific cases is possible to change the priority of trains. Trains carrying single wagon loads between marshaling yards have to get extra care because the delay of such a train affects to the transport times and the regularity of the operation of next trains.
The first step in the infrastructure capacity solution is paths sorting according to transport type. The instrument load the ordered paths from the relevant database. In the next step, the algorithm tries to find a most appropriate path. The first criterion is using of suitable paths for the definite carriage type. If the carriage consists the single load wagons or groups of wagons for which it is possible to use the route dedicated for the single load wagons services, the path is used. By this process paths that are generally suitable for another type of transport are excluded (figure 3). There remains a review of common freight train paths where a specific product factor is not used.

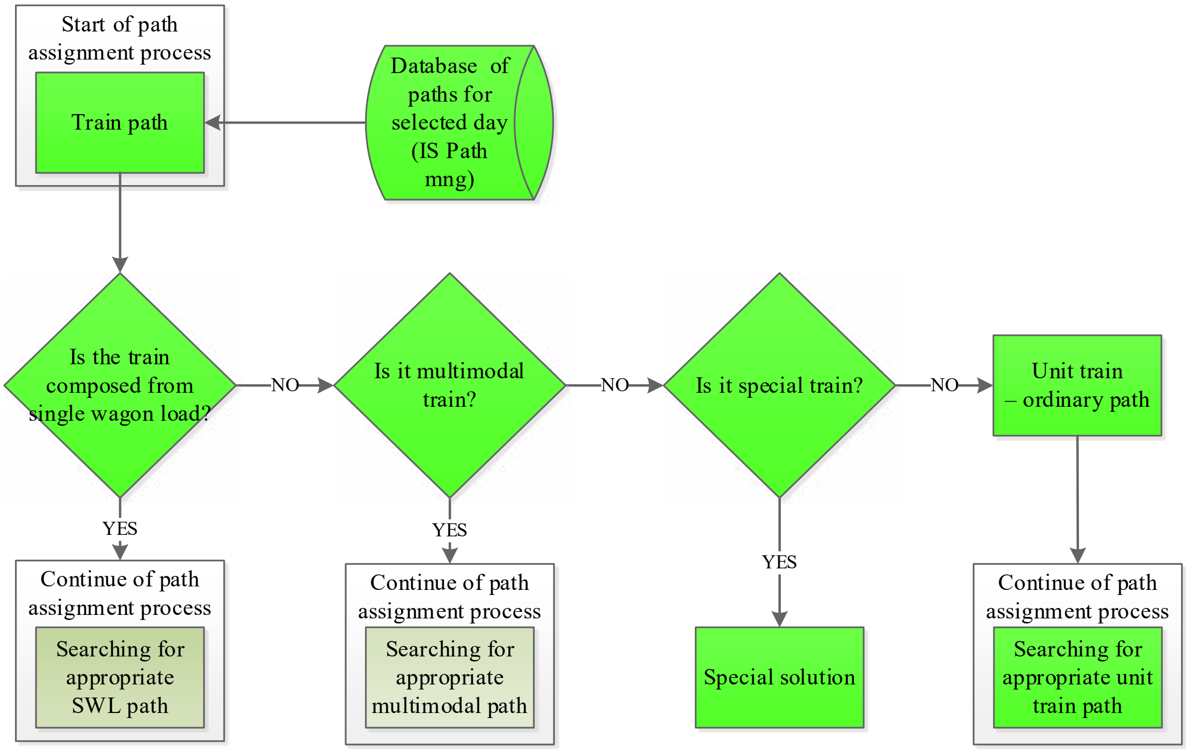

Fig. 3.
Scheme of choosing appropriate assignment process according to products factors
Source: authors

The instrument has been developed mainly as a solution of the process of service provided for unit customer trains without specific features because almost of this type of train are running ad hoc. The freight transport without specific features is a current term of product factor in the price model, which is focused on the trade segment (in this case it means, that it is not passenger transport, single wagon loads or unstandart trains). This case is the most basic one from group of cases with usual unit customer train. The unit customer train is a usual product for propose which is specified in this paper. It checks to see if train path is in the database of ordered paths. If such a path exists, the algorithm assigns that path to a particular train running and after the assignment of the locomotive and the train driver sends a request for activation of the path to the Infrastructure Manager's information system. It is shown in figure 4.
If the algorithm finds the proper path, the algorithm still works. It searching the path with product factor for a usual freight train. The algorithm does not consider the possible combination of the paths and this will be the further scientific activity.
If a suitable train path is found, the path will be assigned and activated as is described in the previous paragraph. If will not be found the proper path with suitable product factor, the algorithm start to find in another product factors (product factors for single load wagon, etc.). If a suitable path is found, a change of parameters (change of the product factor) of the path. This change is realized through the infrastructure manager's information system which ensured in the following process. It includes assigning a route for a given path and then activating the path (figure 4).

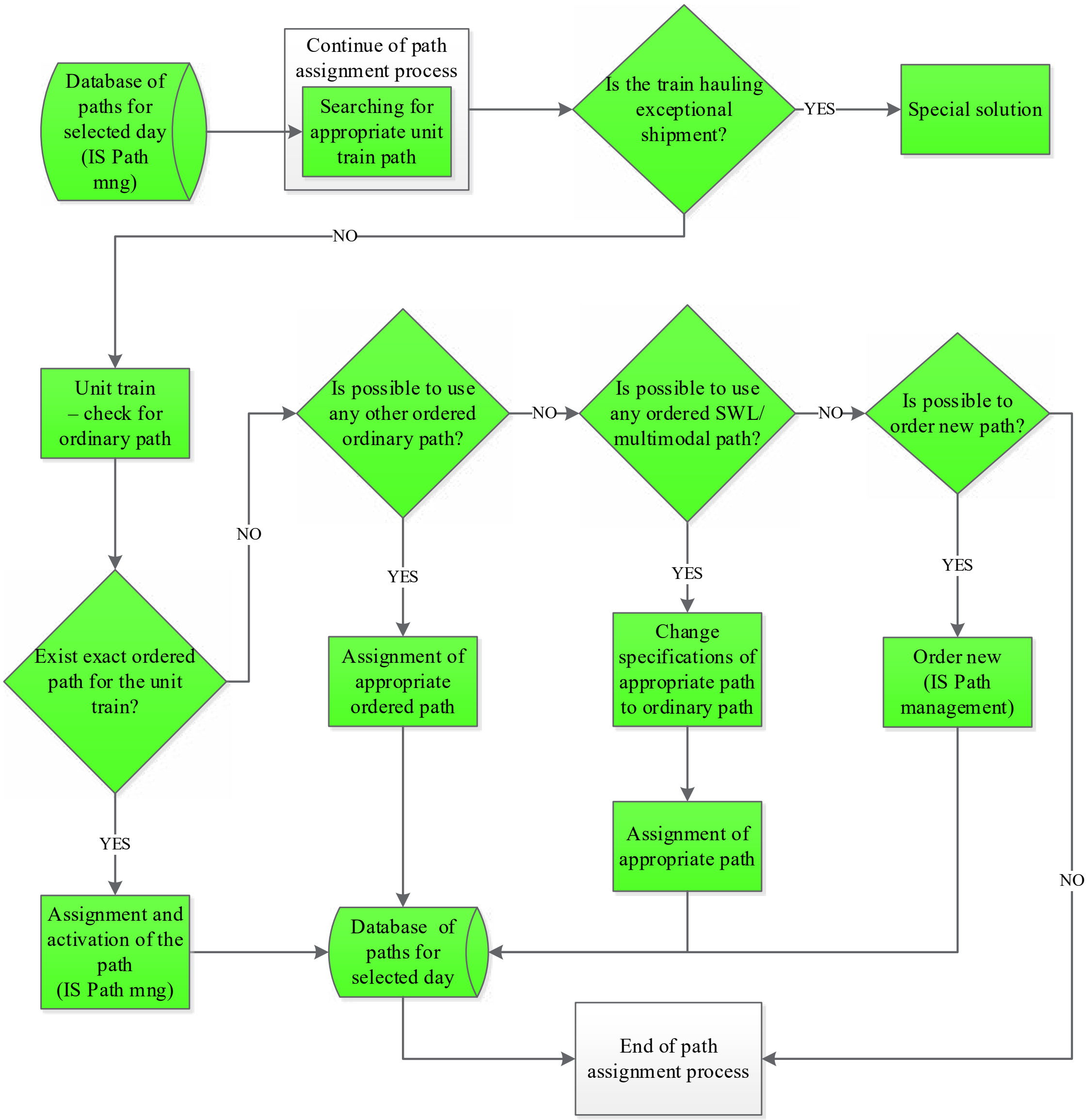

Fig. 4.
Scheme of ensuring train path for ad hoc ordinary unit train
Source: authors

If the path request cannot be accepted, the algorithm uses to the last step, what means sending a request to the Infrastructure Manager's information system to order ad hoc train path. The process of sending a request to ad hoc path is supposed to be used in marginal cases. In the demands for train running, where train path for single loaded wagons is ordered or multimodal train is used the algorithm, too. The specifics of the process are in the different product factor. The process of searching for suitable paths is running similar. In the end of the algorithm the possibility to use specific factors related with ETCS is checked. If the used locomotive is equipped by the ETCS, the specific factor S2 is used (figure 5). If the used locomotive is equipped by the ETCS, the specific factor S2 is used.

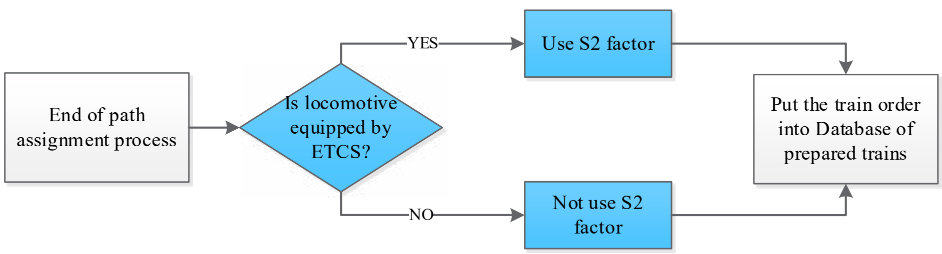

Fig. 5.
Scheme of using ETCS factor
Source: authors

5. Conclusion

The necessity to increase quality, punctuality and efficiency of freight railroad transport on one hand and competitiveness and effort to increase customer service including time flexibility on the other hand put even more pressure on planners and dispatchers. Modern real-time information systems are able to remove routine work in the short-term planning and operational management and simplify the preparation of ad hoc trains running. In this paper is considered the path assignment problem and proposed procedure that allows under real-time information automated assigning of the train paths. The proposed instrument performs dynamic assignment of ad hoc request for train running to appropriate train path through a fast and efficient solution procedure based on the assigning algorithm. The algorithm enables higher utilization of ordered paths. On base of information from customers is possible to reassign the capacities of the sources e. g. locomotives and drives. The capacities that are not at that time assigned are released into the database for other utilization. The procedure has been tested on real-life data from one of the major railroads in Central Europe. Generally, the procedure enables the maximum utilization of train paths and due to that is increasing the efficiency of whole railway system.

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ASSESSMENT OF KADENCE ADAPTIVE TRAFFIC CONTROL EFFICIENCY THROUGH HIGH-FIDELITY MICROSIMULATION MODELING

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Abstract: Various Adaptive Traffic Control Systems (ATCSs) have been evaluated in past studies. Researchers have usually shown either positive or neutral impacts of these dynamic signal strategies, mostly through the field studies. Due to the high costs for performing the field-based experiments, many field ATCSs evaluations were performed without proper experimental design and thus with compromised scientific rigor. Although simulation models can provide a variety of experimental scenarios, they are frequently questioned for their ability to accurately represent field conditions. This study aims to cover lack of both approaches by introducing a way to develop a high fidelity microsimulation model to investigate effectiveness of Kadence adaptive control in an urban network. In order to provide further evidence that the presented model is an accurate virtual representative of field conditions, an additional validation procedure is conducted through the comparison of modeled and observed durations of average green times. Average green times collected from the field are not based on green times programmed in the field controllers, but based on the actual field green times collected from the controllers' logs. The results show that Kadence ATCS, which was evaluated for the first time in microsimulation, outperformed well-fine-tuned time of the day plans with coordinated-actuated traffic control.

Keywords: Adaptive traffic control systems, Kadence, Microsimulation.

1. Introduction and Background

Different types of ATCSs have been evaluated both in the field and through microscopic simulation, addressing performance of ATCSs and their comparisons to conventional signal control strategies (Mirchandani and Head, 2001; Luyanda et al., 2003; Midenet et al., 2006; Kosmatopoulos et al., 2006; Stevanovic et al., 2009; Stevanovic, 2010; Stevanovic et al., 2016; Dakic and Stevanovic, 2017; Dakic et al., 2018). Microsimulation has reached a level of sophistication that enables more meaningful comparisons, due to its ability to capture real-world conditions in traffic flows and model complex road geometries (Park and Qi, 2005). Tools that provide interfaces between ATCSs and microsimulation emerged in the late 1990s (Nguyen, 1996; Martin and Hansen, 1999). Today, Emulation-In-the-Loop-Simulation (EILS), Hardware-In-the-Loop-Simulation (HILS), and Software-In-the-Loop-Simulation (SILS) are available, which can be used to comprehensively assess performance of ATCSs in a microsimulation environment (Stevanovic et al., 2009; Zlatkovic et al., 2010). Examples of such simulations include SCOOT-VISSIM and SCATS-VISSIM interfaces (Stevanovic et al., 2009). Nevertheless, the amount of related research on the calibration and validation efforts is limited.

Several studies used a genetic algorithm (GA)-based procedure to search for an optimal configuration of microsimulation parameters that would minimize the difference between the simulation results and the field measurements (Park and Qi, 2005; Ma and Abdulhai, 2001). Although both studies showed that the use of a GA can minimize the error between the modelled and observed results, they were constrained to the use of a single Measure of Effectiveness (MOE) for calibrating the model. Consequently, other MOEs might not be well calibrated. A more systematic approach was presented in a study conducted by Toledo et al. (2003), who applied a MITSIMLab tool to an urban-freeway network and used the sensor data to calibrate origin-destination flows and route choice parameters. The validation was based on traffic volumes, travel times and queue lengths.

Park and Schneeberger (2003) introduced a nine-step procedure for calibration and validation, using VISSIM tool to perform simulation experiments. Even though the authors used an extensive set of calibration parameters, the validation results indicated that the simulated distribution of travel times did not follow the travel time distribution observed in the field data. Kim and Rilett (2003) presented a sequential, simplex algorithm-based methodology that was tested on CORSIM and TRANSIMS platforms. The objective was to identify a parameter that would yield the best replication of the observed traffic volumes. Moreover, ten microscopic models of different kinds were tested by analyzing the car-following behavior using the data collected via GPS-equipped cars (Brockfeld and Kuhne, 2004). Model calibration and validation were based on the same data set that contained headway time series.

The study conducted by Hollander and Liu (2008) was intended to guide traffic analysts through the basic requirements for calibrating and validating microsimulation models. They conducted a very comprehensive review of methods and data sets used for calibration and validation purpose. Finally, Stevanovic and Martin (2008) assessed the suitability of evaluating macroscopically optimized signal timings using CORSIM, SIMTRAFFIC and VISSIM microscopic tools. The calibration was based on a vast data sets collected from the field. Findings revealed that when a uniform increase in traffic demand was imposed on each model, a large discrepancy in simulation outputs occurred.

In overall, many previous calibrations were focused on the identification of parameters used to calibrate a model, instead of giving the attention to multiple sources of traffic data used to compare simulation results with the field measurements and further confirm whether a model is calibrated and/or validated. In addition, results of the previous

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studies did not always provide a strong match of the disaggregated measurements. This study addresses these issues with the two major objectives:

1. Development of a high-fidelity microsimulation model, which represents an accurate proxy of the real-world traffic conditions.
2. Evaluation of Kadence ATCS for a 15-intersection urban network in Miami Dade County, FL. Kadence evaluations in microsimulation have not been previously published in available literature. Therefore, this study represents a unique contribution by comparatively evaluating performances of Kadence and TOD signal timing plans in a weekday PM peak period.

2. Experimental Design

2.1. Study Area

The study network includes a 19-interesection corridor of SR 112/41st Street in Miami Beach, FL, from Alton Road to Collins Avenue in the E-W direction, and from 39th Street to 44th Street in N-S direction (Fig. 1). This corridor was selected for Kadence evaluation due to the congestion level occurring in the weekday PM peak period (4:00 – 6:00 PM). Annual Average Daily Traffic (AADT) varies between 32,000 and 44,000 vehicles per day.
To perform the simulation experiments, we used microsimulation platform VISSIM (PTV AG, 2014) as it is, so far, the only microsimulation model capable of interfacing with Fourth Dimension (Virtual D4) controllers. D4 controller is the only market-available signal controller that is able to replicate operations of the currently field-deployed 2070 traffic controllers and is compatible with Kadence in microsimulation environment. The simulation model is developed for the PM peak period based on the existing geometry, traffic operations, and traffic control.

Fig. 1.
Test-Bed Network: SR 112/41st Street in Miami Beach, FL

To successfully model the field conditions, the data collection process included the following data sets collected under fair weather and pavement conditions: traffic counts, bus schedule and ridership, the travel times, and the signal timings. Given that travel time measurements were collected by the floating car vehicle moving along different paths of the study network, the following routes were identified and observed for the model calibration and validation purposes (Fig. 2b): EB route (from Alton Rd to Pine Tree); WB route (from Pine Tree to Alton Rd); route A (Pine Tree – Indian Creek – Collins Ave – 43rd Street – 44th Street – Indian Creek – Pine Tree); route B (Pine Tree – Indian Creek – 39th Street – 40th Street – Collins Avenue – Indian Creek – Pine Tree); and route C (Pine Tree – Indian Creek – 43rd Street – Collins Avenue – 44th Street – Indian Creek – Pine Tree)

2.2. Model Calibration

The SR 112/41st ST VISSIM model was calibrated according to the driving behavior captured through multiple traffic metrics collected in the field. The calibration process was performed manually by altering the following elements of the simulation model at intersection approaches: desired speed distribution; saturation flow; and diffusion time. Moreover, signalized intersections were defined as nodes in VISSIM. These nodes were further coded to collect turning counts from the simulation. An Excel spreadsheet was designed to use VISSIM outputs and make a comparison to the field traffic counts (Fig. 2a). This spreadsheet was later used for traffic volume balancing, which included adjustments to routing decisions and traffic inputs in order to reflect field-collected volumes. The calibration results are presented in

Fig. 2d and indicate a good match between the observed and modeled TMCs (the coefficient of determination R2 is approximately 0.98).

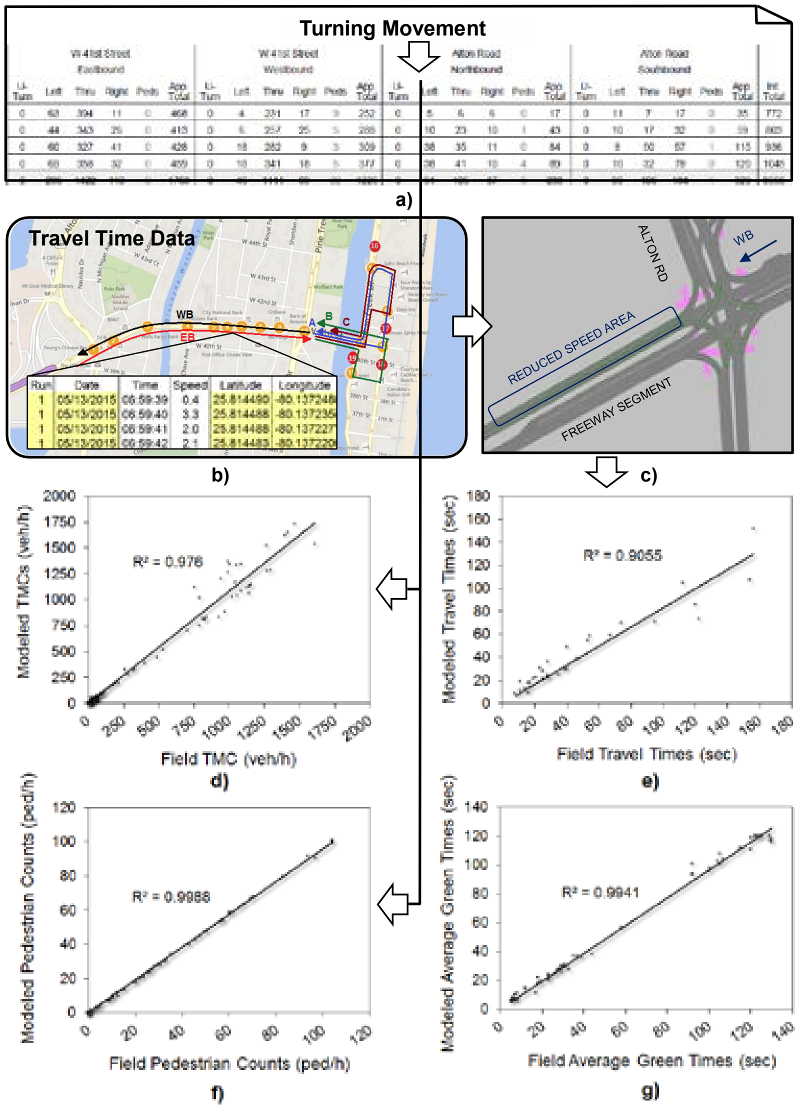


Fig. 2.
Calibration and Validation Results

2.3. Initial Model Validation

The model was validated through a comparison of modeled and field travel times measured along intersection segments. Travel times were collected both by GPS devices (floating car method) and by video recordings of travel runs. The GPS measurements were available in 1-second resolution and contained information regarding the time when the measurement run was performed, the speed of the vehicle, and the latitude and longitude (Fig. 2b). Once again, an Excel spreadsheet was designed to transform latitudinal and longitudinal coordinates and further determine the exact position of the floating car vehicle as it was traveling along the study network for each time stamp. This procedure provided travel times between each pair of signalized intersections. Video recordings were especially instrumental in observing queues and general congestion levels at each intersection; these observations were later used to validate the virtual traffic conditions in the microsimulation model.

One should note that during the initial validation process, even though the model was well calibrated, it was very difficult to obtain a good match with the field travel times in the WB direction (Fig. 2b), as they were underestimated in the simulation. Any effort and change made in the simulation model failed to produce very accurate results. Therefore, it was decided to conduct some additional field observations to identify potential problems. These additional observations revealed that the higher travel times in the WB direction were caused by the existence of downstream queues (spillover from a downstream highway segment), which prevented vehicles to depart from the signal at the Alton Rd intersection. Therefore, reduced speed areas were placed on the downstream segment of SR 112/41st ST in the WB direction to artificially mimic spillover effects from the highway (Fig. 2c). Once this modification was made, a good match between field and simulation travel times was achieved (Fig. 2e). This outcome confirms that the calibration is a very intricate process where multiple factors can impact simulation results. The key factor in this process is spending enough time and effort to observe field conditions and apply proper methods and tricks to realistically replicate those conditions in the simulation model, in spite of all possible constraints.

2.4. Additional Model Validation

In order to further validate the VISSIM model and provide more evidence that it accurately represents field conditions, a comparison was made between: (i) pedestrian counts collected from the field and the ones measured in the simulation model (Fig. 2f); and (ii) the field and simulated duration of average green times (Fig. 2g). Note that the average green times collected from the field are not based on the green times programmed in the field-deployed 2070 traffic controllers, but are computed based on the actual duration of green times collected by the Kimley-Horn Integrated Transportation Systems (KITS) central signal software in Miami's Transportation Management Center database on the days when turning counts and travel-time measurements were collected.
Fig. 3 shows MOE log files that were extracted for that purpose from the field-deployed 2070 controllers. The MOE cycle data was retrieved for the appropriate dates in order to determine the field-averaged green times for all phases/movements at each signalized intersection. The field-averaged green times were further compared with the average green times computed from the simulation using signal log files from Virtual D4 controllers (Fig. 3). These files are given as a VISSIM output at the end of each simulation run, and contain information regarding the distribution of green times for each intersection and phase/movement. The results of the additional validation indicate close match between the field data and VISSIM outputs (with R2 ranging from 0.96 to 0.99). The authors are not aware of any previous studies where such an effort is applied to confirm that signal timings generated in the simulation model match the signal timings from the field. Therefore, these results give an extra weight to the interpretation of the findings achieved from the modeling experiments.

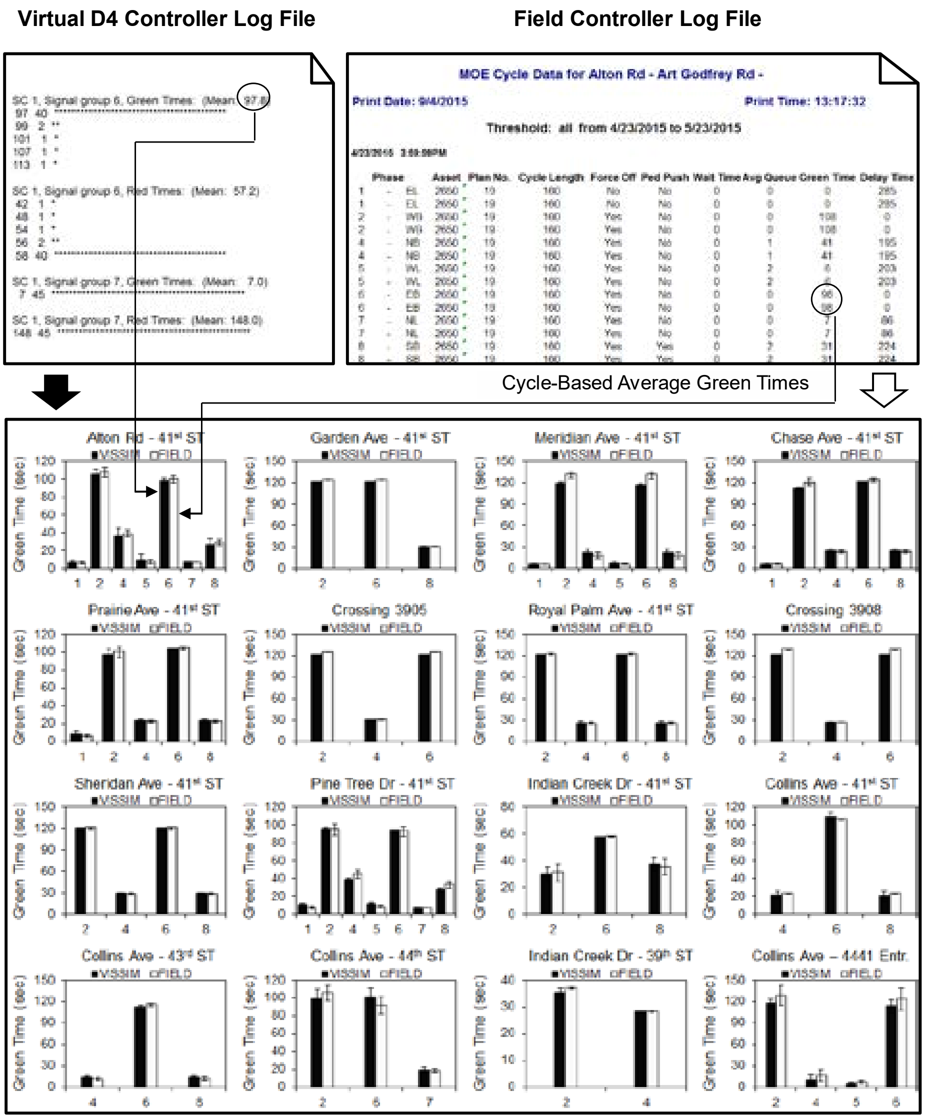


Fig. 3.
Comparison of Modeled and Observed Average Green Times

2.5. Analyzed Signal Control Strategies

The existing TOD signal timings represent actuated-coordinated plans operating with the stop bar detectors placed on the side-street approaches and for the protected/permitted left turn movements. The main-street through phases are coordinated and run under the ‘maximum recall’ function. The cycle length during the weekday PM peak is 160 seconds along the 41st Street, and 140 seconds along the Indian Creek and Collins Avenue. Based on the quality of their performance, it seems that these signal timings were periodically/recently adjusted to accommodate changes in traffic demand.
On the other hand, Kadence is developed by Kimley-Horn and Associates (KHA) and represents an extension from the base ASC Lite algorithms established by the Federal Highway Administration (FHWA). It is integrated as a component of a KHA KITS arterial and freeway management system. The system optimizes signal timing parameters and is comprised of the five principle algorithms for tuning splits, offsets, cycle time, phase sequence, and TOD schedule in real-time. Splits, cycle, and phase sequence adjustments are made based on the data collected from the stop bar detectors, whereas the advanced detectors are used for offsets adjustments and estimation of queue lengths for adaptive operations during oversaturated conditions. Any type of detection (such as inductive loops, radar, video, etc.) is supported.

3. Results and Discussion

The evaluation of the performance of Kadence ATCS related to the existing field traffic operations for the PM peak was performed on different levels: intersection, corridor, network-wide, main-street vs. side-street, and pedestrian levels. To acquire statistical significance of the result, each scenario was modeled multiple times (10 repetitions). The significance level was set at 95%. Each simulation run lasted 2 hours (peak period) and 15 minutes (warm-up time).

3.1. Intersection Level Performance

The most detailed performance measures were assessed on the intersection level (Fig. 4a). First thing to notice is that Kadence outperformed TOD plans in terms of the delay time at the majority of intersections. Due to artificially restricting vehicles from entering the intersection from a westbound residential street by giving priority to the vehicles entering from the left turn lane at the NB approach, we can observe higher delays at Collins Avenue/41st Street in the existing field conditions (TOD). This step was undertaken for model validation purposes, as we determined during the additional field observations that NB left-turn vehicles block the intersection and prevent vehicles from either EB or WB approaches to enter the intersection area, causing higher delay times. This is also an example in which Kadence significantly reduced average vehicle delay. A similar trend was observed when the average number of stops was analyzed at the approach and intersection levels. Once again, Kadence yielded better results than TOD plans at the majority of intersections (Fig. 4b).

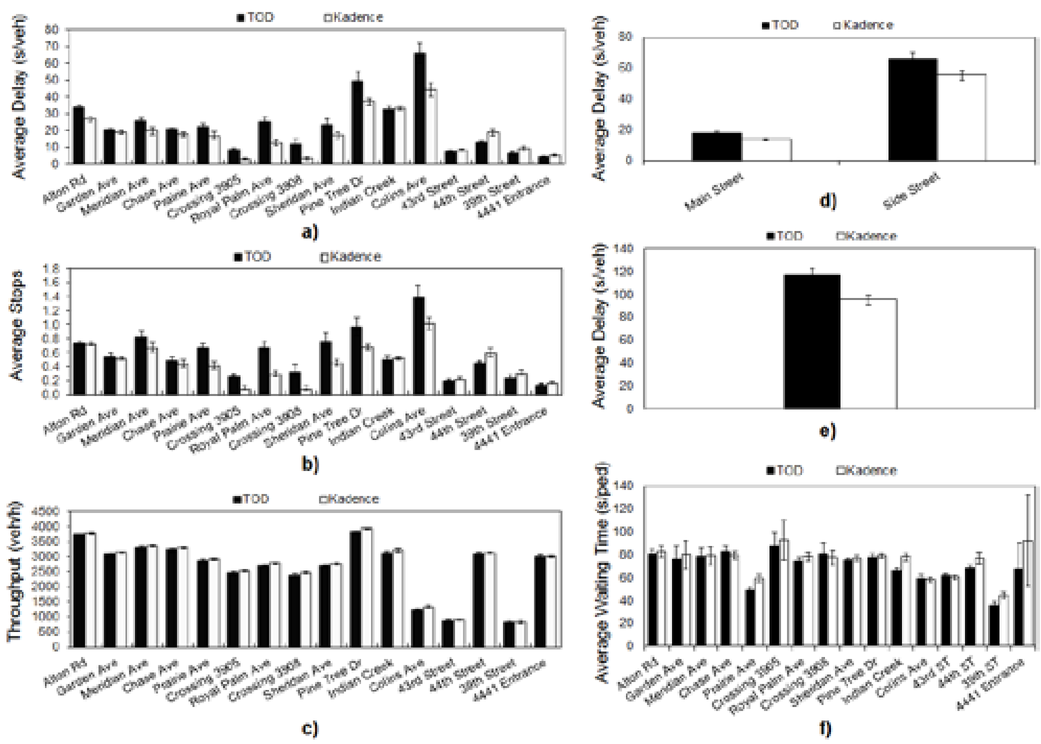


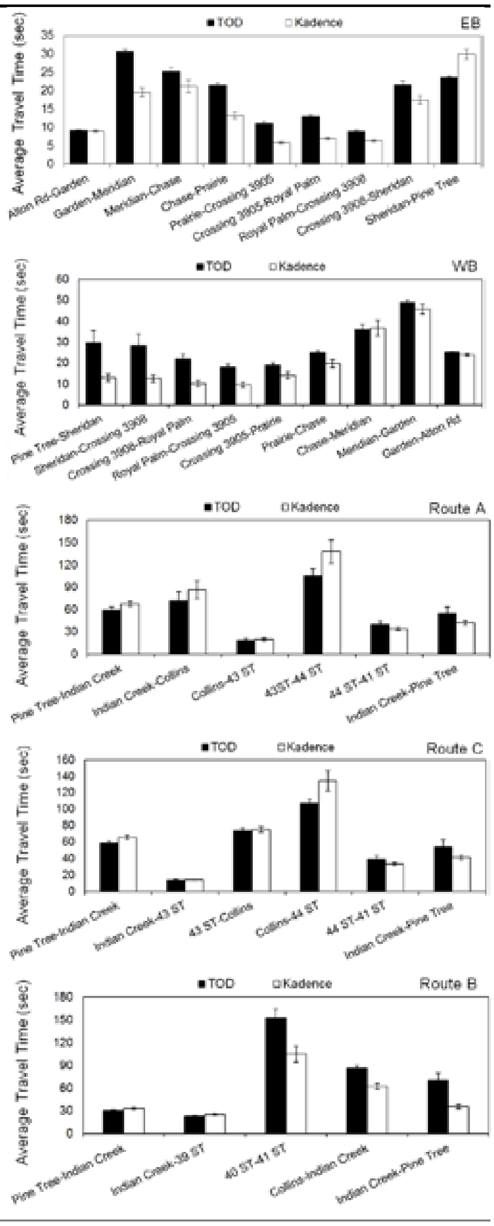
Fig. 4.
Comparison of Measures of Effectiveness on Different Spatial Levels

The analysis of the average throughput (Fig. 4c) shows that the greatest improvements of adaptive control strategy were recorded at the NB approach of Collins Avenue/41st Street intersection, where Kadence increased the average throughput by 7%. These improvements on the approach level are mainly contributed by an increase of 26% in the number of served NB approach vehicles in the left-turn lane, which is one of the most congested segments.

3.2. Corridor Level Performance

The success of signal coordination and traffic progression along the main corridor is best assessed through a corridor travel time analysis (Fig. 5). It can be observed that Kadence reduced travel time on almost every segment in both EB and WB directions along the 41st Street, with improvements ranging between 3% and 56%. The only exceptions are Sheridan Avenue-Pine Tree EB segment and Chase Avenue-Meridian Avenue WB segment, where Kadence increased the travel time by 27% and 2%, respectively (Fig. 5). On the other hand, the benefits of adaptive operations were not acquired on the majority of segments belonging to routes A and C (Fig. 2b). Finally, within route B, one of the most congested segments during the PM peak is a left-turn lane at the NB approach of Collins Ave/41st ST intersection, causing very high travel times in the existing field conditions (Fig. 5). Kadence was able to significantly reduce the average travel time on this segment by 31%. In addition, Kadence also reduced travel time for the following downstream segments: between Collins Avenue and Indian Creek (27%), and between Indian Creek and Pine Tree (49%), further alleviating congestion at Collins Avenue/41st Street intersection.

Travel Time Segment	TOD	Kadence
Alton Rd-Garden	9.2	9.0 [1]
Garden-Meridian	30.6	19.6 [1]
Meridian-Chase	25.4	21.3 [1]
Chase-Prairie	21.6	13.3 [1]
Prairie-Crossing 3905	11.3	5.8 [1]
Crossing 3905-Royal Palm	13.1	7.0 [1]
Royal Palm-Crossing 3908	8.9	6.3 [1]
Crossing 3908-Sheridan	21.7	17.5 [1]
Sheridan-Pine Tree	23.6	29.9 [1]
Pine Tree-Indian Creek	59.0	67.4 [1]
Indian Creek-Collins	71.2	86.0 [1]
Collins-43rd ST	18.4	19.2 [1]
43rd ST-44th ST	104.9	137.4 [1]
Pine Tree-Indian Creek	59.3	65.8 [1]
Indian Creek-43 ST	13.9	14.3
43rd ST-Collins	73.8	75.6
Collins-44th ST	107.2	134.4 [1]
44th ST-41st ST	39.3	34.0 [1]
Indian Creek-Pine Tree	54.5	41.8 [1]
Pine Tree-Indian Creek	30.4	33.1 [1]
Indian Creek-39th ST	22.6	24.9 [1]
40th ST-41st ST	151.9	104.6 [1]
Collins-Indian Creek	86.0	62.5 [1]
Indian Creek-Pine Tree	70.2	35.5 [1]
Pine Tree Ave-Sheridan	29.5	13.0 [1]
Sheridan-Crossing 3908	28.3	12.7 [1]
Crossing 3908-Royal Palm	22.0	10.3 [1]
Royal Palm-Crossing 3905	18.0	9.7 [1]
Crossing 3905-Prairie	18.9	14.2 [1]
Prairie-Chase	24.9	19.6 [1]
Chase-Meridian	36.1	36.6
Meridian-Garden	48.9	45.7 [1]
Garden-Alton Rd	25.1	23.9 [1]



1 – travel time is statistically significantly different from corresponding TOD travel time

Fig. 5.
Average Corridor Travel Times

3.3. Main-Street Versus Side-Street Performance

Taking into consideration that ATCSs provide a good progression for main-street traffic at the cost of increasing delays for the side-street traffic, we investigated main-street vs. side-street performance based on aggregated approach vehicular delays. The results shown in Fig. 4d imply that Kadence outperformed existing TOD plans in terms of both aggregated main-street and side-street delays during weekday PM peak by 23% and 16%, respectively.

3.4. Network Level Performance

The effects of each analyzed system were also assessed on a network-wide level. The average network delay per vehicle was selected as the most representative network MOE. A comparison of the total network delay time for the PM peak period is given in Fig. 4e. The results show that Kadence yielded a statistically significant reduction of approximately 18% when compared to the existing TOD signal timing plans.

3.5. Pedestrian Level Performance

Prioritizing vehicular traffic at a certain intersection can have certain impacts on the pedestrian delays. Generally, ATCSs are optimal solutions for alleviating congestion problems on corridors that do not have high pedestrian demand. Indeed, analysis of the pedestrian waiting time reveals that Kadence neither degraded the level of service, neither provided benefits for pedestrian movements at the majority of intersections during the PM peak (Fig. 4f).

3.6. Discussion of the Results

In general, the results of the research experiments show moderate, yet significant, contribution of the Kadence ATCS. Although improvements in the individual drivers' travel times are small (e.g. delay reduced for 21 seconds, as shown in Fig. 4e), when such improvements are accumulated over the entire fleet of cars using the analyzed network and over the entire period of consideration (several years), they can bring significant monetary savings. This further justifies deployment of the Kadence ATCS. Even though it is difficult to compare results of these experiments with other similar Kadence deployments (since no previous evaluations in a microsimulation environment have been published), the outcomes of this study are in the same general range of expected ATCS benefits as described in other studies (Stevanovic, 2010). Results from the Kadence evaluation study conducted by Sabra et al. (2013) show that the improvements also belong to approximately the same range of expected benefits.

On the other hand, beside improvements are quite noticeable for vehicular traffic, non-motorized users have not benefited much from the use of implemented adaptive control logic (Fig. 4f). These results are expected, as most of the ATCS's logics are designed to help driving population to better utilize available time allocations at the signalized intersections. At the same time, pedestrians are regularly treated as high-priority users who enjoy such priority almost equally within fixed-time, actuated, or adaptive traffic signal system. Thus, deployment of an ATCS usually cannot bring any new benefits that were not already given to the pedestrians within another form of (more conventional) traffic control.

4. Conclusions

The performance of Kadence ATCS was evaluated through high-fidelity microsimulation modeling. The simulation model was calibrated and validated using extensive data sets collected from the field. Uniqueness of this research is validation of the model through comparison of the average green times from the field and the simulation, showing an excellent match and giving a lot of weight to the model's trustworthiness. Such a well-calibrated model can certainly be trusted to truthfully represent the field conditions. The following generalized conclusions were reached from the study:

- Under the existing conditions in weekday PM peak, Kadence yielded better results than the current TOD signal timing plans by significantly reducing the average network delay per vehicle. In addition, when approach delays were aggregated on the main-street vs. side-street level, Kadence also provided significant improvements for both main and side streets. However, benefits were not examined for the pedestrian waiting times.
- In terms of the travel times, one of the most congested segments within route B, a left-turn lane at the NB approach of Collins Avenue/41st Street intersection, experienced a significant reduction in the travel time under Kadence regime. Moreover, Kadence succeeded to significantly reduce the travel time on the neighboring downstream segments (Collins Avenue-Indian Creek and Indian Creek-Pine Tree), further alleviating congestion at Collins Avenue/41st Street intersection.
- Finally, at the intersection levels, Kadence outperformed the TOD plans at the majority of intersections during the PM peak period.

Future research should address analysis of environmental and surrogate safety measures to potentially examine some other benefits of Kadence ATCS than the ones reported in this study. Also performance of Kadence and TOD signal timing plans should be evaluated in cases of unpredictable traffic fluctuations such as incidents, inclement weather, evacuations scenarios, etc. The use of irregular conditions is critical to evaluate the versatility of and adaptive benefit of Kadence system.

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COMPUTER SIMULATION FOR IMPROVING THE TRAFFIC IN AN URBAN INTERSECTION

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Abstract: Road safety is currently a world-wide problem because both from the studies on the causes of global and national mortality as well as from the statistics from numerous organizations (World Health Organization, Romanian Police, Eurostat, The European Statistics Office), road accidents are one of the main causes of global mortality. Intersections are associated with high rates of collision and injury because they include a large number of pedestrian, cyclist, motorcyclist and vehicle conflict points. Safer intersection design typically focuses on reducing the impact of speed and potential conflicts. The aim of this paper is to identify solutions to improve the traffic and to reduce the number of accidents in an urban intersection. The case study is realized on the intersection resulted from the confluence of Romancierilor Street and Timișoara Boulevard from Bucharest city. The intersection has a very high risk of accidents, being one of the 44 "black spots" identified by the Bucharest Road Police. In the case of uncontrolled intersections (such as this one) the risks for all road users is very high. Some measures for traffic calming should be considered: turning lanes, priority control, vehicle-actuated warning signs, speed reduction etc. Also, some solutions to “control” the intersection should be taken into consideration: - one of the most effective options to reduce death and injury is the provision of well-designed roundabouts that reduce approach speeds and reduce the angle of potential impact; - signalized intersections are designed to separate traffic and potential conflicts through time separation. Using AIMSUN simulation software, the proposed solutions are studied and compared by traffic parameters like speed, queue, number of stops, delay time, saturation index etc. The one having the best values is selected.

Keywords: traffic, intersection, speed, accidents.

1. Introduction

Road safety is currently a world-wide problem because both the studies on the causes of global and national mortality (Spainhour, 2005), (Archer & Vogel, 2000), (Baron, 2015), (Cordonescu, 2014) and the statistics from numerous organizations (World Health Organization, Romanian Police , Eurostat, European Statistics Office) evidence that road accidents are one of the main causes of global mortality.
The European Commission adopted in 2011 the "2050 Transport: Major Challenges and Fundamental Measures" strategy, which sets a common goal of zero-fatalities for the member States in road transport by 2050. Thus, the EU's objective is to halve the number of deaths in trafficking by 2020.
Accidents in road transport, especially those with private cars, are the most numerous and cause the greatest number of victims worldwide (fig. 1).

Fig. 1.
Casualties in road accidents within the EU from 2001
Source: (European Commission, 2017)

Figure 2 shows the number of road accident victims in urban areas in 2014 (persons / milion inhabitants). In developing or transition countries, like Romania, the number of serious traffic accidents has a tendency to increase (Iovu, 2008); 63% of road accidents in Romania were recorded in urban areas, the rate of urban road accidents with casualties being 2.8 times higher than the EU average and 8 times higher than in Sweden.

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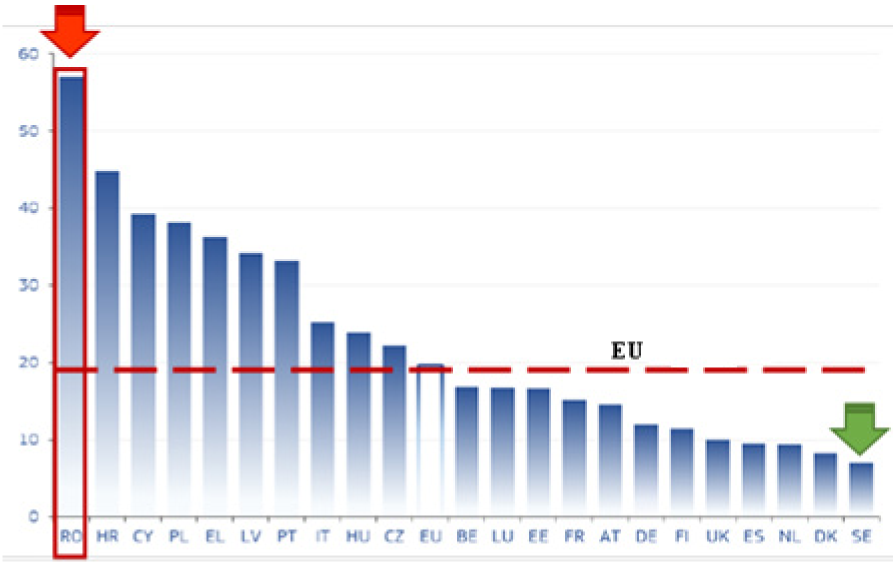


Fig. 2.
Casualties in road accidents within urban areas, 2014 [pers./mil.inh.]
Source: (Iovu, 2008)

At the macroeconomic level, four inter-correlated factors that evidence the risk associated with road traffic are highlighted (Figure 3). Interactions between vehicles, infrastructure and drivers are conditioned by variables characteristic to socio-economic activities. The supply and demand for space mobility, exposure to risk, frequency, location and severity of road accidents bear the impression of the the socio-economic space and, of course, the actions taken to increase road safety.

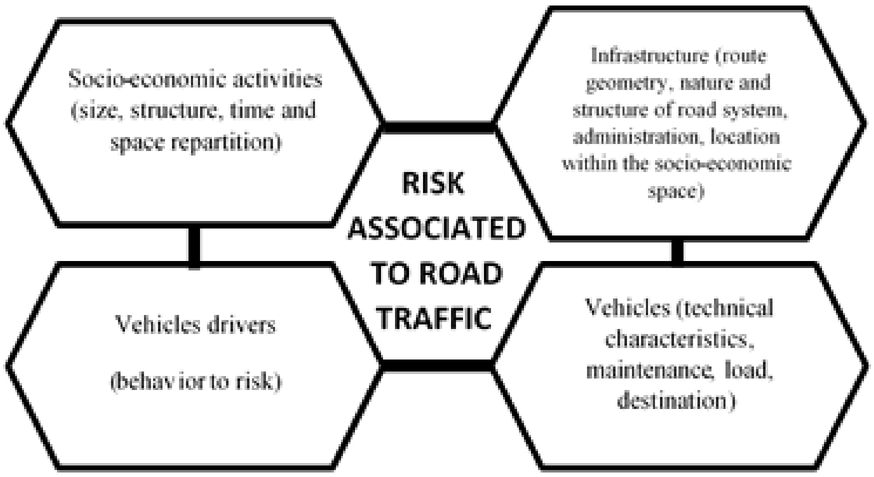


Fig. 3.
Factors affecting the risk associated to road traffic
Source: (EUROSTAT, 2016)

Intersections are associated with high rates of collision and injury because they include a large number of pedestrian, cyclist, motorcyclist and vehicle conflict points. Safer intersection design typically focuses on reducing the impact of speed and potential conflicts. One of the most effective options to reduce death and injury is the provision of well-designed roundabouts that reduce approach speeds and reduce the angle of potential impact to lower-severity side swipes or rear-end crashes.
The provision of overpasses and underpasses (grade-separated interchanges) are cost-effective where large volumes of traffic have to be managed and well-designed merge lanes are provided.
Signalized intersections are designed to separate traffic and potential conflicts through time separation, although they require a level of compliance and road user judgment depending on the detailed design at the location.
In the case of uncontrolled intersections, risks for all road users remain high and the inclusion of lower-cost traffic calming, engineering and technology measures (e.g. raised platform intersections, turning lanes, priority control, vehicle-actuated warning signs, speed reduction) should be considered to reduce risk at such highly dangerous locations on the road network.

The analysis of the intersections is made according to their complexity, taking into account the need to ensure the highest degree of traffic safety that crosses the intersection [3]. The design of intersections must be based on a thorough analysis as they present a high probability of road events happening (accidents). Thus, in order to identify traffic fluidization solutions, an analysis of the existing situation is required.

2. The Study Zone

The analysed intersection is located in Sector 6 of Bucharest and is derived from the crossing of Timisoara Boulevard with the Streets of Romancierilor and Leaota. The intersection has a very high risk of accidents, being one of the 44 "black spots" identified by Bucharest Road Police (fig. 4).
According to the legislation in force, the traffic arteries forming the analysed intersection are classified as follows:

- Timişoara Boulevard falls into category III (collector street) - takes traffic flows from the adjacent streets with 2 and 3 lanes per way, respectively;
- Streets Romanciers and Leaota fall into category IV (street of local use), providing access to current housing and services being provided with one lane per way.

From the point of view of the number of intersecting paths, the intersection is simple, with only two intersecting paths being involved (Timişoara Boulevard with the Romancierilor and Leaota streets).

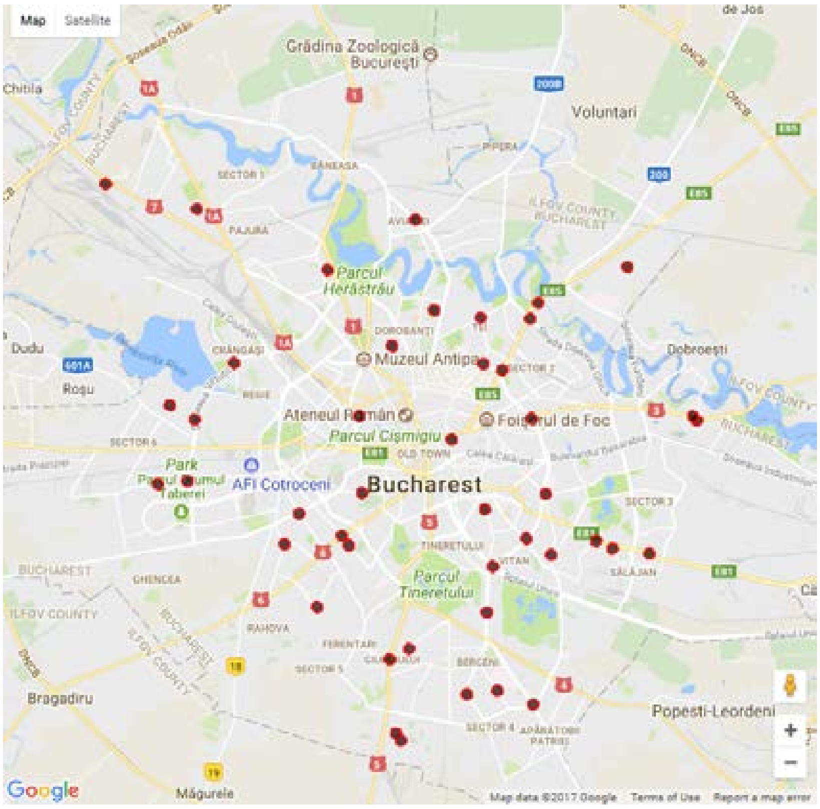


Fig. 4.
"Black spots" in Bucharest
Source: Mediafax

The traffic measurements were realized during the morning and the evening peak hours (7.00 – 9.00 and 17.00 – 19.00) and duaring the off peak hours (11.00-13.00). Traffic flow values obtained from the measurements are presented in figure 5 and centralised in Table 1.

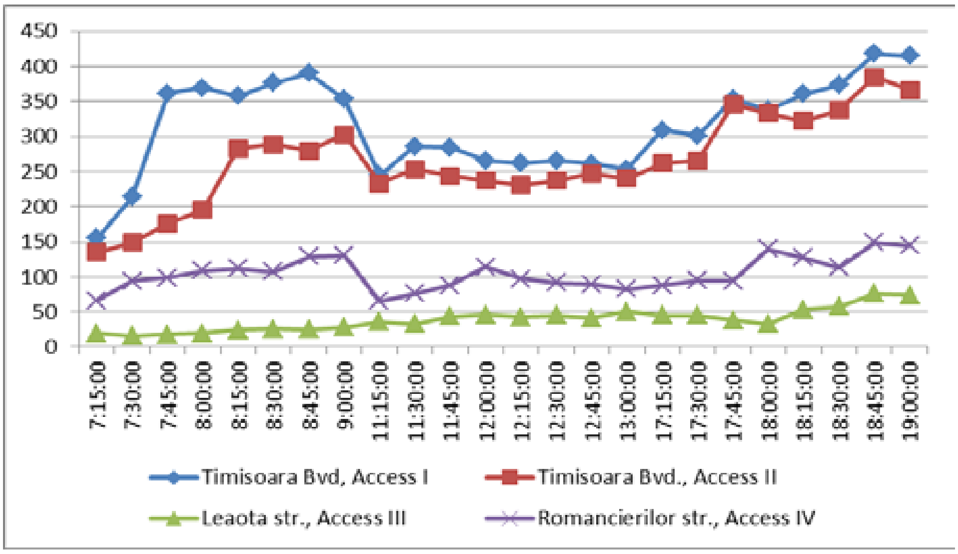


Fig. 5.
Traffic flows [equiv.veh./h]

Table 1
Traffic flows [equiv.veh./h]

ACCESS	**Limit traffic values [equiv.veh./h] [ped/h]**		
	Morning peak	**Off peak hours**	**Evening peak**
Timisoara Boulevard, Access I	1477	1081	1567
Timisoara Boulevard, Access II	1155	955	1411
Leaota Street, Access III	103	180	262
Romancierilor Street, Access IV	478	360	533
Pedestrians	798	432	990

3. Solutions to Improve Traffic

Some solutions to "control" the intersection might be:
- one of the most effective options to reduce death and injury is the provision of well-designed roundabouts that reduce approach speeds and reduce the angle of potential impact;
- signalized intersections are designed to separate traffic and potential conflicts through time separation.

Given the structure of the intersection and taking into consideration that it includes a tram line, a roundabout is not suitable. Further on, we are going to study the case of introducing traffic lights in order to separate traffic and potential conflicts through time separation.
In order to build the model in AIMSUN, the following data was required (TSS, 2018), (Roşca & all, 2013):
- Intersection layout – the map of the area, the number of lanes for every section, possible turning movements, speed limits for every section.
- Traffic Demand Data - vehicle types and their attributes, flows at the input sections (entrances), turning proportions at all sections;
- Traffic Control - location of signals, the signal groups, the cycle duration and the duration of each phase.

The simulation was done under the following assumptions:
- The simulation warm-up is half an hour, long enough to reach the considered regime
- The simulation time is one hour - in the evening peak hours where we reached the maximum traffic flows (table 1);
- Different structures for traffic light cycle TC =90s, 120s, 140s.

Currently, the intersection is not signalised (fig. 6). Using AIMSUN simulation software we simulated the present situation characterised by the measured traffic flows and pedestrians flows (fig. 7).

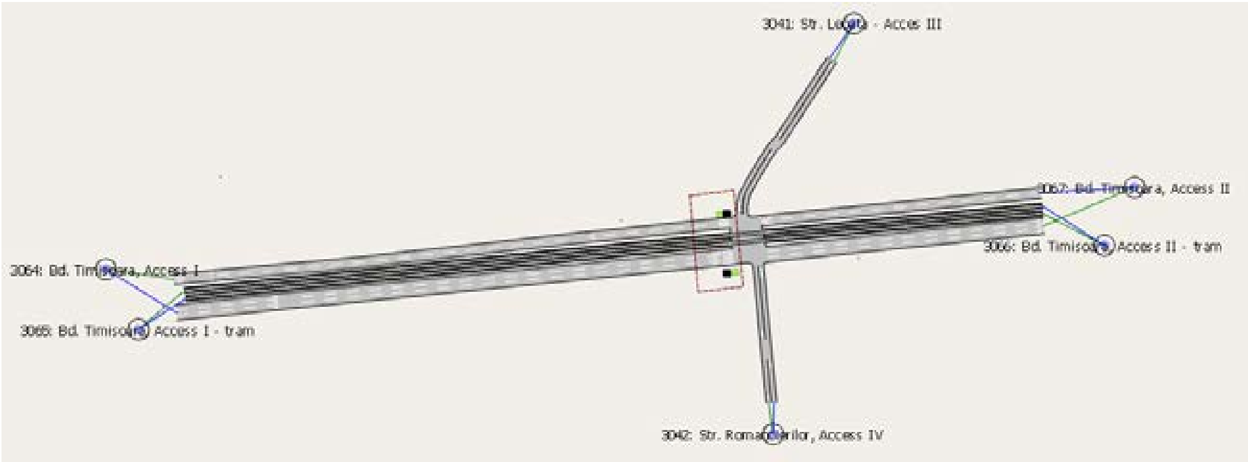


Fig. 6.
Timisoara bvd, Leaota str. and Romancierilor str. Intersection layout

	3041: Str. Leoata - Acces III	3042: Str. Romancierilor, Access IV	3064: Bd. Timisoara, Access I	3067: Bd. Timisoara, Access II	Total
3041: Str. Leoata - Acces III			192	70	262
3042: Str. Romancierilor, Access IV	23		235	275	533
3064: Bd. Timisoara, Access I	57	368		1142	1567
3067: Bd. Timisoara, Access II	23	456	932		1411
Total	103	824	1359	1487	3773

a)

	3065: Bd. Timisoara, Access I - tram	3066: Bd. Timisoara, Access II - tram
3065: Bd. Timisoara, Access I - tram		20
3066: Bd. Timisoara, Access II - tram	20	

b)

	3092	3094	Total
3091	532		532
3093		458	458
Total	532	458	990

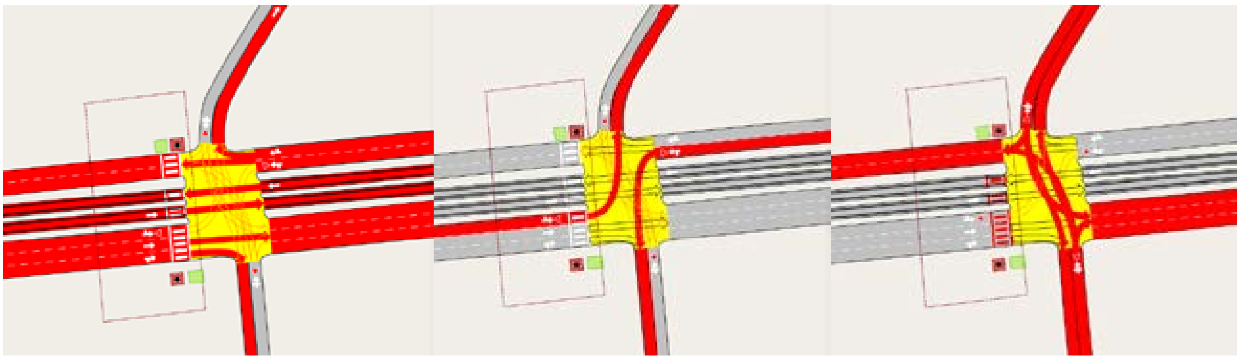
c)

Fig. 7.
OD matrices – a) cars; b) trams; c) pedestrians

By simulating the current situation of the intersection, the performance indicators values are:

- Delay time: 271 s/km
- Mean queue 65 veh.
- Number of stops: 0.59 stops/veh./km
- Speed: 33.88 km/h

Further on we consider the traffic light cycle of 90s, 120s and 140s, each cycle being characterised by three phases (fig. 8; fig. 9).



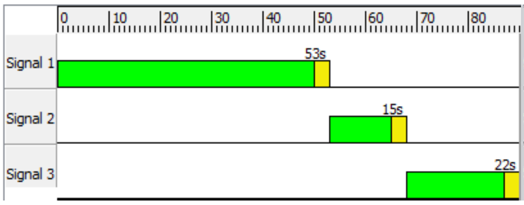
a) b) c)

Fig. 8.
The three phases from a traffic light cycle: a) phase 1; b) phase 2; c) phase 3

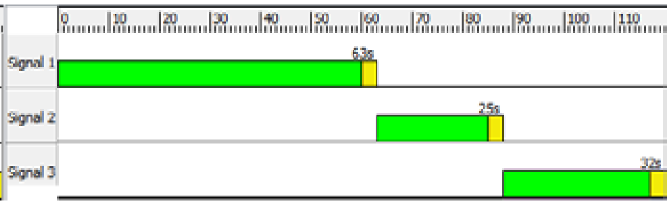
The access into the intersection is saturated when incoming vehicles wait more than one stopping cycle to enter the intersection (STAS 10144/6, 1991). The saturation degree of an access, G_{st}, is:

$$G_{st} = \frac{F_s}{F} \qquad (1)$$

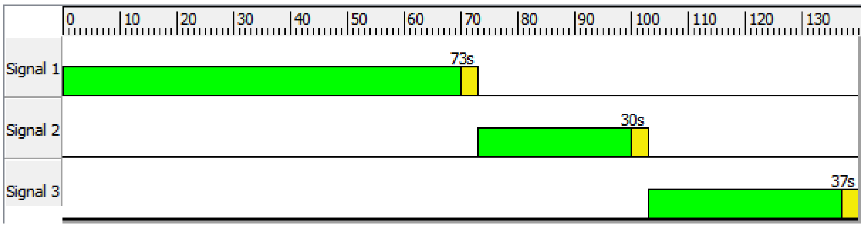
where:
F_s represents the number of saturated green phases in peak hours
F – total number of green phases at peak hours.
For $G_{st} > 0.3$ the intersection redevelopment is necessary - the introduction of a new equipment for routing or a new organization.
For T_C = 120s all the vehicles pass the intersection on the green light in peak hours. The saturation degree is Gst=0.



T_C=90s



T_C=120s



T_C=140s

Fig. 9.
Traffic light charts

In table two a comparison between the measure of performance is realised.

Table 2
Comparison of the measures of performance

Traffic parameters	No traffic lights	Traffic lights					
		TC = 90s	Variation [%]	TC = 120s	Variation [%]	TC = 140s	Variation [%]
Delay time [s/km]	271	173	-36,16%	139	-48,71%	140	-48,34%
Mean queue [veh]	65	45	-30,77%	40	-38,46%	42	-35,38%
Number of stops [#/veh/km]	0.59	0.68	15,25%	0.57	-3,39%	0.57	-3,39%
Speed [km/h]	33.88	31.43	-7,23%	28.42	-16,12%	28.31	-16,44%

As it can be seen from table 2 the best structure of the traffic light cycle is TC = 120s; almost all traffic parameters are improved. The variation of the considered measures of performance is set by a 48.71% decrease of the delay time, a 38.46% decrease of the mean queue, a 3.39% decrease of the number of stops and a 16.12% decrease of the speed. The decrease of the speed is of only 5 km/h; considering the improvement of the other performance indicators, this decrease is insignificant. The queue dissipation is much facile for the proposed traffic lights cycle.

4. Conclusion

Traffic simulation models have proven to be helpful in analysing complex traffic situations that exist beyond the scope of the traditional analytical methods.

Using the AIMSUN simulation software there were analysed some solutions to "control" the intersection, the chosen one being to introduce traffic lights in order to separate traffic and potential conflicts. The performance indicators (average delay, average number of stops, mean queue and average speed) showed that the indicated solution is the one with the traffic light cycle TC =120s.

The saturation degree for the chosen solution is zero meaning that all the vehicles stopped at red light will pass on the green light that follows.

Acknowledgements

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REMODELING APPROACH TO ESTIMATE STOCHASTIC FREEWAY CAPACITY

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Abstract: To study the freeway section capacity and to manage it further, it is necessary firstly to construct a model allowing estimating the dynamics of capacity variation changes. here are certain approaches giving a way to determine freeway section capacity. The main concept still follows the idea that "capacity is the maximum number of vehicles, which could be managed by a particular freeway section under certain conditions". It is worth noting, that capacity does not depend on the traffic flow, however, it depends on the other parameters of the traffic flow. According to American Highway Capacity Manual, German Capacity Manual and Russian Capacity Guidelines, these parameters are geometric characteristics of the road, traffic flow characteristics, traffic light control parameters (cycle time, its distribution through phases, etc.). Naturally, it is a fact that when analyzing the bandwidth, it is advisable to include the values of the selected parameters not only of the current time interval, but also of the interval preceding the current one. This gives the process under consideration natural dynamics. It was found out, that the freeway section capacity varies over time and can be described by a random variable with some statistical distribution. Studies presented this fact, in most cases give the Weibull distribution to describe capacity the best. Based on the thing, that capacity cannot be measured directly, but only at the moment of traffic congestion, a good solution is to use the concept of "black box" to solve the problem to simulate the process. In this case, we operate with the remodeling strategy, when the process described by the model, could be remodeled by the other structure. The paper present the neural network approach to remodel freeway section capacity.

Keywords: stochastic freeway capacity, mathematical remodeling, neural networks.

1. Introduction

Taking into account fast-growing number of vehicles in European and world transportation networks, a special attention should be given to the improvement of existing schemes to model these systems with the goal to their further optimization. Increasing transportation mobility of the population and increasing number of cargo transportations cause supplementary delays in key points of transportation networks. During detailed investigation of such areas, it is necessary to concentrate on freeways as main components of the network, which provide connection between large important transport nodes (for example, big cities and cargo warehouses) of the network. Main characteristic of the freeway, which provides a high quality level of its functioning, is the capacity defined by a number of regulation documents as "the maximum number of vehicles, which could be managed by a particular freeway section under certain conditions".

This definition is very abstract and raises a number of questions. For example, how depends a freeway capacity on a number of external factors? Answers to such questions can be obtained, for example, from Russian Guidelines to estimate road capacity, containing a set of 16 adjustment coefficients, which take into account geometric landscape features, weather conditions, the presence of buildings near the road, etc. However, this approach does include the random factors, generated by combinations of the features mentioned above and supported by instant psychological indicators of vehicle drivers.

It was found, that the freeway capacity is a stochastic value and could be described by some statistical distribution function. Thus, at each specific considered time moment, the capacity has a new random value, and it is only possible to say which distribution fits this value the best. Further this approach will be detailed described. But it seems not precisely right, because it is obvious, that the value of the capacity in every moment depends on the parameters of the traffic flow not only in this moment, but also on moments prior to the analyzed. The paper proposes to build a procedure that would add the dynamics of the stochastic value of the freeway capacity.

2. Study

2.1. Stochastic Approach to Estimate Freeway Capacity

As it was mentioned above, there are two groups of approaches to estimate freeway capacity. The first deterministic group considers that capacity is a constant value. This line is presented in HCM (*Highway Capacity Manual 2010*), HBS (*German Highway Capacity Manual 2015*), Russian Guidelines to Estimate Road Capacity (*ODM 2012, Rosavtodor*) and others (*Sysoev, 2016*). The second stochastic group, unlike approaches from the first group, assumes, that capacity has a random nature and is a stochastic phenomenon. Following this idea freeway capacity could be estimated as a breakdown, which occurs in a flow in a moment when flow equals capacity. It means that one can estimate this value using a mathematical model of statistical distribution function.

The idea to understand freeway capacity as a stochastic number was firstly formulated in *1986 by Van Toorberg*. Further many researchers followed this idea.

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In the year *2000 Lorenz and Elefteriadou* also assumed that the freeway section capacity value could vary depending upon tolerable risk level of agencies. *Brilon and Geistefeldt in 2009* investigated the reliability and efficiency of German freeways to introduce capacity design value. They determined the traffic efficiency of freeway sections and found that the maximum degree of freeway saturation occurs at a flow rate, which is 90% of conventional capacity.
Ozbay and Ozguven in 2007 estimated distribution curve to interpret capacity value. The results of their study demonstrated that a steep 20 curve represents a minimal change in breakdown probability for a specific breakdown value interval. *Geistefelt in 2008* compared the deterministic and stochastic capacity of a freeway in Germany. He proposed to compare the capacity distribution function with the flow-speed diagram. He also introduced a linear relation between the median value of the capacity distribution function and the conventional value of capacity for a number of German freeway sections. *Modi et al. in 2014* compared two capacity estimation methods: Van Aerde flow-speed diagram and the Product Limit to propose the best capacity estimation method. Authors believed the stochastic approach is not suitable because it is complicated in practice for a detailed operational analysis such as ramp metering.
In *1986 Van Toorberg* proposed to use an analogy of lifetime analysis to describe stochastic nature of the freeway capacity. This procedure is called Product Limit method and its function indicates the probability of exceeding the capacity of a section. Constructing the capacity distribution function based on the Product Limit method, we have

$$F(q) = P(q_c \le q)$$

or

$$F(q) = \frac{N_c}{N} ,$$

where $F(q)$ is the distribution function of the capacity, q_c is a capacity value, q is observed flow in the time interval *i*, N_c is the number of observations of $\{C\}$ with $q \ge q_i$, N is the total number of observations of $\{C\}$ and $\{C\}$ itself is a set of congested flow observations setting.
The probability that the capacity is greater than traffic flow is defined by $G(q)$ as

$$G(q) = P(q_c > q) .$$

This function could be estimated by $1 - F(q) = 1 - P(q_c \le q)$ and using Product Limit method

$$G(q) = \prod_{qi} \frac{K_{qi} - d_i}{K_{qi}} ,$$

where K_{qi} is the number of observations in $\{S\}$ with $q \ge q_i$, d_i is the number of failures, $\{C\}$ is a set of congested flow observations setting, $\{Q\}$ is a set of free flow observations setting and $\{S\}$ is the setting of the total observations.
It should be noted, that the Product Limit method is dependent on traffic flow state. To use this methodic it is necessary to choose the criteria indicating moments of switching flow conditions from free to congested. Common criteria used in many papers is traffic flow speed. Speed value indicating this switch could be estimated using speed-flow diagrams. And for example, such speed threshold is 70 km / h for German 2-lane freeways and 60 km / h for German 3-lane freeways.

2.3. Remodeling Concept

The natural fact, that when analyzing the capacity in the current time interval, it is reasonable to include values of the selected parameters from the previous interval, to add the process dynamics. Regardless of which model is used, to estimate the freeway section capacity, this problem has to be fixed. The approach which could provide the new model to describe the capacity based on existing models is Mathematical Remodeling (*Sysoev, 2018* and *Galkin, 2017*).
This is an approach to describe complex and / or composite systems based on the transition from mathematical or simulation models of one type to models of the other unified class. Depending on purposes and specific applied tasks, various interpretations of remodeling are possible. A theoretical model of some dependency built on the basis of its physical background, can have a structure which is quite complex and not appropriate for further analysis. In this case an array of dependency "input-output" data can be generated (which can be inaccessible under real conditions) and a simpler model of some unified structure with the required accuracy could be proposed. This is an approximation remodeling. To construct a new model a neural network and neuron-fuzzy models could be applied. In this case a remodeling has a neurostructural nature (*Saraev, 2018*).

2.4. Neurostructural Approach to Remodel Freeway Section Capacity

The paper presents the algorithm used neurostructural approach to remodel freeway section capacity. It could be formulated in the following way.
Step 1. To divide the whole observed data into two subsets: (a) "congested" intervals, where the capacity rate could be estimated directly and (b) "fluid" (censored) intervals, where the capacity are obtained as Weibull-distributed random value. The criteria to separate intervals must be predefined at this step.

Step 2. Using the data sample obtained on Step 1, to train the neural network model with the predefined structure. On this step the analysis of the model accuracy must be done and corrections (in case of unsatisfied results) should be applied.
Step 3. Using the model obtained on Step 2, to estimate capacity rate within the new data set.
The proposed scheme is concerned to be a remodeling approach because it combines different ways to estimate capacity and presents a unified model to simulate this parameter.
Further are given numerical experiments to prove the sustainability of the proposed scheme.

2.5. Numerical Experiments

2.5.1. Scope of Experiment

The initial for the modeling data obtained by the loop-detector system from German Autobahn A57. They are 1-minute intervals array. Since only one segment of the freeway was involved in the study, some constant parameters (such as number of lanes, geometric characteristics, etc.) were neglected. The average speed in the current and previous time intervals, the percentage of trucks were considered as factors. Since the loop-detector system provides separate information on average speeds of personal vehicles and trucks, the average weighted speed indicator was used. Data were aggregated in 3, 5 and 10 min intervals and their different combinations to train and test neural network were applied.
To remodel the freeway capacity, various different structures of neural network were investigated and it was determined, that the best result demonstrated the network with one input layer, one hidden layer consisting of 13 neurons and the output layer. In its analytic form the model can be written as

$$q_c = \sigma\left(w_{output,0} + \sum_{i=1}^{13} w_{output,i} \cdot \sigma\left(w_{hidden,i} + \sum_{j=1}^{3} w_{ij} x_j \right)\right),$$

where q_c is a freeway section capacity (veh / h), $x_j = \{v_{cars}(t), v_{cars}(t-1), trucks(t)\}$ are factors (average vehicles speed (km / h) in the current and previous time intervals and the percentage of trucks in the current interval); $w_{output,i}$ and w_{ij} are identified weights on output and hidden layers respectively; $w_{output,0}$ and $w_{hidden,i}$ are biases on output and hidden layers respectively, $\sigma(\cdot)$ is an activation function.
Numerical experiments shown, that the best results give the logistic function on a hidden layer

$$\sigma(net) = \frac{1}{1+\exp(-net)}$$

and the linear function on an output layer

$$\sigma(net) = net.$$

To train the defined neural network model, it was prepared a data sample including input parameters mentioned above and output capacity values obtained by the presented algorithm. The criteria to specify the time interval as congested was the average speed below 70 km / h (then the current flow rate was used as the actual capacity value). Fig. 1 presents the speed-flow diagram for the section gathered data from which were used to train the neural network model.

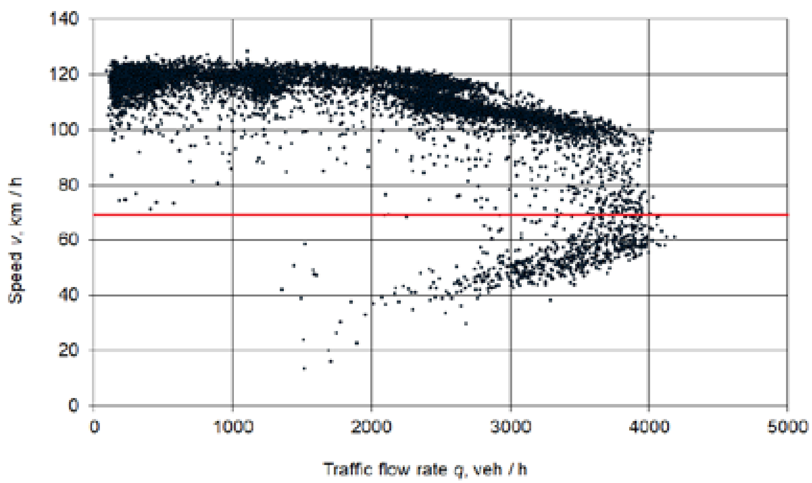

Fig. 1.
Speed-flow diagram for the section applied to the network training
Source: Ruhr-University Bochum research

In cases when the capacity rate value was not measured directly, output values were simulated as a random Weibull-distributed value with defined parameters typical for this freeway section. Different variants of neural network training and testing based on the duration of time intervals were studied. Presented numerical results demonstrate the duration of training intervals of 1 min and the duration of test intervals of 5 min, when the size of training sample was 393 120 intervals, the size of testing set was 26 496 intervals.
To estimate the correctness on the results it was calculated number of cases when the network gave output capacity values smaller than traffic flow rates from the one side and compared with time intervals with average speed below 70 km / h. The accuracy of the network with this approach is about 79%. Fig. 2 shows the comparison of the results obtained by the proposed approach and measured average speed and traffic flow rate. Red boxes showed congested intervals according to speed threshold (smaller than 70 km / h) and according to the traffic flow rate bigger than found capacity.

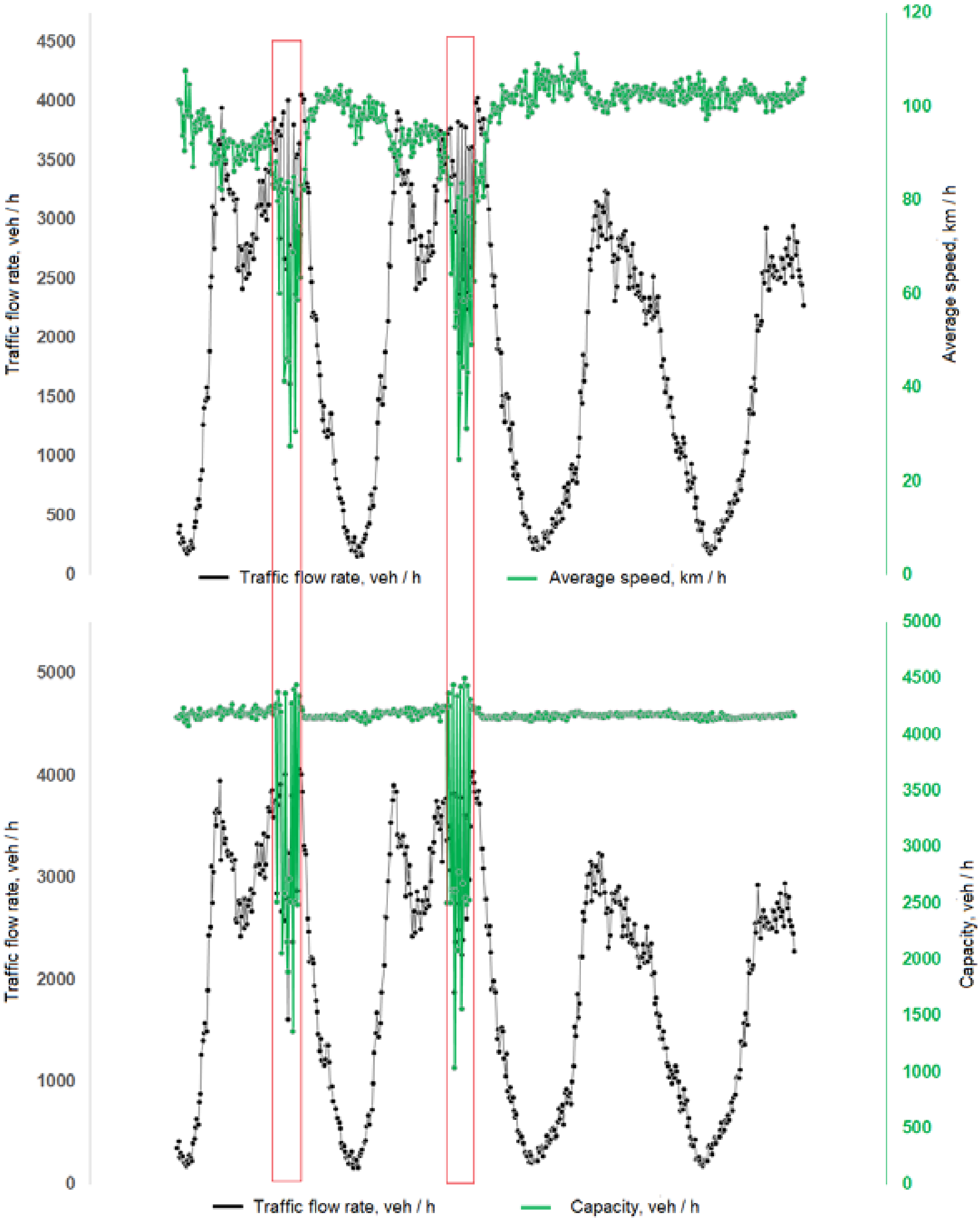

Fig. 2.
Comparing measured parameters of traffic flow within estimated section and found based on the proposed approach capacity

3. Conclusion

There are two groups of approaches allow to estimate the value of freeway section capacity. Natural (and confirmed empirically) way to treat this important parameter as a random value with a certain statistical distribution. Regardless of which approach to estimate capacity is used, there are time intervals where this parameter could be measured directly. It occurs when the traffic flow has a congested regime. In the other time intervals capacity rate could be only estimated. The proposed approach allows to remodel the estimation of freeway section capacity, i.e. to build an analytical model representing the estimated parameter, based on data obtained by direct measurements in some cases and probabilistic estimates in others. The presented neural network model allows adding the dynamics to stochastic capacity in the current time interval by including flow parameters from the previous time intervals. It should also be mentioned, that the traffic flow parameters (primarily section capacity) could be estimated at fixed in the meaning of time duration interval. The perspective problem is to find such a duration of time interval, using of which will give more adequate (in some sense) results.

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MODELLING AND CALIBRATION OF MICROSCOPIC SIMULATION MODEL CORSIM

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Abstract: A simulation method is an effective tool in analyzing the various dynamic problems in recent years. Today, many studies related to Traffic Engineering and Transportation benefit from a simulation method. A simulation model reflects the real system through the instrument of mathematical models of operation relations in the system over determined time. Models are developed in order to evaluate the different design and control scenarios. Traffic flow simulation models are divided into three classes according to the detail level of simulation. These are microscopic, mesoscopic and macroscopic. CORSIM (CORridor SIMulation) has been developed by FHWA (U.S. Federal Road Administration), is one of the tops most used simulation software for transport professionals. The performance of the software has been tested and is used continuously by FHWA in many studies. CORSIM can integrate urban road and highway networks to each other, thus it is possible to test the interaction of the two types of network. CORSIM also offers to intervene to networks thanks to built-in control devices. As an example, Istanbul European side of the Bosporus Bridge near Freeway O1, 2.5 km part, was modeled and calibrated with CORSIM. Traffic Software Integrated System 6.1 software package was used. As a result of the calibration, the selected traffic behavior can be successfully represented by CORSIM according to the test criteria. The Erlang distribution seems to be particularly successful in modeling speed. For this reason, the Erlang distribution will be used in subsequent CORSIM simulations. With the help of calibrated CORSIM, the traffic control methods to be applied to the working segment and the reaction that the traffic will give can be predicted. Thus, it is possible to test the validity of the work in the laboratory environment before applying it.

Keywords: CORSIM, Modelling, Calibration.

Introduction

In general, simulation is defined as a dynamic representation of some part of the real world achieved by building a computer model and moving it through time (Drew, 1968). Simulation is a mathematical and logical representation of real-world system and simulation models aimed to develop to evaluate different control and design scenarios.
Simulation models are designed to emulate the behavior of traffic in a transportation system over time and space to predict system performance (Drew, 1968). Traffic simulation models can be classified based on different criteria's. The most common classification is according to type (microscopic, mesoscopic and macroscopic). In a microscopic modeling, each vehicle movement is evaluated individually according to interactions with other vehicles movement and traffic system. Also, all vehicles are moved through the network of transportation facilities by split-second basis according to the physical characteristics of the vehicle (length, maximum acceleration rate etc.), the fundamental rules of motion and rules of behavior (car following rules, lane changing rules, etc.) (CDOT, 2013). Macroscopic models simulate traffic flow, taking into consideration cumulative traffic stream characteristics (speed, flow, and density) and their relationships to each other (CDOT, 2013). Mesoscopic models combine the properties of both microscopic and macroscopic simulation models. These models simulate individual vehicles but describe their activities and interactions based on aggregate (macroscopic) relationships (CDOT, 2013).
The importance of microsimulation software has been growing rapidly during the last decades. Microscopic simulation software's are frequently used to model the stochastic process of human and driver behavior, design freeways, urban roads, and test scenario are on a whole or partial roadway network. There are many traffic microsimulation software on the market. Each software offers different properties and price to users.
CORSIM (CDOT, 2013) is one of the popular microscopic traffic simulation programs widely used by transportation professionals. CORSIM is able of simultaneously modeling surface street and freeway. CORSIM provides the user with a wealth of output data detailing several system-wide, as well as link-specific, performance measure (McTrans, 2009). The output of CORSIM is an MOE (Measure Of Effectiveness) file. It is processed into tables that summarize the information. For freeway models, the key metrics produced are flow, speed and density. The data for arterial models include throughput flows, control delays and maximum queues (Olariu and Weigle, 2009). CORSIM does not generate outputs in metric. The traffic state variables such as average speed, density, and flows are not offered directly a tabular format, even if they are written an output file. Also, it does not have an interface to directly simulate control measure such as Variable Speed Limits (VSL). TSIS provides a mechanism by which an external application can interface directly with the CORSIM simulation tool. This type of application has become known as a CORSIM Run-Time Extension (RTE) (McTrans, 2008). CORSIM offers users an RTE interface that they can use in their analysis and dynamic control study by creating their own output.

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Fig. 1.
Working Zone of O-1 freeway
Source: (Demir, 2012)

The study includes calibration of CORSIM for a vehicle segment and how to evaluate calibration results under different random distribution such as Normal and Erlang. The freeway used for the data structure is a 2.5 km stretch of O1 Freeway in Istanbul which was modeled and calibrated in CORSIM (Figure 1). The study segment has three entry (origin) nodes and one exit (destination) node. Congestion occurs during evening rush hours in the direction from Europe to the Anatolian side. Geometrical irregularities are available such as a horizontal curve and a bottleneck.

2. CORSIM

Urban traffic control center (UTCS Urban Traffic Control System-1), started with the development of CORSIM in the 1970s. Later the project transformed into NETSIM in order to simulate urban roads. After a while, the development of microscopic simulation software for freeway simulation, FRESIM, continued with a simulation model. Finally, NETSIM and FRESIM have been integrated into a simulation program called CORSIM. FHWA has placed CORSIM into its user-friendly interface named TSIS (Traffic Software Integrated System). McTrans Center is the current developer, maintainer, and supporter for CORSIM which is a part of The University of Florida (McHale et al., 2002)
Users can model any type of networks such as freeway, urban roads or integrated network and apply some traffic control tools with CORSIM. CORSIM can simulate traffic flow vehicle basis. TSIS also includes TRAFED and TRAVFU modules. TRAFED provides a graphical network interface to input network geometry and a tool transforms the graphical network into CORSIM input file. TRAVFU module is off-line visualizing environment depicts vehicle movement and measure of estimation data (MOE). MOE data can be watched in tabular or graphic format, but the module does not support extracting them.
CORSIM models the traffic system as the interaction of the roadway, detectors, traffic control devices, and vehicles; each of which has their own set of attributes (Owen, 2001). CORSIM evaluate vehicle moving on a network by supervising the interacting of the vehicle with other vehicles, traffic control tools, and road geometry.

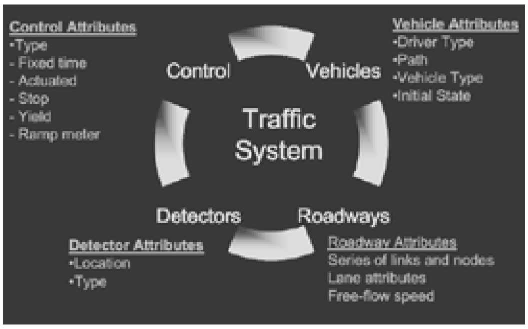

Fig. 2.
CORSIM Attributes
Source: (Owen, 2001)

These properties are seen in Figure 2. CORSIM offers a test of traffic operating scenario, signal control, geometric design proposals, incident management, ramp-metering control and private lanes. CORSIM needs four important steps like other traffic microsimulation software's. These are data collection, describing network in software, calibration, and validation.
Data collection is the most difficult and expensive process. It covers an array of selections. These selections are observation point location, data collection method (manually or automatic), equipment (video camera or other

surveillance equipment such as loop detectors or radar detectors), etc. Collected data should include volume, speed, the geometric dimension of roads (lane width, lane, acceleration, deceleration lane length), and free flow speeds. Besides, there are many predefined parameters in CORSIM. These parameters cover driver behavior, vehicle performance, and road characteristics having default values reflecting average conditions. It is not recommended to change default parameters without important exceptions. Depending on the traffic conditions for a specific scenario it is possible to change the default characteristics.
Each vehicle's location and speed on a network is updated every second based on vehicle performance and driver behavior characteristics, lane changing/car following logic and roadway traffic control signals (Wang, 2008). The interaction of vehicles with other vehicles, traffic control devices, and roadway geometry are modeled.

2.1. CORSIM Modelling and Calibration

For the case study, 2.5 km of the freeway section belongs to O1 Freeway in Istanbul (Figure 4) was modeled and calibrated before creating RTE module in CORSIM. TSIS 6.1 software package was used for modeling of the sample network which has two ramps.

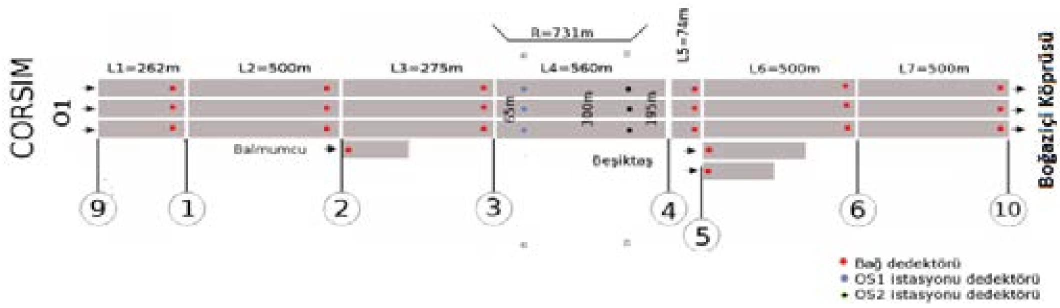

Fig. 3.
Road Geometry and Detectors Location
Sources:(Demir, 2012)

Traffic congestion, shock waves, and queues occurred on the section in rush hours. As part of the way for the creation of the CORSIM simulation model, the road was coded into the CORSIM network format by the aid of the maps (Google Earth and Istanbul Municipality Maps). The geometry of the working area which was composed of TRAFED is shown in Figure 4. Traffic volume data are obtained by video recording for modeling and calibration of the CORSIM model. The record was taken from 16:23 to 17:27 for evening peak period, on 16 October 2007. Then for examining the records, observation stations (Figure 4 represents OS1 and OS2 detector locations on the working zone.) were set using the maps and on-site measurement by GPS devices. Speed and volume data were measured in the one-minute interval. Traffic state variables speed, density, and flow were calculated from counts conducted at these stations. After inputting observed demand values and driver's properties and vehicle performances, CORSIM was calibrated for 65 minutes. The saturation warm-up option was chosen as a warm period. Calibration was confirmed by Theil's test comparing observed speed and flow with CORSIM outputs at two observation stations.

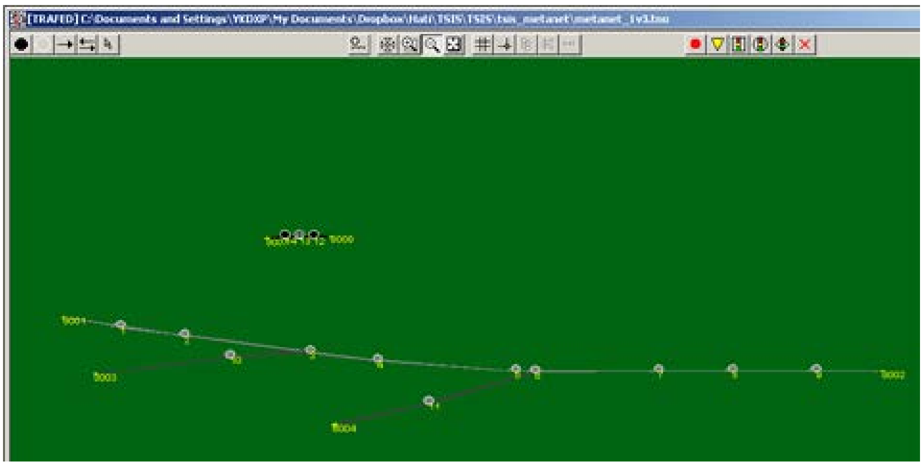

Fig. 4.
The Working Area composed by TRAFED

Theil's *U* statistic is a relative accuracy measure that compares observed flows and speed with the results of the simulation results. It also squares the deviations to give more weight to large errors and to exaggerate errors, which can help eliminate methods with large errors

$$U = \sqrt{\frac{\sum_{t=1}^{n-1}\left(\frac{\hat{Y}_{t+1} - Y_{t+1}}{Y_t}\right)^2}{\sum_{t=1}^{n-1}\left(\frac{Y_{t+1} - Y_t}{Y_t}\right)^2}} \tag{1}$$

where Y_t is the observed value of a point for a given time period t, n is the number of data, and $\hat{Y}_t$ is simulation forecasting. If U is less than 1 it means the forecasting technique is better than guessing. If U is equals to 1, the forecasting technique is about as good as guessing. If U is more than 1, the forecasting technique is worse than guessing.
Theil's statistics for average speeds (mean speed graphics Figure 5) and flows (flows graphics Figure 6) were calculated at 0.07 and 0.08 respectively at both stations (Demir, 2012).
CORSIM completes a simulation along a timeline including time intervals which is called "call points". There are six main call points and some of them have sub-call-points. These are;

1. Initialize;
2. Begin simulation (startup);
3. Time step complete;
4. Time interval complete (end of each time specified by the user - *end of 10s in the study*);
5. Time period complete (end of the time period specified by the user - *after 5 minutes in the study*);
6. Simulation Complete - *4500s in the study.*

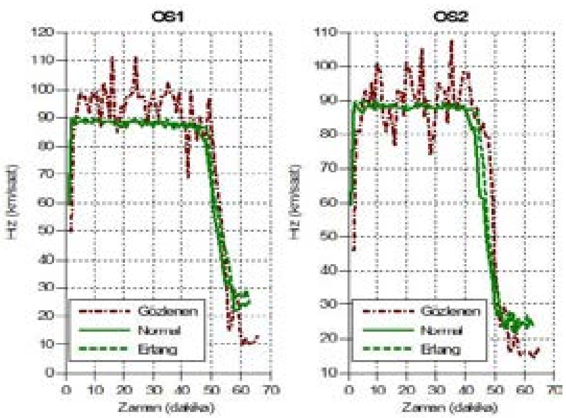

Fig. 1.
Mean Speeds

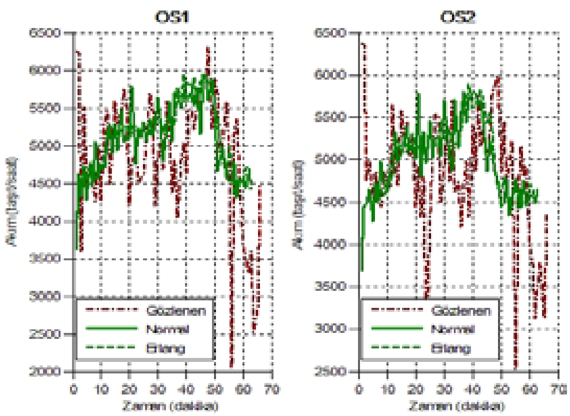

Fig. 2.
Flows

Any custom RTE function should be assigned one of these points. Functions are executed one or more times by CORSIM depending on selected time steps.

3. Conclusion

Evaluation of calibration results is given below.
OS1 Speed: The observed speed is more compatible with the Erlang distribution results. The mean error of normal distribution and Erlang are 4.61 and 2.65 respectively so that Erlang distribution has a lower error in the speed prediction. On the other hand, when you look at the error sign, both for the distribution of observed (on average) of lower CORSIM speed values produced can be seen. When looking at the average absolute error, two distribution have close values with respect to each other. Mean absolute percentage error has two similar values in the distribution. The *U* statistic, which measures the success rate of CORSIM's time series as it produces observations, approaches zero for both distributions. This means that CORSIM has successfully produced the observed speeds in the working segment. Having Erlang distribution lower error than the normal distribution point that Erlang is more suitable for modeling the working section.
OS1-Current: The values of the measurements obtained in the tests made for both distributions are very close to each other. The mean error measure for both distributions is negative. This shows that CORSIM estimates the current values at a higher average than the observations. Observations show sudden changes in the current graph which causes this (Fig. 5). When we look at the average absolute error percentage, it can be seen that CORSIM estimates the current values proportionally with a lower error rate. For both distributions, the *U* statistic has the same values and the near zero value.
Os2 Speeds: In general, the error values of this station are lower than the error values in the OS1 monitoring station, and the Erlang distribution, as in OS1, has lower error values than the normal distribution in terms of unbiased and unbiased error values.

OS2 Flow: All test criteria for both distributions have close values. *U* (0.08) shows that the current values of this station can be successfully represented by CORSIM for both distributions.
As a result of the calibration, the selected traffic behavior can be successfully represented by CORSIM according to the test criteria. The Erlang distribution seems to be particularly successful in modeling speeds. For this reason, the Erlang distribution is more suitable for simulations. With the help of calibrated CORSIM, the traffic control methods can be being applied to the working segment and the reaction that the traffic may be predicted. It is thus possible to test the validity of the work in the laboratory environment before applying for the work.

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A BICRITERIA APPROACH FOR ORDER PICKING OPTIMIZATION PROBLEM IN WAREHOUSE

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Abstract: Warehouse is a key element of logistics networks, regardless of the functions it performs. The efficient functioning of the storage process can significantly affect the efficiency of material flows throughout the entire logistics chain. The order picking process is an extremely important part of the warehouse process and its one of the most cost-intensive operations. It is estimated that the cost of order picking represents about 55% of the total warehouse operating costs. The main target of the paper is to present a bi-criteria picking routes optimization problem considering goods susceptibility stacking on picking device, expressed by products weight classes. The proposed model aims at minimizing the total travelling time and the picking time of handling activities during the picking process. The presented approach has been verified throughout a numerical example based on real data from the warehouse with manual picking order process. Additionally, an analysis of optimal Pareto solutions has been performed and the potential benefits of a multi-criteria approach in the considered issue highlighted.

Keywords: the travelling salesman problem, pick path optimization, order picking an optimization.

1. Introduction

The storage process is a very important part of most logistics systems. Its main purpose is storage and buffering of products, from raw materials and parts, finally to finished goods at any nodal point in logistics network. Therefore a pressure to increase a warehouse performance among the logistics chain actors has grown in recent years due to many reasons. For example the rapid growth of the number of on–line shopping and retailer transactions, globalization, greater amount of logistics providers, orders managed directly by the warehouse, require warehouse quicker time response to meet customer high expectations and forces to handle a large number of orders (Davarzani & Norrman, 2015; Gong & De Koster, 2008; Merchet et al., 2015). Among the many warehouse operations, the picking process is one of the most time-consuming and labour-intensive, especially in warehouses with a low degree of automation. Order picking is defined as the process of retrieving products from storage (or buffer areas) in response to a specific customer request. It is estimated that the order picking process is responsible for 55 – 75 percent of warehouse total operation costs (Chang et al., 2011). The order picking activities are especially important in manual picker to parts picking system, where the order picker walks or drives along the warehouse's aisles with a picking device to collect the requested goods from proper locations. This type of system is still most common from all order picking systems in Europe (De Koster et al., 2007). In general, two types of picker-to parts systems can be distinguished: low-level picking and high-level picking. According to first one, the order picker picks the items from storage racks or bins travelling along the storage aisles, while the second system uses high storage racks and order picker uses a lifting order-pick truck or crane. An alternative approach is the parts of the picker system based on the use of automatic storage and retrieval cranes. Decisions in the context of the picking process optimization and control can be divided into three areas: storage policy, order consolidation policy, and routing policy. These usually relate to tactical and operational level characterized by different time horizon (Rouwenhorst et al., 2000). Respectively they concern the following issues: shape, layout design, selection and dimensioning of the storage system (tactical level), products assignment to proper locations in storage zone (tactical and operational level), assigning orders to pick batches and grouping aisles into work zones (batching and zoning) (tactical and operational level), order picker routing (routing) (operational level), sorting picked units per order and grouping (operational level) (De Koster et al., 2007). All of these issues are interrelated and determine the effectiveness of the order picking process. Since last decades many authors dealt with the above issues both separately and by trying to combine several planning problems into one optimization model as well as approaches in which they were solved sequentially in order to increase the efficiency and reliability of the picking process (Celik et al., 2014; Valle et al., 2017). Of the many publications considering the order picking planning, a significant part focuses on the picking routes optimization using both accurate and heuristic methods, as well as different routing strategies (for example S-shape, Return, Mid-point and Largest gap strategy). The picking process consists of several operations. First, a picking order is composed for which a setup time is needed. After then the order picker starts travelling to the proper storage locations, search and pick required items. In some cases (orders split across zones or batches) orders are additionally sorted and consolidated before shipping (Dekker et al., 2004). Among them, travelling time is the crucial component and responsible for more than 50 per cent of the total order picking (Tompkins, 2010). Accordingly, the order picking time consist of many time-consuming operations like setup time, travel time, search and pick a time, waiting time, sorting time and others (Gils et al., 2018). Such activities may include, inter alia certain transhipment operations on the picking device due to the specific characteristics of the products, e.g. different products weight classes, which can significantly increase the picking time. Therefore, in order to improve the performance of the order picking process, the key element is to reduce the travel time and minimization of handling operations. Most of the articles focus on distance and travel time minimization by picking routes optimization, storage location assignment as well as order batching policies (Scholz & Wäscher, 2017; Scholz et al., 2016; Zhang et al., 2017; Theys et al., 2010;

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Hong et al., 2017). Additional performance measures taken into account in the problem are related to tardiness rate of order picking, service level or labor optimization (Henn, 2015; Gong & De Koster, 2008; Hsieh, & Huang, 2011; Quader, & Villar, 2016) Despite of many studies the problem of considering the products characteristics especially the product's weight class is still underestimated . However, in publications, it is difficult to find a solution for routing problem respecting product's weight (Chan & Chan, 2011). Therefore the proposed in the paper approach consider, in addition to the travelling time, the minimisation of the transshipments number due to a product weight conflict as a result of the assignment to different classes.

2. Problem Description and Mathematical Formulation

The model for bicriteria order picking optimization problem (OPOP) can be presented using the graph theory, where it is assumed that: there is a directed graph **G** = <**V**,**A**>, where **V** = {0,1,2,…,n} is the set of vertices (it represents the storage picking locations), and **A** = {(i,j): i^j**V**, i≠j} is the set of directed graph arcs. The vertice V={0} is the input/output point for storage. To each arc (i,j) from the set **A** assigned were weights: travel time **T**={t_{ij}: ∀(i,j)∈**A**}. It is assumed that the travel time is calculated by using the shortest path problem between a pair of locations in the warehouse. In every picking location, the product with the specified amount and weight class is stored. The amount of product is formulated by **S** = {s_i≥0: i∈**V**}; the weight class is noted as **P** = {p_i≥0: i∈**V**}. The highest weight class, the higher product susceptibility to damage is, hence the product should be on the top of on picking device. There are the following variables in the model: **X**={x_{ij} ∈{0,1}, ∀(i,j) ∈**A**}, which means whether the arc (i,j) is in the picking route. This assumption is similar to popular integer formulation of well known travelling salesman problem. The quantity of the stored product and device unit capacity is omitted. This assumption describes the decision process where the assignment problem of picking products to devices is the upper-level decision process to the OPOP in the warehouse.
The aim of OPOP is to find the optimal solution including two criteria:

- the minimization of picking travel time,
- minimization of the penalty for handling activities related to the product weight class.

The first criterion f_1>0 relates to travelling time from input/output point to first storage picking location, between the storage picking locations, and back to the input/output point from the last storage picking location. It could be formulated as:

$$f_1 = \sum_j^n \sum_i^n x_{ij} \cdot t_{ij} \qquad (1)$$

The second criterion f_2>0 based on a differential matrix of weight product classes. It is described indirectly the picking time and the handling activities, such as products reloading on picking device, which is related to the weight class of the products. Any misstatement in picking order led to increasing the picking time. Hence, it is assumed, that any nonoptimal picking order (different solution from an ideal picking order) is modelled as an extra penalty occurred in the second criterion. The ideal picking order is understood as a sequence of picking storage locations where reloading process determined by weight class of product is minimized. If the solution for picking order reaches the optimum, the penalty is not added. The penalty k_{ij} between any pair of the storage location is computed as:

$$k_{ij} = |p_i - p_j|, \forall (i,j) \in \mathbf{A} \qquad (2)$$

Considering above ve assumption, the penalty for picking order is modelled:

$$f_2 = \sum_j^n \sum_i^n x_{ij} \cdot k_{ij} \qquad (3)$$

The aim of the second criterion formulation is not to increase the complexity of the proposed model. Basing on popular mixed integer approach for routing part of OPOP, a mathematical formulation for products reloading process on picking device could bring nonlinearity in the model. It is due to two main issues. Firstly, to model directly the packing/repacking process, it is necessary to create a new continuous variable, which describes the commodity flow during the routing process in the warehouse. Secondly, by the multiplication of two variables, because the handling activities depend on picking point sequence (the variable x_{ij}) and depends on the quantity of handling commodity (the commodity flow variable). Hence, having regard to the NP-hard nature of the TSP formulation, it is not recommended to increase the complexity of the proposed model. As is shown in further part of the paper, proposed formulation (equation (2) and (3)) gives a quite good approximation of real process of the handling activities, which are related to the weight class of the products.
Considering the above assumption and problem specification, the OPOP is formulated as:

$$(OPOP): \quad \min_{f_1,f_2}\left[w_1 \cdot \frac{f_1 - F_1^{min}}{F_1^{max} - F_1^{min}} + w_2 \cdot \frac{f_2 - F_2^{min}}{F_2^{max} - F_2^{min}}\right] \qquad (4)$$

$$f_1 \geq \sum_{i\in V}\sum_{j\in V} x_{ij} \cdot t_{ij} \qquad (5)$$

$$f_2 \geq \sum_{i\in V}\sum_{j\in V} x_{ij} \cdot k_{ij} \qquad (6)$$

$$\sum_{i=1}^{2} w_i = 1 \qquad (7)$$

$$\sum_{i\in V} x_{ij} = 1, \quad \forall j \in \mathbf{V} \qquad (8)$$

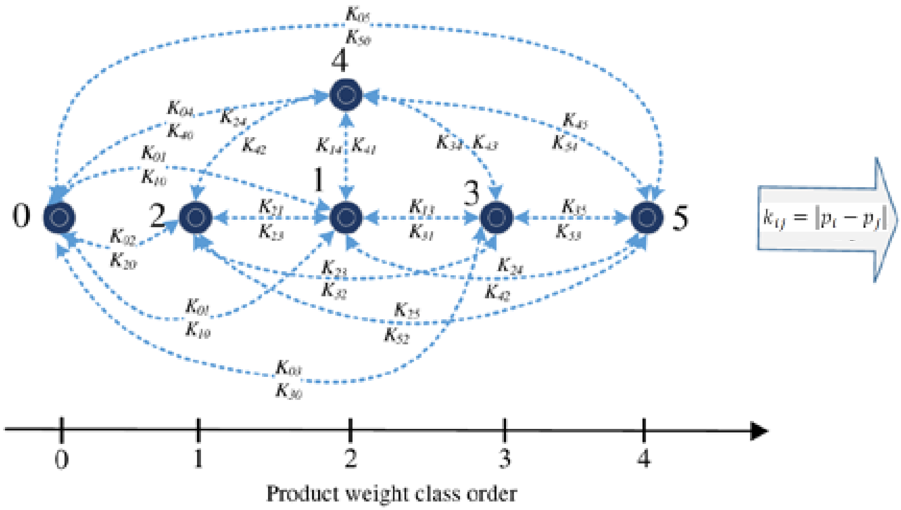
$$\sum_{j\in V} x_{ij} = 1, \quad \forall i \in \mathbf{V} \qquad (9)$$

$$u_i - u_j + 1 \leq (n-1)\cdot(1 - x_{ij}), \quad \forall i \in \mathbf{V} \setminus \{0\} \wedge \forall j \in \mathbf{V}\setminus\{0\} \wedge i \neq j \qquad (10)$$

$$0 \le u_i \le n-2, \quad \forall i \in \mathbf{V}\backslash\{0\} \tag{11}$$
$$x_{ij} \in \{0,1\}, \quad \forall (i,j) \in \mathbf{A} \tag{12}$$
$$f_1, f_2 \in \mathbb{R}^+ \tag{13}$$

The criterion function (4) has been written in the normalized form. The normalization has been introduced due to the fact of adding two different criteria with varying units of measure. Parameters $\{F_1^{min}, F_1^{max}\}$ mean respectively the minimum/ maximum picking travel time in a warehouse for a given graph, and parameters $\{F_2^{min}, F_2^{max}\}$ - respectively the minimum/ maximum penalty for additional manipulation due to the improper order of picking products. The minimum value could be understood as the case where the picking order in the route is created by sorting the weight class of product, and the maximum penalty is the worst case, where almost all product pickup form storage place is associated with additional handling operation (e.g. reloading). The additional parameters $\{w_1,w_2\}$ was introduced in order to be able to assign appropriate weights to a given member of the criterion. Constraint (5) and (6) describes assumed criterions. Equation (7) ensures the convexity of the main function and the Pareto-optimality of the obtained solution. The limitations (8) and (9) correspond to flow constraints in the graph. Formulation (10) is the Miller–Tucker–Zemlin subtour elimination constraints, and (11) help to give precise meaning to each additional variable u_i. Rest of the constraints define the nature of variables.

For clarify the concept of second criterion approximation, let consider the illustrative example. Let assume that problem contains 5 pickup location in warehouse: **V**={0,1,2,3,4,5} and its corresponding product weight class: **P**={0,2,1,3,2,4} and product amounts: **S**={0,3,2,4,5,2}, respectively. The problem of minimization picking travel time, usually, is modelled as a directed graph, where the attributes of arcs are shortest travelling time between two storage points. The solution to such a problem is the sequence of order picking points (picking route). The concept assumes that to every arc of the graph the second attribute is added. It is the absolute difference of weight product classes between origin storage pick point and destiny storage pick point. This mechanism is described in Figure 1.



Kij	0	1	2	3	4	5
0	-	0	0	0	0	0
1	0	-	1	1	0	2
2	0	1	-	2	1	3
3	0	1	2	-	1	1
4	0	0	1	1	-	2
5	0	2	3	1	2	-

Fig. 1.
Example graph for the order picking optimization problem and its corresponding complementary differential matrix of weight product classes
Source: own elaborations

Continuing with the example (see Figure 2), if we assume that picking route: 0-2-1-4-3-5-0 is optimal only for the second criterion, using (3), the penalty for such solution will equal f_2=3 (in optimization model (OPOP) after normalization in (4) it will equal 0). Nerveless, if the solution will be determined as picking route: 0-2-1-3-4-5-0, the value of the second criterion will equal 5. Hence, that value could be interpreted as an extra penalty for improper picking order in the picking process.

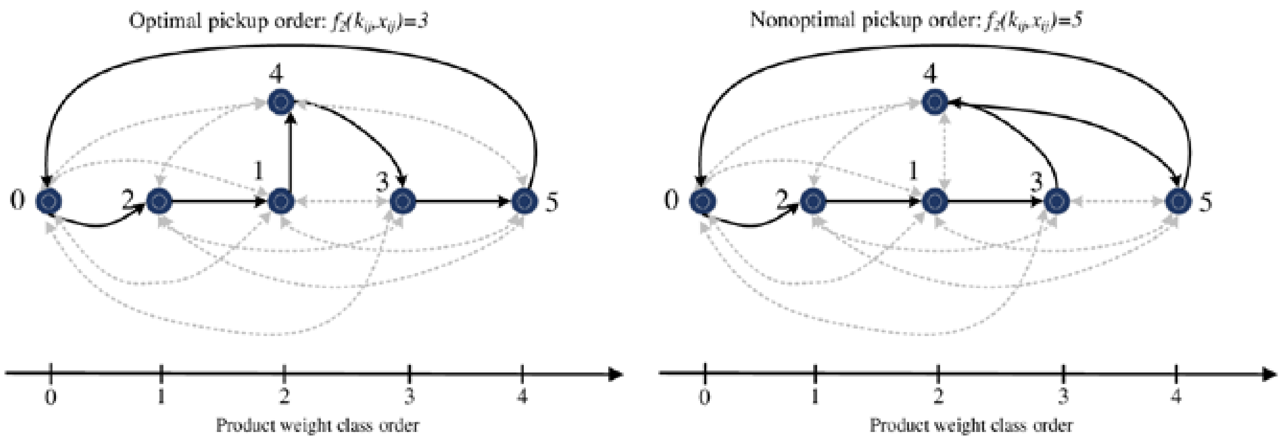


Fig. 2.
Penalty evaluation example for a non-optimal order of picking route in the warehouse
Source: own elaborations

As it was mentioned earlier, the proposed approach does not include an amount of picking product s_i and related with it picking time. However, for comparison purpose, the additional indicator $F_2^{(R)}$ was estimated. It describes the picking time of manipulation activities which have to been done by non-optimal order of picking. This time is also dependent on the amount of picked product. If we assume that mean handling time for one unit of product is 1 seconds and referring to above example, for solution presented on the Figure 2, the picking time for handling activities will equal: $F_2^{(R)}=4$ (only product from 3rd picking point has to be unloaded and loaded again on the transportation device, when the 4th products are receiving from rack). That assumption was used to further numerical experiments.

3. Characteristic of the Proposed Model

The proposed method was used for real picking lists data from the medium warehouse (2 500 m2). The warehouse layout is subsequent: number of rows of the rack in stock - 20 pieces, number of racks in a row - 43 pieces. Traveling time between storage picking point was calculated before the optimization process with assumptions of moving time between the racks: length of a single rack: 1.4 meters, single rack width of 0.9 [m], corridor width: 2.5 [m], travelling time of one meter in a straight line: 1.2 seconds and travelling time of a corner: 2 [s]. Four real testing instances were analyzed: 5, 15, 33 and 57 number of picking points (the real datasets). It also assumes that picking time for one unit of the product equals 1 second.
Based on real data sets, the stochastic characteristics of input data was retrieved (travelling times, the quantities of product in the picking process and products priority). Theoretical probability distribution and its parameters were used to generate random instances from 10 to 90 picking points at the warehouse (the simulation datasets). All solutions ware obtained in CPLEX 12.0 software and the model was optimized by an exact method with two stopping criteria: 5 minutes of computation and 1% of the absolute difference between temporary solutions in a node of the algorithm.

3.1. Simulation Datasets

Firstly, the accuracy of the second criterion approximation was examined. The aim of such simulation is to check what is the degree of relationship between the assumptions for the second criterion in the model (OPOP) and its approximation to the real value for picking time connected with handling activities. Each solution of tested instances was used to evaluate picking time caused by the non-optimal order of picking with dependence on product amount (indicator $F_2^{(R)}$). Evaluated parameters were used to estimate the Pearson correlation coefficient (PCC) and the coefficient of determination (R^2) between the model's value for second criterion and its real value for handling activities. The results are presented in Table 1.

Table 1
Pearson correlation coefficient and coefficient of determination for approximated and real value of the second criterion in the model (OPOP)

	Problem size	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**Mean**
Model $f_2(F_2^{(R)})$	**PCC**	93,04%	90,31%	92,24%	87,33%	80,08%	73,58%	79,82%	97,08%	91,13%	**87,18%**
	R^2	60,57%	84,48%	85,72%	91,07%	85,75%	83,16%	83,53%	82,29%	83,04%	**82,18%**

Source: own elaborations

Obtained results prove that the proposed formulation of product picking order criterion is a good quality approximation of real picking time, such loading and unloading on the transportation device. The fitness degree is related to problem size, its decrease with problem size and up to 90 picking tasks the quality is on a high level.
Next analysis concerns model utility depending on weight structure and problem size. Table 2 presents the analysis results. The complexity of the problem increases with the size of the problem, what is quite a predictable phenomenon. Optimization time depends also on the relation between the considered criteria. Model with the only minimization of handling activities is complex; hence the computation time is large. The reason is the indirect connection of the second criterion with problem constraints defining proper of flow in the graph, e.g. with subtour elimination constraints. Moreover, including in model, the minimization of picking travel time decreases the computing time up to few seconds for the largest instances. Referring to the exact method of optimization and the bi-criteria character of the problem, the obtained result is very effective. It needs to be more investigated in further research, but an explanation of such effect could be the normalized weighted construction of the main criterion. For a more excellent illustration, in Figure 3, the normalized sum of criteria and the normalized weighted sum of the criteria were presented. The assumption for that experiment was the omission of the constraint (7). The range of changeability for weight was [0;1] with 0,1 interval step. It can be observed, that weighted formulation of optimization model's criteria, transform the main criterion into the convex surface, which changes the model to be more tractable (in computing sense). Additionally, even if the computation takes the maximum time, the benefits in operational field compensates the waiting time for obtaining a solution.

Table 2
Computing time depending on instances size and weight values of criteria function

		Computation time [s]								
Weights value [-]		**Problem size**								
w_1	**w_2**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
0	1	0,03	0,25	0,75	300,11	300,16	300,17	5,28	300,27	300,31
0,1	0,9	0,01	0,25	0,63	82,33	300,13	300,22	13,61	300,31	302,39
0,2	0,8	0,01	0,13	0,16	7,84	28,06	300,23	2,78	300,27	300,09
0,3	0,7	0,03	0,11	0,24	1,25	5,41	27,28	1,13	7,02	119,11
0,4	0,6	0,06	0,16	0,14	0,76	5,27	5,44	0,91	4,55	9,17
0,5	0,5	0,02	0,14	0,08	0,33	0,80	1,72	0,64	5,03	9,86
0,6	0,4	0,03	0,08	0,16	0,20	0,80	2,33	0,81	1,25	8,06
0,7	0,3	0,02	0,05	0,16	0,22	0,25	1,02	0,97	1,11	2,19
0,8	0,2	0,02	0,05	0,08	0,30	0,13	1,02	0,80	1,11	1,97
0,9	0,1	0,02	0,08	0,13	0,16	0,17	0,80	0,42	1,36	1,44
1	0	0,02	0,06	0,09	0,16	0,20	0,67	0,84	1,36	0,91
Mean		**0,02**	**0,12**	**0,24**	**35,79**	**58,31**	**85,54**	**2,56**	**83,97**	**95,95**

Source: own elaborations

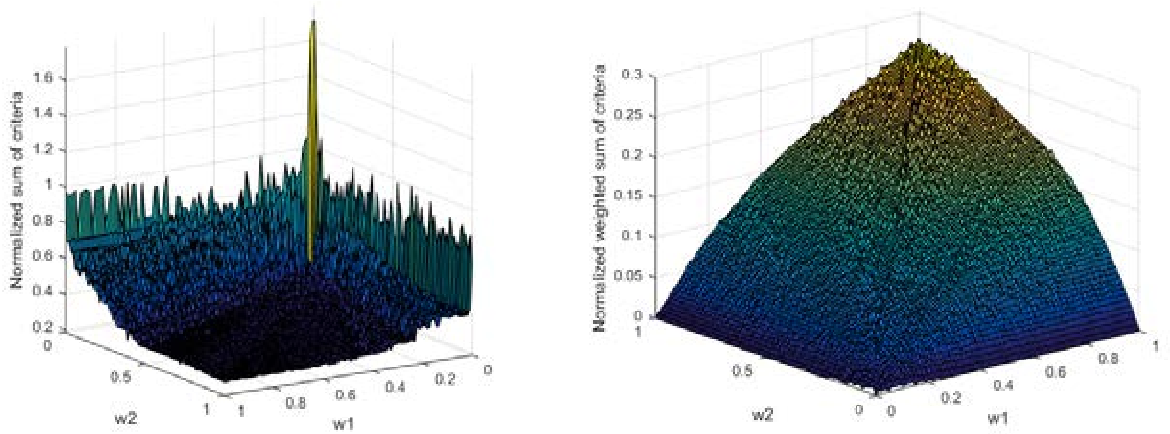


Fig. 3.
Solution surfaces for the normalized sum of criteria (on left) and the normalized weighted sum of criteria (on right)
Source: own elaborations

3.2. Real Data Sets

The proposed approach was tested on data from a real warehouse and detailed results are presented in Table 3 and in Figure 4. The picking time in extreme cases could be larger than the picking travelling time. This is especially observable in one criterion optimization. If the optimal value for picking time is reached, the picking travelling time is extremely large, and vice versa. Only using both criteria in optimization in the warehouse could bring the mutual benefits, which would be realized in decreasing the operational cost of storage.
Figure 4 was created in similar condition as Figure 3, the constraint (7) was omitted. It presents the Pareto set for picking travelling time and approximation of picking a time (our approach) and it corresponding Pareto set for picking a travelling time and the real value of picking time. It can be observed the similarity of both sets, which again proves the conclusion from previous simulations.

Table 3
Selected result for real data set

Instances	**Weights**		**Normalized criterion function [-]**	**Picking travel time [s]**	**Penalty for improper**	**Picking time [s]**	**Computing time [s]**
n	w_1	w_2	F	f_1	f_2	$F_2^{(R)}$	t
5	0,00	1,00	0,00	244,44	0,00	0,00	0,02
	0,10	0,90	0,05	244,44	0,00	0,00	0,00
	0,50	0,50	0,27	244,44	0,00	0,00	0,00
	0,90	0,10	0,10	183,60	4,00	15,00	0,00
	1,00	0,00	0,00	183,60	4,00	15,00	0,00
15	0,00	1,00	0,00	2661,88	0,00	0,00	0,34
	0,10	0,90	0,04	1339,68	0,00	0,00	0,53
	0,50	0,50	0,15	863,44	11,00	2572,00	1,53
	0,90	0,10	0,08	534,40	53,00	3130,00	1,42
	1,00	0,00	0,00	480,04	98,00	3293,00	1,03
33	0,00	1,00	0,00	1488,72	0,00	0,00	0,08
	0,10	0,90	0,05	960,04	0,00	0,00	0,13
	0,50	0,50	0,16	563,92	8,00	632,00	0,25
	0,90	0,10	0,07	348,16	33,00	1426,00	2,22
	1,00	0,00	0,00	338,88	56,00	1651,00	94,22
57	0,00	1,00	0,00	2661,88	0,00	0,00	0,34

Instances	Weights		Normalized criterion function [-]	Picking travel time [s]	Penalty for improper	Picking time [s]	Computing time [s]
	0,10	0,90	0,04	1339,68	0,00	0,00	0,53
	0,50	0,50	0,15	863,44	11,00	2572,00	1,53
	0,90	0,10	0,08	534,40	53,00	3130,00	1,42
	1,00	0,00	0,00	480,04	98,00	3293,00	1,03

Source: own elaborations

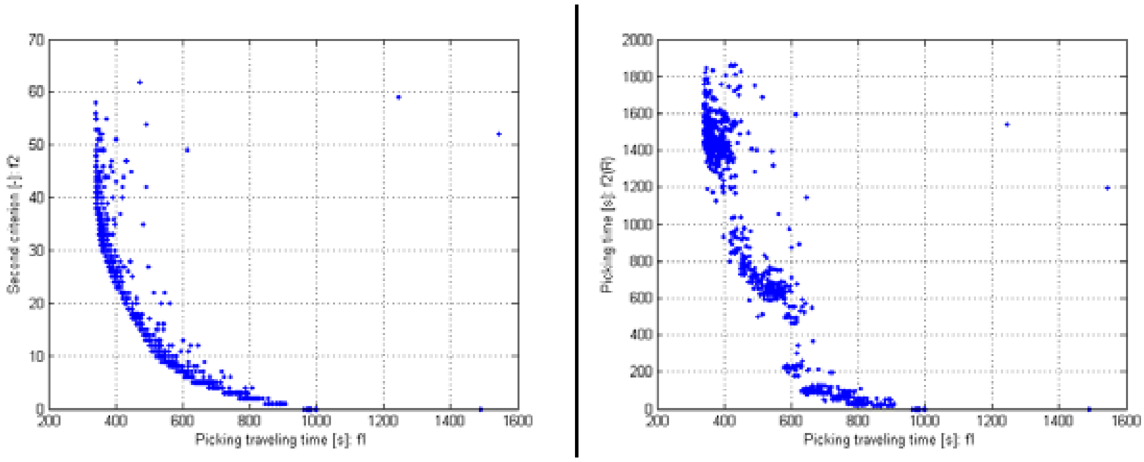


Fig. 4.
Pareto set for bicriteria order picking optimization problem: the proposed formulation (on the right) and relation to picking time (an instance of 33 picking points)
Source: own elaborations

4. Conclusions and Further Research

The current dynamic specificity of the market caused by the popularity of electronic commerce, globalization, growing customers expectations referring to the quality of logistics services provided and delivery times, forces warehouses to handle a growing number of orders in shorter time windows. Thus, the order picking process is one of the key issue affecting the performance of the whole warehouse. In the paper, a bi-criteria approach to picking routes optimization problem has been presented and tested. The analyzed problem concerned a warehouse with a manual picking system. The aim of the first criterion of the proposed model was to minimize travelling time through an optimal sequence of visited collection points in the storage area. The second criterion referred to handling operations minimization connected with products transhipment on a picking device. Consequently, the second criterion was reduced to the shortest path problem, where the attributes on the arcs of the graph representing the considered problem were expressed by the abstract value of the differences in product's weight classes. For this purpose, a differential matrix of weight product classes has been constructed and used. The proposed model has been verified based on sets of numerical examples with the use of real picking lists from the warehouse. The calculations have been executed for a different number of picking points (from 10 to 90 picking points). In the optimization process, the two formulated criteria have been replaced by a standardized weighted sum of partial criteria. The obtained results show that a linear combination of criteria forms a convex surface which had a positive effect on the calculation time. Calculated set of non dominated Pareto solutions, indicated that the transshipment operations referring to products weight classes can significantly affect the total picking time (in some cases travelling time equals 480 s corresponds to the significant time of transshipment 3293 s). This explains the necessity of taking into account alternative product-specific criteria in the order picking optimisation process. Further studies will focus on respecting the impact of products allocation in the storage zone on the obtained final solution.

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ENHANCING PERFORMANCE IN RAILWAY OPERATION BY APPLICATION OF KRONECKER ALGEBRA

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Abstract: Within the Shift2Rail-Project "GoSafeRail" so called Kronecker Algebra is applied on the railway line from Zagreb to Rijeka for traffic flow optimisation. Kronecker Algebra consists out of Kronecker Product and Kronecker Sum to describe concurrency of tasks as well as their interleavings. The railway line from Zagreb to Rijeka has been successfully modelled by software tool called OpenTrack. In this project data from OpenTrack model is automatically converted into input for Kronecker Algebra to manage railway operation in an efficient manner.

Keywords: Kronecker algebra, rail traffic flow optimization, rescheduling.

1. Introduction

One of the objectives of the Shift2Rail project Global SAFEty Management Framework for RAIL Operations is the development of an evolutionary Decision Support Tool that self-learns (evolves) based on machine learning algorithms and artificial intelligence with the main goal of offering safer, reliable and efficient rail infrastructure. Due to a low number in failures on the infrastructure network, this leads to a lack of data crucial for machine learning. This will be solved by implementation of Near-Miss Concept; in other words, low-consequence events will be also included in the model and enable use of statistically significant data for model training. Furthermore, a new train mounted multiple sensor system for Object Detection will be developed.
Moreover, with OpenTrack micro-simulation modelling tool, traffic model will be developed that will use multi-criteria optimization algorithms to address complex requirements, for both passenger and freight transport. Using Kronecker algebra, which showed good results in dealing with optimization scenarios in railway traffic flow, especially avoidance of deadlocks, simulation of the line between Zagreb and Rijeka in Croatia has been performed as well as a optimisation based on Kronecker Algebra.

2. Kronecker Algebra and its Application in Railway Operation

One of the constantly present problems in railway systems is the problem with deadlocks. Since there were no applicable solutions in the middle of 20th century, computer scientists tried to solve this problem by implementing Kronecker algebra in the analysis (Mittermayr *et al.,* 2012).
Before going into solving deadlock issue, a proper definition is needed. Stallings (2001) defines Deadlock as 'an impasse that occurs when multiple processes are waiting for the availability of a resource that will not become available because it is being held by another process that is in a similar wait state'. There are four preconditions for a deadlock to occur according to Coffman (1971); in other words, if one of these conditions is not met, there will not be a deadlock. There is a mutual exclusion, where a resource can only be used by one process at a time. Second, hold and wait includes processes already holding resources and requiring additional resources held by other processes. Third, the so called no preemetion, no other than the process itself can release the resource. Finally, the circular wait that requires at least two processes to form a circular chain in which each process waits for a resource that is being held by the previous process in the chain. Clearly, these four conditions can be applied to railway systems.
After defining conditions for deadlock occurrence, possible ways to deal with deadlocks can be identified. These are deadlock prevention, or removing one of the above mentioned conditions in order to prevent deadlock from even occurring; deadlock avoidance, or decision about resource allocation in advance; and finally, after deadlock detection, termination and restart of the process. For the railway systems, only deadlock avoidance is applicable (Mittermayr *et al.,* 2012).
Kronecker algebra is a mathematical model that consists of Kronecker Sum and Kronecker Product. For the explanation of these two operations, set of matrices (1) is defined

$$M = \{M = (mi, j)mi, j \in L\} \tag{1}$$

where$L$denotes a set of labels with$\langle L, +, 0\rangle$being a commutative monoid and$\langle L, *, 0\rangle$a monoid (Mittermayr and al., 2012). For this case, only matrices$M \in M$with o (M) referring to the order of matrix. Additionally, n-by-n (2) matrices will be used.

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$$Z_n = (z_{i,j}) \text{ where} \forall\ i,j: z_{i,j} = 0 \tag{2}$$

Kronecker product is denoted by A □ B and results in mp-by-nq block matrix, as it can be seen in (3). Matrix A in this case being m-by-n and matrix B p-by-q matrix. As already mentioned above, Kronecker product is used for modelling synchronisation.

$$\text{A □ B} = \begin{pmatrix} a_{1,1}B & \cdots & a_{1,n}B \\ \vdots & \ddots & \vdots \\ a_{m,1}B & \cdots & a_{m,n}B \end{pmatrix} \tag{3}$$

Kronecker sum of matrices A of order m and matrix B of order n, denoted by A □ B (4), is a matrix of order mn defined by

$$\text{A □ B = A □□} I_n + I_m \text{ □□B} \tag{4}$$

where Im and In (n-by-n matrix with ones on the main diagonal and zeros elsewhere) denote identity matrices of order m and r, respectively.

Application of Kronecker algebra in optimization of railway traffic flow lies in its functionality to detect and avoid any deadlocks within the whole analysed railway system, not just on one section. To put it differently, it can is represented as a matrix that includes all possible train movements in a system. In other words, deadlock-free solutions are overall best calculated solutions that take schedules, delays and different types of restriction on the tracks into account (Volcic, 2014). Whereas Kronecker Sum calculates all possible interleavings of all trains not using the same track section, Kronecker Product ensures that those using common track sections can sequentially enter only free sections, namely, sections previously released by another train. Kronecker Algebra delivers results as a matrix. However, these can be represented as a graph, especially time-speed diagram.

3. Data Converter from OpenTrack into Kronecker

Starting with the OpenTrack model of a railway line, two files are generated and exported using existing filters. Based on the itinerary covering the main track from first to last station of an OpenTrack model, a text file in so called IVT format is generated. The structure of an IVT file is always the same and contains the following information:

- position;
- vertex name up;
- vertex name down;
- vertex km up;
- vertex km down;
- speed up 1;
- speed up 2;
- speed up 3;
- speed up 4;
- speed down 1;
- speed down 2;
- speed down 3;
- speed down 4;
- gradient;
- radius;
- tunnel type;
- signal up;
- signal down;
- station name.

The four speed limits have their origin in the Swiss regulation for track speed limits for passenger, cargo (two braking settings) and tilting trains. This file in IVT format is used to create the so called tracks.csv file for Kronecker Algebra. The content of tracks.csv is:

- edge ID;
- initial condition for semaphore;
- maximum valu of semaphore;
- start;
- end;

- sigh position for start;
- release position for end;
- sight position for end;
- release position for start.

Here, the macroscopic structure of a railway line is defined. In addition, there is a micro tracks file for the description of the microscopic structure, including gradients and speed limits. This input is required for the calculation of running times later on. The timetable is exported as a text file in OpenTrack format which has the following structure:
- course ID;
- interval course ID;
- time to interval reference;
- station index;
- station sign;
- track name;
- arrival time day offset;
- arrival time;
- departure time day offset;
- departure time;
- use departure time ;
- dwell;
- stop at station;
- mean delay;
- distribution;
- delta mass.

Based on this information about the timetable of all trains running in a project, for each train a text file trainID.csv is generated as input for Kronecker with this structure:
- start node ID;
- end node ID;
- direction;
- arrival day;
- arrival month;
- arrival year;
- arrival hour;
- arrival minute;
- arrival second;
- departure day;
- departure month;
- departure year;
- departure hour;
- departure minute;
- departure second;
- stopping point;
- time integer;
- virtual stop;
- Kronecker operation (block "p" or release "v).

Additionally, train movements are calculated in accordance with their tractive-effort and braking characteristics:
- train ID;
- Kronecker train ID;
- mass engine;
- mass trailer;
- train length;
- number of trailers;
- train type;
- maximum speed of train;
- factor for recuperation;
- minimum position of train;
- maximum position of train.

4. Use Case of Croatian Railways

Within GoSafeRail project the railway line from Zagreb to Rijeka has been selected. As a first approach, the edges for the Kronecker algorithm were created between signals, speed changes and gradient changes. With this ruleset, the resulting number of edges was 1067 for the Zagreb Rijeka line, which was a fairly high amount for the Kronecker algorithm. In order to reduce execution time of the Kronecker algorithm, the infrastructure was partitioned in a macroscopic view (tracks.csv) and a microscopic view (tracks-micro.csv). For the macroscopic view, edges where only created from signal to signal. With this measure, the number of edges for the Zagreb Rijeka line was cut down to 250. Figure 1 depicts the result of this reduction, reimported into OpenTrack via IVT input.

Fig.1.
Reimported Graph of Zagreb-Rijeka Line

Another major aim in building the infrastructure for Kronecker was the simplest possible representation of the stations. The o2k converter takes care of this by producing only one edge per station, which receives the number of available tracks at this station as the maximum value for its semaphore.
After creating the infrastructure, the second step includes the production of all train course data files required for Kronecker operation by the o2k converter. OpenTrack's timetable data gives information about the passing location of the individual train. If corresponding data is available, time passes from the timetable are used as so-called measure points for Kronecker optimization. Train course files for Kronecker must reserve and free edges in a proper sequence. Especially at stations where a train should stop, the pattern for reserving and freeing edges seems to be somewhat complicated. The screenshot shown in figure 2 of a train course file generated by the o2k converter is presented in order to clarify what the proper solution to this problem shall look like.

```
# iteration 163

# station: DUGA-RESA ; stopAtStation: true virtual_stop: false
# at_semaphore: flush needed:
169 170 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v167
170 171 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v166
171 172 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v165
# at_semaphore: flush done.

# main output for iteration 163:
172 173 20  29  11  2017  01  23  00  29  11  2017  01  27  00  165308  123
0 p163

# iteration 163: doing v final for 164
173 174 2 00  00  0000  00  00  00  00  00  0000  00  00  00  0 123 0 v164
```

Fig.2.
Sample Snipped of a Train Course File with a Real Stop at Station Duga-Resa

The lines starting with a hash mark (#) are comments and will be ignored by the input parser of the Kronecker implementation. These comments have proved to be useful for finding errors contained in the original data from OpenTrack, which has been entered by manually and thus may be erroneous.
For this explanation, lines will always be called by the number at their beginning. Line 172 shows a real stop taking place. Real stops contain the code 10 or 20 at the third field, depending on this course's direction: 10 is for the up direction, 20 is for the down direction. The direction is set by the itinerary of the original IVT file from OpenTrack.
The last column of each line contains a P or V operation for a given edge of the Kronecker infrastructure, which can be found in the tracks.csv file. Following common naming conventions, P is used for reserving an edge and V is used for freeing an edge.

At line 172 in this example, a stop takes place when reserving edge 163. Consulting the generated infrastructure file tracks.csv for the Zagreb Rijeka line, it can be seen that edge 163 is the station area of Duga-Resa with a maximum semaphore value of 3, meaning that there are three tracks in Duga-Resa which can be used for halting trains or overtaking stopped trains.
Line 173 shows the next operation which takes place after the train has stopped at Duga-Resa. This operation is of high importance for Kronecker algorithm. The train arrives via the edges 167, 166, 165, 164 until it halts at edge 163. The edges 167, 166 and 165 are freed in the lines 169 to 171 as can be seen in the sample snipped above. This always happens as a preparation prior to a stop and is called a "flush" in terms of the o2k converter. The edge 164 must not be freed before the train stops at edge 163, but must be freed immediately after. The o2k converter takes care of this.
When a train arrives at its final station, the codes 100 or 200 are used for the third column. As mentioned above, prior to a real stop, a flush is conducted for all but the last edges. Similarly, the last edge before the stop is freed immediately after the stop. The station edge, where the real stop itself is performed, will be freed five minutes after the stop has occurred.
Table 1 compares results from simulation in OpenTrack of all 57 daily passenger trains using the entire or parts of the Zagreb-Rijeka line with calculated delays by Kronecker. While trains arrive earlier in OpenTrack simulation, delays are reduced by application of Kronecker. Further investigations will be carried out on the level of each single train run to validate the calculations of Kronecker by simulations of OpenTrack. Thereby, the recommendations from Kronecker can be used as input for the actual performance of each single train.

Table 1
Overview on Delays in Seconds Calculated by Kronecker and Simulated in OpenTrack

	Earliness in OpenTrack	**Earliness in Kronecker**	**Delays in OpenTrack**	**Delays in Kronecker**
Sum	-3143	-2395	1407	990
Number of trains	42	33	14	23
Average	-75	-73	101	43

Source: www.gosaferail.eu

5. Conclusion

OpenTrack, being a sophisticated micro-simulation model allows the determination of impact of safety decisions on operational network performance. Thus, by incorporating both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement), effective delivery of maintenance or new works while maximising the connectivity and adaptability of the overall surface system will be enabled. As a performance indicator for Kronecker Algebra the delays of trains at their final station are used as a benchmark criteria. First test runs on the railway line from Zagreb to Rijeka show at least a reduction of delay of 30 %.

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METHODS FOR EVALUATION OF BUSINESS CONTINUITY MANAGEMENT SYSTEM IN TRANSPORT

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Abstract: The proactive approach is necessary to reach the essential goals in the area of transport resilience. One option to improve the plan during crisis is the implementation of the Business Continuity Management System. This can improve planning of transport services during the crisis situation in the affected area. The level of efficiency depends predominantly on which evaluation method is used. During the selection of the method for business continuity is important to take into account the fact that this method must cover all the aspects of activities, must be easy to understand to evaluators and last but not least this method must provide the required outputs for evaluation. It is advisable that this method allows to use outputs for further use and further evaluation.

Keywords: resilience, transport, BCMS (Business Continuity Management system), evaluation.

1. Introduction

This paper follows up the paper "Business Continuity Management in the Transport". The previous paper introduced analysis describing and synthesizing realization of the Continuity System in the Transport Branch. In this paper we concluded that BCMS can be characterized at a certain time by its CCB capacity. It determines BCMS ability to absorb inactivity in demanded activities and the size of which can be affected by individual activities. Individual activity can be evaluated by the determined criteria.

2. Multicriterial Evaluation of Activities Continuity

Business Continuity Assessment is a typical task of multi-criteria assessment. The evaluation uses expert-level input data. It is therefore important that the method itself is in the most comprehensible form understandable to the evaluator. The aim of the expert assessment of the continuity evaluation is to maximize the consensus of the experts, but also to get as many original expert opinions as possible. Although expert methods can also be used to work with groups of experts (so-called group methods), expert methods for working with individual experts (so-called individual methods) seem more appropriate in assessing the continuity of activities.

It is advisable to obtain the expert opinions of the evaluation of the continuity of activities in several stages. In the first stage, the steering group will be assembled and the head of the group will be appointed. The rights and obligations of individual group members will be defined. In the second stage, the scope for the preparation for the survey itself will be proposed. In the third stage, specific experts will be identified. In the fourth stage the respective expert estimates will be proposed. Here, the experts will learn about the subject and purpose of the expertise, they will receive the information about the problem, the basic approaches to its solution and the planned course of expertise. It is then possible to obtain their assessments for processing. We can assume that the individuals (experts) are influenced by different motives, needs and interests and will be therefore subjective in their testimonies, while keeping the overall objectivity of evaluation during the survey, there is no direct communication between experts allowed.

From the analysis we can see that the input values of BCMS are vague and therefore we have to use to solve this problem the theory of fuzzy sets and fuzzy logic. In contrast to common quantification procedures, the fuzzy logic and its sets are variable and capable of working with variable intermediate values. Unlike sharp sets that have clearly defined ranges of values, fuzzy sets have these ranges variable. Since fuzzy theory is attempting to cover the reality in its inaccuracy and uncertainty (2) and furthermore, given the nature and complexity of BCMS, BCMS assessment using fuzzy logic evaluation system is a possible solution.

3. Evaluation Criteria

The choice of criteria relevant to the evaluation have affects the outcome. Individual activities can be evaluated according to the monitored parameters. Partial values can be used for the overall evaluation of the department, section or enterprise.

Creating a purposeful set of criteria for the continuity assessment of activities is an important step that can significantly influence the final results. The specified set of evaluation criteria should therefore meet certain requirements. The set of criteria should be such as to allow assessment of all significant long-term and short-term, both positive and negative, direct and indirect impacts. Each criterion must be clearly and conclusively defined. Furthermore it must be also defined the way it is going to be measured. Each aspect should only come into the evaluation once, the criteria should not overlap. It is most important to choose the correct number of criteria (properties). Too many features can make it difficult or even impossible to find solutions. If there is too few of them, there is a risk of omitting some important aspects vital for valid evaluation. It is therefore essential to find a sufficient number of characteristics with sufficient

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information and discernment. The rationality of creating assessment criteria depends on the thorough knowledge of the assessed object, on the structural as well as functional system of understanding.
The system analysis shows that the partial value of the continuity h activity depends on the questions:

- how much it can be done in extraordinary event (e. g. crisis events);
- how long the activity being evaluated does not have to be carried out without the consequent problems;
- how many activities are interconnected with the disturbing activities;
- it is possible to replace the activity, if this activity can be performed by another worker or at another workplace;
- how much is required the specialization of resources for activity;
- there are effective measures, steps or practices addressing risk reduction.

To assess the continuity of activities, 6 basic criteria are proposed, which are relevant to the previous concerns. Table 1 lists the individual criteria for with their label.

Table 1
Criteria for Evaluation of Activities Continuity

Criterion Name	Label
Fulfilment of Activity	p
Continuity of Activity	k
Interconnectivity of Activity	v
Reachability of Activity	d
Difficulty of Activity	n
Vulnerability of Activity	z

Source: Authors

Fulfillment of an activity p is the parameter that evaluates the overall use of the activity in any situation, both in the normal state and in crisis situations. The value of the Fulfillment of an Activity p can indicate that the activity is suitable only for a normal situation, a normal day-to-day regime without the possibility of its use in emergency situations or crisis situations. Under normal circumstances, all activities are valued equally because they meet the essential requirements for the outcome of the activity resulting from the expected benefit of performing the activity. In crisis situations, this standard expected performance requires more effort which is positively related to increasing intensity of the crisis. The value of this criterion of given activity is directly linked to individual crisis situations. For the actual evaluation of the value of the continuity of activities, a direct link to non-military crisis situations has been used.
The continuity of activity k is the very essence of continuity of activity, the basic observed parameter. It is assessed by the time lag between termination of the activity and the renewal of the performance without any subsequent problems.
The interconnectedness of the activity v indicates a number of previous and subsequent activities in general. For this evaluation, only a two-member causal chain was used in the sense of the cause (the activity under consideration) and the consequence (the amount of follow-up activities per activity evaluated). The resulting value v can then be determined by the relationship:

$$v = v_p + v_0$$

In the formula v_p stands for Interconnectivity, which tells about intra-company synergies, and it is the number of links of individual activities to other activities in the department, in the unit or in the enterprise. Second part in the formula v_0 is stands for External Link, which is the number the activity is connected to the surroundings outside of the enterprise.
The reachability of activity d is understood here as the representation of a worker who normally carries out the work by a worker from another, from another department, section, enterprise or outside the enterprise. In other words, it is about the substitution or substitutability for the worker who performs the activity and which, in the event of an emergency, would not be able to perform the activity himself. The term "reachability" was chosen from the point of view of its letter d, because letters z and n are already used for following parameters. In the short term, the job performed by one worker can be divided among other workers who perform the same work in parallel workplaces. In the long-term absence, workers cannot be overloaded, as their fatigue would negatively influenced their job performance. Therefore, it is also possible to consider the possibility of substitution of a worker who has been absent for a long time with a worker from a different workplace who would be able to perform the activity after a short period of training. In the partial evaluation of Reachability of Activity d, the required quality of representation can be expressed by the weight of the criterion, depending on whether a worker from the workplace is required (by increasing the weight of the criterion) or whether the worker can work from external sources (by reducing the weight of the criterion).
Criterion the Difficulty of activity n is characterized for this purpose as the number of workers involved for achieving this activity. If the number of people performing the activity is dropped consequently the performance is reduced and the desired result is not achieved. The value of this parameter can be extended by the financial cost, possibly space requirements for its implementation.

The Vulnerability parameter is *z* is reduced by rules, steps, or procedures. Measures to eliminate risks can only be partial or complex, depending on the degree of practice and their form.
The relationship between the criteria is also important for evaluation. It is also important to find the possible interdependencies or similarities between the various aspects of the assessment.
The basic concept for examining the relationship between two characters is their independence. The two criteria are independent if the assessment of the first one does not depend on the value achieved by the latter.
There is interconnection between Activity *p* and the continuity of activity *k*. It has its justification both in its normal state in terms of meeting its expected benefit and speed and the need for its use. It has its justification both in its normal state in terms of meeting its expected benefit and speed and the need for its use. If the activity is fulfilled even in crisis situations when the time demands for the activity are usually increased, then the period of possible interruption of the given activity should be one day at the most, in order to avoid the risk of delay. Therefore, if the *p* performance of the *p* activity is highly valued, there should not be too long interruptions, so the value of Continuity of activities *k* should be also high. Otherwise, there is a logical disproportion.
Indirectly there is also relation between the parameters of the activity Interconnectivity *v* the Fulfillment activity *p*. The low value of the activity *p* leads to the assumption of the low connectivity to the surrounding activities, in other words, the greater the demand for performing the activity, the more other activities require such an activity and the more requirements for the results of given activity. It is not a direct link with no exceptions, however the general trend the connection is significant. Therefore, it can be generally assumed that the higher the value of the Fulfillment activity *p* higher the Interconnectivity activity *v*.
The Reachability activity *d* has a direct link to the Fulfillment Activity *p*, therefore, the activity *p* can be maintained in the long-term even in crisis situations. There is also another parameter for the need for the performance of the activity. If the activity is not sustained and continuously claimed, the activity is less necessary and for this reason it is not necessary to provide substitution.
There was no immediate link between the Fulfillment Activity *p* and the Difficulty Activity *n*. Both parameters are independent of each other. However, if the number of workers carrying out the activity in normal condition is reduced to a smaller number of workers in a crisis situation, the difficulty in performing the activity will consequently increase.
If the Vulnerability of activity *z* is defined like a resulting effect of the threat elimination procedures, is quite obvious that the performance of the activity *p* is fully independent on it.
The continuity of activity *k* influences the relevance of activity *v* and vice versa. An activity that has several previous and sequential activities is clearly more required and has a higher requirement for continuity of activities *k*. The more people participate in the performance, the more difficult is to achieve the imperceptibility of such activity. Changes in the performance of the original activity can happen if the conditions change. The severity of activity *n* is therefore indirectly dependent on Continuity of activity *k*.
Indirect dependence is also between the Vulnerability of Activities *z* and the Continuity of Activities *k*, because the more the risk is eliminated, the less the activity is interrupted. It is an indirect dependence.
The link between Achievements of Activity *d* and Continuity of Activities *k* is quite obvious. The more the activity is substitutable, the less interruptible it becomes. There is a direct relationship here. On the other hand, no direct relationship has been found between the parameters of the Fulfillment activity *v* and the Difficulty activity *n*, between Interconnectivity activity *v* and Reachability activity *d*, Interconnectivity activity *v* and the Vulnerability activity *z*. If the activity is limited or stopped as a result of the negative impact, then it will disturb or fully stop the follow-up activities, respectively, their number will be limited according to their priority.
The Difficulty activity *n* has no direct relation to the Reachability activity *d*. If is possible to replace the employees with the full required number, the difficulty of the activity must remain on the same level.
The vulnerability activity *z* does not have direct effect on the Difficulty activity *n*. In the case that the substitution is full within required scope, it will fulfill given activity and thus there is no direct link between the parameters of Reachability activity d and the Vulnerability activity *z*. Table 2 shows the relationships between the criteria.

Table 2
Relation Between Criteria

	p	***k***	***v***	***d***	***n***	***z***
p	-	Direct	Direct	Direct	-	-
k	Direct	-	Direct	Direct	Indirect	Indirect
v	Direct	Direct	-	-	-	-
d	Direct	Direct	-	-	-	
n	-	Indirect	-	-	-	-
z	-	Indirect	-		-	-

Source: Authors

The partial value of the continuity activity can be noted as h and its magnitude is determined by the dependency of the observed continuity criteria.

4. Description of the Evaluation Procedure

Each activity is evaluated based on six criteria. Both criteria and their relationships are considerably complicated in terms of evaluation. The evaluation itself has two basic segments. The first are the measuring instruments (prepared scales), which are presented to the experts. The second segment is the experts themselves. The evaluation procedure is devoted to the creation of a measuring instrument. This was implemented in Microsoft Excel using a language-oriented fuzzy expert model.

In order to evaluate the continuity of activities, criteria are the input variables. At the beginning, these parameters must be measured. Here is the display of the measured quantities on the appropriate scale. Then the input values are converted to data. Each criterion related to a particular activity can be worded with the verbal characteristic. For this purpose we can use a 10-parts language scale complemented by language descriptions. This section is called fuzzy inference.

In Table 3, as an example, we can see an assessment of the range of Continuity of Activity *k*, which characterizes smooth performance of the activity. The maximum tolerable disruption of the activity is chosen up to one month when the crisis situation is resolved. Table 3 is the rating range for the maximum tolerable interruption of the activity.

From the logical realities, it is possible to consider and to infer further interconnections of how to deal with individual parameters. A relevant function of connectives must be assigned to partial valuation of the characteristics. The result of fuzzy inference is the fuzzy value of an individual activity criterion.

The defuzzification transforms the result of the previous fuzzy inference operation using the language assessment of the continuity of activities to the real values. The goal is to convert the fuzzy value of the output variable so as to best represent the result of the fuzzy calculation verbally. It is necessary to set the relevant terms. In defuzzification, there are language variables of the continuity of activity values defined by five terms. After assigning of evaluation terms follows the assignment of minimum and maximum values to individual terms. Table 5 lists the maximum and minimum values for each valuation of the single language terms.

Table 3
Evaluation of the Activities Continuity k

The scope Verbal characteristic in the Continuity of Activity *k*	**Point rating of the Continuity of Activity *k* (1–10)**	**Maximum tolerable time of the activity disruption**
Critical Activity	10	up to 1 hour
Semi-critical Activity	9	up to 2 hours
High Importance Activity	8	up to 3 hours
Semi-high Importance Activity	7	up to 6 hours
Important Activity	6	up to 9 hours
Semi-important Activity	5	up to 12 hours
Medium Importance activity	4	up to 1 day
Low Important Activity	3	up to 3 days
Unimportant Activity	2	up to 1 week
Insignificant Activity	1	more than 1 week (up to 1 month)

Source: Authors

In the next step, language terms are defined using truth functions. The rating "inadequate" is defined by L functions. For truthful functions of terms, sufficient, good, and very good, a function having a triangular form is used.. The term excellent have the Γ truthful function.

Table 1
Deadlines of Evaluation in the Continuity of Activity with Their Evaluation

Language valuation of continuity of activities	**min**	**max**
insufficient	0	0,3
sufficient	0,1	0,5

good	0,3	0,7
very good	0,5	0,9
excellent	0,7	1

Source: Authors

Because the partial rating of the characteristics is expressed by fuzzy numbers, the fuzzy weighted average is used to calculate the continuity activity evaluation. The resulting fuzzy number, which expresses the value of the criterion of the activity under investigation from the point of view of continuity, is assigned the appropriate weight of the criterion. The normalized weight of each criterion was calculated by modifying the Fuller method. The resulting scales then express the meaning of the criteria. The more important is perceived the criterion, the higher its weight.

5. Calculation of Continuity Evaluation

It is advisable to use the computing tool to evaluate the continuity of activities themselves. The computational tool was created in the Microsoft Excel for creation of the method. The user interface of the calculation tool has been subordinated to the Microsoft Excel environment with the need for interaction and combination of elements. For the entire evaluation, the computing tool works only through one Excel workbook, by inserting data into the unlocked cells of the respective worksheets. It is advisable to include contextual help in the calculation tool. In addition, the cells on the computational algorithm sheets that are needed for computation were hidden and locked when using the tool. Each activity evaluated is processed on one sheet of the workbook. The structure of sheets for sub-evaluations of individual activities must be the same. Criteria are evaluated in the tool using group frames and switches inserted in them for each word expression that characterizes the activity level. With the switch stored in the frame, you can always specify only one size for each awarded criterion. The data entered here is transmitted as a point in the graph, which here represents the basic features of the relevant function. Depending on the properties of the individual attributes, the appearance of the graph here uses the linear function as either increasing or decreasing. Using the point position in the graph, the fuzzy value of the criterion is determined. This is illustrated by Figure 1.

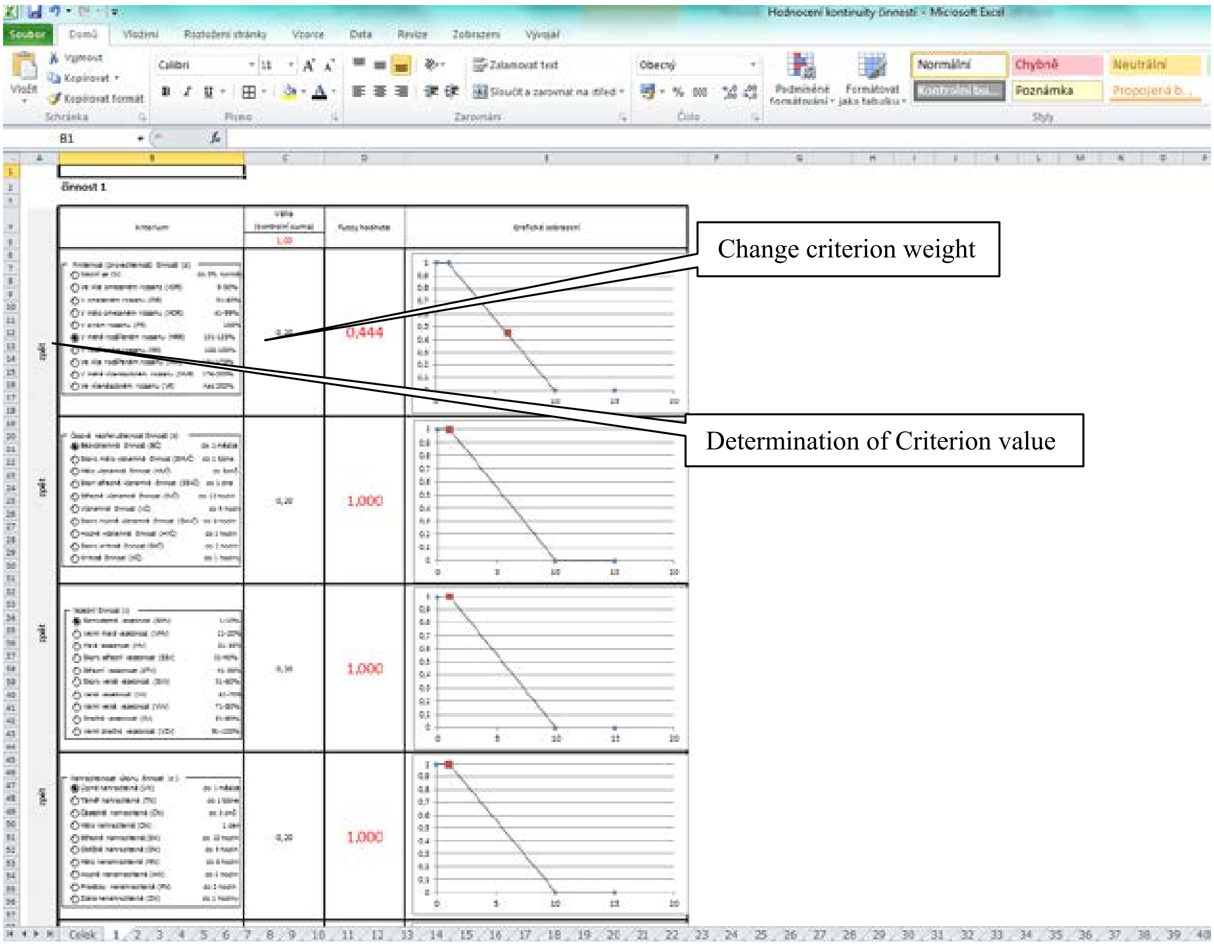

Fig. 1.
Sheet with the Valued Activity
Source: Authors

The evaluation tool itself was applied to the newly created "fuzzy" feature that extended the commonly-offered Microsoft Excel options. This is a subprogram that performs an action and returns a value. It is written to the module using formatted source code. The basic idea of function is the similarity of triangles. The two triangles are similar when they coincide at two angles. If the two triangles are similar, then the ratios of all the corresponding sides of the triangle are the same. For illustration, Figure 2 shows a graph with similarity. The fuzzy value is expressed by the y-axis, the criteria being evaluated on the x-axis.

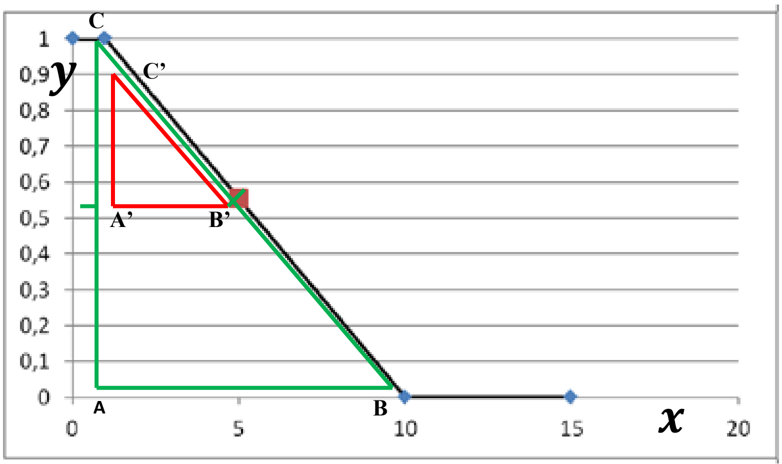

Fig. 2.
Graph of the Fuzzy Value with the Triangular Similarity
Source: Authors

The fuzzy weighted-average is used to express the overall fuzzy value of activity because the sub-criteria corresponding with the individual criteria constitute a disjoint decomposition of the overall evaluation and the partial fuzzy evaluation of the criteria expresses the fuzzy degree of fulfillment of the evaluation.
For the overall activity continuity assessment, the enumeration tool applies two newly created functions. The new "defuzzification" function combines the resulting fuzzy number of the activity being evaluated with the second table, with the language values. The function determines the percentage expression of the language value. Another new feature here used is called "rating." The function works with language valuation and the result of defuzzification. It projects a verbal and visual expression of the continuity of activities in its value form.
Experts were presented with a calculation tool that is only one workbook in a Microsoft Excel spreadsheet application. On sheet 1 "The whole" of the set, a pre-arranged list was added to complete all the titles of the evaluated activities and the overall evaluation of the whole enterprise. The first sheet of the file provides aggregate results for the entire rated area. There are four tables. In the first are the cells for the names of the entire rated object, the individual names of the activities in the object, the weight of the activities and the specific fuzzy values of the activities. For textual evaluation of the overall continuity of activities, the same calculation terms were used for both the minimum and maximum valuations as in the evaluation of individual activities. Using the resulting fuzzy value, the entire field under investigation can be evaluated and the result can be plotted graphically. Figure 3 shows the evaluation tool sheet 1.

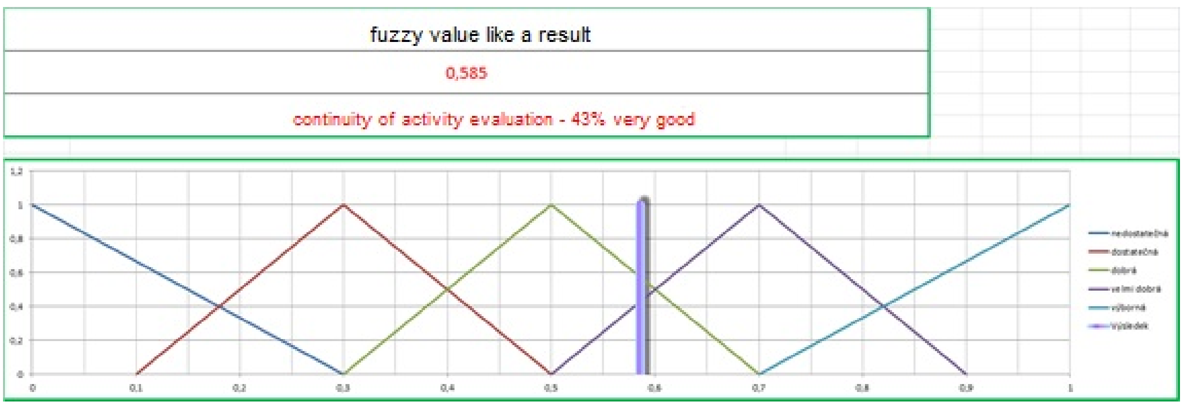

Fig. 3.
Calculation Tool – Final Evaluation
Source: Author

If the calculation determines that the activity does not affect the continuity of activities, the weight "0" is added on sheet 1, and this does not count towards the total result. Additional sheets of the file are for each activity evaluation. The visual form of the evaluation of individual activities was presented in Figure 1. Other data are not required. The calculation tool determines the value of the individual activity as well as the rated entity (enterprise).

6. Conclusion

The properly configured BCMS of the transport company or infrastructure manager copies the optimal limits that BCMS has to reach. From the assessment of the BCMS activities we will see which ones need to be addressed.
By assessing BCMS, it is possible to optimize the continuity of individual activities and thus reduce the possibility of interruption of traffic and transport services of the area.

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LITERATURE REVIEW TOWARD DECENTRALIZED RAILWAY TRAFFIC MANAGEMENT

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Abstract: This paper addresses the analysis of the state of the art to tackle problems which may help in designing a decentralized railway traffic management system. The goal is the study of new ways for modelling railway traffic flow, for example, based on the idea of multi-agent systems. In the first part, we discuss the possibility of exploiting the existing research works on driving agents in road traffic management. The analysis of these works makes it clear that road and railway traffic management are not so similar as far as decision making is concerned. Hence, we consider three different approaches. First, we analyse existing consensus problem papers dealing with multi-agent systems. Then, we study the problem of reaching a common decision in decentralized systems using the approach of hierarchical self-organization. Finally, we consider task allocation models. After the overview, a brief analysis about further possible directions is discussed, focusing the attention on some promising models.

Keywords: Railway traffic management, Multi-agent system, Consensus problem, Hierarchical self-organization, Task allocation.

1. Introduction

Traffic management describes the process of coordinating, controlling and organizing traffic to achieve efficiency and effectiveness in the use of existing infrastructure capacity. Currently, railway traffic is managed by dispatchers in a centralized way: a dispatcher has a control area where he operates. The work of the dispatcher can become very demanding, making decisions on the precedence between trains which must cross a junction, which is a location where multiple lines cross, and on the routes of the trains for the minimization of delay propagation in case of perturbation. Indeed, in the timetable, precedence and routes are determined so that trains can travel at the planned speed never encountering congested traffic conditions. However, when an unexpected event perturbs operations, trains travelling at the planned speed may require the use of some parts of infrastructure concurrently, which corresponds to the emergence of conflicts. When this happens, the deployment of a good traffic management solution becomes crucial.
Following current practice, all decision support tools proposing optimization techniques for traffic management consider a centralized decision making (Cacchiani *et al.,* 2014; Corman *et al.,* 2010; Pellegrini *et al.* 2015). Here, decisions are made and imposed to trains so that a system-level utility function is optimized. This utility function is typically related to delay propagation and is then to be minimized.
In this paper we consider a radically different approach for railway traffic management, in which decisions are made in a decentralized way: trains themselves make decisions on how to solve conflicts, choosing precedence and routes.
Specifically, here we propose a literature review on possible ways of modelling such a decentralized system for railway traffic management.
As we will see in the following, and as intuition suggests, an interesting possibility is based on the idea of multi-agent systems (MAS). A MAS (Ferber, 1999) is an aggregation of agents, intelligent autonomous entities with the capability of observing the environment, communicating with each-other and finally making decisions based on these observations and communications. The organization and co-operation factors, together with the capability of quickly changing opinion based on external considerations, make agents a good choice for controlling many different vehicles. Although this modelling is widely used in road traffic management, it represents a very novel idea in the railway system.
Initially, we summarize the very little literature existing on decentralized railway traffic management. Then, we discuss the possibility of using the existing research works on driving agents in road traffic as a basis. The analysis of these works clarifies that the road traffic problems tackled with multi-agent systems in the literature are different and not really compatible with the one we are interested in for railway. Specifically, major differences exist in the need for collaboration and agreement in general. Hence, we focus on the more general literature concerning these needs, mostly in MAS, and in particular on three different decision making approaches. First, we analyse the rich literature on consensus problems. Then, we study the problem of reaching a common decision in decentralized systems in general using the approach of hierarchical self-organization. Finally, we consider the possibility of applying task allocation techniques.
The structure of this paper is organized as follows. In Section 2 we take stock of the situation on decentralized railway management. In Section 3 we provide an overview of existing decentralized road traffic systems. In Section 4 we analyse the problem of consensus in decentralized systems. Respectively in Sections 5 and 6 we describe hierarchical self-organization approaches and task allocation techniques. Finally, in Section 7 we draw conclusions.

2. Decentralized Railway System

In the existing literature, when railway traffic management is said to be tackled in a decentralized way, the system is actually split into subsystems, each one relying on one individual to make decisions and provide directions (Corman *et*

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al., 2014; Corman *et al.,* 2010; Johnson & Nguyen*,* 2016). Therefore, traffic in a railway infrastructure is not really managed in a decentralized way but is simply partitioned into geographically smaller areas where a centralized management is in place.
To the best of our knowledge, the only two papers dealing with an actual decentralized system are (Yong *et al.,* 2017) and (Fay, 2010). In (Yong *et al.,* 2017), decentralized railway management is achieved through swarm intelligence: trains that are locally moving in the same direction and facing a possible common conflict situation are grouped into a swarm. To coordinate with its neighbours in the swarm, each train uses a train-to-train communication system. To occupy a resource, trains have to send the request to a decentralized dispatching algorithm which verifies the feasibility of such request. If the requested resource is free the algorithm allows the train to occupy it, otherwise the request is put in a pending list.
Although this paper presents an innovative idea, it represents a theoretical starting point that does not give tangible solutions. For example, no investigation is made on the mechanism to define and adapt swarm compositions in complex networks and throughout time. Moreover the dispatching algorithm, which in our eyes constitutes the most important part of the approach, is only sketched.
An approach using autonomous agents is proposed in (Fay, 2010). The paper describes how agents could be used for both planning long term schedules and making short term changes when needed. A peculiarity of this work is that agents represent trains and tracks: when a journey has to be planned, the considered train (T-agent) creates a list of all possible routes it may take, ordered in terms of its own priority criteria, and starts negotiating with tracks (S-agents) the cost of using them. If the cost is too high for all the possible routes, the journey is cancelled. In this system, the interest of the T-agent is finding the more suitable route at a convenient price; at the same time, S-agents aim to fix costs so as to satisfy as many trains as possible to maximize revenues. Hence, both T-agents and S-agents have an active role in the negotiations. As (Yong *et al.,* 2017), this paper proposes an innovative idea but does not deepen it, remaining a hypothetical notion. Specifically, no explanation is attempted to define track costs, for example in case of competition. Moreover, only one to one negotiation is envisaged, neglecting traffic conditions even in real time. In any case, no proper algorithm for the negotiation is discussed. Hence, no actual solution for decentralized traffic management has been proposed yet.
In the next session we consider a different means of transport for which a substantial amount of literature exists: we propose a review of some decentralized road traffic methods that have been proposed.

3. Road Traffic System

Approaches for decentralized traffic management have been widely studied in the field of road transportation. The number of vehicles moving on road or public highway has significantly grown in the last years and traffic congestion has become a major issue in many metropolis and crowded areas. To analyse this issue, many works regarding the idea of constructing simulation models for road traffic management have been presented (Burmeister *et al.,* 1997; Ehlert Patrick & Rothkrantz Leon*,* 2001; Li *et al.,* 2003). These models describe the use of MAS to deal with vehicles and infrastructures, with the goal of testing principles and making useful traffic control plans of action.
In (Burmeister *et al.,* 1997) agents are used to simulate traffic situations. Driver/vehicle agents are modelled having beliefs, desires and intentions as internal states (Haddadi & Sundermeyer*,* 1996). Each agent can communicate with the others. Based on this communication, together with the information it receives from external sensors and its own motivation, it makes decisions.
In (Ehlert Patrick & Rothkrantz Leon*,* 2001) it is described the use of reactive agents in controlling a road vehicle in a simulated traffic environment. Each driving agent receives external information about the environment through sensors and, based on these, makes its own decisions. The behaviour that an agent applies is given by a set of rules which describes actions that each vehicle should follow in order to keep a civil conduct, e.g., always driving on the streets or decelerating when a crossroad is met. These rules are influenced by several behaviour parameters with the aim of creating different driving styles, as happens in real life. In this way, it is possible to let some vehicles drive more or less aggressively, or regulate their speed as preferred, making every agent in some way dissimilar from each other.
Also in (Li *et al.,* 2003) MAS are used to design a microscopic traffic simulator. Each vehicle is described independently leaving the possibility of local interactions.
Apart from simulations, some works focus on the use of agents in the implementation of policies and guidelines on road traffic control. In (Dresner & Stone*,* 2004), agents are used to study systems to primarily reduce traffic jams in crossroads. As before, the system is decentralized and each agent can autonomously make its own decisions submitting to road rules. The paper proposes a reservation-based procedure to be used instead of traffic lights, so that vehicles have time gaps during which they are allowed to cross the crossroad.
A policy for collision control between multiple vehicles is given in (Pallottino *et al.,* 2007). The article uses MAS to study the cooperation between several vehicles on the same route, with the possibility of leaving or entering the scene at any time, focusing on collision avoidance.
MAS are also used to study cooperative control in road traffic management, namely the coordination of a group of vehicles that travel on the same route. For example, the collaboration between autonomous vehicles is the central topic of (Fax & Murray, 2004). The main goal of the paper is to get a control approach of the formation of groups of agents, robust to communication network changes.

A possible solution to the problem of railway decentralization would be to take the research work made on driving agents in road traffic management and use it as a starting point. However, even if they may look like similar problems, road and railway traffic management have some features that make them dissimilar in some important aspects. Indeed, common road traffic vehicles have some rules to follow, such as stop at red traffic lights, slow down at yellow ones or keep a safety distance with others. However, in general they tend to have a selfish behaviour, not caring about each other. This attitude is called human error in (Djelassi *et al.,* 2006), where failures are analysed in order to understand and predict car driving violations.

In this regard, some works focus on the importance of driver violations in the case of road traffic simulation. For example, in (Doniec *et al.,* 2008) agents are used to describe a simulation, taking as a model real drivers dynamic behaviours. The aim of the article is to make the simulation as realistic as possible, focusing on some features that are an important part of real driver decision making processes. In particular, the model relies on opportunistic strategies.

In railway traffic, this kind of behaviour cannot be accepted. It is enough to think of a junction where conflicts among several trains occur: it is of primary importance that trains come to a common decision on who passes first and strictly follow it.

Although not in traffic system, this problem of coming to a common decision is object of a rich branch of literature. It is often modelled as the problem of reaching *consensus* and is a fundamental matter in distributed environments such as MAS. In the next section we propose a review of this literature.

4. Consensus Problem

The decision making process in decentralized systems is often modelled as the *consensus* problem. Here, consensus means getting all the components to reach a common decision about certain tasks of interest.

In MAS, reaching consensus consists in a procedure where all the agents in the network interact with each other, with the purpose of reaching an agreement on a common behaviour. The process that leads to consensus is modelled through iterative interaction algorithms where, at each iteration, agents reveal their opinion to the others, moving toward a common behaviour.

In principle, in railway traffic management, reaching a consensus may be seen as the process of getting a common decision that all the components of the system need to observe and follow.

Over the last decades the increasingly frequent use of distributed systems has made the design of converging consensus algorithms a central research topic. Overviews focusing on recent works on consensus and MAS are given in the surveys (Cao *et al.,* 2013) and (Olfati-Saber *et al.,* 2007). Both studies analyse consensus in complex dynamic systems, taking into account the effects of time delay in the general performance.

The problem of consensus under time delays is also studied in (Tian & Liu*,* 2008). Two different types of time delay are considered: input delay and communication delay. The first defines the delay given by the necessary time for the input to arrive at the agents, the latter is given by the time gap between transmitting information and receiving it. The paper analyses the consensus problem with input delay only and when both information and input delay are present.

A particular kind of consensus problem in MAS is the one that considers one agent as special, with dynamics independent of the others, and is known as *leader-following* consensus problem. For example, (Ni & Cheng*,* 2010) considers the leader following consensus problem in the case of time-varying interaction topology, i.e., when the structure of the interconnection between agents is not fixed but changes over time.

Similarly, (Ren & Beard, 2005) considers topologies that change in a dynamic way. It examines the conditions that guarantee the convergence in time-varying networks when the information exchange is not complete and trusted.

Anyway, an important feature that generally characterizes consensus algorithms in MAS is that, in order to reach an agreement, all the agents have to choose the same solution between a set of feasible ones. To do so, every consensus algorithm performs a number of iterations before converging. For example, it may be necessary to reach a consensus on the speed of several agents sharing an infrastructure. Initially all agents travel at different speeds. Throughout iterations, they progressively start moving uniformly, converging to a somehow average speed, or to the speed of the leader. In railway traffic management, we aim to solve problems of different nature: for example, which train goes first if several ones must cross a common point. Such problems cannot be effectively dealt with through iterative adjustments. Hence, the algorithms proposed to tackle the consensus problem are not suitable.

In the next section, we consider a different decision making approach based on hierarchies.

5. Hierarchy

A *hierarchy* is the organization of components or individuals into groups, based on their degree of importance. The development of hierarchical systems is very common in social structures of any kind. In these systems, the higher the importance of a member is, the more it has privileges and power.

Dominance hierarchy formations are a common peculiarity of animal kingdoms, where animals behave based on their hierarchical ranking. The accepted explanation for the presence of animal hierarchies is the so called winner-loser effect. With winner-loser effect it is defined the condition in which the individual possibility of winning or losing a contest is affected by previous results. Namely, if an individual wins a contest, this raises its probability of winning the following one; respectively, with the losing effect, losing a contest decreases the probability of winning in the future.

Developing a hierarchical structure in the problem of decentralized traffic management may be considered as defining a hierarchy of trains. As we will see, this hierarchy may be caused by many factors and defines the order of passage of trains in a junction.

Winner-loser effects have been widely discussed in animal groups. In (Dugatkin, 1997) a model for the formation of hierarchies is proposed. In the paper, each individual is characterized by two factors: the winner-loser effect and the resource holding power (RHP). The first one, as already explained, is strictly related to the results of the previous contests; instead the RHP is a physical attribute that defines the capability of an individual of winning or losing (e.g., its strength). An important feature of the proposed model is that, when a contest occurs, each individual has no information about its opponent, except for a time invariant assessment of its RHP. The model is used to examine how winner-loser effects affect the formation of hierarchical structures. It considers different cases: when only one between the winner and the loser effect is significant and if both winner-loser effects matter.

The fact of having no information on the opponents is no longer present in (Dugatkin & Dugatkin, 2007), where the same research group presents an updated version of the model. In the paper, each individual has an estimate of its opponent's RHP. The accuracy of the estimation changes and its effects on the formation of hierarchies are studied.

The two models just mentioned are the central topic of (Kura *et al.,* 2015). The paper evaluates and analyses the results of these models on the basis of simulations, mainly focusing on the number of contests necessary for the emergence of hierarchical structures.

A review of previously published works is also proposed in (Lindquist & Chase, 2009). It analyses (Dugatkin, 1997) together with the models in (Bonabeau *et al.,* 1999) and (Hemelrijk, 2000) both examining the emergence of hierarchies due to winner-loser effects. Apart from examining the accuracy of these models to represent the observed behaviour of groups of individuals, an interesting aim of the review is to try finding alternative ways of defining the RHP. As already said before, the RHP is an inner value that specifies the strength of each individual and, therefore, the models do not give a mathematical formulation to quantify it. The paper links the RHP of an individual to the number of times it won and lost, making it easily calculable.

The idea proposed by these models could fit well for our goal of modelling decentralized decision making in railway traffic management. Both winner-loser effect and RHP value are adaptable concepts in the case of railway traffic management. In our case, a contest takes place when more than a train wishes to cross a junction at the same time. It is trivial to see that if only two trains are meeting, winning a contest is equivalent to going first. Instead, if several trains meet, it is less immediate to understand who wins and who loses. A way of dealing with more trains could be to establish a ranking list of the trains having to cross a junction and assign a value to each train based on its position on this list.

The winner-loser effect can be seen as based on the history of each train, defined by what happened in the previous meetings. The RHP value could represent the different types of trains that may have different priority, e.g., high-speed trains, conventional trains, freight trains and dangerous freight trains.

Note that, using this kind of model makes the background information and the type of each train affect its path, but does not consider any other factor which may have an impact on the importance for a train to go first.

Somehow allowing the consideration of other factors, a different approach is proposed in (Broom & Cannings, 2002), where hierarchy formations are established using game theory. In particular, this work uses a multi-player version of the Hawk-Dove game. In this game, when two players aim to the control of a resource, they can chose between an aggressive hawk strategy or a passive dove one. The choice of the strategy depends on the expected reward obtainable with it. When two haws fight, they go on until one decides to leave because of the injuries sustained; if two doves meet, they don't fight but equally share the resource; when a dove and a hawk meet, the dove leaves and the hawk gets the entire resource. Hence, this model has the peculiarity of not having past results interfering with the possibility of winning or losing a contest: no winning-losing effect is present but, based on the strategy chosen, an individual has a defined probability of winning. An earlier and more elaborated version was proposed by the same research group in (Broom *et al.,* 1997), where more than two individuals can compete at the same time. Although this version may be suitable to represent many situations, it comes with a significant increase of complexity. This complexity is not always acceptable, especially in dynamic environments.

The idea of using strategies as proposed in (Broom & Cannings, 2002) and (Broom *et al.,* 1997) could be interesting for the problem we are considering. To apply it, it would be necessary to define what the reward associated to a strategy is in the trivial case of several trains meeting at a junction: these rewards may be linked to the features of the trains but also to external factors such as the delay, or the number of passengers or the importance of the goods transported. As a further step, this model could be extended to a more complex system, with the consequence of having to deal with multiple agents and a large set of all possible strategies, for example based on the need to cross several junctions one after the other. Moreover, the possibilities of having or not perfect information on other agents' rewards would be an interesting development, particularly suitable for the railway traffic context in which we may think of different railway undertakings not wanting to share their utility functions. As mentioned above, unlike the winner-loser approaches, this model can value how important is for a train to go first. In this way, the model allows to better deal with peculiar situations, for example when two trains meet right after the departure, and hence without any background on previous contests.

The last section considers a different approach based on the idea of task allocation, which is not related to hierarchies but could represent a valid alternative.

6. Task Allocation

The problem of assigning tasks among a collection of agents is known as *task allocation* and is a very common problem in everyday life applications. A remarkable example is easily recognizable in all the most famous electronic commerce companies, such as Amazon or eBay, funded in the last couple of decades. In fact, when an order arrives, it is assigned to an agent, usually a robot, that takes care of the preparation tasks. These companies usually have to deal with a huge number of shipments per day, making the process of organizing the distribution of tasks among different agents essential.

In railway traffic management, assigning tasks to a set of trains needing to cross a junction may mean deciding the order of the trains: the tasks may be going first, second and so on.

The definition of a taxonomy of task allocation problems is the central topic of (Gerkey & Matarić, 2004) and (Nunes *et al.*, 2017). In (Gerkey & Matarić, 2004) multi-robot task allocation problems are classified using three features: robot, task and time. Different approaches are proposed if: robots can manage only one task at a time or are capable of handling more tasks; tasks require one or more robots; allocation time must be immediate or can be planned in advance. Similarly, (Nunes *et al.*, 2017) classifies task allocation problems but focusing on temporal and ordering constrains. Hence, tasks are classified based on their urgency of being carried out and on the specific order they need to be executed in. In (Gerkey & Matarić, 2004) all the approaches considered are performed in a centralized way, while (Nunes *et al.*, 2017) gives a brief categorization of decentralized approaches underlying, however, the limited number of existing works.

In (Fatima & Wooldridge, 2001) the problem of task allocation is analysed in the context of MAS, proposing a model called TRACE (Task and Resource Allocation in Computational Economy). The paper characterizes each task by four factors: type, duration, deadline and priority. The type factor specifies the necessary characteristics that an agent should have in order to accomplish the task; the amount of time needed to complete the task is the duration; the deadline gives information about the latest possible time for a task to be carried out; the priority tells how important the task is. Each agent, to whom a task can be allocated, can be different and have dissimilar abilities from the others. The TRACE model groups agents in so-called organizations. In each of them there is an agent in charge or resource management and a set of agents who may be either permanent or marketable. A task can be allocated either to an agent or to an organization. When it is allocated to an agent, the resource manager can ask for help to the other agents in the organization. When it is assigned to an organization, the resource manager decides if it can be accomplished with the available resources. Otherwise, he can ask for extra help to the other organizations who may accept to temporarily share their marketable agents. This model is not suitable for the case of railway traffic management because of the too specific characteristics that define each task (i.e., type, duration, deadline and priority). In the specific case of railway, tasks characteristics strictly depend on the agents (i.e., trains) they are allocated to. For example, if the task "going first through a junction" is allocated to a high-speed train running at full speed, it will have a very short duration. If it is allocated to a freight train right after a stop, the duration will be much longer.

A mathematical approach to the task allocation problem is presented in (Fanti *et al.,* 2016). The paper studies the problem of allocating tasks to a set of agents represented as nodes in a graph: two nodes are linked if the corresponding agents can communicate with each other. The authors propose a distributed iterative algorithm to perform a task allocation through a linear programming model. At each iteration a subset of tasks are allocated to agents in neighbourhood of a randomly selected one. If throughout successive iterations all tasks can be allocated, the algorithm stops. Otherwise some constrains in the local allocations are relaxed.

In (Gao & Luo, 2008) the task allocation problem is studied in the field of a multi-robot system using an Artificial Immune Network model. In the system, B cells produce antibodies that interact with antigens, with the feature that each antibody can interact only with one specific type of antigen. In the paper, robots behave as B cells and tasks as antigens. When a task has to be allocated, each robot is associated to a specific value that describes its capability to perform the task. The proposed algorithm chooses the robot for a specific task based on this value.

The last two models proposed could both represent interesting solutions for modelling decentralized railway traffic management. In particular, the global solution presented in (Gao & Luo, 2008), can be almost directly used in our case. The cells allocated to each antigen may be the trains which have to cross a specific junction. The value describing the capability to perform a task may reflect aspects as trains priorities, current state and possibly the cost of the delay which may come from the task allocation.

Instead, for applying (Fanti *et al.,* 2016) to our problem, the model proposed should be adapted. However, it is particularly interesting due to the use of the concept of neighbourhood. In our case, the neighbourhood may be interpreted in temporal terms: the task allocation may be done only considering the trains which get at a junction in a certain time interval. As time passes, the interval may shift and, hence, the neighbourhood may change.

7. Conclusions

In this paper we proposed an analysis of the state of the art aiming to identify possible ways to model decentralized railway traffic management. After describing the current literature on decentralized railway systems, we focused on the wide existing one on decentralized road traffic systems. Although intuitively the two systems may appear quite similar, we realized that important differences exist and this convinced us to head toward other directions. In particular, we analysed the process of making decisions in decentralized systems, specifically the consensus problem in MAS. Then,

we considered two different decision making approaches, respectively using hierarchical models and task allocation, finding promising ideas that could be actually used for modelling decentralized railway traffic management.
In the future we wish to extend the work with the study of game theory models, which we believe may represent an interesting development and we only very quickly considered in this paper.

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SETTING UP COMMUNITIES OF INTEREST FOR THE ITS INDUSTRY

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Abstract: The concept of Communities of Interest (CoI) is used in a variety of landscapes to describe an agglomeration of entities that can be of any type of organizations or people that are concerned with the exchange of information in some subject area or that share a common goal or environment. In the landscape of Intelligent Transport Systems (ITS), important actors include enterprises, academia, policy makers, associations, consultancies, and, of course, the public as end users. The paper presents an approach for setting up CoI in the ITS field. These can be structured around specific cases, which can act as examples of good practice and bases for gathering relevant stakeholders. In this paper, four cases of CoI, focused on particular sub-fields or activities such as traffic management, water-based transport of goods and railway safety, are examined. The creation of these Communities, according to the proposed approach, should follow a structured process with clearly defined incentives and processes for ensuring their goals. The proposed approach advocates the functioning of CoI in two or three different tiers, from an "internal" one that includes only the CoI organizers and administrators to an "external" one that is open to the general public. Certain paradigms of this approach based on "NEWBITS", EC-H2020 funded project, are provided in the paper. As a critical component for the efficient functioning of the CoIs a web-based platform is proposed, on which the interactions between the members of a CoI and their engagement to new initiatives and projects can be organized, motivated, supported and monitored. The key role of CoI is to support a more intensive and productive interaction between ITS stakeholders, which in turn can facilitate and accelerate the application of ITS solutions in practice and advance the field forward.

Keywords: communities of interest; intelligent transport systems; processes; online platform; innovation; smart solutions.

1. Introduction

The concept of Communities of Interests (CoI) has been used in a variety of different environments and settings (Aiello et al., 2005; McDaniel et al., 2006). One of the identified definitions of a Community of Interest (CoI) is an agglomeration of people -or actors in general, such as organizations- that are concerned with the exchange of information in some subject area (Renner, 2001, p.4) or that share a common goal or environment (Aiello et al., 2005).
Using the above definition, it seems that the CoI is a broad concept that can be used for any group of actors, organizations or stakeholders operating within a given field and/or environment that exchange information and strive towards a common goal. CoI however, should not be confused with other structures, such as networks. Communities and networks can be viewed as two different aspects of social structuring which, as a result, require different forms of developmental work. In a "network", which is viewed as a set of nodes and links, identifying information flows and helpful linkages, the emphasis lies on the personal interactions and connections among participants. On the other hand, the concept of "community" places greater emphasis on the development of a shared identity around a topic that represents a collective intention (Wenger, Trayner & de Laat, 2011).
In practice, communities and networks are often difficult to differentiate. Very few groups have one of the above aspects so clearly pronounced that can be easily identified as "pure" communities or "pure" networks. For most groups, the two aspects are combined in various ways. A community usually involves a network of relationships, while many networks exist because participants are all committed to some kind of joint goal or venture (Wenger, Trayner & de Laat, 2011). Communities and networks produce social capital, the networks and connections among people, which complements "traditional" resources such as physical and human capital, in order to produce better outcomes for innovation and growth (Akcomak & Ter Weel, 2009). Communities also allow the exploration and support of interaction between actors, which enhances collaborative practice (Davis & Mason-Jones, 2017).
It follows that in the field of ITS, CoI can consist of stakeholders that are working -or at least communicating- with each other while striving towards the common goal of developing and establishing an intelligent transport system or promoting an innovative service / solution into market (Angelidou et al., 2015). Therefore, joining together an assortment of ITS actors and stakeholders into a CoI, that makes them operate one with other, can be an important step towards enhancing ITS and moving from ITS to Collaborative ITS, and the benefits that they entail (Piorkowski, 2010).

2. The Profile of the ITS Industry

2.1. General Information on ITS, Market Value, etc.

The ITS domain covers all modes of transport and considers all elements, i.e. the vehicles, the infrastructure, the drivers and users, all interacting together dynamically (ITS Handbook, 2011). More specifically, ITS cover travel information services, transport management systems, a broad range of mobility services (e.g. smart travel cards, integrated ticketing services), vehicle control and safety systems (e.g. anti-collision warning and control systems) and transportation pricing systems (e.g. electronic toll collection, variable parking fees) (Optimism Project, 2011).

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Cooperative ITS (C-ITS) is a subcategory of ITS that has been defined by the European Committee for Standardization (CEN) and European Telecommunications Standards Institute (ETSI) as: “A subset of the overall ITS that communicates and shares information between ITS stations to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone systems” (NEWBITS Deliverable 2.1 Overview of ITS initiatives in the EU and US).

In other words, C-ITS comprises communication between vehicles (V2V), between vehicles and infrastructure (V2I), infrastructure to vehicle (I2V) and/or between vehicles and other transport participants (V2X), such as pedestrians and cyclists.

Regarding the market areas, in two recent studies (ITS Market Analysis, 2016; ITS Market Insight, 2016), ITS market is segmented by a) component, b) type, and c) application. The component segment relates to market characterisation by technology, comprising surveillance camera, interface board, monitoring & detecting system, telecommunication network, software and others.

The second classification segments the market into five (5) types: Advanced Traveler Information System (ATIS); Advanced Traffic Management System (ATMS); Advanced Transportation Pricing System (ATPS); Advanced Public Transportation System (APTS); and Cooperative Vehicle System (CVS).

The third ITS segment is divided into eight application categories, namely: Traffic management; Road safety and security; Freight management; Public transport; Environment protection; Automotive telematics; Parking management and Road user charging.

According to a report by Global Industry Analysis of April 2014, the global ITS market will reach $26.3 billion by 2010, driven by continued rise in vehicular traffic and the need to regulate traffic flow, enhance road safety, and escalate awareness of the socioenvironmental implications of traffic congestion. From a geographical point of view, it is estimated that Asia-Pacific is foreseen to dominate the ITS market in the forecast period of 2016 – 2022 (Market.biz).

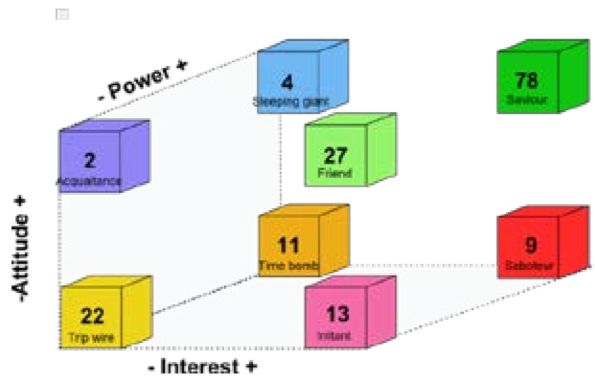

Fig. 1.
Categorisation of stakeholder by interest, power and attitude.
Source: NEWBITS Project (2018), D6.1 CoI Configuration Synthesis Report

2.2. Important Actors

The NEWBITS Project mapped ITS stakeholders, which was not necessarily based on stratified sampling, as the primary factor was ease of accessibility, but it still yields interesting results concerning some features of the ITS industry. The mapping identified 166 stakeholders from 150 unique organisations, which in turn are professionally associated with 4,006 global entities.

The first component included stakeholders interest-power-attitude mapping which, has been performed according to the methodology proposed by Murray-Webster and Simon (2006). This creates a three-dimensional grid based on three characteristics which are important to know when initially considering stakeholders: Power (potential or actual influence), Interest (in the project or program) and Attitude (to the project or program). The grid produces eight different labels based on the position of stakeholders along the dimensions.

The relatively high number of stakeholders (78 or 52% of the total) that have high power, attitude and interest for the project can be considered extremely positive and very hopeful for the functioning of the CoI, as is the fact that a very low number (9 or 6% of the total) have high power and interest combined with low attitude and can be listed as saboteurs.

In short, the vast majority of the mapped stakeholder (90%) were based in the EU, and mainly in Spain, Greece, the UK and the Netherlands. Roughly one third of the stakeholders came from the field of academia, another from the field of industry, while the rest were mostly ITS associations and policy makers. Nearly half of the stakeholders specialised in all or potentially all ITS market segments, while out of those who specialised in a particular segment, advanced traffic management systems (ATMS) was the most common one. Finally, regarding stakeholders’ target market, 42% mainly targets the public market, 31% the private market and 14% focuses on B2B.

Table 1
Identified top ten important entities through number of connections

Label	Number of connections
ITS America	159
International Road Transport Union (IRU)	135
Connekt / ITS Netherlands	126
ISINNOVA	112
Dpt of Mechanical Engineering, Univ. of Western Macedonia	102
Shenzhen Huaru Technology Co., Ltd.	101
ITS Taiwan	88
ITS Finland	82
ITS Spain	78
TREDIT S.A.	70

Source: NEWBITS Project (2018), D6.1 CoI Configuration Synthesis Report

After the creation of the list of the 6,951 connections, a social network analysis tool was used, to identify key components about the network. Social network analysis (SNA) is a powerful way to organize a connected world. Network analysis revealed insights into the ways that the identified entities connect with one another and form groups.
The graph presented in Figure 2 has been constructed using force-directed placement according to Fruchterman- Reingo algorithm. Using the SNA tool, we could focus and analyse specific nodes to understand how each node is connected and its importance to the global ITS landscape.

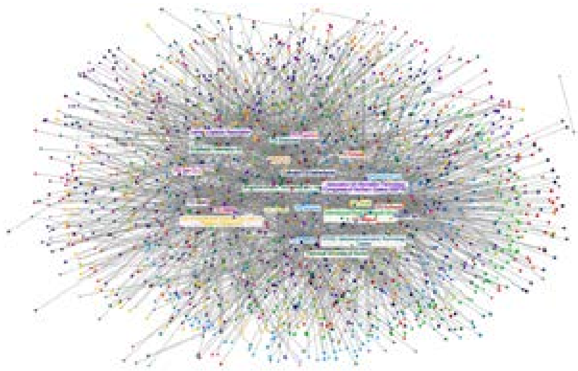

Fig. 2.
Fruchterman- Reingo Network Map
Source: NEWBITS Project (2018), D6.1 CoI Configuration Synthesis Report

3. A Novel Approach for setting up ITS Communities of Interest

Strategy-consulting businesses rely extensively on consultants' tacit knowledge to solve clients' problems and often invest on building strong knowledge networks or communities of interest to develop people-to-people connections (Venkitachalama & Willmottba, 2017). However, while there are plenty of references in the literature about the form, features and functioning of CoIs (Briard & Carter, 2013; Fischer, 2001) there seem to be no specialized defined frameworks for setting up such CoI. Perhaps it is assumed that setting them up is a straightforward process that needs no special definition, or that they come together naturally in the context of particular projects and initiatives. The experience of several experts involved in the NEWBITS project, however, suggests that the success and active functioning of CoI is not guaranteed.

3.1. The Proposed Novel Approach

The proposed novel approach includes the following four steps presented in Figure 3.

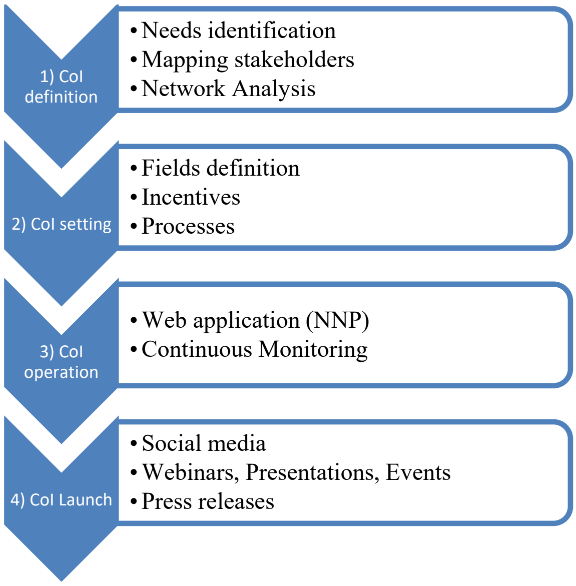

Fig. 3.
A novel approach for setting up CoI
Source: NEWBITS Project (2018), D6.1 CoI Configuration Synthesis Report

To configure the proposed CoI effectively, first it should be justified why potential members would participate in the CoI. The reasoning of such an action is considered a quite complicate multi variable process. The participation in any Community of Interest has both tangible and intangible benefits. CoI are considered as one form of socialization for serving specific scopes. There are different forms of associations or groups of interests that attempt to fulfil similar scopes as the proposed four, NEWBITS, CoI.

The members of CoI can get insight from leading actors such as industry associations and other stakeholders on issues related to the (C) - ITS field regarding the four case studies. The case studies, target key priority areas applicable to ITS and C-ITS across Europe. Initiatives on ITS and C-ITS in Europe and elsewhere, demonstrating best practices from different points of view and how to implement similar in a variety of circumstances, will be also included. The content created by the project's consortium members during the development of the NEWBITS project will be available for discussion among the CoI members. The interaction with other members featuring companies and associations is one of the key benefits. These interactions are the realization of the networking opportunities between the members of the CoI.

The foreseen benefits for the potential members will be further elaborated, though according to initial feedback from the consortium: i) raising the awareness on the state of the art on the fields of (C-) ICT; and ii) the development of common initiatives (Projects EC funded, national and private) are considered important. Potential match making of suppliers and customers of the C-ITS solutions / services and the potential opportunities to implement crowdfunding campaigns look promising.

The operation of communities requires time and effort from their members, so members need motivation in order to contribute effectively (Abouzahra & Tan, 2014). The issue of potential incentives that can be used to motivate stakeholders and actors into joining the different tiers of membership has been pointed out between the NEWBITS partners. What follows is the result of a brief study on potential incentives that are used in forming CoIs.

Incentives that can be used to motivate actors into joining the CoI can be divided into categories, such as practical, financial, social and emotional. Financial incentives are usually a main driver. However, direct financial incentives obviously require the availability of funding for this purpose, which is not always available. The literature shows that incorporating economic incentives can even be counterproductive (Camerer & Hogarth, 1999), or that economic incentives have a tendency to increase quantity but not quality (Mason & Watts, 2009). When considering financial incentives, it is also possible to open up the focus and include not only tangible but with intangible incentives, such as the access to future benefits or access to funding sources, as it is usually found in start-up accelerators' environments. The consideration of potential incentives should not ignore the sociological and psychological aspects stemming from these approaches, which are vital as means for the self-organisation of such communities and are often missing from peer-to-peer systems (Antoniadis & Le Grand, 2007).

Each of the four CoI includes three tiers. Each tier is defined by its scope, members and visibility to public. Tier 1 is comprised of the project partners and the organisations directly involved with the project, aiming to internally support the NEWBITS work packages. Tier 2 has the role of an advanced group of ITS experts. Tier 3 is essentially open to all and has the role of promoting ITS and ITS-related initiatives and collaborations. The following diagram (Figure 4) presents the structure of the web platform that was created to support the above four CoIs and their three Tiers.

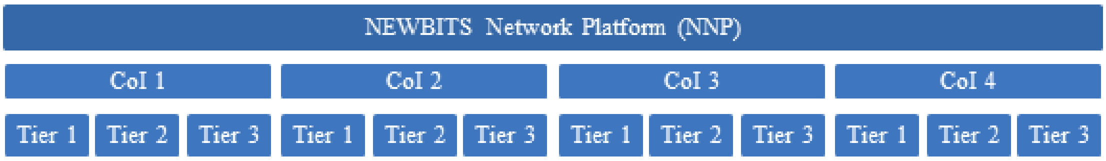

Fig. 4.
NNP to support four Communities of Interest and three tiers per CoI
Source: NEWBITS Project (2018), D6.1 CoI Configuration Synthesis Report

Nowadays, the development of digital platforms and online applications is expanding radically, affecting significantly human activities at all levels, from policy making and governance, to socioeconomic models of production (Kakderi, Psaltoglou and Fellnhofer, 2018). Collaboration platforms, as the proposed NNP, support collective participation in the innovation process, to boost network effects, and enhance the collaboration and creation of bottom-up innovative solutions to complex problems by their members.

3.2. Examples of this From the NEWBITS Project

The NEWBITS project, exploring new business models for ITS, featured the creation of four different CoI, each structured around a particular sub-field of ITS, and each based on one of the project's case studies. Each initial case study, along with the small group of actors directly involved in it, formed the nucleus of each CoI. Other actors and stakeholders that are active in each particular sub-field were subsequently drawn or invited into the CoI. The four communities are presented in more detail below:

CoI 1: Sustainable Intercity Mobility; Intelligent carpooling services for city communities

It regards a CoI built around intelligent carpooling and car-sharing services made possible by advanced C-ITS platforms that provide state of the art capabilities, such as coordinating different route planners and providing real-time routing advice. The scope is to improve traffic flows, reduce emissions and increase urban road transport efficiency. End users also benefit from lower cost. This CoI aims to involve all relevant stakeholders' groups identified in the related case study: city authorities, transport authorities, Academia, ITS service providers, funding bodies, ITS associations, social media, marketing companies and end users (consumers of the ITS service).

CoI 2: Efficient Traffic Management Systems; An energy efficient service for city intersections

This CoI is structured around the installation and use of intelligent traffic management control systems that provide adaptive traffic control strategies, such as the installation of bi-directional communication system between traffic lights and vehicles, which instruct drivers on how to move efficiently in order to expend less time and energy in intersections. The scope is to improve the flow of traffic and reduce delays and carbon emissions. The CoI will involve the following stakeholders' groups: cities, automotive suppliers, Original Equipment Manufacturers, transport operators, end users, ICT service providers.

The main incentive of the CoI is the identification of new business opportunities on collaborative intelligent transport systems.

CoI 3: Synchro-modal solutions for goods transport on water; Using real-time data to decrease idle time and increase efficiency of hinterland transport

This CoI is built around water transport with efficiency-maximizing solutions using synchromodality, which refers to the possibility of choosing the most optimal transport modality at transhipment points. This is achieved by collecting and transmitting real-time data on container transport, from ship tracking, container handling at port, inland ship and truck transport and handling of the containers at the inland terminal and eventually at the warehouse. The scope is to achieve better planning and shorter transport times by better insight into the logistics chain and the resulting decrease of idle time.

The main stakeholders of this CoI are parties in the supply chain of container transport: shippers, terminal operators, warehouse operators, research organisations, ITS and ICT service providers, Governmental and funding agencies, Port Authority.

The core incentive for joining the CoI is the improvement of the collaborative decision-making process across the various stakeholders.

CoI 4: Railway customer satisfaction and safety; Predictive maintenance for cost reduction and safety in railway operation

It concerns a CoI being built around predictive maintenance for railway networks, identifying and reporting potential issues requiring repair before damages and delays appear. The scope is to improve service efficiency and increase passenger safety. The main stakeholders in this CoI are organisations within the Railway Industry: train manufacturers, Railway infrastructure owners, train operators, service delivery organisations, Railway Regulatory bodies, Railway industry organisations, research organisations. The main incentive for this specific CoI is to foster a fully integrated business network modelling approach to railway industry.

The core functions and tools to support the four CoI through the NNP are the following: Set of tools to support NEWBITS implementation; a Content Management System (CMS); a networking space; a showcase of ITS and C-ITS applications and a Crowdsourcing / Crowdfunding function.

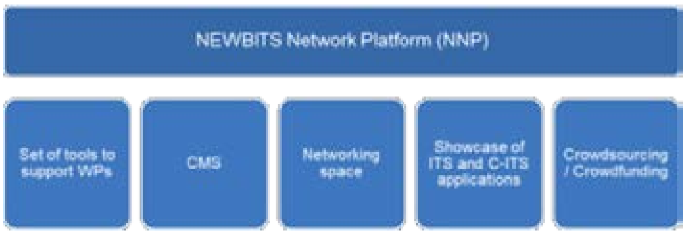

Fig. 5.
NEWBITS Network Platform NNP Core Functions
Source: NEWBITS Project (2018), D6.2 Definition of NNP

4. Conclusions

4.1. What the Novel Approach Offers

The proposed methodology is considered novel since it addresses the design and implementation of a CoI in a holistic aspect, taking into consideration from the very beginning the needs of its multi variable stakeholders. As it has been presented, the usual process of implementing a CoI was to identify a specific issue and, following that, to identify its potential members. In the described process, the key members of the CoI have been the ones who are gathered initially, and the CoI has been based upon their know- how and needs in terms of collaboration, in order to address key related issues.
CoI should be supported by online applications in the current networked business ecosystems. One of the success factors of innovative business models is the connection of the companies with each other, as well as with other important actors including the public authorities, to address common challenges in fast, resource-efficient and innovative ways. Online applications, such as the one being developed during the implementation of the NEWBITS project, aim to gather a large number of members, independently of their place of origin, to pursue specific goals and address common issues.

4.2. Further Research

The design and implementation of a CoI is a very challenging and multi-disciplinary issue. It does not only include technical issues for the implementation of the supporting platform but also human capital management issues and social capital ones. To construct CoI and make them successfully operational, initiatives should encourage people to be part of them and motivate them to be "active" as members. There are different theories on how tangible and intangible incentives are working in specific areas, which can be further examined.
In the latest years the emergence of cloud computing paradigm, has increased interest on the adoption of cloud computing from municipalities and city governments towards their effort to address complex urban problems. The analysis of the "STORM CLOUDS" paradigm as a solution for municipalities everywhere in order to (i) deploy a portfolio of smart cities applications related to governance, economy and quality of life on a single cloud-based platform and (ii) use the platform and its accompanied tools to migrate their existing applications to the cloud environment (Kakderi, Komninos and Tsarchopoulos, 2016) can be utilised as a basis to examine the opportunities and threats of migrating the NNP platform, ITS and C-ITS applications to the cloud to support new challenges.
Another issue that can be theoretically examined and justified is how the attitude of CoI members is changing while being part of community as an individual or as part of a company. As part of a company, the CoI member carries norms, values and regulations of the company, while as an individual member, such restrictions do not apply.
Humans are very social. One of the characteristics that we as humans distinguish from other life forms is that we effectively exchange information. Communities of Interest cover both our social aspect and the effective exchange of information, enhancing social capital, which, after all, is the mediating mechanism which transforms innovation to economic growth (Akcomak & Ter Weel, 2009). Communities of Interest cover both our social aspect and the effective exchange of information.

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CONCEPTUAL SCHEME OF REGIONAL MODULE FOR INTELLIGENT TRANSPORTATION AND LOGISTICS SYSTEM

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Abstract: The relevance of creating an intelligent system to manage traffic flow in transportation corridors is an important and actual problem due to the fact of Russia assessing to the World Trade Organization, integration into the global transportation and communication space and the implementation of the federal transit potential, used today only by about 20%. The European Union plans to ensure functioning of TEN-T multimodal European transportation network on the whole its territory. This system will require bringing technical and technological parameters of the Russian transportation system to be included into international transport corridors. The trend of developing the world automobile industry is to create and to implement pilotless vehicles, which will require the creation of appropriate organizational, technical and information infrastructure for their operation. Mechanisms to implement such projects vary from country to country, but the key components are the same. Existing intelligent transportation systems in Russia are semi-structured set of applied programs to solve particular problems arising in traffic flow managing for manned vehicles on certain sections of the transportation network. The development of regional intelligent transportation and logistics modules and their further integration into a single system is a strategic plan, determines the overall competitiveness of Russia in the global market of transportation and logistics services. The problem involves a conceptual approach to using regional transportation network as a module for the global transcontinental network. Such modules should be positioned into this network with minimal investment while ensuring the management of logistics capacities, investments, construction and coordination of transportation and logistics infrastructure compatible with global traffic management systems. In other words, regional modules integrated into a single ITL (which will be integrated into the European and Asian its) will be used to coordinate physical infrastructure and "soft infrastructure" (e.g. coordination of services to be provided in the transportation network). The paper presents a conceptual model to construct a regional module for the intelligent transportation and logistics system.

Keywords: intelligent systems, transportation system, regional module.

1. Introduction

Now Russia faces the problem of creating an international conceptual transportation system to connect existing European and Asian analogical systems. This paper proposes a conceptual project of a regional module for the intelligent traffic management system, controlling motor vehicles along transport corridors, within a single information space. This system has to optimize transportation and logistics processes and to improve the system safety of the transportation process.

The importance of creating an intelligent system for managing the traffic flow within transportation corridors is explained by Russia's accession to the World Trade Organization, the integration into the global transportation and communication space and the implementation of the transit potential of the country, which is used today in approximately 20%.

The European Union plans to ensure the functioning of the TEN-T multimodal trans-European transportation network throughout Europe (by the year 2050 they plan to ensure high quality and capacity of the TEN-T network with an appropriate set of information services). This will require bringing the technical and technological parameters of the Russian transportation complex to the level of the parameters that international transportation corridors require. This will ensure its competitiveness at the level of world analogues. The trend of developing the world automotive industry is to create and to implement unmanned vehicles, which will require the creation of appropriate organizational, technical and information infrastructure for their operation.

In the world practice, intelligent transportation systems (ITS) are recognized as a common transportation ideology to integrate telematics achievements into all types of transportation activities in order to solve economic and social problems such as to reduce accidents, to improve transportation efficiency, to increase general transportation safety, to improve environmental performance. Developing and implementing such systems are a potentially effective competitive innovation business decision and an incentive for the development of a new high–tech industry sector, which is an important anti-crisis factor.

The experiences of the European Union, the United States, Japan, China, Singapore and other countries show that in a market economy, only a single state policy allows to combine the efforts of the state, the subjects of the Federation, business at all levels and sectors of the economy to achieve national goals in the transport sector.

Implementation mechanisms to develop such systems vary from country to country, but key components are the same. Existing ITS in Russia are semistructured sets of applied programs to solve particular problems of managing vehicles within certain sections of the transportation network (e.g., the system to inform drivers about environment conditions, to guide speed limit, etc.).

The development of regional intelligent transportation and logistics modules and their further integration into a single system has a strategic nature and determines the overall competitiveness of Russia in the global market of transportation and logistics services.

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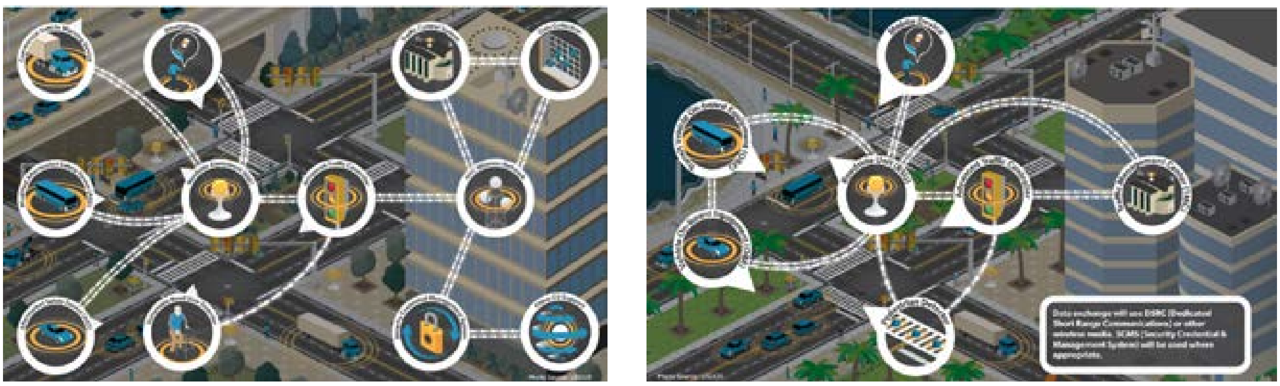
The problem depicted above assumes a conceptual approach to use the transportation regional network as a module of the global transcontinental network, which must be integrated into this network with minimal investment while ensuring the management of logistics capacities, investments, construction and coordination of transportation and logistics infrastructure compatible with global traffic management systems. In other words, regional modules integrated into a single ITLS (which will be integrated into European and Asian ITS) will be used to coordinate physical infrastructure and "soft infrastructure" (e.g. coordination of services to be provided in the transportation network).

2. State of Art in Intelligent Transportation Systems

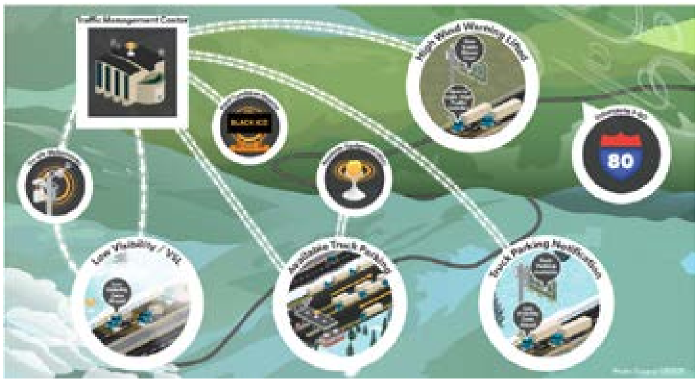
ITS-organizations actively develop and implement projects to forecast traffic volumes and flow-control. These organizations actively work in Japan, America, European Union, Australia, Brazil, China, Canada, Chile, Korea, Malaysia, New Zealand, Singapore, Taiwan, UK. In India, Thailand and some countries of South Africa such scientific schools and organizations are just beginning to develop the concept of smart roads.
Nowadays, the most advanced technologies in the field of ITS are designed in Japan, The USA, Singapore and South Korea. The main directions of developing ITS in these countries are connected vehicle technologies, connected corridors, well-managed and resilient traffic flows, Smart Roads and integration these technologies into Smart City Systems and Internet of Things.

2.1. ITS-America

A single control system of ITS in the United States is "ITS America" (*ITS-America*). The Intelligent Transportation Society of America advances the research and deployment of intelligent transportation technologies to save lives, improve mobility, promote sustainability, and increase efficiency and productivity. The main tasks "ITS America" which it was created to solve are the following: reducing travel time; environmental safety; reduction of accidents and increase transportation system efficiency and productivity. ITS America brings together different organizations from all the relevant sectors: state departments of transportation (DOTs), regional and local transportation and planning agencies, private companies providing ITS products, services and technology, auto manufacturers and suppliers, research organizations, academic institutions and transportation associations.
ITS-America has 3 big projects of ITS-deployment (*Connected Vehicle Pilot Deployment Program*). The first one is NYCDOT Pilot and its applications are the following: Vehicle-to-Vehicle Safety Applications (Forward Crash, Emergency Electronic Brake Lights; Blind Spot Warning; Lane Change Warning; Intersection Movement Assist; Vehicle Turning Right in Front of Bus Warning), Vehicle-to-Infrastructure Safety Applications (Speed Compliance; Curve Speed Compliance; Speed Compliance in Work Zone; Red Light Violation Warning; Oversize Vehicle Compliance; Emergency Communications and Evacuation Information) and Pedestrian Applications (Pedestrian in Signalized Crosswalk; Mobile Accessible Pedestrian Signal System). The second project is THEA Pilot and its applications are the following: Morning traffic backsups (End of Ramp Deceleration Warning, Forward Collision Warning, Emergency Electronic Brake Light Warning), Wrong-Way Drivers (Wrong-Way Entry, Intersection Movement Assist), Pedestrian Safety (Mobile Accessible Pedestrian Signal System, Pedestrian in a Signalized Crosswalk Vehicle Warning), Transit Delays (Transit Signal Priority, Intersection Movement Assist), Streetcar Conflicts (Vehicle Turning Right in Front of Transit Vehicle, Pedestrian in a Signalized Crosswalk Vehicle Warning) and Traffic Progression (Intelligent Signal System, Probe Data Enabled Traffic Monitoring, Intersection Movement Assist). The last of projects is WYDOT Pilot System and its applications are the following: Forward Collision Warning, Infrastructure-to-Vehicle (I2V) Situational Awareness and Work Zone Warning. The conceptual models of these systems are shown in Figure 1.



(a) (b)



(c)

Fig. 1.
The conceptual model of American Intellectual Transportation Systems
(a) NYCDOT Pilot System; (b) THEA Pilot System; (c) WYDOT Pilot System
Source: Connected Vehicle Pilot Fact Sheets (Connected Vehicle Pilot Deployment Program)

ITS-America helps to deploy not only Smart Roads and Smart Cities projects. From the point of view of big corporations and high mobility citizens Integrated Corridor Management (ICM) is the most interesting direction of ITS. ICM (*Connected Corridors Program*) is an entire transportation network—including freeways, arterial streets, transit, parking, travel demand, agency collaboration, and more—and considers all opportunities to move people and goods in the most efficient and safest way possible. The Connected Corridors ICM Architecture is shown in Figure 2.

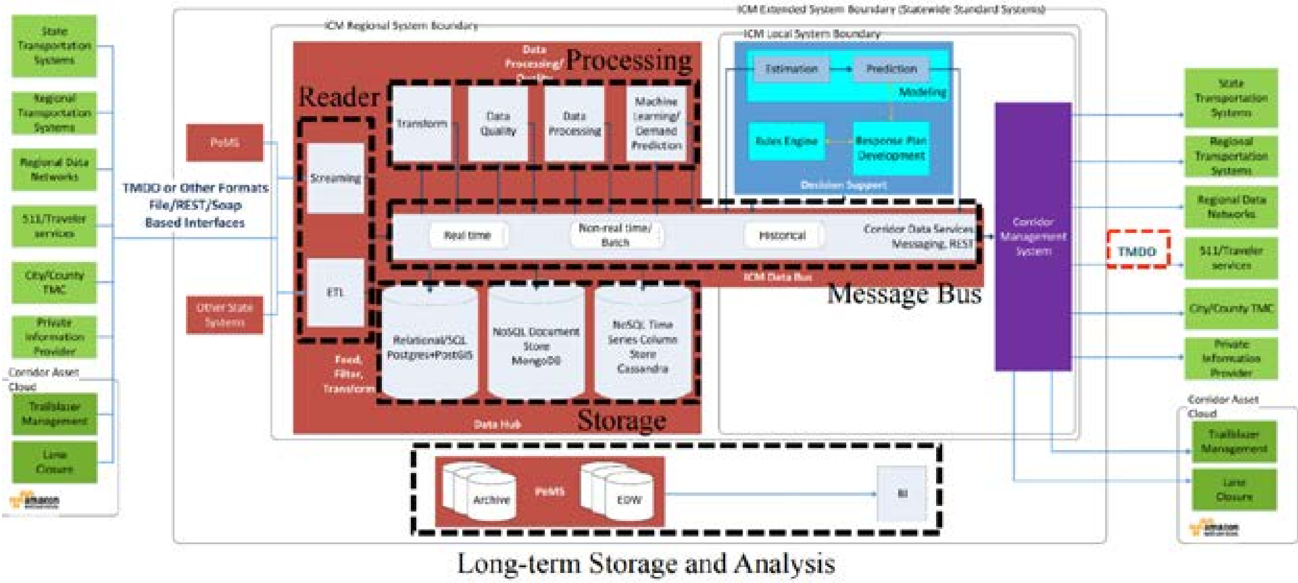


Fig. 2.
Connected Corridors ICM Architecture
Source: (Gan, 2018)

2.2. ITS-Japan

According to ITS Japan concept ITS is a system for solving problems such as safety, efficiency, environment, convenience and recreation (*Hasegawa, 2005*). It was deployed as a set of different application designed to solve a particular problem. So the system architecture (is shown in Figure 3) can be represented as aggregation of user services which have special interfaces to interact among themselves. All user services provide opportunities in the following development fields: sophisticated navigation system, automatic toll collection system, safe driving system, traffic management optimization, road management efficiency, public transport support, commercial vehicle efficiency, support for pedestrians, emergency vehicle operations support.

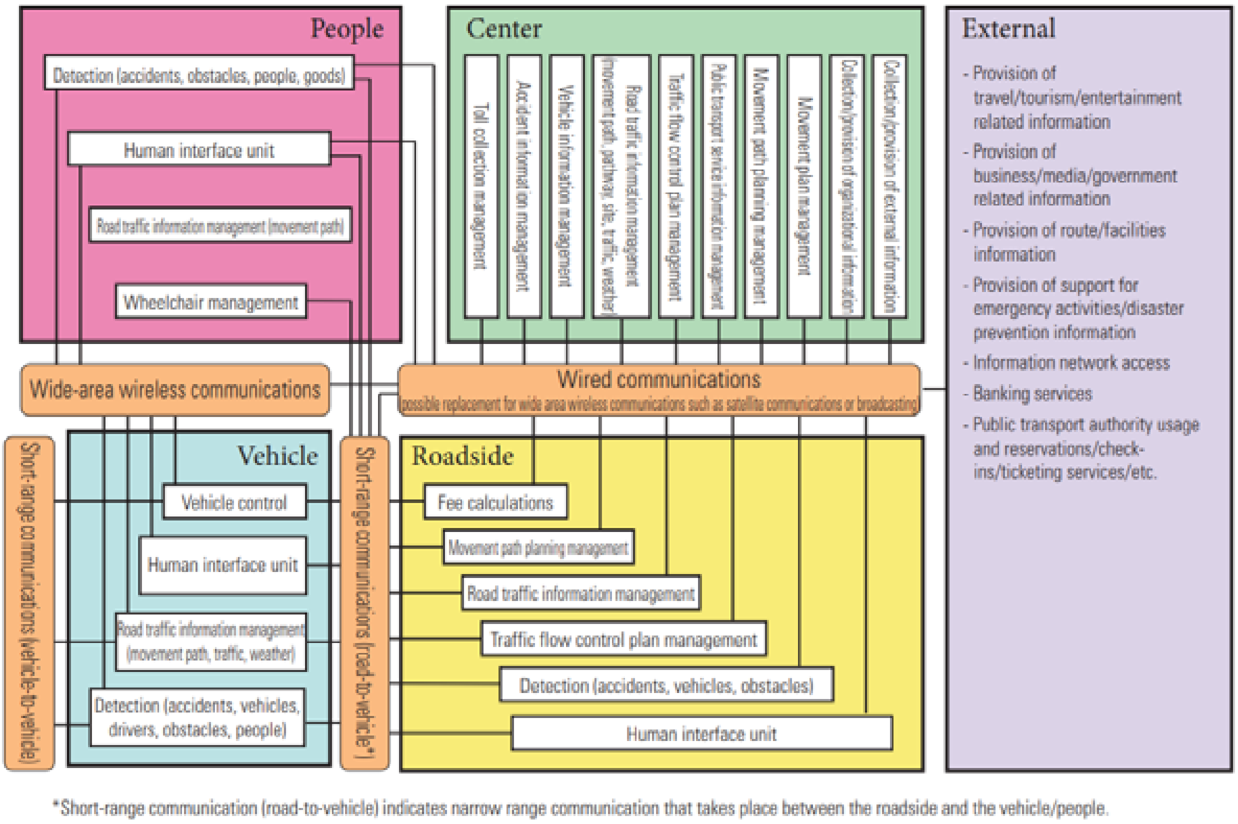


Fig. 3.
Japan ITS Architecture (interconnected subsystems)
Source: (Hasegawa, 2005)

2.3. ITS - Singapore

Singapore officials and researchers deploy ITS as a whole city ecosystem which helps to provide their citizens with a smarter urban mobility. Singapore Land Transport Authority and Intelligent Transportation Society Singapore developed Singapore ITS strategic plan – SMART MOBILITY 2030. According to this paper Singapore's ITS vision is "Moving towards a more connected and interactive land transport community". The central areas of Singapore ITS are Informative, Interactive, Assistive and Green Mobility. The conceptual model of Singapore Intellectual Transportation Systems is shown in Figure 4.

Fig. 4.
Singapore's ITS vision
Source: (Smart Mobility 2030)

2.4. IBM Intelligent Transportation

Not only ITS-organizations of different countries developed their ideas and strategies: nowadays the largest IT-corporation has their own projects connected with ITS. For example, IBM introduced their vision of ITS which meets the needs of the end user while maintaining the benefits of a common architecture. The design of this transportation systems framework conforms to the National ITS Architecture (US). IBM Intelligent Transportation architecture is shown in Figure 5.

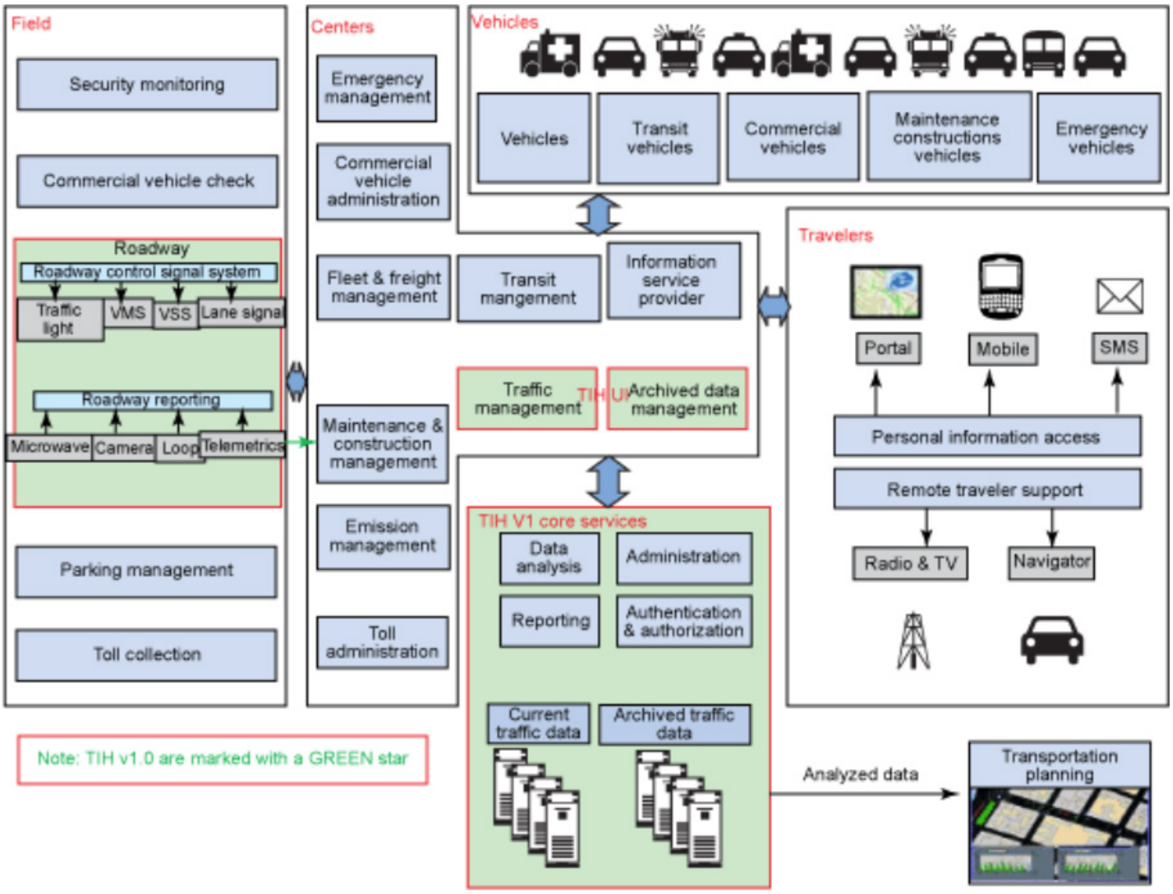


Fig. 5.
IBM Intelligent Transportation high-level architecture
Source: (Laffoon, 2011)

It is clear from these observations that national ITS projects, ideas and strategies has been developed in the same way: to connect all participants of land traffic, collect the data which can be received from their devices and a lot of sensors and automate control and making decisions in transportation systems.

3. Conceptual Scheme of the Regional Module for the Intelligent Transportation and Logistics System

Based on existing researches in Lipetsk State Technical University we propose the following structural scheme to organize the regional module for the intelligent transportation and logistics system of the country. Figure 6 depicts the proposed structure.

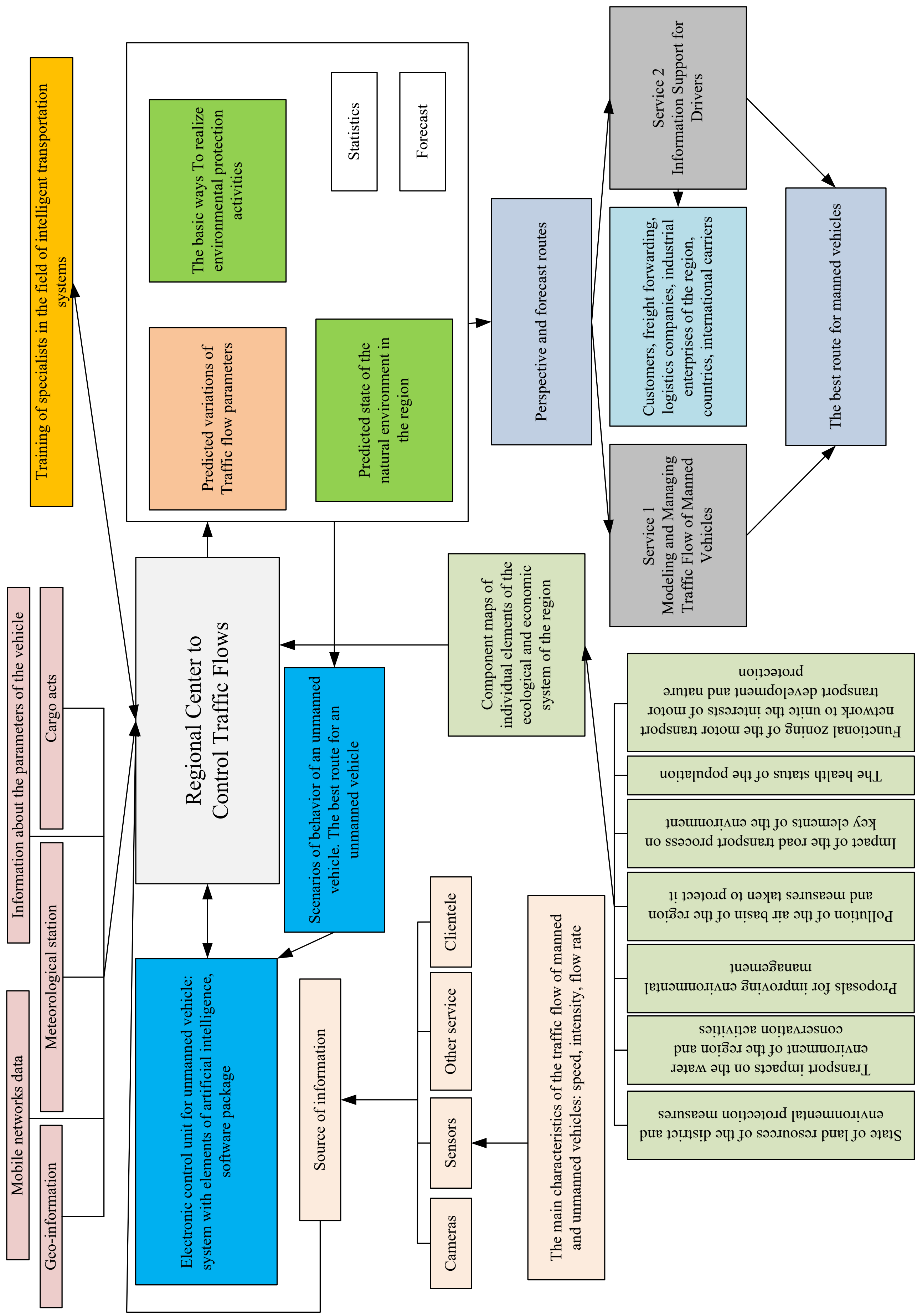


Fig. 6.
Conceptual scheme of the intelligent transportation and logistics system on the regional level

Regional Center to Control Traffic Flows (RCCTF) (*Korchagin, 2011*) consisting of manned and unmanned vehicles delivers following functions: collecting of information about traffic conditions (detailed information about the factors is given on the scheme, cf. Fig. 7) and cargo acts, also processing, analyzing and storing big data; as well as the training of specialists in the field of intelligent transport systems. RCCTF is an academic, scientific-educational center aimed at solving transportation problems using the achievements on intellectual transportation management. Proposed structure should become a platform to implement regional modules of the intelligent transportation and logistics system (ITLS) of the Russian Federation.
Some of the center features are of strategic importance for developing regional transportation system. They are designing system modules of the regional ITLS, forming and developing the strategy of the regional ITLS and the expertize of the proposed features to develop regional ITLS.
To make quick and effective decisions, operators of transport networks used data obtained from information sources in a real-time regime.

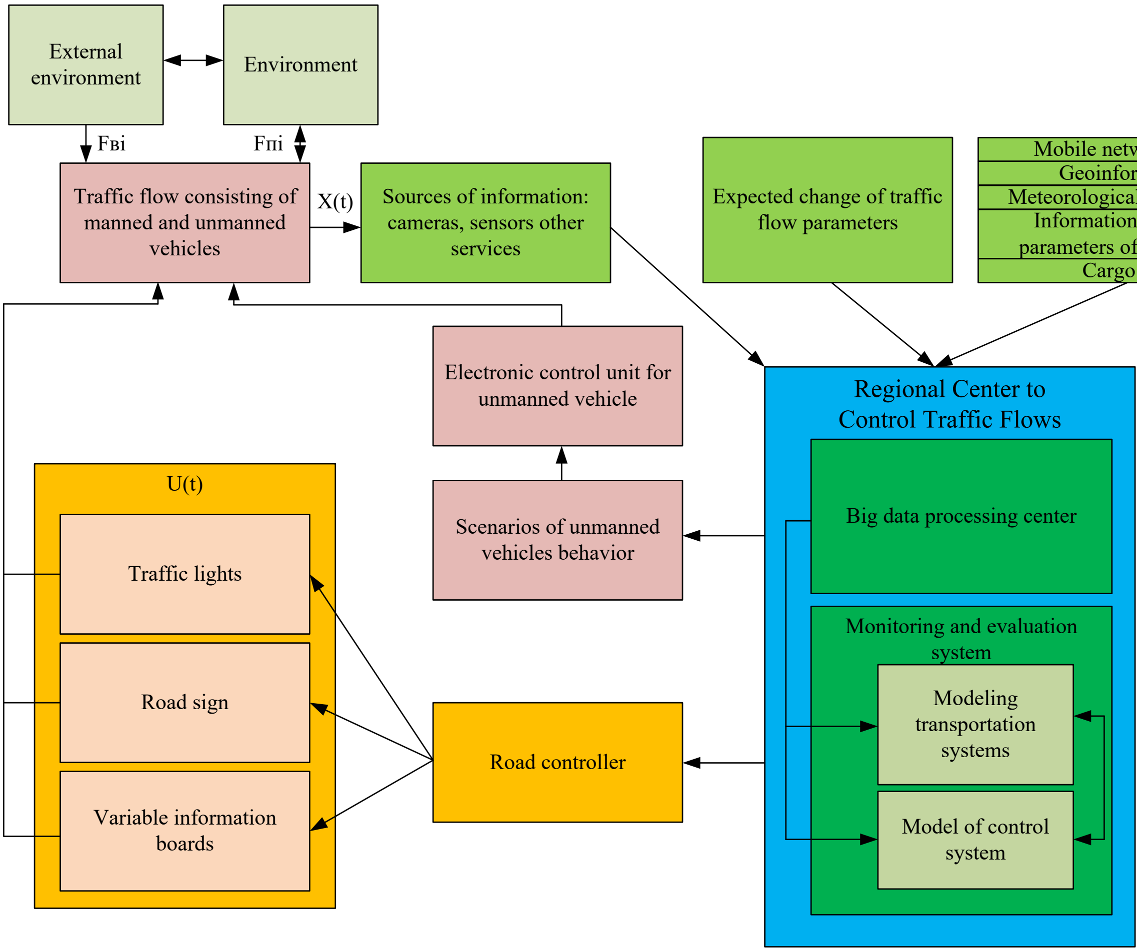


Fig. 7.
Structural model to control traffic flow
Here X(t) is the state of the system (traffic flow parameters), U(t) is control parameters and F are measured parameters of environment effects

Depending on the detected deviations of the characteristics of traffic flow characteristics and based on some quality criteria, the control system (which is a part of RCCTF) changes modes traffic signaling modes and / or information on the managed road signs (including adaptive management) to achieve optimal values of the observed criteria. Depending on the task to be solved, it is possible to use various system quality criteria (partial system security criteria, just-in-time principles and other logistic principles). Assumes using a system of traffic controllers switching traffic signals and traffic signs symbols. In addition, the necessary information for road users has to be constantly placed on the variable information boards.
RCCTF also analyzes ecological and economic system of the region, providing algorithms to systematize heterogeneous data and their integration in uniform system and transfer them to Service 1 “Modeling and Managing Traffic Flow of Manned Vehicles” and Service 2 “Information Support for Drivers”.
Service 1 contains transport simulation models to provide optimal impacts on traffic flow, to develop conflict-free and smooth transportation corridors, to control an access of vehicles to these transportation corridors. Simulation modeling of traffic flows adequately reflects the behavior of traffic flows. Existing transportation models are usually used to test

proposing organizational solutions, allowing to evaluate alternative projects before their implementation to traffic management activities. Created transportation models involve so-called digital twins of vehicles and the road network, which can be used to analyze their operation and control, as well as to optimize the parameters of the traffic flow and service in real time. It is also possible to analyze the effectiveness of traffic control in real operating conditions and accurately forecast it. It is expected that it will reduce delays and the time of communication, as well as the cost of time of vehicles, drivers and passengers (*Kadasev, 2018*).
Service 2 informs drivers about the current and forecasting traffic situation, congestion, provides the information about routing, taking into account the environmental situation in the region. Data depicting current traffic situation are delivered with sensors, cameras, mobile networks and other services. To predict the road situation, main factors affecting traffic flows are used: socio-economic statistics (population and level of employment), statistics on using personal and public transport, changes in the road network, as well as the cost estimate of drivers and passengers time.

4. Conclusion

Existing intelligent transportation systems in the Russian Federation are a semi-structured set of applications for solving particular emerging problems of manned vehicle flow control in certain parts of the transport network. Study proposes a conceptual model of controlling structure for the regional intelligent transportation and logistics system. The regional module of such system within transportation corridors in a single information space can contribute to the reduction of accidents, improve transportation efficiency, provide a higher level of transport security and improve environmental performance.

Acknowledgement
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THE USE OF SOCIAL NETWORKS IN LOGISTICS COMPANIES IN SERBIA

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Abstract: The aim of this paper is to analyze the use of social networks in logistics companies in Serbia. We used the available data from the National Bureau of Statistics of Serbia to identify trends of the use of social networks in (1) small, medium-sized and large logistics companies in Serbia and in (2) logistics companies in different geographical regions of Serbia. After that, we conducted a survey analysis to identify the number of logistics companies in Serbia that used social networks in 2017 and to compare our results with the data provided by the National Bureau of Statistics of Serbia. Furthermore, we have identified the correlations between the percentage of employees with a university degree and the number of computers per company and the intention of logistics companies to use social networks. The obtained results indicate that the percentage of employees with a university degree and the intention of logistics companies to use social networks have statistically significant and positive correlation.

Keywords: information and communication technologies, social networks, logistics companies in Serbia.

1. Introduction

Information and communication technologies (ICTs) have been regularly used in today's businesses, particularly in logistics (Ilin and Simić, 2012; Ilin and Groznik, 2013). In the new economic and social environment, the understanding of the developments and transformations undergone by ICTs with the advancement of social networks and Web 3.0 technology is vital because of the influence of recent innovations in the competitiveness of organizations (Garrigos-Simon et al., 2012).

The online information environment has evolved from a traditional one-way flow of information (from sender to receiver) to a two-way flow of information (from sender to receiver and vice-versa). The former refers to Web 1.0 and the letter refers to Web 2.0. The further evolvement of the web towards Web 3.0 relies on intelligent, contextual decisions of the semantic web, along with the Internet of Things paradigm which requires different devices to be connected to be able to create a large stream of data. In supply chains, Web 3.0 capabilities could be applied for the optimization of the distribution flow of trucks or cargo ships (Harris et al., 2015).

Development of semantic web technologies and different social networks have a potential to create new business environments. According to some predictions, the attention of individuals and companies towards social media, and particularly towards social networks is growing exponentially (Rutsaert et al., 2013). Social networks are widely available and mostly free medium that allows individuals and/or companies to establish communication and cooperation. Recently, the fast development of the Internet use – above all Web 3.0 and online social networks has increased interest in the marketing sector. Many companies have decided to incorporate social marketing (Marketing via social networks) to support their commercial activities (Mata and Quesada, 2014).

In logistics, social networks represent the medium through which manufacturing companies, distribution companies, customers and other stakeholders exchange business information, and thus improve existing cooperation and increase the number of business partners they are cooperating with. Social networks allow logistics stakeholders to be part of global logistics networks, which is the precondition of efficient and effective supply chain (Gligor, 2014). Taking a social network potential to provide sharing of real-time information between all stakeholders in supply chains as well as coordination and cooperation allow stakeholders to better map supply chains structure and to better understand network characteristics and interrelationships between members (Wichmann and Kaufmann, 2016). In addition, Web 3.0 and social networks have a potential to be applied for the identification of objects in supply chain.

According to the statistic portal Statista (2017), the number of monthly active social network users in Serbia is projected to reach 3,5 million individuals in 2022. This would be an increase of over 470.000 new users from 3,03 million users in 2016. However, the statistic portal made no predictions for the use of social networks in companies in Serbia. According to the National Bureau of Statistics of Serbia (2017), all surveyed logistics companies in Serbia had the internet connection in 2017. Simultaneously, 85,5% of surveyed logistics companies in Serbia used a broadband internet by portable devices, such as tablets, laptops, and smartphones. The internet connection is the precondition for the use of social networks, and the broadband internet connection facilitates the use of new ICT concepts in business, such as big data and Internet of Things.

The aim of this paper is to analyze the use of social networks in logistics companies in Serbia. We used the available data from the National Bureau of Statistics of Serbia to identify trends of the use of social networks in (1) small, medium-sized and large logistics companies in Serbia and in (2) logistics companies in central Serbia, AP Vojvodina and Belgrade. After that, we conducted a survey analysis to identify the number of logistics companies in Serbia that used social networks in 2017 and to compare our results with the data provided by the National Bureau of Statistics of Serbia. Additionally, we have examined the correlations between the percentage of employees with a university degree and the number of computers per company and the intention of logistics companies to use social networks.

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The rest of the paper is organized as follows. After the introduction, in section 2 the use of public and professional network services in logistics is introduced. The use of social networks in different industries in Serbia is presented in section 3, while the use of social networks in logistics industry in Serbia is presented in section 4. In section 5 we presented the results obtained from a survey analysis in logistics companies in Serbia and we compared them with the results presented in section 4. Concluding remarks and directions for future work are given in the last section.

2. Public and Professional Network Services In Logistics

Public social networks, such as Facebook and Twitter, bring revolutionary changes in the way how individuals communicate. Public network services could be used in the transport and logistics environment to facilitate instant communications between various stakeholders, such as manufacturers, suppliers, producers and others. Professional network services, such as LinkedIn, Xing and Yammer bring revolutionary changes in the way how companies communicate. For example, companies such as Tesco, Vodacom, and LG Electronics have started to use professional network services for communication between business partners. For instance, management in Tesco use Yammer to share examples of best practices, often by posting photos as well as to share messages and ask for feedback (Tesco Annual Report 2012).

Together with professional network services, blogs and wikis have a great potential to improve business communication between stakeholders in supply chains. The blogs and wikis are primarily used to strengthen cooperation between stakeholders. The general concept of a wiki is an open platform with a self-organization of the content (Ebersbach and Glaser, 2005). This might be used to display information relevant for identification and selection of potential suppliers. Blogs are publications written by individuals or groups on specific topics that are accessible to stakeholders from various business categories. They can also be used for identification of new suppliers. Schrödl (2012) used a metric classification to perform an assessment of advantages that professional network services, blogs and wikis have on the strategic development of supply chain networks.

Table 1

Assessment of the use of digital social networks in procurement process

Procurement process	Characteristics	PNS	B	W
Identification of suppliers	Search Capabilities	4	3	4
	Integration of self-information	5	4	4
	Usage of classification standards	3	2	2
Selection of suppliers	Integration of additional information	4	4	4
	Integration of external rating information	4	4	2
Qualification of suppliers	Maintaining linkage	5	1	1
	Distribution of information updates	5	4	4
	Establishment of closed groups	5	3	1

Note: PNS - professional network services; B - blogs; W - wikis; 1 - inapplicable; 2 - less likely; 3 - neutral; 4 - limited use; 5 - very likely.

Source: (Schrödl, 2012)

Professional network services provide a high potential to be used in all three segments of the procurement process, particularly for the identification of suppliers and their qualification (Table 1). Blogs are the most suitable to be applied for the selection of suppliers, whereas wikis have a potential to be used for the identification of suppliers (Table 1).

3. The use of Social Networks in Different Industries in SERBIA

In 2010, Serbia developed the strategy for the development of an information society (Serbian IT strategy, 2010) with the objective of being capable of obtaining the adaptation and usage levels that are currently possessed by the EU countries. The Serbian IT strategy reveals that the development of e-business and overall electronic communications are the basis for the progress of an information society (Ilin et al., 2017). Since web-based applications are nowadays necessary for the use of almost all social networks, the main aim of the Serbian IT strategy correlates with the development and the recent extensive use of social networks in companies from different industries in Serbia. According to the National Bureau of Statistics of Serbia, 63,3% of firms from different industries in Serbia used social networks in 2017, compared to 63,2% of firms in 2016. We analyzed the available data from the National Bureau of Statistics of Serbia[3] to identify trends of the use of social networks in companies from different industries in Serbia for the period from 2013 to 2017 (Figure 1).

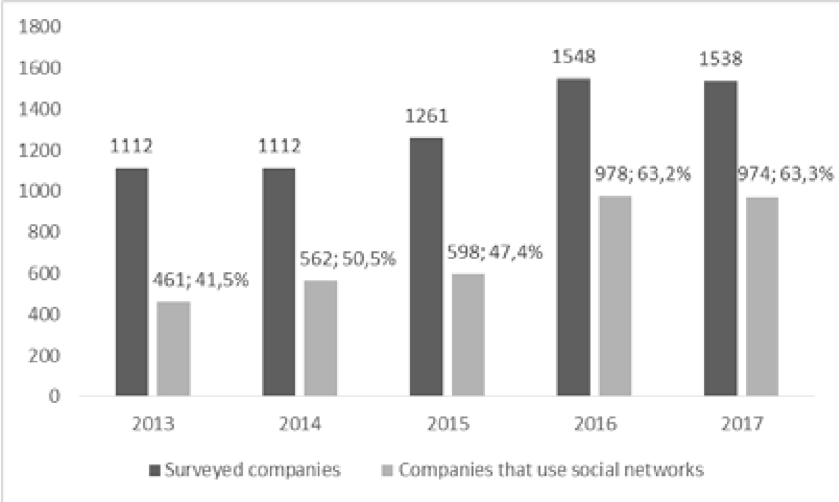


Fig. 1.
The use of social networks in companies from different industries in Serbia

The presented data show that there is a positive trend of the use of various social networks in companies from different industries in Serbia (Figure 1). It can be noticed that there is an increase of 21,8% of surveyed companies that used social networks in 2017 compared to 2013. The more detailed visualization of the diversity of the use of different social media in companies from different industries in Serbia is shown in Table 2.

Table 2
The diversity of the use of social media in companies from different industries in Serbia

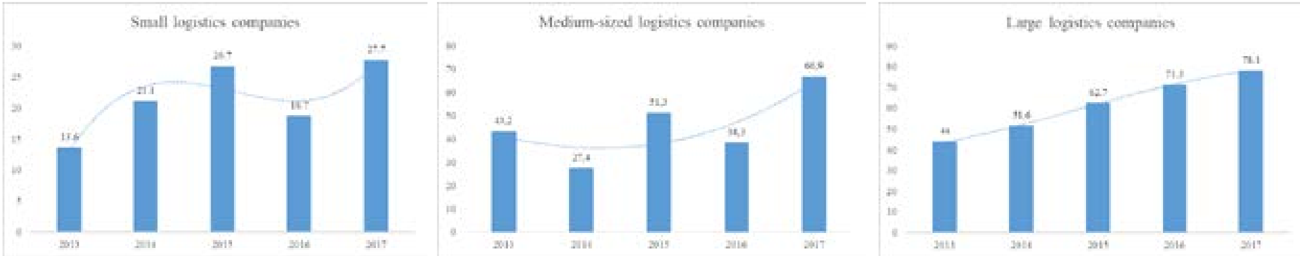
	Year				
	2013	**2014**	**2015**	**2016**	**2017**
Social networks	**Percentage**				
Facebook, Twitter, LinkedIn, Xing, Yammer	30,8	36,6	37,4	48,6	48,7
Increase (+) / decrease (-)*		+ 4,8	+ 0,8	+ 11,2	+ 0,1
YouTube, Flickr, Picasa	10,7	13,9	10	14,6	14,6
Increase (+) / decrease (-)*		+ 3,2	- 3,9	+ 4,6	/
Online encyclopedia	**Percentage**				
Wikipedia	6,2	5,1	7.5	8,3	6,8
Increase (+) / decrease (-)*		+ 0,9	+ 2,4	+ 0,8	- 1,5

*Note: * Increase and decrease are measured for the observed year compared to the previous year.*

Public and professional network services (Facebook, Twitter, LinkedIn, Xing and Yammer) attract new companies from different industries in Serbia each year (Table 2). However, this is not the case with some other social networks (YouTube, Flickr, Picasa) and online encyclopedia (Wikipedia).

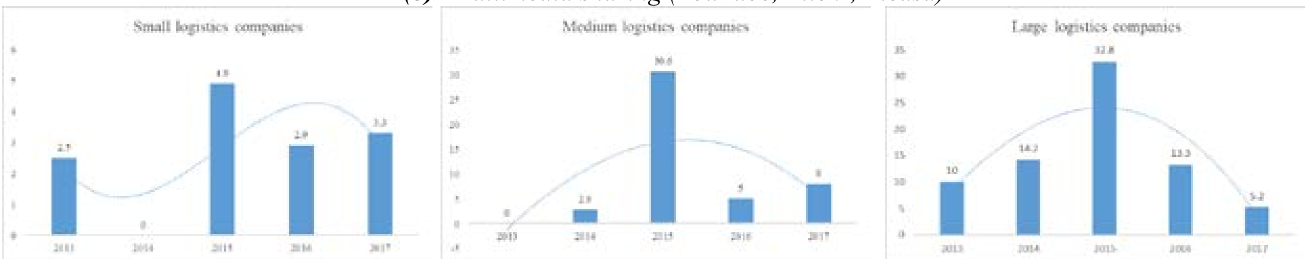
4. The use of Social Networks in Logistics Industry in Serbia: an Official Statistics

We used the available data from the National Bureau of Statistics of Serbia (http://www.stat.gov.rs) to conduct analysis regarding the use of social networks in logistics companies in Serbia and to identify trends of the use of social networks for the period from 2013 to 2017. The traffic and warehouse companies are observed as logistics companies. The analysis is performed by two criteria: the size of the logistics company and the geographical region where the logistics company is located. The use of different social networks and online encyclopedia in small, medium-sized and large logistics companies in Serbia is presented in Figure 2. Classification of logistics companies in Serbia has been performed in the following way. Small logistics companies are those that have more than 10 employees and less than 50 employees, medium-sized logistics companies are those that have more than 49 employees and less than 250 employees and large logistics companies are those that have more than 249 employees. The use of different social networks and online encyclopedia in logistics companies in central Serbia, AP Vojvodina and Belgrade is presented in Figure 3.



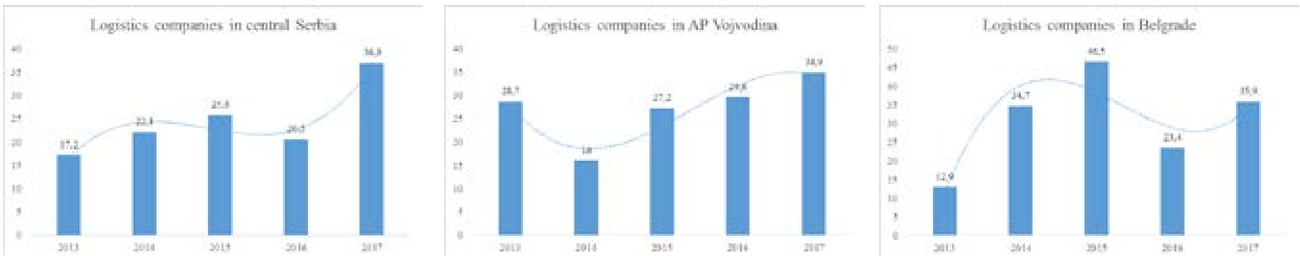
(a) Public and professional network services (Facebook, Twitter, LinkedIn, Xing, Yammer)

(b) Multimedia sharing (YouTube, Flickr, Picasa)

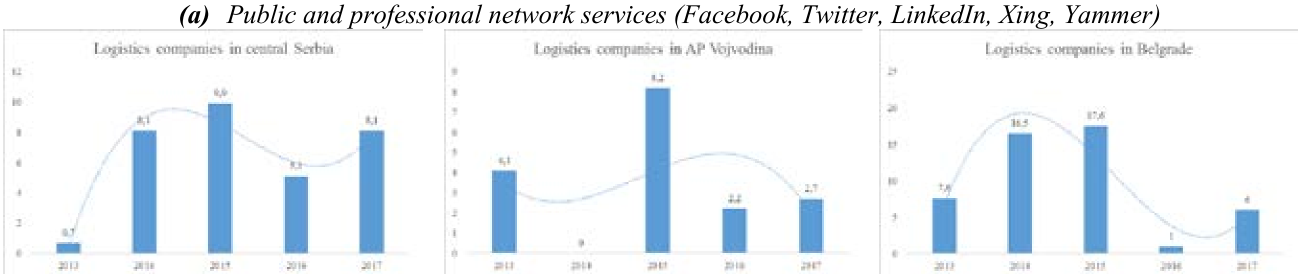


(c) Online encyclopedia (Wikipedia)

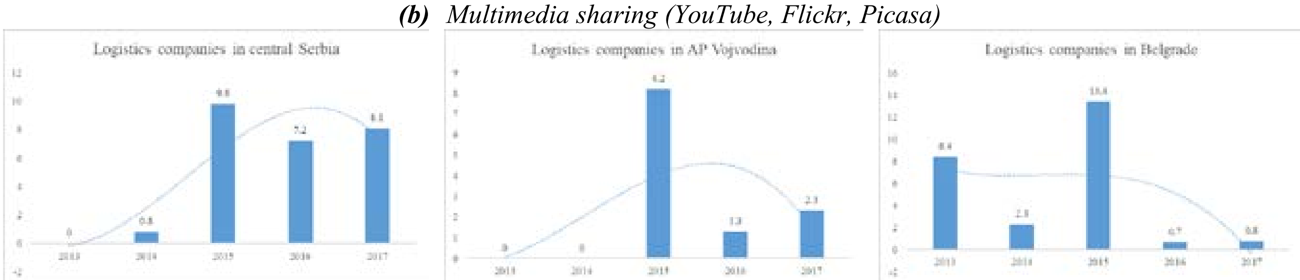
Fig. 2.
The use of social networks and online encyclopedia in small, medium-sized and large logistics companies in Serbia



(a) Public and professional network services (Facebook, Twitter, LinkedIn, Xing, Yammer)



(b) Multimedia sharing (YouTube, Flickr, Picasa)



(c) Online encyclopedia (Wikipedia)

Fig.3.
The use of social networks and online encyclopedia in logistics companies in different geographical regions of Serbia

Public and professional network services (Facebook, Twitter, LinkedIn, Xing, Yammer) have noticeable growth of the number of small, medium-sized and large logistics companies in Serbia that used social networks in 2017 compared to the period from 2013 to 2016 (Figure 2a). The use of multimedia sharing (YouTube, Flickr and Picasa) as well as online encyclopedia (Wikipedia) was declining in small, medium-sized and large logistics companies in Serbia in 2017 compared to 2015 and/or 2016 (Figure 2b and Figure 2c). The exception of previously noticed trend is the use of multimedia sharing in large logistics companies. It can particularly be noticed that the use of Wikipedia in small, medium-sized and large logistics companies in Serbia reached the peak in 2015 (Figure 2c).

Public and professional network services (Facebook, Twitter, LinkedIn, Xing and Yammer) have noticeable growth of the number of logistics companies in central Serbia and AP Vojvodina in 2017 compared to the period from 2013 to 2016 (Figure 3a). The use of public and professional network services in logistics companies in Belgrade was at the pick in 2015. The use of multimedia sharing (YouTube, Flickr and Picasa) as well as online encyclopedia (Wikipedia) was declining in logistics companies in central Serbia, AP Vojvodina and Belgrade in 2017 compared to 2015 and/or 2016 (Figure 3b and Figure 3c).

5. The use of Social Networks in Logistics Industry in Serbia: a Survey Analysis

In order to confirm identified trends in Section 4 we conducted a survey analysis in logistics companies in Serbia and compared the obtained results from our research with the results presented in the previous section. The empirical data were collected through a mail survey during 2017. The potential respondents in this study were obtained from a website: http://logistikausrbiji.rs. The final sample included 23 logistics companies that use social networks and 7 logistics companies that do not use social networks. According to the authors' research, 76,7% of surveyed logistics companies used social networks in 2017 compared to 63,3% of surveyed logistics companies in the same year according to the National Bureau of Statistics of Serbia. The identified difference between two studies can be explained by a lower number of potential respondents that are included in the survey analysis conducted by the authors. The sampling data were stratified by size and respondents' title (Table 3).

Table 3

The characteristics of the sampling firms and respondents (N = 30)

Category	Percentage
Number of employees	
10-49	43,3
50-249	36,7
> 250	20
Respondent title	
Non-IS managers	76,7
IS managers	23,3

Furthermore, we have examined the impact of two parameters on the intention of logistics companies in Serbia to use social networks (labelled as USN). The first parameter is the percentage of employees with a university degree (labelled as PoUD) and the second parameter is the number of computers per company (labelled as NoC). We used software Origin 2016 for the calculation and visualization of Pearson correlation coefficients between USN, PoCD and PoCD. The correction matrix is presented in Table 4. Only correlation between USN and PoCD is found to be statistically significant.

Table 4

Correlation matrix for likelihood of social network use in logistics companies

Parameters	PoUD	NoC	USN
PoUD	1		
p-value	-		
NoC	-0,073	1	
p-value	0,703	-	
USN	0,397*	0,168	1
p-value	0,030	0,376	-

*Note: * p-value < 0,05; ** p-value < 0,01 (two-tailed).*

The scatter matrix with confidence ellipse of 95% is presented in Figure 4. The presented results confirm that there is a positive correlation between USN and PoCD.

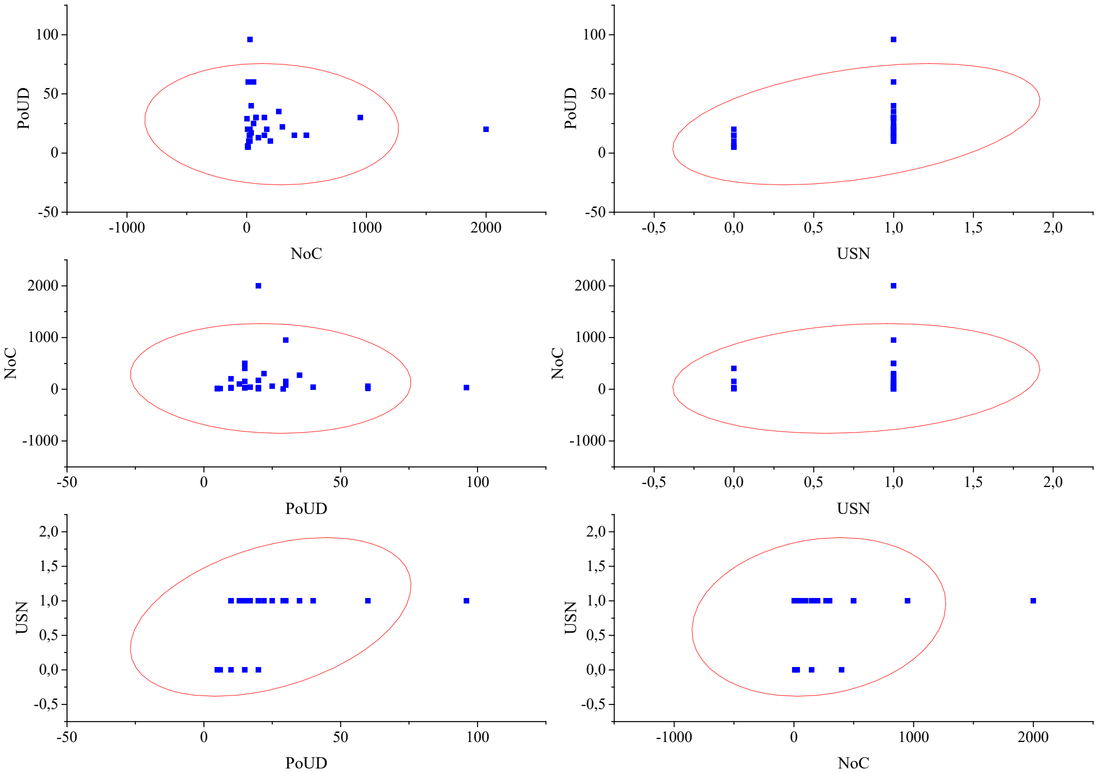


Fig.4.
Scatter matrix with confidence ellipse of 95% for likelihood of social network use in logistics companies

It can be noticed (Table 4 and Figure 4) that the percentage of employees with the university degree and the intention of logistics companies to use social networks have statistically significant and positive correlation (p-value < 0.05). It means that if a logistics company in Serbia has a higher percentage of employees with a university degree, the use of social networks in the company will be more likely. However, the number of computers per company and the intention to use social networks in logistics companies do not have statistically significant correlation (p-value > 0.05). Therefore, if the logistics company in Serbia invest money in the procurement of new computers that decision will not impact the intention of the company to use social networks.

6. Conclusion and Future Work

In this paper we performed an analysis of the use of social networks in logistics companies in Serbia. First we identified trends of the use of public and professional network services, multimedia sharing and online encyclopedia in (1) small, medium-sized and large logistics companies in Serbia and in (2) logistics companies in central Serbia, AP Vojvodina and Belgrade based on the data provided by the National Bureau of Statistics of Serbia. After that, we conducted a survey analysis to confirm the identified trend of the use of social networks in logistics companies in Serbia in 2017. The obtained result indicates that logistics companies in Serbia use extensively social networks in their businesses. One plausible explanation of the obtained finding is that the use of social networks in logistics companies may be triggered by the increased awareness of the significance of ICT development through numerous EU supported projects, strategies, initiatives and public programs in Serbia. A second plausible explanation is that the use of social networks is free and widely available to companies from different industries. Future research could examine the causalities of identified trends of the use of social networks in logistics companies in Serbia.

Furthermore, we have examined the impact of the percentage of employees with the university degree and the number of computers per company on the intention of logistics companies to use social networks. The obtained results indicate that the percentage of employees with the university degree and the intention of logistics companies in Serbia to use social networks are statistically significant and positively correlated. It is also found that the number of computers per company is not relevant parameter when logistics company in Serbia decides to use or not to use social networks.

In order to monitor further process of ICT development of logistics companies in Serbia similar research should be performed with the focus on some other technologies and information systems, such as radio-frequency identification technology, barcode technology, warehouse management system and transportation management system. The number of parameters whose impact on the intention of logistics companies to use social networks is examined should also be increased.

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CFD SIMULATION OF A PLANING HULL

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Abstract: The availability of the robust commercial Computational Fluid Dynamics (CFD hereafter) software and high speed computing has led to increased use of CFD for solution of fluid engineering problems across industry and boat building is no exception. In the recent years, fast composite planing hulls show an increasing interest in the scientific research field. An extensive range of both civil and military applications require precise data for loading forces acting on the hull surface and the shape of the wetted area. The current study presents a numerical simulation of the free surface flow around the hull of a composites power boat used on the Danube River for several speed values ranging between displacement and planing, including the transition period. A general numerical method to predict planing behavior of a boat is presented in the paper, using the NUMECA/FineMarine commercial code to compute the flow solution on a multiblock, high-performance parallel computing method. The RANSE VOF solver computation method is employed to evaluate the flow field in planing condition and to estimate the pressure field on the hull surface. The flow around planing hulls involves different and complex physical phenomena such as thin spray flow, wave breaking, air trapping and turbulent boundary layer. In this particular case, an inverted keel design was used in order to achieve a lower resistance of the hull due to the air entrapment in the semitunnel. The phenomena is captured well and detailed in the illustrations. In order to validate the results, the trim angle calculated by the CFD software is compared with the trim measurement conducted in full scale experiment.

Keywords: CFD, planing hulls, full scale experiment, validation, composites hull, river boat.

1. Introduction

The accelerated development of computing and the use of simplified numerical methods to solve the problems of fluid flow alongside a ship's hull create the premises for CFD methods to be a powerful verification tool in naval architecture. Whether it comes to leisure boats, commercial applications or naval operations, planning hulls show a constant interest since their early development in the end of the 18th century. The resistance of the hull is a problem solved by an analytical method in a pretty simple approach, with reasonably accurate results (Savitsky, 1969). The hull geometry particularities however present an important aspect in the matter of trim estimation and with that the prediction of the planing speed estimation might slightly differ, even when using the improved versions of the initial method (Savitsky et al, 2007). Recent CFD studies prove a proper evaluation of the trim and resistance estimation (Caramatescu, 2016)

On another approach, the dynamic pressure estimation and its distribution map on the wetted surface is a complex problem that cannot be solved in an analytical approach. Due to different phases involved, the free surface position is difficult to predict. Pressure distribution is the load a hull of the boat is subjected to, and usually that is roughly evaluated by the register rules or more recently by the ISO standards.

This paper presents the ability of the software to perform simulations of a complex hull form in preplaning conditions (Fr=0.57) to high speed full planing conditions (Fr=1.71).

2. Hull Geometry and Simulating Conditions

The craft that is the subject of this CFD simulation is a leisure composite craft, produced in Romania and used on the Danube river. A particular shape of the hull is used by the manufacturing company (Plasma SRL) in order to acheive a shallow draught - especially important in the Danube Delta. The hull presents an inverted keel on a width of 550 mm, forming a semitunnel with a depth of 50 mm. This section also seeks to reduce the frictional resistance at high speed by creating an air cushion therefore reducing the wetted surface.

The simulations are carried out for a range of hull speeds between 4 m/s corresponding to full displacement to 12 m/s when the boat is in full planing condition, declared as the maximum speed of the boat in the corresponding loading condition.

The main particulars of the craft are presented in Table 1; in Figure 1 there are presented the body lines of the hull, while in Figure 2 there is shown a rendering of the hull shape.

Table 1
Main particulars of the boat used in the CFD simulation

Length over all	5.65 m
Beam	1.78 m
Depth	0.70 m
Empty draft	0.27 m
Hull weight	220 kg
Max displacement	600 kg
Propulsion power	40 CP

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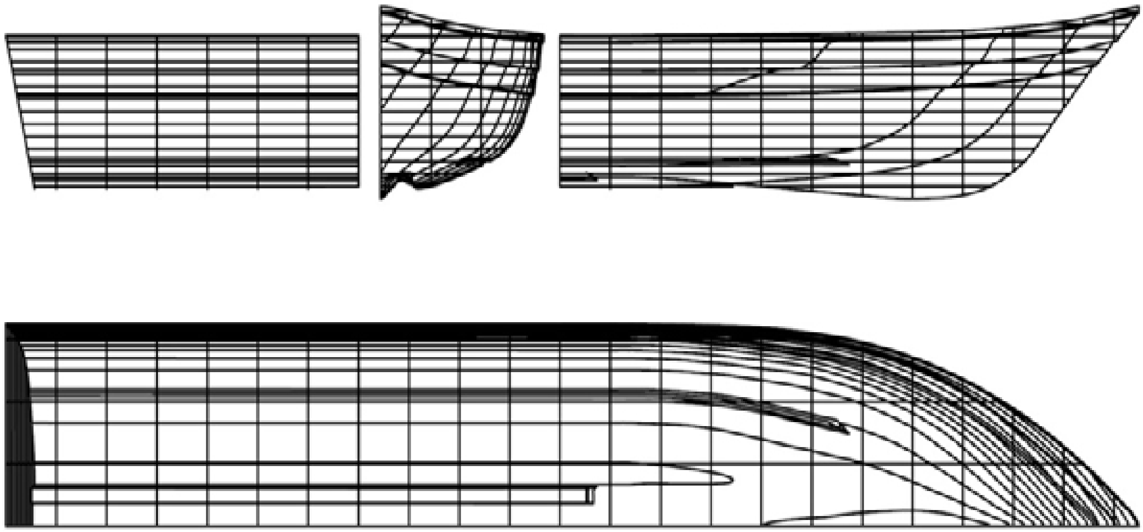


Fig. 1.
Lines plan of the boat used in the experimental research

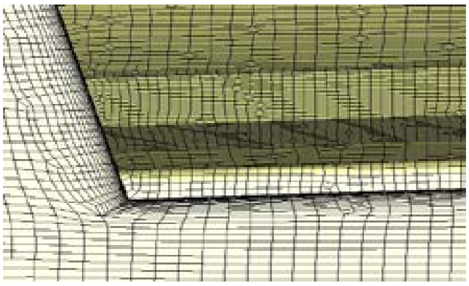
Fig. 2.
A 3D rendering of the CAD model used in the CFD simulation

3. CFD Simulations

The numerical code NUMECA FineMarine was used to perform the planing simulations. The solver uses RANSE VOF computation method to evaluate the final position of the hull for each simulation speed, having the trim and heave free while the other motions are blocked. To discretization of the hull surface was done using unstructured monobloc cartesian grid. The topology of the grid is H-H type, composed of adjacent hexahedral elements. Together with the computing field, an average of 2.5 million cells were generated for each of the travel speed values. The applicable boundary conditions are:

- constant velocity equal to the speed of the ship moving at entry into the computing field (upstream);
- sliding conditions at the exit of the computation field (downstream), as well as for the outer boundaries of the domain, on the free surface and in the symmetry plane;
- on the surface of the body is required the adhesion of the fluid to the wall (no slip).

Grid refinement is done by dividing the cells so that a greater density of cells is present in areas of interest such as the free surface in the contact area with the hull, spray rails, intersection of the transom with the bottom (Battistin *et al,* 2003). In Figure 3, there can be seen the refinement of the bow and stern area for the simulation ran at 8 m/s.
For the purpose of accurately modeling the turbulent layer and taking into account the available processing power, the value of the non dimensional wall function coefficient was chosen y+=5.



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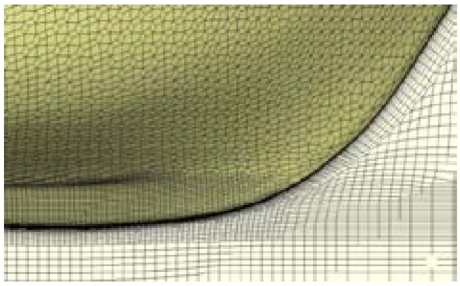

b). fore

Fig. 3.
Refinement by dividing cells in areas of interest for turbulent flow phenomena

3.1. Computational Strategy

A number of studies have addressed the issue of solving the numerical flow around a planing hull based on the theory of potential flow (Wackers *et al,* 2009), (Ghasemi *et al,* 2009) but in these cases the disadvantage is that these methods can be used only in simulations for very high velocities, and cannot reproduce the formation of waves and spray curtains that appear. The subsequent solutions that emerged were based on new approaches to large Froude numbers, characterized by multiple phases. In these situations, the components of viscous resistance and pressure resistance are non-linearly correlated with hydrodynamic lifting forces and trim angle (Battistin *et al,* 2003), (Yumin *et al,* 2012), (Azcueta, 2003). The calculation model used by simulation software used (Numeca FineMarine) is based on the Reynolds-Averaged Navier Stokes equations (RANS) for hydrodynamic performance estimation, the VOF method for estimating the free surface of an incompressible and non-miscible liquid with the second fluid (Caponnetto, M. 2001), (Queutey *et al.,* 2007) and the turbulence model k-omega.
The equations describing fluid flow alongside a body moving in this fluid are the continuity equation and the Navier-Stokes equations. These equations model the flow of fluids by viscosity, considering the fluid as Newtonian and the viscous forces being directly dependent on the velocity gradients. These equations together form a system of partial nonlinear equations. Considering water as an incompressible liquid with negligible density variations, the two equations can be written as:

$$\frac{\partial U_i}{\partial x_i} = 0$$

$$\rho\frac{\partial U_i}{\partial t} + \rho\frac{\partial\left(U_iU_j\right)}{\partial x_j} = \rho R_i + \frac{\partial \sigma_{ij}}{\partial x_j}$$

where U_i are the instantaneous components of fluid velocity in the cartesian coordinate system x_i, ρ is the density of the water, t is time and σ_{ij} is the tensor of total tensions. One of the most used turbulence models currently applied is the k-omega model, originally proposed by Wilcox in 1998 and then improved in 2008. In this turbulence model, two differential equations are used for two variables, k and ω, the first describing kinetic energy and the second specific rate of kinetic energy conversion into internal thermal energy. The formulation of the two variables are:

$$\frac{\partial k}{\partial t} + U_i\frac{\partial k}{\partial x_i} = \tau_{ij}\frac{\partial u_i}{\partial x_j} - b^*\kappa\omega + \frac{\partial}{\partial x_i}\left[(\nu + s^*\nu_T)\frac{\partial k}{\partial x_i}\right]$$

$$\frac{\partial \omega}{\partial t} + U_i\frac{\partial \omega}{\partial x_j} = a\frac{\omega}{k}\tau_{ij}\frac{\partial u_i}{\partial x_j} - b\omega^2 + \frac{\partial}{\partial x_j}\left[(\nu + s\nu_T)\frac{\partial \omega}{\partial x_i}\right]$$

To define the free surface demarcation area, a numerical method called Volume Volume Fluid (VOF) is used. In the sense of this method, based on a fractional volume function α the fluid density and viscosity are modified as follows:

$$\mu = \mu_{water} + \mu_{air}(1-\alpha)$$
$$\rho = \rho_{water} + \rho_{air}(1-\alpha),$$

where μ_{water} and μ_{air} are the dynamic viscosity of water and air and ρ_{water} şi ρ_{air} are the densities of water, respectively air. The position of the free surface of the liquid is governed by the volumetric fraction transport equation, and this is solved for each discreet volume cells in the calculation range:

$$\frac{\partial \alpha}{\partial t} + \nabla(\alpha U) = 0,$$

where $0 \le \alpha \le 1$, U is the speed of the flow and ∇ is the cell's volume.
Solving the equation we can obtain 3 results:

$\alpha = 0$	if the cell si full of air;
$\alpha = 1$	if the cell is full of water;
$0 < \alpha < 1$	if the cell contains free surface.

4. Results and Discussions

Pressure distribution calculated on the wetted surface is represented graphically in the series of pictures shown in Figure 4.

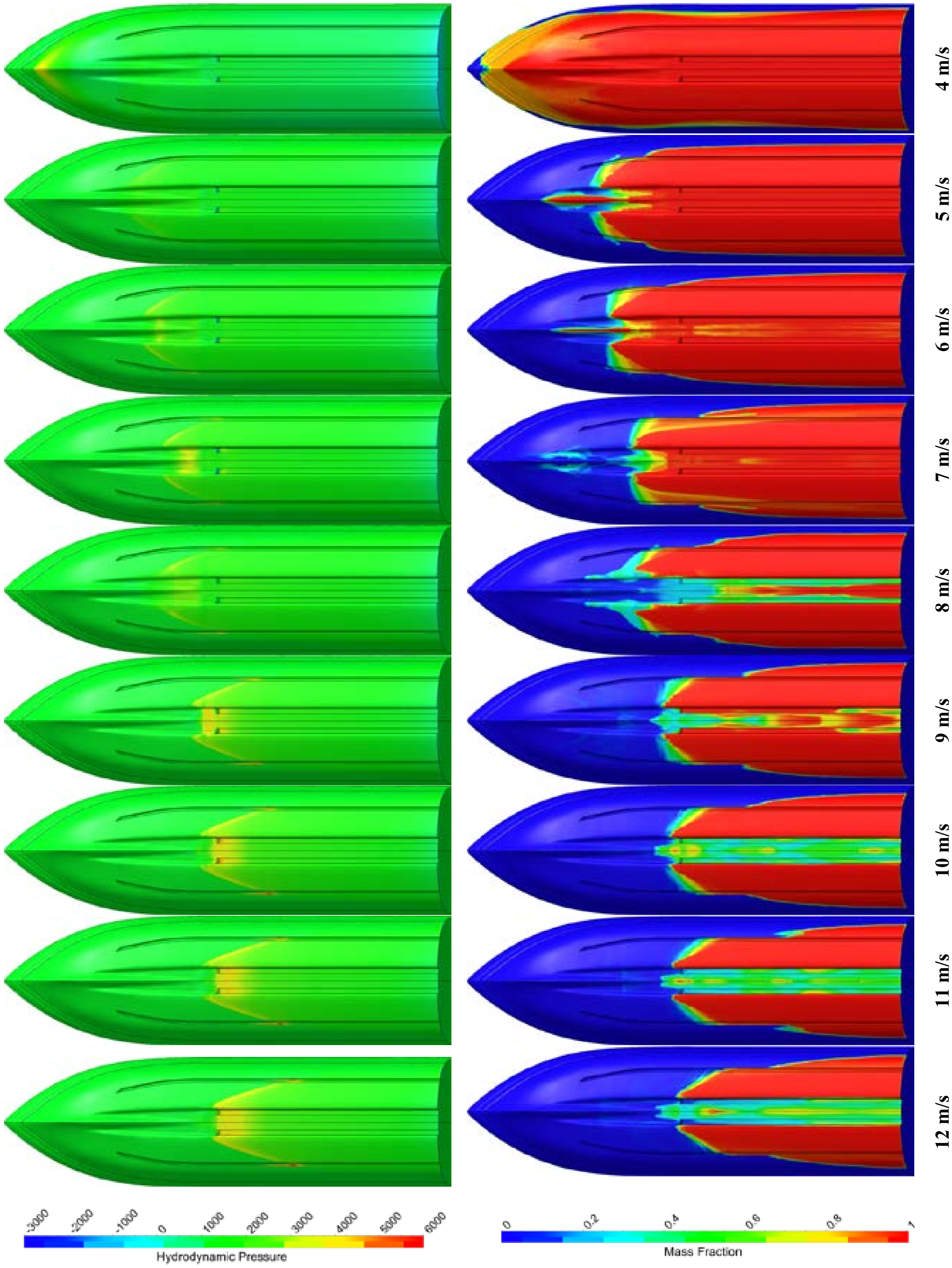

Fig. 4.
Pressure distribution (N/m^2) as well as volume fraction for each speed

As it can be observed, the largest pressure gradient is recorded at the stagnation point, at the entry of the hull into the water. This large pressure area is also properly predicted by the register rules as well as the ISO standards. Numerical results of the pressure calculated in each of the hull surface cells can be extracted and transferred to a FEM software via a polynomial interpolation.
As from the air entrapment point of view, the hull design creates the expected air cusion in the semitunnel, delivering the frictional resistance reduction. Mass fraction maps show the initial formation of the air vortices at 8 m/s, while at 10 m/s the entire bottom of the boat within the semitunnel is separated from the water surface. A different rendering with the same phenomenon can be seen in Figure 5 below:

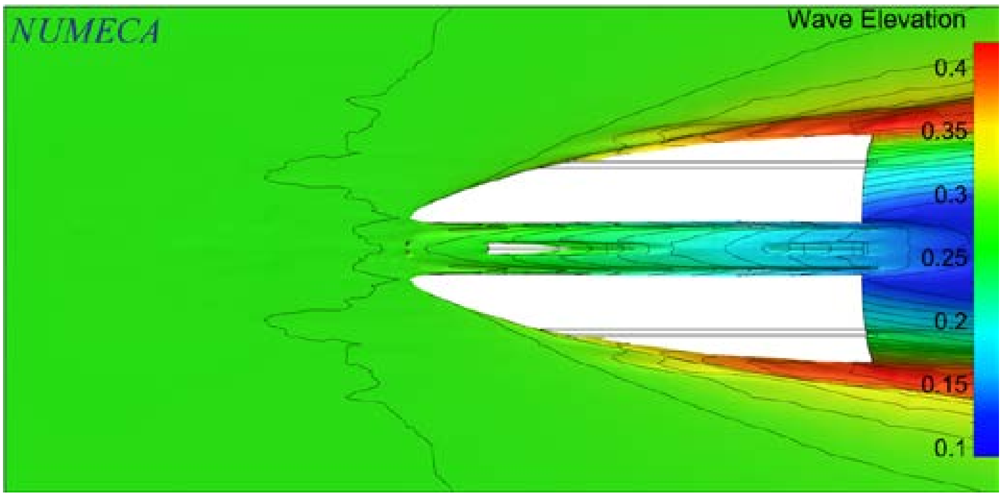

Fig. 5.
Bottom view of the hull showing the free surface depth isocurves. Wetted hull is represented in white for better contrast

5. Experimental Validation

Trim angle measurements have been conducted for each of the hull speed values considered in this simulation, using a full scale boat, equipped with an inclinometer, model Turck B2N45H-Q20L60-2LI2-H1151, connected to a measurement bridge Spider 8. The trials have been conducted in calm water, so as not to viciate the results with the effect of the encountered waves. Afew aspects of the trials are represented in Figure 6 below.

Fig. 6.
Experimental trials conducted with full scale model. The installation of the inclinometer in the bilge (middle) and the electronic circuit built for the data acquisition (right)

Trim angle measurements recorded during the trials have been compared with the Savitsky (1964) estimation and the CFD calculations, showing a reasonable error between the CFD and experiment, while Savitsky method shigtly underpredicts the trim for the low speed values and overpredicts the trim angle for the range of speeds comprised between 5 to 10 m/s. The reason of errors for the low speed values is due to inaccurate results of the method for non planning speed values, while the overprediction errors are due to the geometry particularities not accounted for by this simplified method, as the semitunnel.

Table 2
Computed trim and experimental data

v (m/s)	θ_{EFD} (°)	θ_{CFD} (°)	$\theta_{Savitsky}$ (°)
4	3,12	3,21	2,54
5	4,26	4,29	4,35
6	4,23	4,20	4,72
7	4,14	4,16	4,71

8	4,04	4,05	4,41
10	3,59	3,61	3,57
11	3,20	3,25	3,18
12	2,99	3,03	2,83

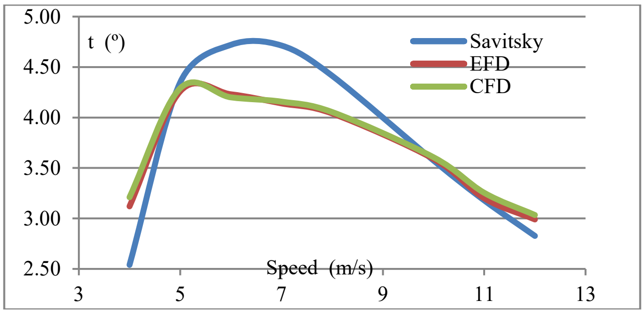

Fig. 7.
Trim variation

6. Conclusions

As the numerical simuations seem to be a tool with an increased usage in the field of naval architecture, complex geometries can be studied in the stage of early design, allowing the engineers to perform detailed analyses of flow fields around a planing hull. Full scale experimental data provides a valuable pool of benchmark values with wich the numerical simulations can be compared and properly adjusted. While the variety of the software solutions used for this urpose increases, a numerical valdation must be conducted each time this is possible.
The comparative evaluation of the values of the trim angle of the experiment and of the CFD analysis shows a good correlation, with variations between 0.3 and 2.8 percent, with a good tracking of the experimental values. The Savitsky method evaluates the angle of trim using an empirical and rapid calculation but has an error rate between 0.4 and 22.8 percent from the experimental values. The overall trend of the variation of trim angle is the same, increasing during the transition period and at the beginning of the planing, then stabilizing and decreasing as the speed increases. At the estimated start of planing, at 5 m/s, the values calculated for the trim are very close, which means that the planing start point is very well estimated by the Savitsky method.

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USE OF GIS TECHNOLOGY TO SUPPORT THE NAVIGATION ON THE DANUBE RIVER

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Abstract: Natural mineral aggregates transported by the Danube River are generated by the natural disintegration of the rocks under the action of frost and repeated thawing and their rollover to torrential waters, streams and the rivers, which are used in the manufacture of concrete (ballast, gravel, and sand). The target area of this study is located on the Danube River between Km 521–Km 524. In this sector, it takes place the exploitation of mineral aggregates. From this perspective, a study will be conducted through which it will be seen whether those operations interfere with the navigation on the Danube River. The study is performed using GIS applications and assessing the influence of the dredging executed in this perimeter on the movement of the ships and boats on the river. On the other hand, it has to be highlighted that at different times of the year, on the Danube different sand islands of various sizes are formed, making very difficult the navigation of the ships. Their shape and dimensions are constantly changing, under the influence of the water level changes, the speed of the water flow and the waves caused by the crafts passing on the Danube. From this perspective, the present work follows the way in which these aggregate exploits influence the appearance of the sand islands along the Danube, appearance which is very dangerous for the inland navigation. The study is based on 'in situ' measurements performed in two different recent time periods, namely during the autumn of 2016 and continuing later in the summer of the following year, 2017. The results are obtained by processing the data using the GIS methods and representing a comprehensive picture of the sector analyzed in different viewing modes. All these aspects present a special interest for a safer navigation on the Danube River.

Keywords: inland navigation, Danube River, exploitation, measurements, GIS.

1. Introduction

In Romania, the Danube River forms the southern border of the country with Bulgaria. Approximately 38% of the length of the river and the most important part as flow and navigation, including its mouths, are located in the Romanian territory. The lower course of the Danube runs at a distance of 1,075 km between Bazias and Sulina, making a border with Serbia 235, 5 km, Bulgaria 469, 5 km, Republic of Moldova 0, 6 km and Ukraine 53, 9 km. Because the Danube crosses a multitude of natural regions, the lower course is divided into 5 sectors, as follows: Carpathian Defile 144 km, South-Pontic Sector 566 km, Pontic Oriental Pond Sector 195 km, Predobrogean Sector 80 km and the Deltaic Sector 90 km (Banescu *et al.*, 2018).
The Danube River collects most rivers in Romania except those in Dobrogea, which flow into the Black Sea.
In the evolution of the hydrographical network of the territory of the lower basin of the Danube, two stages can be distinguished: the pre-quaternary stage, when the relief has been consolidated and the main water accumulations have formed; the quaternary stage when the current hydrographic network developed on the old terraces took place. At this time, the lower course of the Danube stretches between the upstream Bazias and the Black Sea, draining the waters from the Carpathians and the Balkans, extending over a length of 1075 km (Ivan *et al.*, 2012).
The main Danube course on this sector is located at the beginning west, northwest, east, southeast, to the front of Calafat, where it acquires the west-east orientation that is maintained until Zimnicea. Between the localities of Zimnicea (where the Danube reaches the southernmost point, 43^0 37 'north latitude and 25^0 25' east longitude) and Silistra, the Danube course is oriented southwest and northwest. Downstream of Silistra, Dobrogea hills oblige the Danube to change its orientation from the east to the north, describing a very large curve. This orientation is maintained up to the city of Galati, where, due to the resistance opposite Dobrogea's old mountains, the course of the Danube turns abruptly to the east, thus maintaining its shedding into the Black Sea (Vlasceanu *et al.*, 2015).
As far as the hydrographical basin is concerned, it is asymmetric, being more developed on the left side; this characteristic is also observed in the morphological aspect of the riverbed, with the right bank being higher, with a general appearance of hilly plateau which rises locally by 200 m. The left bank presents itself as a wide plain. If we are talking about the Danube tributaries in this sector, they are bigger on the left, on the territory of Romania (Jiu, Olt, Arges) and smaller on the territory of Serbia and Bulgaria, although more in number (Timok, Ogosta, Iskar, Vit, Osam, Iantra, Lom). It includes the most beautiful and longest defile from Europe - the Iron Gates (144 km), a subsector with obvious asymmetry (Drobeta Turnu Severin - Calarasi, 566 km) (Murariu *et al.*, 2013).
A quite characteristic subsector is that of the valleys between Călăraşi and Braila, where the Danube spreads in several arms, encompassing among them the meadow itself called Balta Ialomiţei (or Borcea), bounded by the arms of Dunarea Veche and Borcea and Balta (Vâciu, Mănuşoaia, Cremenea, Pasca, Caila, Arapu), forming smaller islands in the west and Măcin Arm (Old Danube) in the east. In this subsector, the Danube collects smaller tributaries - Ialomita and Calmatui on the left, after which, in the last subsector, the Danube receives, as larger tributaries, Siret and Prut.
From Ceatal Izmail, there is the Deltaic sub-sector of the Danube, between Chilia (117 km), Tulcea (19 km) and Sfântu Gheorghe (109 km after the meander correction 77 km in the south) and which sums up 2540 km^2 (on the territory of Romania), and in the middle of the delta the Sulina arm, which after correction, is 63 km long. This continuously developing territorial geographic unit as a result of the action of the river through those 6473 m^3 / s of water and 58

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million tonnes per year of alluvial on the one hand and the action of the waves on the shore on the other hand has constituted and constituted a thesaurus for the fauna and the folklore unique in Europe (Ivan et *al.*, 2012).

From the point of view of the water resource, the Danube River, which has an average stock at the entrance to the country of 174 billion cubic meters per year, could be the richest source of water. Its international character imposes certain limitations on the use of its waters and for this reason is considered only half of the average multiannual volume drained on the Danube in the Baziaş section, ie approx. 87 billion m^3. The ratio between minimum and maximum flows varies between 1/5 and 1/8. The water transport is an important branch being provided by the most important navigable waterway in Romania. The main river ports in the Romanian part of this sector are: Orsova, Drobeta-Turnu Severin, Calafat, Corabia, Turnu Magurele, Zimnicea, Giurgiu, Oltenita, Calarasi and Cernavoda. Fluvial-maritime ports - Galati, Braila, Tulcea. These are traditional harbours, situated at the intersection of the two types of waterways, sea and river. Two hydro technical facilities are in operation on the Romanian Danube sector: Iron Gates I and Iron Gates II, both for hydroelectric power generation and for ease of navigation (Gasparotti, *et al.*, 2012).

2. The Flow on the Danube

The average multi-annual flow rate of the Danube is not constant, depending on the length of the time period considered. Thus, in 1967, the average annual flow rate at the Orşova hydrometric station was 5420 m^3/s for a calculation interval of 122 years and 5390 m^3/s, if the calculation interval was 41 years (1921-1962). Further studies give different values for multiannual average flows. Thus, Table 1 and Table 2 show the multi-year average/maximum flow rates for different ranges (Banescu *et al.*, 2018).

Table 1
Multi-Annual Average Flows

Hydrometric station	Multi-annual average flows
Bazias (interval 1931-2011)	**5**590
Tr. Magurele (interval 1931-2010)	6040
Giurgiu (interval 1931-2010)	**6060**
Calarasi – Br. Borcea (sir date 1932-2003;), SH Calarasi (2001-2007) SH Unirea 2003-2006	560
Galati	6310

Source: Report– Preliminary Flood Risk Assessment Danube Hydrographic Basin

Table 2
Maximum Flows

Hydrometric station	Multi-annual average flows
Bazias (year 2006)	15800
Tr. Magurele (year2006)	16400
Giurgiu (year 2006)	**16300**
Calarasi – Br. Borcea (year 2006), SH Calarasi (2001-2007) SH Unirea 2003-2006	2290 1790
Galati (year 2010)	16480

Source: Report– Preliminary Flood Risk Assessment Danube Hydrographic Basin

Generally, in the course of one year, the minimum drain on the Danube is recorded at the beginning of spring, on classes of debit values and the lowest flow rates occur in the winters with very low temperatures, when influenced by the evolution of ice formations. Between 1965 and 2012, on the Danube there were recorded floods with maximum flows of more than 10,000 m^3/s, in 24 years maximum annual flash-floods that are on classes of debit valuess: maximum flows between 10000 m^3/s and 13000 m^3/s in 20 years; maximum flows between 13000 m^3/s and 15000 m^3/s in 3 years; maximum flows higher than 15,000 m^3/ s, in a year. Typically, the maximum flow rates on the Danube occur in the spring-summer period, the peaks occurring more frequently in April and May. However, there are some exceptions when flood waves occur either in December and January or late summer in August-September. As maximum flow rates, however, those that occur during the spring-summer period, which are actually considered as big waters on the Danube, stand out (Rusu *et al.*, 2014).

3. Arrangements to Ensure Navigation Conditions

The first engineering works on the Danube were initiated between 1834 and 1837 and consisted of river settlement works in order to improve the navigation conditions at the Danube exit in to the defile.

As for the works that took place on the Sulina arm, they consisted in the construction of two dams located at a distance of 180 m between them.
At the inauguration of the works (3 September 1861), the northern dike was 1412 m long and the southern dike 1212 m. The depth at the bar was 17 feet and a half (5.33 m), that is, the double depth at the beginning of the works with 2 feet longer than the one designed. This first success resulted in the transformation of the works initially conceived as temporary works in permanent works. There followed (1858-1902) works for the rectification of the Sulina branch by cutting the meanders, deepening and calibrating its cross section.
The route was shortened by 21.2 km (from 83.8 km to 62.6 km). Correction of the route did not raise special problems except in terms of landfill volumes (about 25 million m3). Instead, the consequences were completely unforeseen. The liquid flows transported on the Sulina branch, due to the shortening, doubled, the contribution of this arm increasing from 7% to 16% of the total flow of the Danube.
It is obvious that the same proportions also increased the solid flows, which led to difficulties in maintaining the depths at the mouth of the spill. It is interesting to note that due to the favourable situation of the depths, the dredging works on the Sulina arm and its mouth began only in 1894 (Gasparotti *et al.*,2016).
Difficulties are not delayed due to the growth of the south bank and the sanding of the Mosura bay due to the considerable contribution of alluviums of the Starâi-Stambul arm from the secondary delta of Chilia, the natural depths at the bar have decreased in recent years in a worrying proportion.
As a result, the volumes of works increase considerably.
The length of the dykes reached almost 8 km in 1973 and the volume dragged almost 50 million cubic meters. In order to improve navigation conditions on the Romanian Danube sector, after 1900 many works were carried out, but more local and smaller (Iticescu *et al.*,2013).
The hydrological regime, fuelled by rain and snow, made it possible to navigate the Danube throughout the year, and the environmental conditions and food resources offered facilitated the development of human settlements. Many river ports were created, true gates to the European world, where a large number of travellers, tourists and large quantities of goods circulate.
Among the well-known Romanian ports are Orsova, Turnu Severin, Giurgiu, Turnu Magurele, and Oltenita. The ports of Braila, Galati, Tulcea and Sulina are classified as river - sea ports. There are four river ports on the Danube-Black Sea and White-Gate - Midia-Năvodari waterways (Ivan *et al.*, 2009).

4. Exploitation of Mineral Aggregates on the Danube

The extraction activity of the mineral aggregates on the Danube, the left bank is made for subsequent sorting and use in various construction activities. This activity, even if controlled, can induce changes in the flow regime such as changes in flow rates, changes in the transport regime of the Danube alluviums which may lead to the appearance of sand beams at different times of the year, thus making difficult to navigate the ships. At low levels of the Danube, the ballast extraction - Figure 1 has somewhat influenced the occurrence of sand islands in the area of exploitation.
The sand formations are transported by the Danube and are deposited in favourable areas along the river. This may make the transport regime on the Danube uncomfortable, especially in the period when the river's share is low (Vlasceanu *et al.*, 2015).

Fig. 1.
The Exploitation Of Mineral Aggregates Using the Digging Machine

The study was conducted over a period of 2 years, starting in the autumn of 2016 and ending in the summer of 2017. During this period, 2 measurements were made on the Danube between 521 km and 524 km. In the respective perimeter, exoplanets took place only in 2016. The study consisted in the performance of topo-hydrographic

measurements on the Danube, namely: topobatimetric measurements, flow and speed measurements. The results of these measurements can be seen in Figure 3, Figure 4, Figure 7, and Figure 8.
The measurements on the Danube were made using a multi-beam multi-beam sonar, equipped with a high-performance GPS system that records real-time water depth, depth water velocity, the flow on section and position x and y. The data processing was done using specialized GIS (Geographic Information System) programs. Various cartographic materials (topographic maps, orthophotoplanes) have been used to generate 3D models. These materials were processed in GIS software (ArcMap and Global Mapper) to select the study area and bring it to the suitable reference system (Stereo 70) with the Black Sea 75 reference system (Arseni *et al.*, 2017) (Basarab et al., 2006).
The anthropic impact of the analysed area after the implementation period of the exploitation activity is manifested by the appearance of a sand land with a significant surface, reducing the surface of the water glistening on the Danube. This may affect the flow regime and, implicitly, ship transport on that area (Rusu *et al.*,2014).
The objectives of this study are to present the effects of mineral aggregate extraction activities on the Danube km 521 - km 524 left bank – Figure 2, in order to create an image of the impact that sand land could have on the movement of vessels on the river, both for ships that run from downstream to upstream and for those running from the opposite direction.

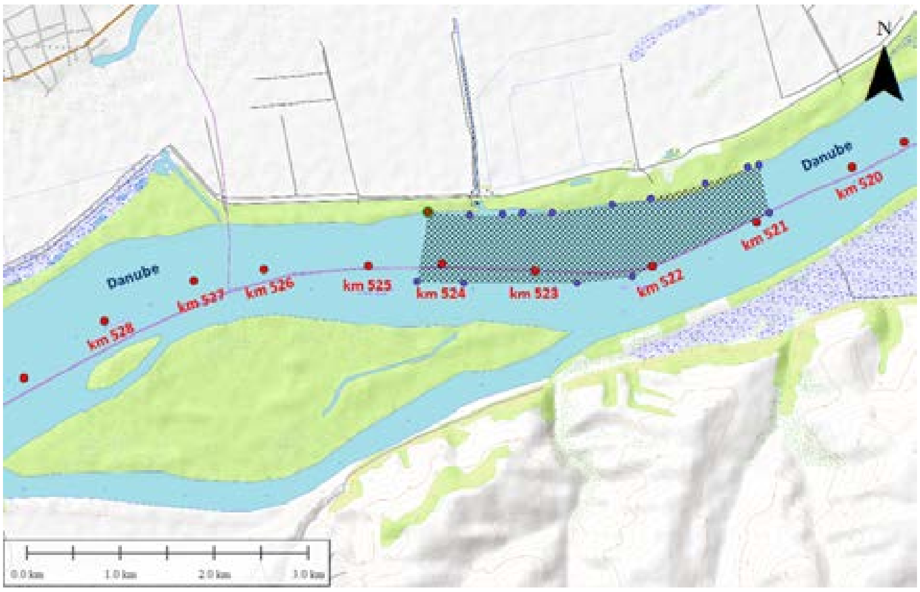

Fig. 2.
Perimeter of the Analyzed Area - Danube km 521-km 524 Left Bank

Measurements were made by over lighting with the multi-beam sonar in the analysed area following a classical procedure, namely data collection on the longitudinal axis (longitudinal profiles along the proposed length of km 521-km 524) and data collection across the cross-section (cross sectional profiles from 50 to 50 of meters).
The GIS methods used have contributed to the generation of digital maps where we can easily observe the 3D model of the Danube bed in the perimeter under consideration and the areas where the excavations were made. The breakdown of these results is presented in Figure 3 and Figure 7. Following the data processing, a cross section (section 1) was generated in the first phase on the model created in 2016 and in the second phase on the model created in 2017 in the same place respecting the same coordinates - Figure 4 and Figure 8.

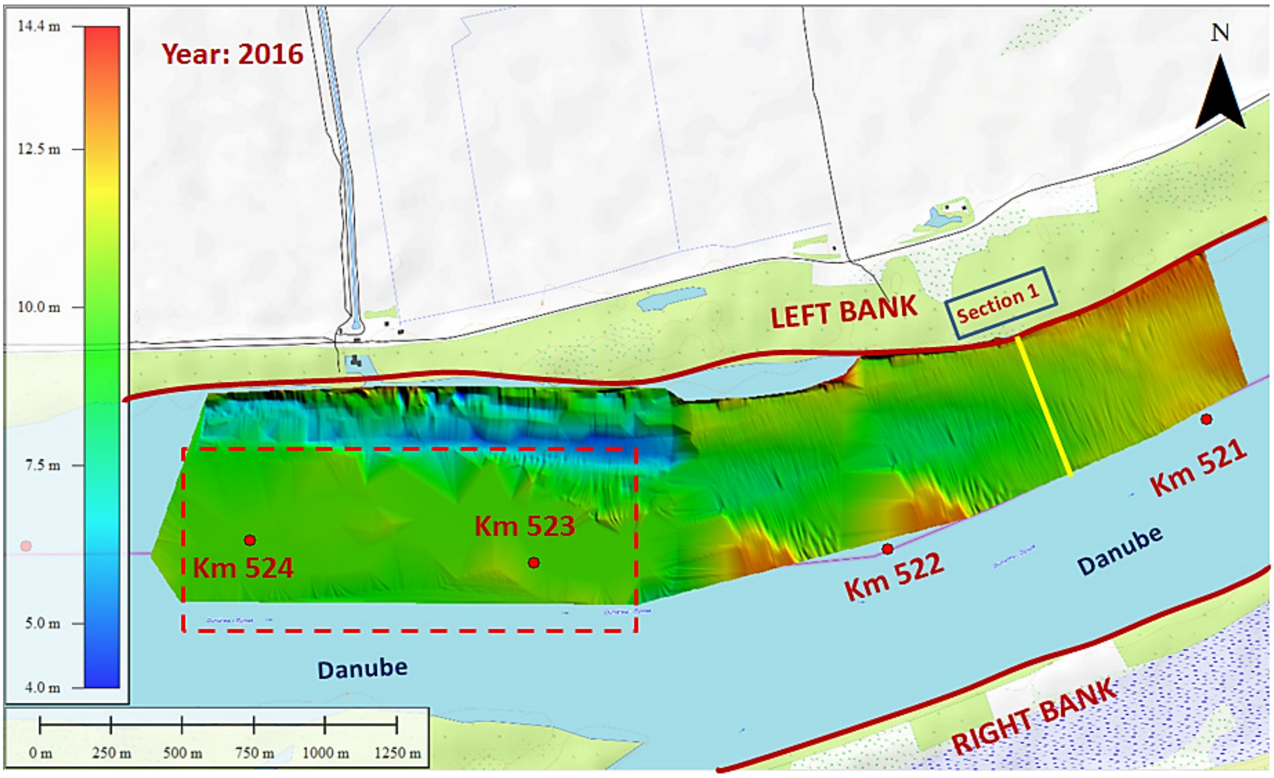

Fig. 3.
The 3D Model Made Using GIS Methods - Measurements in 2016

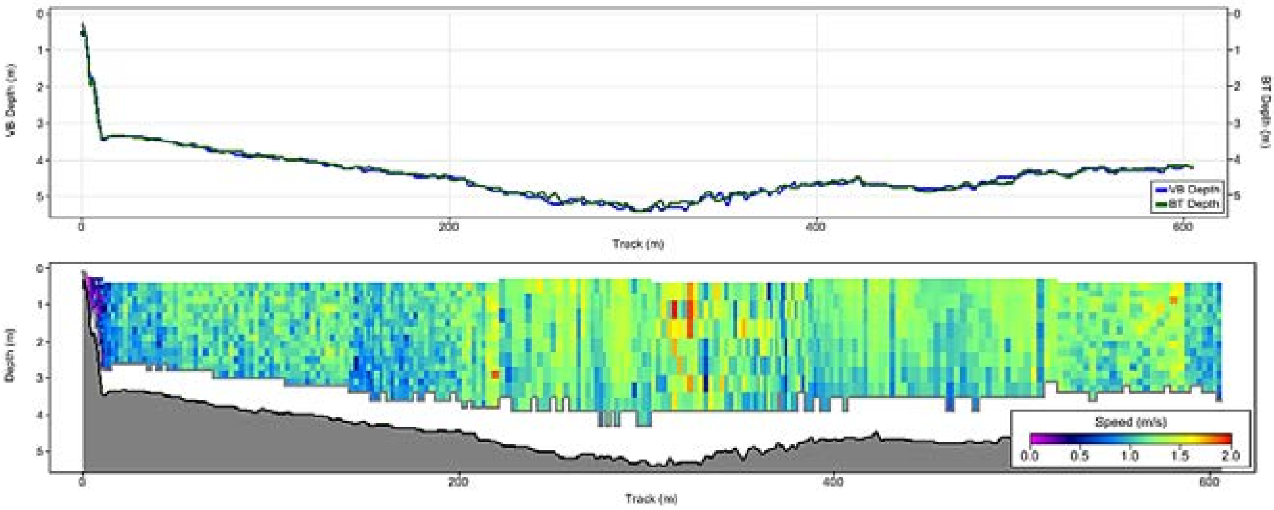

Fig. 4.
Cross-Section on 3D Model (Year 2016)

The mid-section method involves making a series of velocity and depth measurements at a specific number of locations (more commonly known as stations, panels or verticals) across a river cross-section. At each station, the depth and mean velocity profile are measured. The depth is computed using either the 4-velocity beams, the low-frequency vertical beam, or manu-ally measured (using a rod or other device) and entered into the software. The mean velocity profile for each station is computed from data from all valid cells above the riverbed (Figure 5). The width of a single station is determined to be the sum of half the distance to the previous station and half the distance to the following station. This method assumes that the velocity profile at each station represents the mean velocity for the entire rectangular station area.

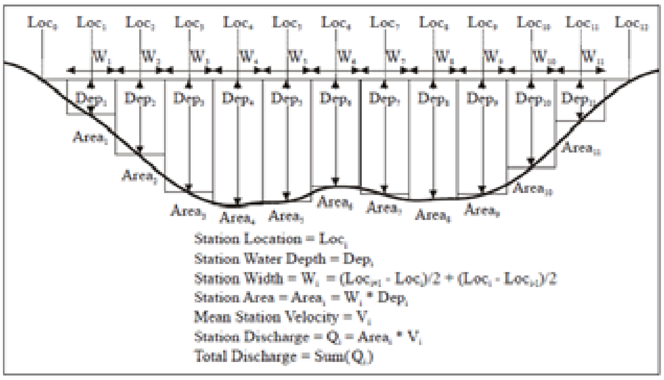

Fig. 5.
Cross Section Details

Each station is measured for a significant time to remove any environmental and temporal variation in the water velocities. Typically within the operation, the recommended duration of measure-mint for a single station is 40 seconds. However, in particularly turbulent waters, extremely low-velocities, or in areas or rapidly changing water-level, a longer period may be required.
The basic procedure for making a discharge measurement using the Stationary- Measurement system is as follows:

1). Setting up the Location:
- a measurement section is selected based on the criteria
- a graduated tag line is strung across the river. In an ideal measurement site, the flow should be perpendicular to the tag line at all points with no flow reversals or obstructions
- the spacing of the stations along the tagline is se-elected so as to provide about 20-30 stations. Each of these stations should also be positioned so that no station is expected to yield more than 10 % of the to-tall discharge. Ideally, no station should have more than 5% of the total discharge. This generally means that the stations are not equally spaced but are instead spaced closely together in deeper and high velocity areas and further apart in shallower and slower flowing are-as.
- the magnetic-north heading (azimuth) of the tagline is measured. This is the compass orientation of the tagline in the direction of the right river bank. Setting the tagline azimuth is important because it allows the device to rotate freely around the sample location and still measure the correct mean-station velocity by using its internal compass to resolve the true direction of velocity and then calculate the normal velocity to the tagline.

2). Setting up the Software:
- Connects to the software
- The information is entered into the system. This information includes the site name, number, location, starting bank, gauge heights, azimuth, velocity-reference meth-od, depth reference method

3). Making the measurements:
It's starts at a margin (the start bank), recording the starting-edge location, water depth and gauge heights.
- The procedure is forwarded to the first station and enters the station location, transducer depth, and gauge heights. If ice is present, the values for the ice thick-ness, depth of water and slush thickness should also be entered
- The positioning is done with the transducers submerged and the system as vertical as possible. Ideally the system will be mounted to a platform, vessel, or mounting structure.
- Thus, data collection is performed and is measured the 3D current velocities and bottom depth throughout the water column
- Only the component of water velocity perpendicular to the transect line (or azimuth) is used to ensure proper discharge calculations, regardless of the flow direction. This nor-mal component of the velocity is known as the ―Normal Velocity

Basically, the total discharge is the amount of water flow (or net flux) through a section and is computed from the mean water velocity and the cross-sectional area of the measurement section. A single moving boat measurement of discharge can be broken into three key components: the Start Edge, the Transect and the End Edge. These components are shown in Figure 6 below:

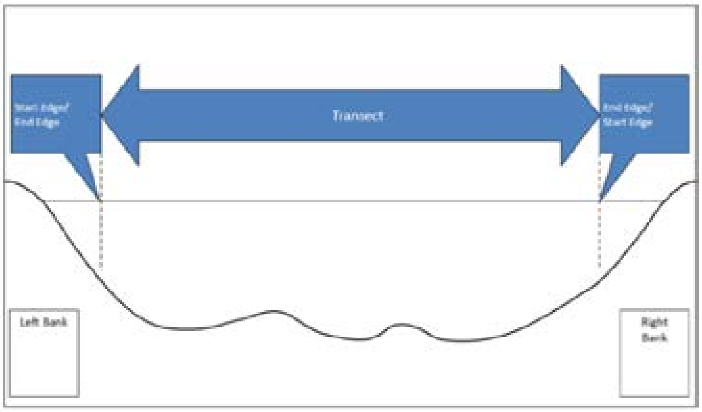

Fig. 6.
Steps for Making a Measurement

Each profile displays dates about the length of the section (track in meters from 0 to 600 meters), depth of water (depth in meters from 0 to 5 meters), water speed on depth (m/s at speeds of 0 m/s - 2 m/s). If we compare the two profiles we can observe that the appearance of sand in the studied perimeter does not greatly influence the speed of the water on the depths, the values of 2017 are slightly higher than those of 2016. Danube level compared to the Black Sea reference system 75 (rMN75) was approximately the same at the time the measurements were made. The difference between the two odds is only 60 cm. In the autumn of 2016, the Danube's share of the measurements was 14.45 m rMN75, and in the summer of 2017 the Danube's share reached 15.05 m rMN75.

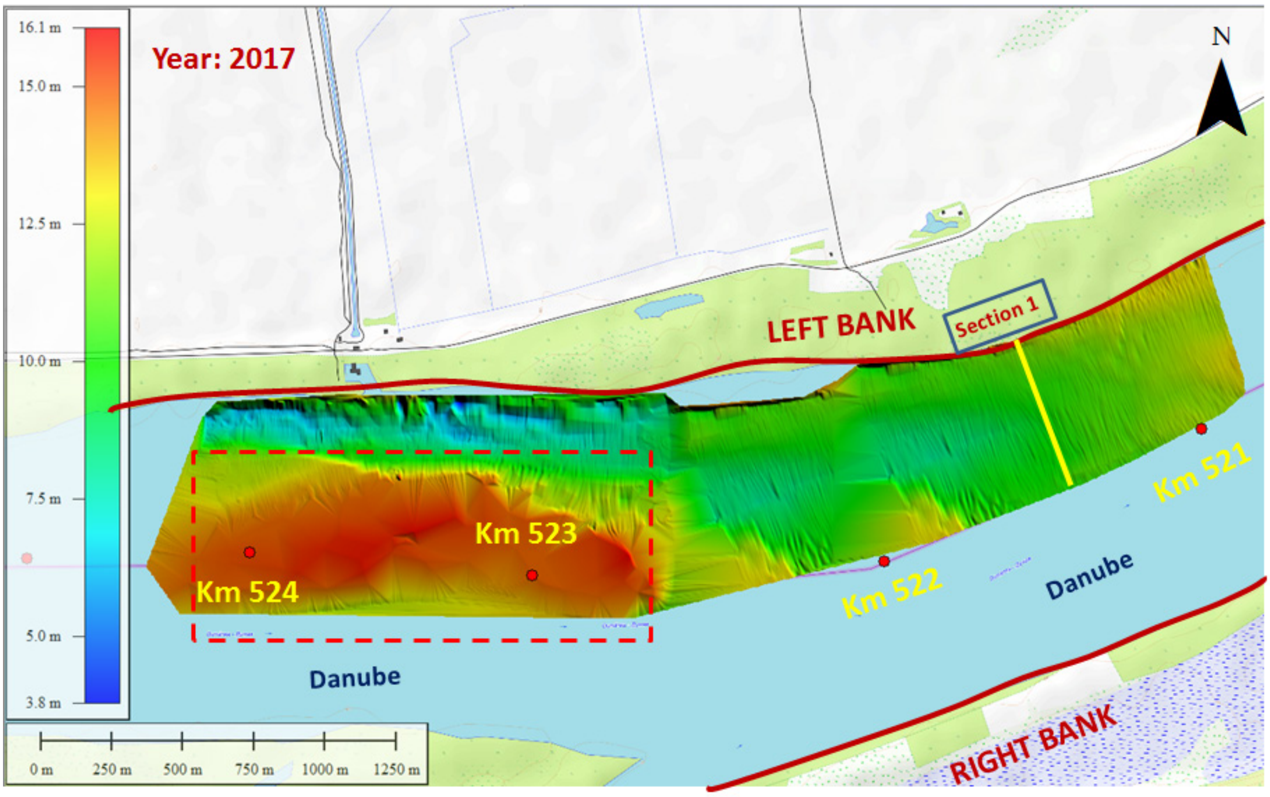

Fig. 7.
The 3D Model Made Using GIS Methods - Measurements in 2017

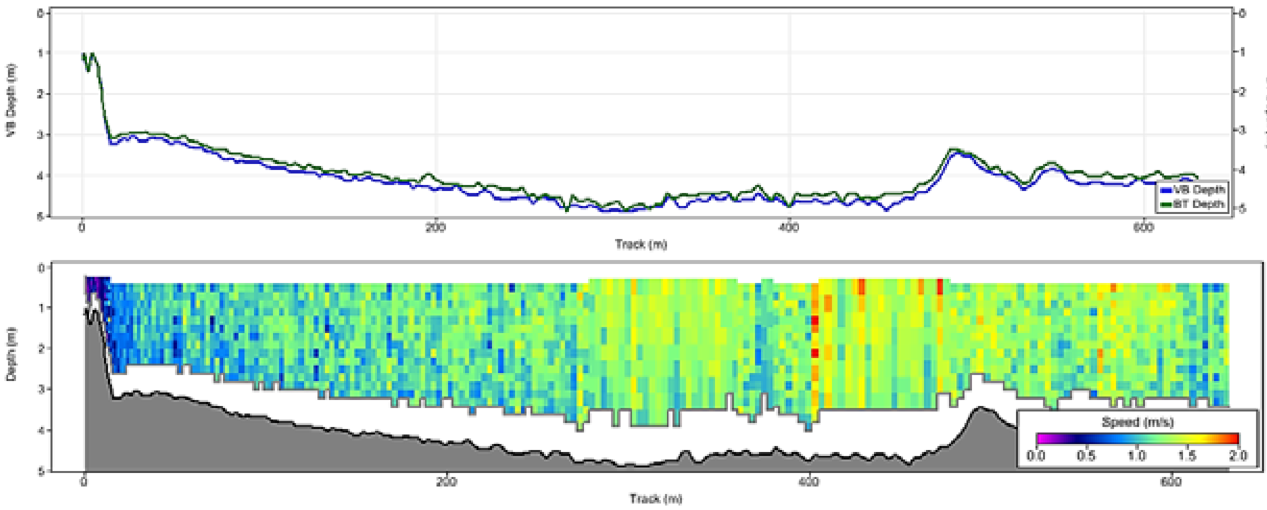

Fig. 8.
Cross-Section on 3D Model (Year 2017)

The water level regime is of particular interest to navigation, because knowing the water levels recorded on the river can determine depths on the navigable channel, the thresholds, the navigable axis of the navigable system and the navigable gauge (Rusu, 2010).
Water levels across different Danube sectors vary depending on hydro meteorological conditions, surface slope, bottom relief, ice and wind regime, regularization works, aggregate exploitation works, etc.
Sand lands on the Danube are formed on the basis of solid particles crossing a section of the river during a time unit called alluvial flow and expressed in units of weight per second. The alluvium flow is composed of suspended particles and pushed particles on the bottom of the bed. The bottom particles are continuously affected by the current speed that pulls them from the bottom of the bed to push them (Rusu *et al.*, 2014).
The particles on the bottom of the bed move on the bottom of the bed or remain suspended in the water. On the upper course of the Danube, alluviums are generally made of coarse sand. As it approaches the confluence, the suspended particles become, in large part, bottom alluviums (Gasparotti *et al.*, 2013).
The presence of sand lands on the Danube is considered in navigation, zone of difficulty. Areas of difficulty are portions of the sailing line where, due to the reduction in water scarcity or due to particular hydrological conditions, navigation of vessels and, in particular, convoys cannot take place under normal conditions, requiring specific measures and restrictions for the safety of navigation through these sectors (Vlasceanu *et al.*, 2015) (Murariu *et al.,* 2009).

5. Conclusions

The works carried out on the exploitation of natural aggregates in river beds can induce states of imbalances, so they must be carefully monitored, analysed, and approved by competent administrations in this area.
It should be underlined that different islands of different sizes are formed along the Danube at different times of the year, which makes them very difficult for the river navigation. Their shape and dimensions are constantly changing under the influence of the water level changes, water flow rates and aggregate exploitations.
From this perspective, the present paper follows how these aggregate exploits influence the appearance of the sand islands along the Danube. The study is based on "in situ" measurements carried out in two different time periods, ie in the autumn of 2016 and continuing later in the following summer, 2017. The measurements were based on a multi-beam mille beam sonar that recorded over time real water depth, water flow rate and flow, and the position of the measured points x and y.
The results were obtained by processing data using GIS methods and representing a comprehensive picture of the analysed sector in different viewing modes.
The GIS methods used have contributed to the generation of digital maps, where we can easily see the 3D model of the Danube bed in the perimeter of exploitation. Various cartographic materials (topographic maps and orthophotomaps) in general were used to create 3D models to select the area of study and to bring it to the appropriate reference system.
All these aspects are of particular interest for safer navigation on the Danube for both large ships and small craft.

Acknowledgement

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QUANTIFYING THE EFFECT OF THE SHIP VIBRATION ON CREW FOR THE INLAND NAVIGATION- CASE STUDY A CARGO NAVIGATING IN THE LOWER DANUBE SECTOR

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Abstract: This paper studies how the vibrations of a cargo ship are transmitted to crew members. The measurements were made on the navigating bridge, on the main deck and in the engine room during various maneuvers: start-up, shore, idling with generator engine, mooring manoeuver. The accelerations transmitted to the body were measured and were calculated: Partial VDV (Vibration Dose Value), Partial exposure A(8), Time to reach EAV (VDV option), Time to reach EAV(A(8) option only) (Exposure Action Value), Total VDV, Total exposure A(8). In the engine room were measured accelerations of up to 6.743m/s^2, while the calculated VDV is extremely high: 56.3m/s$^{1.75}$, time to reach EAV (Exposure Limit Value) is 2-3 min and time to reach ELV is 14-21 min. In conclusion, the working conditions of crew members must be improved.

Keywords: Danube River, navigation, vibrations, human response, crew.

1. Introduction

Vibrations transmitted by equipment to the human body during work hours are dangerous to the health of the crew. There are a lot of studies on the negative effects of vibrations on people working in such an environment: industry (vehicles, cranes); constructions (excavating machines, trailers, cranes, bulldozers, crawlers); transports (buses, trucks, cars, planes, ships, helicopters, metros, railway engines); agriculture (tractors, dirt mover) (Picu, 2012, 2013).

"There are two types of occupational vibrations: of one segment and of the whole-body. The vibrations from the steering wheel are transmitted through the hand and arm and lead to some specific disorders like Raynaud Syndrome. The whole-body vibration is transmitted through the support surfaces of the body: legs, for the vertical position case, or buttocks and back, for the seated position." (Picu and Nastac, 2011)

In respect with this there are a lot of standards that regulate work in a vibrant environment (EN 1032; ISO 2631-1; ISO 2631-4; ISO 5349). An activity with special characteristics is that of sailors who spend most of their time on the ship.

The sailors' body is exposed to vibrations during the entire journey. It was proved that vibrations lead to disorders of the muscular and skeletal system, of the hand as well as of the arm, neck and back (Picu and Nastac, 2011; Picu and Rusu, 2017).

For this reason, Directive 2002/44 / EC clearly states: "In the case of sea and air transport, given the current state of the art it is not possible to comply in all circumstances with the exposure limit values for whole-body vibration; provision should therefore be made for duly justified exemptions in some cases" (DIRECTIVE 2002/44/EC).

Mariners are exposed to ship movements due to waves that can cause "seasickness". Vibrations generated by engines and other sources of excitation, can cause increased discomfort. The perception and the response to these disturbing factors as well as the influence on work performance were investigated (Gasparotti and Rusu, 2012; Ivan, Gasparotti and Rusu, 2012; Rusu, Butunoiu and Rusu, 2014). This influences both their physical and mental abilities (Bittner, 1985).

The way in which vibrations are transmitted through the structure of the ship, whether due to waves or equipment, should be taken into account when designing the vessel (Carlton and Vlasic, 2005; IFSTTAR, 2014).

The objective of this paper is to study the way a cargo ship transmits vibrations to the crew members. Vibration accelerations transmitted to the whole-body were measured on the navigating bridge, on the main deck and in the engine room.

2. Materials and Methods

In this paper the measurements of whole-body vibrations (WBV) were made on a cargo ship on the Danube, over a distance of 175 km (Picu, 2015; Picu and Nastac, 2010).

The atmospheric conditions were good (T = 16^{0}C, no wind, moderate waves). At the beginning of every test the each sailor was asked if he/she feels comfortable in the desired position; the measurement system was calibrated.

The vibrations were measured in normal working conditions, according to International Standard ISO 2631-1. The whole-body vibration, in different conditions, was measured on the 3 axes x, y and z from the centre of the human body.

The whole-body vibrations were measured using: 01dB NetdB Multichannel digital recorders and real-time analysers with 12 activated channels acquisition, triaxial whole-body accelerometer SEAT-pad (Seat Effective Acceleration Transmissibility), triaxial whole-body accelerometer PCB Piezotronics 356A16.

The accelerometer was fixed with clips, according to ISO 5349-2:2001. The axes were oriented in the directions specified in EN 1032:2003. The accelerations generated by vibrations were calculated using the weight factors set by ISO 2631. The calibration of the accelerometers was made with VE-10 Rion.

The data processing was made with dBFA Suite-Control Software for data acquisition and post-processing (http://www.acoustic-glossary.co.uk/vibration-dose.htm). The data acquired during the experiments were processed using the calculation given by ISO 2631-1:1997. The ISO 2631-1 parameters evaluated included:

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a) Root mean square average vibration (A_w) calculated at the floor, lumbar, cervical and forehead:

$$A_w = \left[\frac{1}{T}\int_0^T a_w^2(t)dt\right]^{1/2} \quad (m/s^2) \qquad (1)$$

b) Vibration dose value (VDV). This value is more sensitive to impulsive vibration and reflects the total, as opposed to average vibration:

$$VDV = \left[\frac{1}{T}\int_0^T [a_w(t)]^4 dt\right]^{1/4} \quad (m/s^{1.75}) \qquad (2)$$

c) The time period needed to reach the value of the exposure which triggers the action (EAV) and the limit exposure value (ELV):

$$T_{EAV_{A(8)}} = 8\left(\frac{0.5}{A_w}\right)^2 \quad (h) \qquad 3)$$

$$T_{ELV_{A(8)}} = 8\left(\frac{1.15}{A_w}\right)^2 \quad (h) \qquad (4)$$

The measuring conditions on human were different: the start from the shore, running, idling with generator engine, mooring manoeuver. To determine the noise on ship, in different places of that, were made measurements with SOLO soundmeter: in wheelhouse, on the main deck and the engines room, on the navigating bridge and in the rest area.
As for the daily exposure value from which the action is triggered (8h/day) at European level, the following practices are met: 4.5 m/s^2 - 4h/day of exposure; 6 m/s^2 - 2h/day of exposure; 9 m/s^2 - 1h/day of exposure and 12 m/s^2 - 0.5h/day of exposure.

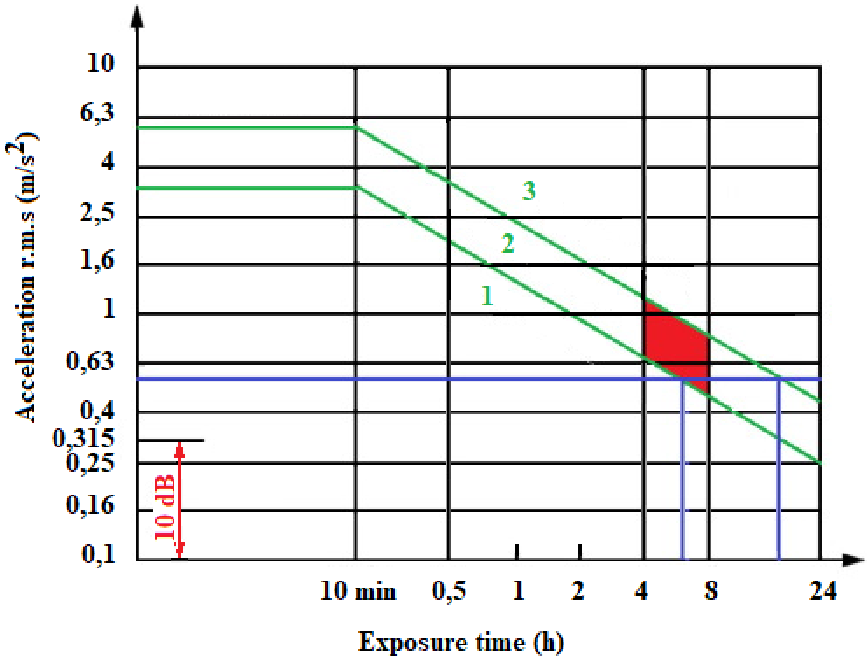

Fig. 1.
Areas of Attention in Health Warnings (ISO 2631-1)(1) - Risk-Free Area; (2) - Area With Risk Potential; (3) - Risk Area, ( ) - Attention Area

Whole-body vibrations values were calculated over the whole route, as well as by individual segment. A GPS was also used to collect and integrate the data and to identify the location and the velocity associated with the WBV exposures. Each experiment was repeated 5 times in order to obtain an accurate averaging of the experimental data.
Five male subjects were chosen for this experiment with different body weights, ages and work experience (Table 1).

Table 1
Information About Subjects

Subject	Weight (kg)	Age (years)	Smoker	More than 2 glasses of wine/day	Seniority (years)
1	≤70	≤50	Yes	Yes	21
2	71–93	≥50	Yes	Yes	38
3	71–93	≤50	Yes	Yes	41
4	≥94	≥50	-	-	35
5	≥94	≥50	Yes	-	33

3. Calculations and Results

Tables 2 present the mean values of accelerations measured on the navigating bridge, on the main deck and in the engines room (the accelerometer is fixed on the floor).

Table 2
The Mean Values of Accelerations Measured (m/s^2)

	Start from the shore	Running upstream	Idling with generator engine	Mooring manoeuver
on the navigating bridge	1.245	1.014	0.852	1.322
on the main deck	1.044	0.874	0.759	1.216
in the engines room	5.447	6.041	3.858	6.743

Table 3
Calculation of Characteristic Values for the Accelerometer Placed on the Floor on the Navigation Bridge

	Vibration magnitude m/s^2 r.m.s.	Exposure duration minutes	Partial VDV $m/s^{1.75}$	Partial exposure m/s^2 $A(8)$	Time to reach EAV (VDV option)			Time to reach EAV (A(8) option)			Time to reach ELV (A(8) option only)			Total VDV $m/s^{1.75}$	Total exposure m/s^2 A(8)
					9.1 $m/s^{1.75}$ VDV		time in hours	0.5 m/s^2 A(8)		time in hours	1.15 m/s^2 A(8)		time in hours		
					hours	minutes		hours	minutes		hours	minutes			
shore	1.245	5	7.2540	0.1270	0	10	0.2063	1	17.4181	1.2903	6	49.5417	6.8256	10.5476	0.3038
running	1.014	20	8.3552	0.2069	0	28.1417	0.4690	1	56.7092	1.9451	10	17.3920	10.2898		
idling	0.852	10	5.9034	0.1229	0	56.4603	0.9410	2	45.3111	2.7551	14	34.4958	14.5749		
mooring	1.322	5	7.7026	0.1349	0	9.7403	0.1623	1	8.6622	1.1443	6	3.2235	6.0537		

Table 4
Calculation of Characteristic Values for the Accelerometer Placed on the Floor on the Main Deck

	Vibration magnitude m/s^2 r.m.s.	Exposure duration minutes	Partial VDV $m/s^{1.75}$	Partial exposure m/s^2 $A(8)$	Time to reach EAV (VDV option)			Time to reach EAV (A(8) option)			Time to reach ELV (A(8) option only)			Total VDV $m/s^{1.75}$	Total exposure m/s^2 A(8)
					9.1 $m/s^{1.75}$ VDV		time in hours	0.5 m/s^2 A(8)		time in hours	1.15 m/s^2 A(8)		time in hours		
					hours	minutes		hours	minutes		hours	minutes			
shore	1.044	5	6.0828	0.1065	0	10	0.4173	1	50.0982	1.8349	9	42.4195	9.7069	9.2572	0.2656
running	0.874	20	7.2016	0.1784	0	50.9866	0.8497	2	37.0935	2.6182	13	51.0249	13.8504		
idling	0.759	10	5.2590	0.1095	1	29.6468	1.4941	3	28.3040	3.4717	18	21.9283	18.3654		
mooring	1.216	5	7.0850	0.1241	0	13.6071	0.2267	1	21.1547	1.3525	7	9.3087	7.1551		

Table 5
Calculation of Characteristic Values for the Accelerometer Placed on the Floor in Engine Room

	Vibration magnitude m/s^2 r.m.s.	Exposure duration minutes	Partial VDV $m/s^{1.75}$	Partial exposure m/s^2 $A(8)$	Time to reach EAV (VDV option)			Time to reach EAV (A(8) option)			Time to reach ELV (A(8) option only)			Total VDV $m/s^{1.75}$	Total exposure m/s^2 A(8)
					9.1 $m/s^{1.75}$ VDV		time in hours	0.5 m/s^2 A(8)		time in hours	1.15 m/s^2 A(8)		time in hours		
					hours	minutes		hours	minutes		hours	minutes			
shore	5.447	5	31.7369	0.5559	0	10	0.0005	0	4.0445	0.0674	0	21.3954	0.3565	56.3003	1.6165
running	6.041	20	49.7773	1.2331	0	0.02233	0.0003	0	3.2882	0.0548	0	17.3947	0.2899		
idling	3.858	10	26.7317	0.5568	0	0.1342	0.0022	0	8.0622	0.1343	0	42.6493	0.7108		
mooring	6.743	5	39.2881	0.6882	0	0.0143	0.0002	0	2.6392	0.0439	0	13.9614	0.2326		

Tables 3÷5 present the calculated values for: Partial VDV, Partial exposure A(8), Time to reach EAV (VDV option), Time to reach EAV (A(8) option), Time to reach ELV (A(8) option only), Total VDV, Total exposure A(8). The calculation was done with: Vibration exposure calculator - Telenet.

4. Discussions and Conclusions

a) Parallel between the root mean square average vibrations, measured at the floor, in the 3 cases**:** on the navigation bridge, on the main deck and in the engine room.
Figure 2 shows that all acceleration values are located above the EAV limit ($0.5m/s^2$) for people on the navigation bridge and on the main deck (in all cases: the start-up, shore, idling with generator engine, mooring manoeuver). There are a few situations for which the acceleration values are below the ELV limit ($1.1m/s^2$). The situation is changing dramatically for people in the engine room: accelerations of up to $6.743m/s^2$ were measured here.

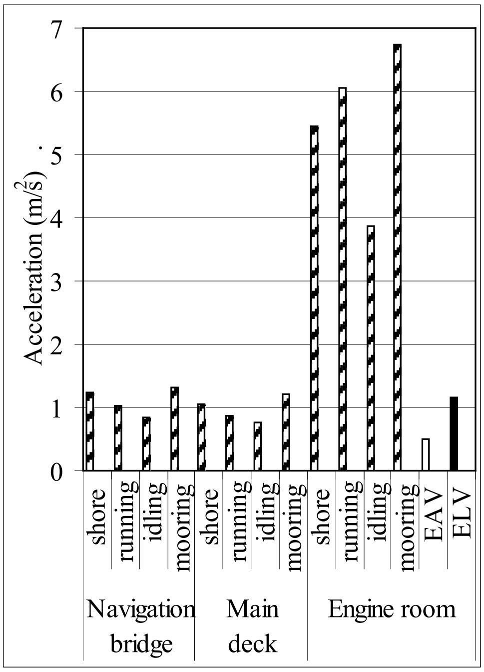

Fig. 2.
Average acceleration measured with accelerometer on the floor of the navigation bridge, the main deck and in the engine room; (□) –EAV limit; (■) –ELV limit

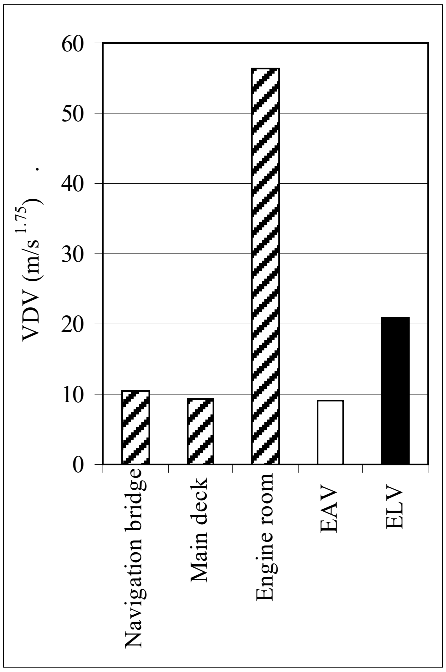

Fig. 3.
Average VDV calculated on the navigation bridge, on the main deck and in the engine room (□) –EAV limit; (■) –ELV limit

b) Parallel between vibration dose value, calculated at the floor, in the 3 cases: on navigation bridge, on main deck and on engine room
Figure 3 shows that all calculated values are below the EAV limit ($9.1m/s^{1.75}$) for people on the navigation bridge, the main deck and the engine room (where an extremely high value was reached: $56.3m/s^{1.75}$).
c) Parallel between time periods to reach the exposure value which triggers the action and time periods to reach the limit exposure value
Another value interesting value for studying vibrations which are transmitted to the crew is the time period necessarily to reach the exposure value which triggers the action. Figures 4÷6 clearly show that these values are particularly low for the staff on the navigation bridge: T_{EAV}=1.14h and T_{ELV}=6.05h and on main deck: T_{EAV}=1.35h and T_{ELV}=7.15h for mooring. For the engine room workers the values are dangerously small for all maneuvers: T_{EAV}=0.04-0,06h (2-3 min) and T_{ELV}=0.23-0,35h (14-21 min).

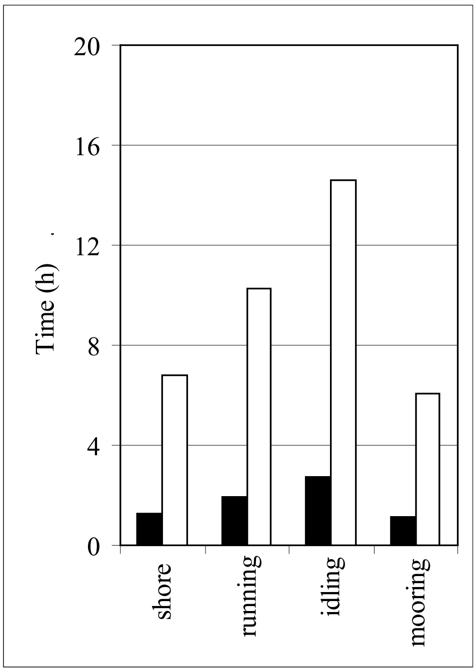

Fig. 4.
Parallel between T_{EAV} (■) and T_{ELV} (□): Navigation Bridge

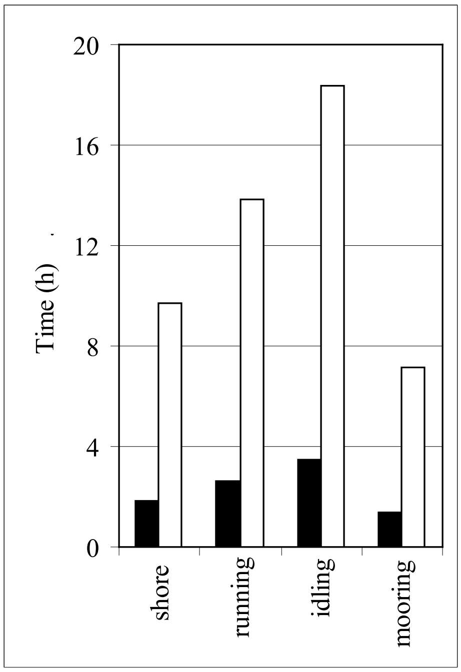

Fig. 5.
Parallel between T_{EAV} (■) and T_{ELV} (□): Main Deck

In conclusion, this paper analyses the vibrations to which the crew of a cargo ship is exposed while travelling on the Danube. It can be seen that all values characterizing the vibrations transmitted by the ship to the hole body of the sailors (A_w, VDV, T_{EAV}, T_{ELV}) lead to the same conclusion: it is necessary to improve working conditions. Of all the areas on the ship, the most dangerous is the engine room; the legal norms are exceeded a few dozen times. The 8h work schedule or even more, in such conditions is extremely harmful to people's health.
It is imperative to improve the working conditions of crew members. All solutions that can be applied according to the specificity of each ship (gloves, boots, supports, antivibration mats) will be used. The antivibration supports will be replaced if damaged and will be installed where they are missing. Where possible, soundproofed and antivibration rooms will be built for the mechanics to use while supervising the engine room and when they are not working on a repair. The remarks on the high level of discomfort caused by vibration-producing equipment will have to be taken into account as early as ship design and material selection.

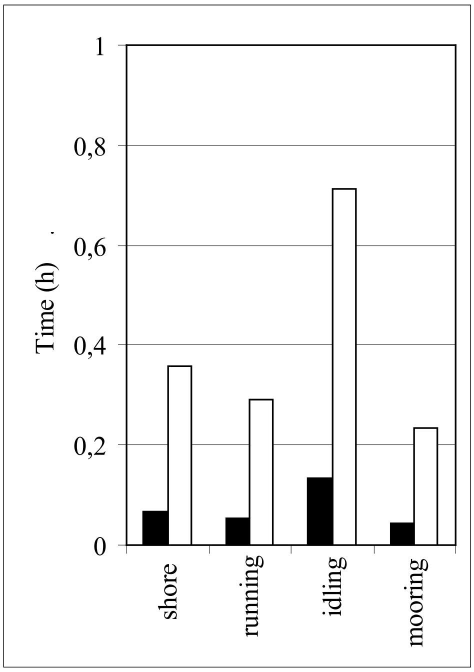

Fig. 6.
Parallel Between T_{EAV} (■) and T_{ELV} (□): Engine Room

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A CHALLENGE FOR THE INLAND NAVIGATION – A CONNECTION BETWEEN THE BALTIC AND THE BLACK SEAS

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Abstract: The transportation sector is directly related to almost any activity in Europe. Transportation and mobility play a fundamental role in today's world. The European Commission's aim is to promote the mobility that is efficient, safe, secure and environmentally friendly, serving the needs of citizens and businesses. At the European Union level, the transportation sector aims to promote efficiency on the European single market and to sustain connectivity on a global scale. To achieve these goals, EU must implement actions of decarbonization, digitalization, investment, people's benefits, innovation and global leadership, which are sustainability components Transportation has a major impact on Europe's social, economic and environmental development. That is why this is considered a strategic sector of the EU economy. At the local and regional levels, transportation contributes to economic growth, creating new jobs, helping SME's global competitiveness and trade and helping people and goods to move across Europe. From this perspective, the creation of a waterway which links the Baltic and the Black Seas fits perfectly into the objectives of the European Union. From this perspective, in this paper we analyze the sustainability of this project idea, taking account of the economic, financial, operational, social and environmental considerations. The analysis of these factors presents a clear and concrete situation of the decisions to be taken by the policymakers. This paper examines the feasibility of establishing a navigable route along the Vistula-Prut rivers waterway, connecting Baltic and Black Seas through the Danube River. The new transport waterway will became an alternative with the competing modes of rail and road. The waterway service offers an alternative from energy and carbon to roads and railway freight. The inland waterway transportation (IWT) could have a high potential in the Eastern Europe countries, with an inland waterway which will connects the Black and Baltic Seas under some conditions (e.g. improving infrastructure, increasing the size of vessels, increase cooperation between authorities). Inland transportation will gain a competitive advantage against other modes of transportation, particularly in the junction area with roads and seaports handling facilities.

Keywords: inland navigation; challenge; Black Sea, Baltic Sea, sustainability.

1. Introduction

The transportation sector is directly related to almost any activity in Europe. Transportation and mobility play a fundamental role in today's world. The European Commission's aim is to promote the mobility that is efficient, safe, secure and environmentally friendly, serving the needs of citizens and businesses.

At the European Union level, the transportation sector aims to promote efficiency on the European single market and to sustain connectivity on a global scale. To achieve these goals, EU must implement actions of decarbonization, digitalization, investment, people's benefits, innovation and global leadership, which are sustainability components represented in Figure 1.

This paper examines the feasibility of establishing a navigable route along the Vistula-Pruth rivers waterway, connecting Baltic and Black Seas through the Danube River. The new transport waterway will became an alternative with the competing modes of rail and road. The waterway service offers an alternative from energy and carbon to roads and railway freight.

The inland waterway transportation (IWT) could have a high potential in the Eastern Europe countries, with an inland waterway which will connects the Black and Baltic Seas under some conditions (e.g. improving infrastructure, increasing the size of vessels, increase cooperation between authorities). Inland transportation will gain a competitive advantage against other modes of transportation, particularly in the junction area with roads and seaports handling facilities.

Creating an inland waterway on the Prut River to connect the Baltic Sea and the Black Sea is not a new idea. Since 1926, the state authorities from Romania and Poland made diplomatic efforts to open a new waterway connecting the Prut, Dniester, San and Vistula rivers. Recently according to European strategies, which aim to develop a North-South transport corridor, the member states and their partners have the possibility to establish an integrated approach to economic and social opportunities.

The Black Sea is today a complex economic area undergoing development. From a strategic point of view, the Black Sea is located between Europe and Asia, being connected with the Mediterranean Sea. The economic activities are diverse, besides the transportation and tourism sector, the energy sectors, the exploitation of the natural deposits and the agricultural sector are growing.

The Baltic Sea is a developed economic space, with the riparian countries making efforts to systemize and streamline the cross-border cooperation methodologies. From this perspective, the European Union's strategy is to connect the Baltic Sea with other regions of Europe through a waterway system.

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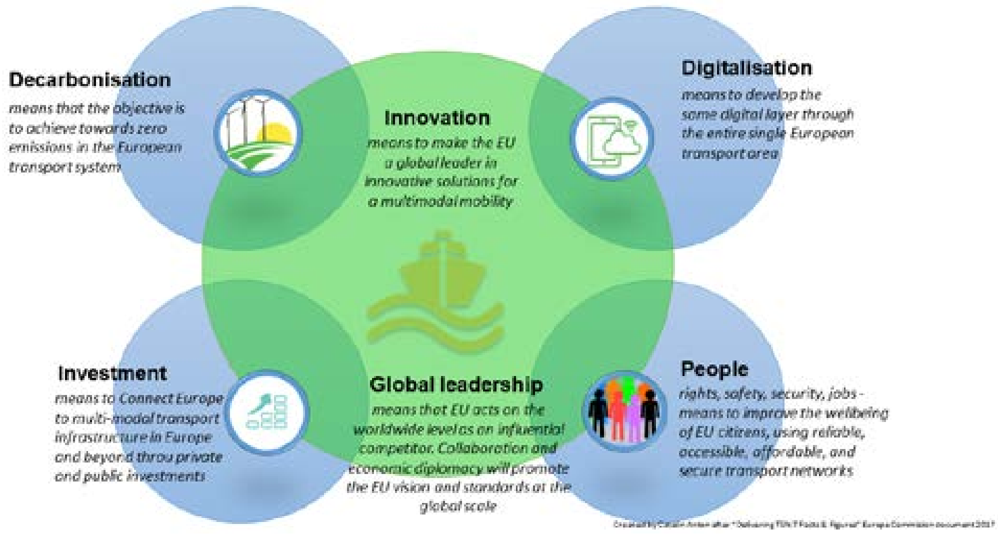

Fig. 1.
Actions to implement the EU transportation policies

Furthermore, the project to create a navigable channel between the Baltic Sea and the Black Sea is in line with the North-South European transportation corridor and it will bring to the same table Romania, Moldova, Ukraine and Poland, countries that will have to work together to complete this ambitious project. Navigation on the new waterway will begin at Gdansk in Poland, will continue on the river Vistula, will go on the San River, which will connect with the Dniester river and will continue on the Prut River, going to the Danube, near the city of Galati (Romania). From Galati it can be reached the Black Sea by two ways, the Sulina branch or the Danube-Black Sea canal having the final port of Constanta.
The Gdansk-Galati inland waterway would have a length of 1,900 km, of which only 72 km would involve excavated channel areas to make connections between the rivers the Vistula - San - Dniester – Prut. (Fig. 2) The distance between the Baltic Sea and Black Sea will be reduced from 7911 km (4272 nm) to 2068 km (1117 nm). The Prut River is the eastern border of the European Union, with a length of 716 km. The Prut River basin has an area of 28,396 square km, out of which 10,990 square km in Romania. The sectors on which the course should be modernized are the upper sector - from the source to the exit of the mountains, the Cernăuţi area, the Cernăuţi district to Ungheni and the Lower Prut, from Ungheni to the Danube, to Galati.
Aside from the economic and political benefits of the project, which more than justify the complex development of the Prut River, the current context poses an unique historic opportunity which requires consideration and acknowledgment.

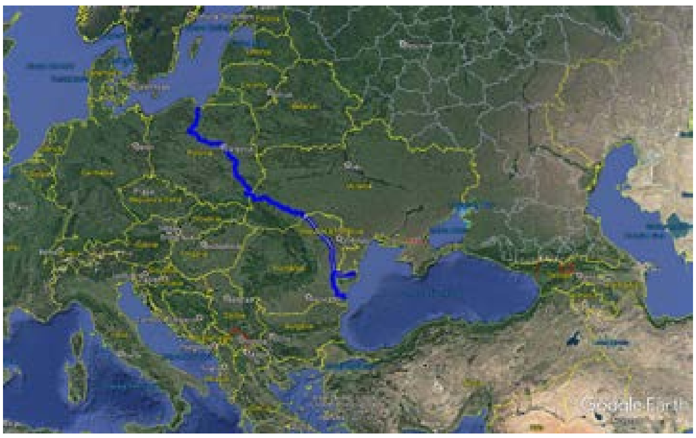

Fig. 2.
Connections between the rivers Vistula - San - Dniester – Prut
Source: (figure processed from Google Earth)

2. Methodology

The EU Transportation Strategy defines sustainability in transportation systems as having economic, financial, operational, environmental and social dimensions. When we discuss about the IWT industry in Europe, these dimensions can be interpreted as components:

Economic sustainability. This involve the management of all resources of economic interest, which is necessary to meet the needs, in a manner that provides lasting positive economic value to society as a whole. With regard to IWT, the management of waterways (inc. their infrastructure) and riverboats towards securing adequate and reliable operations without compromising the needs of other water users.
Financial sustainability. The transportation sector must have access reliable and sufficient funds for the construction, operations and maintenance necessary for the availability of the offered services. Infrastructure owners and operators as well as service providers meet their financial needs through a multitude of sources ranging from public and/or private funds to revenue from end users.
Operational sustainability: The capability in terms of management, technical and technological issues to construct IWT infrastructure, and to operate and to maintain an increasingly busy and sophisticated inland waterway transport system more efficiently, safely and reliably.
Environmental sustainability: The inland waterway transport industry should meet ever-increasing political and public expectations of environmental high standards, including the energy efficiency and low carbon generation, as well as more stringent environmental regulations;
Social sustainability: This component ensures that the inland waterway transport industry is as a good partner of riparian communities that caters for the livelihoods of all affected by its presence.
These five dimensions are interdependent. If the inland waterway transport policy does not touch any of these components it may have an adverse impact on the others. For example, the industry will not be able to afford the adequate environmental standards if it is not financially sustainable. Similarly, if it is not environmentally sustainable, then it will not be able to meet its social sustainability commitment. Inland waterway transport policies need to address all the components of sustainability.
In order to have a tool for components evaluation in terms of sustainability, we have identified a number of 14 results areas (Figures 3, 4, 5 and 6) and 30 monitoring indicators. These indicators which belong to the sustainability components need to be scored on a scale from -3 to 3 (see scoring scale below – Figure 7).

ECONOMICS and FINANCIAL

1	INDICATOR	DESCRIPTION	SCORING RANGES								INDICATOR SCORE
The ability of the IWT industry to offer, maintain and continuously improve competitive transport services to freight customers in accordance with market needs and in a way that is financially viable.	Increase and diversify IWT traffic levels	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
				-2							
	Maintain or increase modal share carried by IWT	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
							1				
	Improve competitiveness of shipping services	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
								2			
	Ensure the financial sustainability of navigation	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
									3		
	Number of indicators considered in the score calculation										

Fig. 3.
Economics and Financial component

OPERATIONAL											
1		**INDICATOR**	**DESCRIPTION**	**SCORING RANGES**							**INDICATOR SCORE**
The capability to construct IWT infrastructure and operate an increasingly busy and sophisticated IWT transport system more safely, efficiently and reliably	Implement the EU plan and provincial navigation plans	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
							1				
	Increase the efficiency of administration of navigation	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
								2			
	Modernize the barge fleet	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
								2			
	Improve port performance	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
									3		
	Number of indicators considered in the score calculation										

Fig. 4.
Operational component

ENVIRONMENT											
INDICATOR		**DESCRIPTION**	**SCORING RANGES**								**INDICATOR SCORE**
The ability of the IWT industry to meet ever-increasing expectations of environmental performance and more stringent environmental regulations	Increase energy efficiency	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
							1				
	Reduce spillages of dangerous cargo on waterways	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
					-1						
	Reduce spillages of dangerous cargo in ports	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
									3		
	Increase industry safety	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
								2			
	Number of indicators considered in the score calculation										

Fig. 5.
Environmental component

SOCIAL WELL-BEING											
INDICATOR		**DESCRIPTION**	**SCORING RANGES**								**INDICATOR SCORE**
IWT as a good neighbor and one that considers livelihoods in small boat sector	Monitor impact of IWT and ports on waterside communities	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
	Monitor social conditions in small barge sector	Please indicate on a scale from -3 to 3 and clarify with examples	No, strong negative effects	No, considerable negative effects	No, weak negative effects	No changes	Yes, weak positive effects	Yes, considerable positive effects	Yes, strong positive effects	No Data	
			-3	-2	-1	0	1	2	3	X	
	Number of indicators considered in the score calculation										

Fig. 6.
Social component

-3	-2	-1	0	1	2	3

Fig. 7.
Indicators scale for sustainability components

3. Results

The present work will describe next the challenge of a possible future role of the inland navigation between the Baltic Sea and the Black Sea. The goal is to present a sustainability analysis with reference to the economic & financial, operational, environmental and social components. Taking into account the EU transport policy objectives the present study will summarize the main issues which have to be analyzed towards the long term sustainability of IWT. The results will be divided into those concerned with the **navigation infrastructure** (i.e. channels, locks, ship-lifts, navigation aids etc) – Figure 8 – to the **ports** (Figure 9), and to the **transport services (barging) industry** (Figure 10).

Economic and financial sustainability will be treated together, through their close interdependence with the operational, environment and social sustainability.

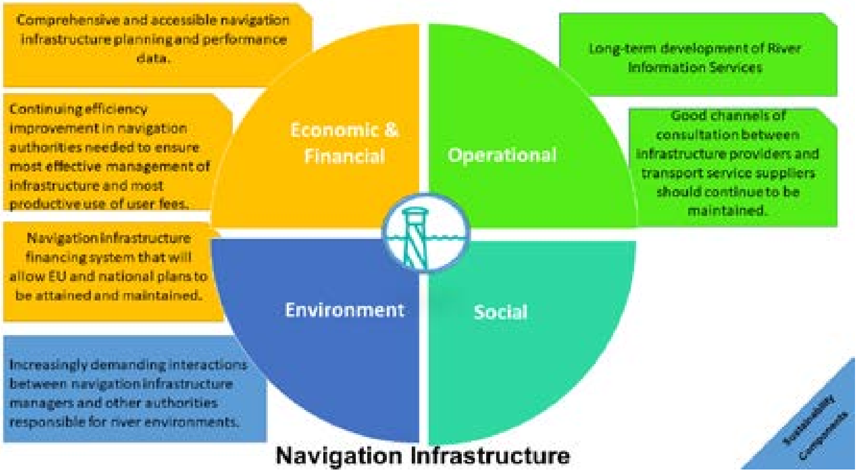

Fig. 8.
Sustainability components – Navigation Infrastructure

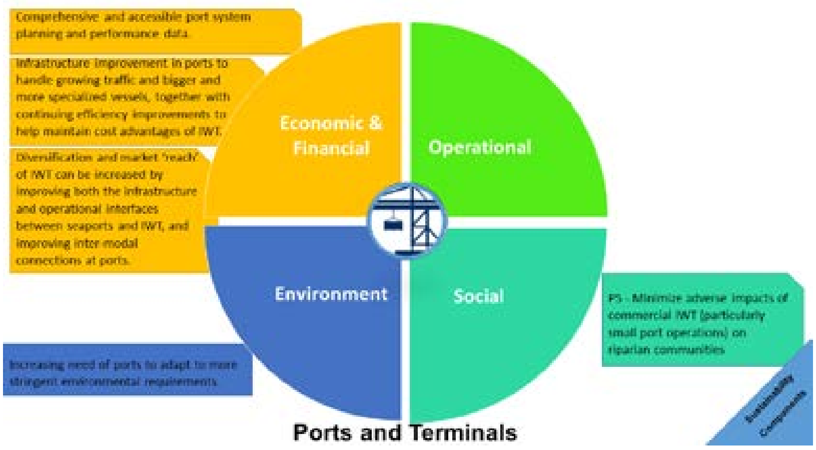

Fig. 9.
Sustainability components – Port and Terminals

Fig. 10.
Sustainability components – Barge Transport Industry

In this next stage, there is summarized the proposed monitoring framework for the project sustainability. Detailed observations are given on the right part of the figures below. As noted, the framework is indicative rather than definitive, and it can be adapted by every involved country to include or exclude particular result areas, for the figure of Economic & Financial (Figure 11), Operational (Figure 12) or Environmental and Social (Figure 13) or to modify the performance indicators to be monitored within each result area. It can also be implemented in stages over time, depending on the development of the information systems.

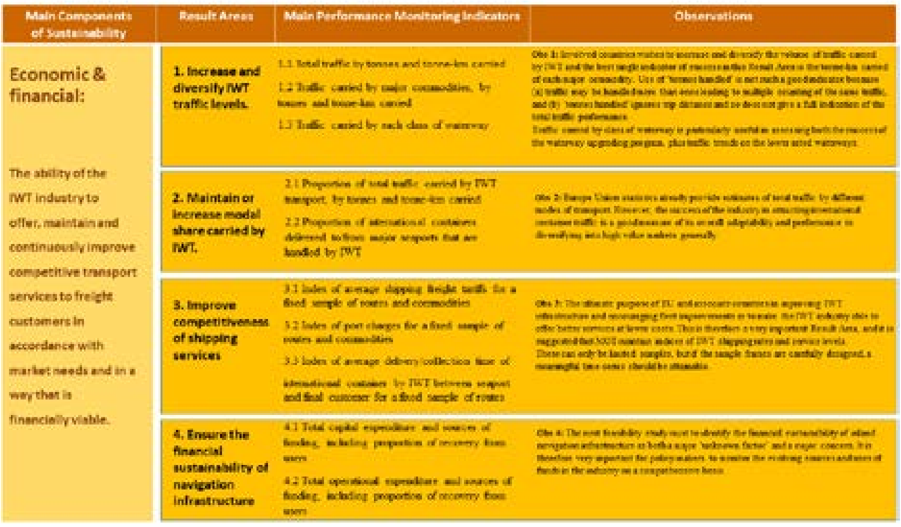

Fig. 11.
Sustainability of the IWT Industry - High-level Results Framework (Economic & Financial)

Fig. 12.
Sustainability of the IWT Industry - High-level Results Framework (Operational)

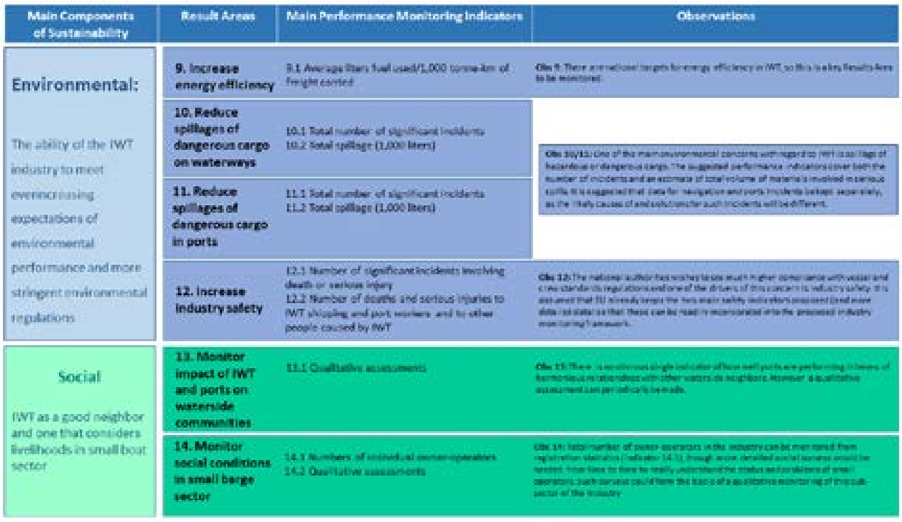

Fig. 13.
Sustainability of the IWT Industry - High-level Results Framework (Environmental & Social)

4. Discussions

In the European Union, there are fewer documents that look comprehensively across all transport modes, including IWT. Table 1 shows estimates the marginal costs of construction and maintenance of infrastructure, of the safety, emissions and other environmental costs of the three main modes of inland freight transport in the EU.
The major EU study in terms of GHG emissions, estimated that CO2 emissions per tons/km in EU freight transport are 672 grams for airfreight, 86.3 grams for road freight (in 40 tons-trucks), 34.4 grams for inland waterways vessels, and 29.4 grams for railways.

Table 1
EU Estimates of External Costs of Transport (EUR/100 tons-km)

Mode of Transport Construction and	Maintenance Costs	Safety, Social and Environmental Costs	Total External Costs (Excluding Operating Costs)
Roads	0,51	1,94	2,45
Railways	1,86	0,43	2,29
IWT	0,82	0,1	0,92

Source: Prognos Consultants, estimates for the European Commission

Sustainability of the IWT components is closely interconnected. If we refer to “Improve the competitiveness of shipping services” result area from Economic/Financial component, this has correspondent to 6,7 and 8 positions from operational table, respectively “Increase the efficiency of administration of navigation”, “modernize the barge fleet” and “improve port performance”. Similarly, we can discuss any of the components.
Using tool for components evaluation in terms of sustainability, with indicators scored from -3 to 3 scale, results a final sustainability indicators table (Table 2) and indicator-based assessment graph which you can see in figure 14.

Table 2
Sustainability indicators table

COMPONENTS	INDICATORS AND AREAS		SCORE
ECONOMICS & FINANCIAL	Increase and diversify IWT traffic levels.	Total traffic by tonnes and tonne-km carried Traffic carried by major commodities, by tonnes and tonne-km carried Traffic carried by each class of waterway	**2**
	Maintain or increase modal share carried by IWT.	Proportion of total traffic carried by IWT transport, by tonnes and tonne-km carried Proportion of international containers delivered to/from major seaports that are handled by IWT	
	Improve competitiveness of shipping services.	Index of average shipping freight tariffs for a fixed sample of routes and commodities Index of port charges for a fixed sample of routes and commodities Index of average delivery/collection time of international container by IWT between seaport and final customer for a fixed sample of routes	
	Ensure the financial sustainability of navigation infrastructure.	Total capital expenditure and sources of funding, including proportion of recovery from users Total operational expenditure and sources of funding, including proportion of recovery from users	
OPERATIONAL	Implement the EU plan and provincial navigation plans	Total length of waterways of each class operational at the end of each year, in total and compared to plan targets Total number of new berths of various types/capacities operational at the end of each year in total (and compared to plan targets if available)	**2**

COMPONENTS	INDICATORS AND AREAS		SCORE
	Increase the efficiency of administration of navigation	Indices of productivity for each navigation administration and in total (e.g. cubic meters dredged/dredging employee, or river-kms maintained/maintenance employee)	
	Modernize the barge fleet	Total fleet numbers by barge type/class Average capacity, power rating and age by barge type/class Number of new vessel registrations by barge type/class	
	Improve port performance	Total port and berth numbers by berth type/class Average capacity of berths by type/class Index of vessel turnaround times for a fixed sample of port terminals Number of ports with regular rail service connections	
ENVIRONMENTAL	Increase energy efficiency	Average liters fuel used/1,000 tonne-km of freight carried	**1,25**
	Reduce spillages of dangerous cargo on waterways	Total number of significant incidents Total spillage (1,000 liters)	
	Reduce spillages of dangerous cargo in ports	Total number of significant incidents Total spillage (1,000 liters)	
	Increase industry safety	Number of significant incidents involving death or serious injury Number of deaths and serious injuries to IWT shipping and port workers and to other people caused by IWT	
SOCIAL	Monitor impact of IWT and ports on waterside communities	Qualitative assessments	**0,5**
	Monitor social conditions in small barge sector	Numbers of individual owner-operators	
		14.2 Qualitative assessments	

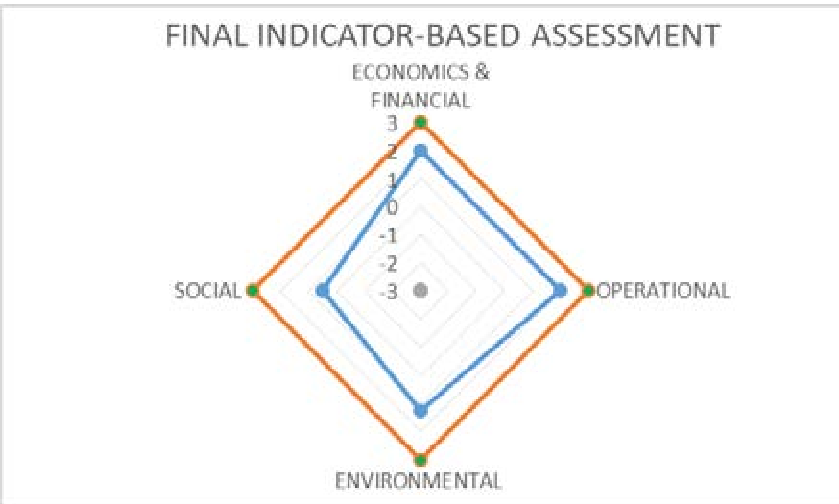

Fig. 14.
Indicator-based assessment graph

Inland navigation in Europe and in this case the waterway transportation between the Baltic and the Black Seas is neither automatically damaging nor beneficial to any sustainability component. This can be a very environment-friendly means of transport of goods and people if it is made within a framework of conditions: IWT have had and it always has some certain limits. With a careful planning and thoughtful consideration of how and under what circumstances navigation can be carried out it is possible to achieve a sustainable IWT.
For this, it is necessary that persons which are engaged in protecting the environment and managing water bodies to define more clearly the limits of the river related to the navigation. In a similar manner, the navigation managers should clarify the current and future needs of the inland navigation and how they want to achieve those most important objectives (not only in terms of infrastructure) in an environmentally sensible way.
A challenge – a new Vision requires:

- Taking into account the special environmental quality and requirements of each water body and the river sections and its tributaries;
- Working within the legal and policy frameworks that exist for integrated the river basin management and inland waterway development;
- Learning new experiences from other areas about the feasibility or negative impacts of certain waterway transportation, as well as about the introduction of the modern, integrated techniques of waterway and vessel design, market and logistics conditions, that limit or improve such transport;
- Before taking the investment decisions, sharing the information on the interests and needs of developing and the navigation strategies and actions for the waterway and river basin management that take account of these needs.

To achieve a Vision for a sustainable transportation there will be a need to focus on both questions of process and specific technical considerations related to the specific projects that form part of an overall strategy. A SWOT analyze is useful for developing a coherent mid-term vision which is affordable, sustainable and socially and economically acceptable (figure 15).

Fig. 15.
SWOT analyze for developing IWT mid-term strategy

The goal of this process is to achieve an agreement among the stakeholders involved in development and maintenance of the navigation/waterway transport and in managing the quality of revering resources – based upon the principles and criteria of the sustainability. It is a goal that is both necessary and realizable for all interests.
The challenge of a new waterway between the Baltic and the Black seas means to serve a wider social and economic purpose than they have in the past. The proposed Gdansk-Galati waterway can, therefore be expected to have a wide range of economic impacts:

- Tourism and recreation – the tourist and locals can offer opportunities for the economic impact for IWT;
- Boating – the new project offers the possibility to construct or to hire boats which can be used for the waterway activities;
- Visitors to the waterway – a new IWT will become attractive for the local residents and for tourists. For these groups, is necessary planning and investment which is required to maximize the level of activity that can be supported. If we are looking from an economic perspective, the attracting and retaining tourists from outside the area is very advantageous;

- Iconic structure – to complete the IWT it will be necessary to choose an engineering approach to overcome the height difference in this area. This is a good opportunity for the project to develop an iconic structure visible to the millions of visitors;
- Place shaping – is connected to both the recreational uses of the IWT and the iconic structure, the use of place shaping is to establish a local or regional identity and communicate it nationally or internationally;
- Transport is the natural use of the waterway system, competition from road and railways has meant that the waterways network in Europe is now used for bulky, non-perishable goods and some limited passenger transport. There are EU policies to increase the use of waterways as a transport conduit to reduce the social and environmental impacts from other forms of transport;
- Ecosystem services – IWT provides a range of what are known as ecosystem services, like as flood control and water transport. While these benefits are difficult to cost, they contribute to a sustainable economic development; and
- Property uplift and regeneration – Waterfront locations will raise the value of properties located close to them, for the residential properties by up to 20% of their value.

Prut River has been the object of several development projects and initiatives in the past decades. Hydropower potential was the primary objective of those initiatives, but the economic benefits could also result from its development as a navigable route.
Prut River had a strategic interest for policymakers and decision-makers from the three riparian countries: Ukraine, Moldova and Romania. Even if these interests have been often opposed or competitive, the riparian countries have understood that a sustainable development of the river based on mutual trust is necessary for the context in which Romania is already a member of the European Union and Moldova and Ukraine aspire to join the EU.
For the Prut River area, the economic, social or environmental benefit is included in the new concept of development for the river:

- A hydropower potential, the total estimated power of projects proposed in this concept is around 120 MW, which is a needed for Moldova who imports 80% of its energy requirement;
- Creating the navigable facilities of Prut River provides an alternative, more cost-effective exit to the Black Sea and a cheaper alternative to the rail and road transport, especially since all of Romania's existing waterways are concentrated in the south;
- The construction of the new bridges across the river would strengthen commercial ties between the three riparian states;
- The development of the irrigation networks and secure water supply for communities along the river;
- The implementation of flood protection systems.

The political impact of this initiative could improve the bilateral relations between Ukraine and Moldova with Romania and with the European Union, receiving support for integration and the adoption of the democratic values and principles towards a common future.

5. Conclusion

The conclusions can be structured on some relevant directions as follows:
1: A feasibility study is necessary to define the scope of best processes, institutional responsibilities and resource requirements for the implementation of a Comprehensive Inland Navigation Database for the new inland waterway.
2: Financial experts are commissioned to design a detailed financial investigation of the needs and funding sources of the inland waterway navigation infrastructure, including provincial, national and trans-border uses and sources of funds; quantify the long-term need and case for national and provincial budgetary financial support for every country.
3: The performance of countries' navigation authorities should be considered as a matter of the importance to the long-term sustainability of the inland waterway transport; their performance in terms of financial and operational records should be gradually improved to enable monitoring and comparisons of the value for money in the use of funds; the navigation authorities should be encouraged to undertake the pilot programs of the competitive maintenance procurement (including both specification-based and/or performance-based dredging and other maintenance contracts).
4: High priority is to be given to implementing the EU transport policy objectives, including for non-EU countries.
5: The navigation authorities from Romania, Ukraine, Moldova and Poland must continue to contribute actively to the inter-departmental consultations and planning of the water resources to ensure that the interests of the inland waterway transport are positively and comprehensively represented in decisions, policies and projects that may have an impact on the inland waterway transport industry; and similarly that the channels of communication with all stakeholders in the transport services industry, and with major freight shippers, are kept active and harmonious.
6: The port reform policies need to encourage more diverse participation and investment, and higher private participation in the specific terminals and competition in the port services where feasible.
7: The participant countries need to investigate how the market reach of the inland waterway transport can be expanded by improving the infrastructure and operational interfaces between the seaports and inland waterway transport and by improving inter-modal access at river ports, where such connections may be shown to be economically desirable.

8: The participant countries will prepare and disseminate the guidance to the inland waterway transport ports and operators about the importance of harmonious relationships with the local communities, the need for compliance with prevailing environmental standards, and practical measures that can be taken for the inland waterway transport activities to become a better 'neighbour' to others who live and work alongside rivers.
9: Market-based policies existing today for the barge transport services industry will be retained in which the competition is encouraged, industry capacity quotas and tariff regulations are avoided, and standards-based regulation is retained to ensure the navigational competence, safety and environmental performance.
10: The navigation authorities from Romania, Ukraine, Moldova and Poland must consider the case for the progressive introduction of vessel engine efficiency and emissions standards while increasing their efforts to ensure by the provincial navigation authorities comply with all EU environmental, safety and competency standards for vessels and crews.
11: Long-term policies for the sustainable development of the inland waterway transport industry should explicitly contain the mitigation measures for those small entrepreneurs, property owners, barge operators, who may be adversely affected by the modernization process.

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ON A RIVER-COSTAL TUG OPERATION SAFETY ASSESSMENT IN IRREGULAR WAVES

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Abstract: For inland and costal harbours cargo transport and special operations between the shipyards, a specific type of tug has been designed to cover the river-costal routes. One of the design criteria for the tug operation safety assessment is based on the seakeeping analysis in irregular waves. As study case we have analysed the behaviour of a river-costal tug with 48 m total length, one loading condition. The design route includes the connection between the Romanian harbours and shipyards, at the Danube River and at the Black Sea Coast. According to the navigation scenario in irregular waves, the statistical significant wave height limits are considered with maximum levels on the river route 2 m and on the costal route 4 m. The extreme condition of 5 m irregular wave significant height is also considered. The numerical analysis is done using the eigen program DYN, modules for seakeeping (OSC), with two main steps: response amplitude operators and statistical significant response in irregular wave's computation. The analysis is developed considering: speed range 0-20 km/h, wave significant height range 0-5 m and heading angle range 0-360 deg. This study analyzes the river-costal tug navigation capabilities on inland and costal waterways, by the design seakeeping safety criteria.

Keywords: river-costal tug, irregular waves, safety operation on inland and costal waterways, design seakeeping criteria.

1. Introduction

For the Romanian inland and costal waterways transport, one of the most used navigation route is between the harbours and shipyards at the Danube River and those at the Black Sea Coast (Figure 4). Besides the standard cargo transport with barge convoys, special operations as floating docks or ship construction blocks relocation between the shipyards have to be done. For this purpose, several river-costal tugs have been designed (ANR, 2006), that have to navigate also in irregular wave conditions. Among many design criteria by shipbuilding rules (DNVGL, 2018), the tug navigation operations (DNV, 2014) have to be assessed by the seakeeping safety criteria. This study is focused on the seakeeping analysis of a Romanian river-costal tug for the navigation safety assessment, under several wave conditions.

2. The Seakeeping Analysis Method

The seakeeping analysis method is based on a linear strip hydrodynamic theory for response amplitude operators *RAO* computation (Söding, 1982; Voitkunski, 1985; Domnisoru, 2001; Kornev, 2012) and the short-term statistical response prediction in irregular waves' theory (Price and Bishop, 1974; Bertram, 2000; Lewandowski, 2004, DNV, 2014).
For the numerical seakeeping analysis we have used the eigen program DYN (Domnisoru, 2017), with the logical scheme presented in Figure 1, with five main modules. The last version of the DYN program has been validated by towing tank experimental data, including head, beam and follow sea cases (Obreja et al, 2017).
Module 1 includes the pre-processing of the input ship data: CAD model of the external shape, mass diagram, hydrostatic curves, still water equilibrium position and transversal stability diagrams. Also, the ship's speed range and the irregular waves' characteristics are selected.
Module 2 includes the computation of the hydrodynamic radiation, inertial and damping, terms of the motion equations system, by a 2D potential flow model, where the ship's stations are parameterized by a conformal transformation (Voitkunski, 1985; Domnisoru, 2001), being constant in time and taking as reference the ship's still water position. Also, the hydrostatic term is computed, using a linearized formulation. The hydrodynamic diffraction term is computed for a regular wave excitation with unit amplitude.
Module 3 includes the computation of the response amplitude operators *RAO*, by solving in the frequency domain the motions equation system for regular wave with unit amplitude. There are considered the following parameters: the wave circular frequency in the range ω=0-3 rad/s, with step 0.001 rad/s; ship-wave heading angle in the range μ=0-360 deg., with step 5 deg.; tug speed values v=0, 5, 6, 10, 12, 15, 18, 20 km/h. For the river-costal tug the motions on heave, pitch and roll are analyzed.
Module 4 includes the computation of the short-term statistical most probable *RMS* motions and RMS_{ac} accelerations for a selected irregular waves' power density spectrum. At the Black Sea area, for many years the sea state has been recorded, including also several extreme storms (Rusu et al, 2014). For the Romanian Black Sea Coast the long-term wave significant height histogram is presented in Figure 6, with the occurrence probability of 99,5% of the waves in the range of H_s=0-4 m. Figure 5 presents the Black Sea Romanian Costal average wave power density spectrum $\Phi_w(\omega)$.
Module 5 includes the computation of the admissible polar diagrams for the navigation safety, expressed in terms of limit significant wave height $H_{slimit}(v,\mu)$ and Beaufort level $B_{limit}(v,\mu)$. The polar diagrams are obtained by the seakeeping criteria, formulated as most probable admissible values, applied for: vertical motion at aft, mid and fore; pitch and roll motion; heave, pitch and roll accelerations. For the navigation capabilities assessment of the river-costal tug the following limit significant wave height levels are considered: on the river route IN 0.6, 1.2, 2 m and on the costal route C 2.5, 3, 4 m.

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Seakeeping Analysis / Package code DYN – modules OSC

Module 1
- Input data: ship shape and mass, speed range, wave's characteristics
- Computation of ship still water equilibrium position
- Computation of the transversal stability diagrams

Iterations on ship speed range $v = v_{min} \div v_{max}$
and on ship-wave heading angle $\mu = 0 \div 360\, deg$.

Module 2
Computation of the terms of the time domain motion equations system for regular wave with unit amplitude $a_w = 1$ and a range of circular frequencies $\omega = 0 \div \omega_{max}$.

$$([M]+[A(\omega_e)])\{\ddot{Q}(t)\}+[B(\omega_e)]\{\dot{Q}(t)\}+[C(\omega_e)]\{Q(t)\}=\{\overline{F}_w(\omega_e)\}e^{-i\,\omega_e t}\,;\ \{Q(t)\}=\{\overline{Q}(\omega_e)\}e^{-i\cdot\omega_e t}\,;\ \omega_e=\omega-\omega^2/g\ v\cos\mu$$

- the ship's own mass matrix: $[M]$;
- hydrodynamic radiation (inertial and damping) and hydrostatic matrix: $[A(\omega_e)],[B(\omega_e)],[C(\omega_e)]$;
- hydrodynamic diffraction vector from the regular wave excitation: $\{\overline{F}_w(\omega_e)\}$;

where: g is the gravity acceleration, ω_e is the ship-wave encountering frequency, $\{\overline{Q}(\omega_e)\}$ is the motion amplitude.

Module 3
Computation of response amplitude operators RAO_j for j motion components, solving in the frequency domain the motions equation system for regular waves $a_w = 1$ and $\omega = 0 \div \omega_{max}$.

$$\{\overline{Q}\}=[D(\omega_e)]^{-1}\{\overline{F}_w\};\quad \{\overline{Q}\}=\{Q_1\}+i\,\{Q_2\};\quad [D(\omega_e)]=-\omega_e^2([M]+[A(\omega_e)])-i\,\omega_e[B(\omega_e)]+[C(\omega_e)]$$

$$RAO_j(v,\omega,\mu)\big|_{load\ case}=\sqrt{Q_{1j}^2+Q_{2j}^2}$$

Module 4
Computation for each response component j the short-term statistical most probable motion RMS_j and acceleration $RMS_{ac\,j}$ values for irregular waves with power density spectrum $\Phi_w(\omega_e)$.

$$\Phi_j(\omega_e)=RAO_j^2\cdot\Phi_w(\omega_e);\ m_{0j}=\int_0^\infty \Phi_j(\omega_e)d\omega_e\,;\ m_{4j}=\int_0^\infty \omega_e^4\Phi_j(\omega_e)d\omega_e\,;\ RMS_j=\sqrt{m_{0j}}\,;\ RMS_{ac\,j}=\sqrt{m_{4j}}$$

Module 5
Computation of the admissible polar diagrams in terms of limits for significant wave height $H_{s\,limit}(v,\mu)\big|_{load\ case}$ and Beaufort level $B_{limit}(v,\mu)\big|_{load\ case}$, by the seakeeping criteria on the main ship's dynamic components.
- vertical motion at aft, mid and fore, by combination of heave, pitch and roll motions most probable values:

$$RMS_z\big|_{aft,fore}=RMS_\xi+RMS_\theta(L/2\pm LCF)+RMS_\varphi\,B/2+H_s/4\,;\ RMS_z\big|_{mid}=RMS_\xi+RMS_\varphi\,B/2+H_s/4$$

$$RMS_{z\,max}\big|_{aft,mid,fore}=H_{aft,mid,fore}-F_s-T_{aft,mid,fore}\ge RMS_z\big|_{aft,mid,fore}\ ;\ RMS_{\zeta ac\,max}=0.1g\ge RMS_{\zeta ac}$$

- pitch motion most probable values:

$$RMS_{\theta\,max}=3\,deg.\ge RMS_\theta\ ;\ RMS_{\theta ac\,max}=max\{0.15g/(L/2\pm LCF)\}\ge RMS_{\theta ac}$$

- roll motion most probable values:

$$RMS_{\varphi\,max}=8\,deg.\ge RMS_\varphi\ ;\ RMS_{\varphi ac\,max}=0.1g\cdot 2/B\ge RMS_{\varphi ac}$$

Plot diagrams: $RAO_j(v,\omega,\mu)\big|_{load\ case}$ and $H_{s\,limit}(v,\mu)\big|_{load\ case}$ & $B_{limit}(v,\mu)\big|_{load\ case}$ / END DYN

Fig. 1.
The logical scheme of program DYN - modules OSC (Domnisoru, 2017) for ship's short-term seakeeping analysis

3. The River-Costal Tug Numerical Model

The numerical seakeeping analysis is developed for a Romanian river-costal 4000 HP tug with the main characteristics presented in Table 1 and the offset-lines presented in Figure 2. The tug hull numerical model has 83 stations, with finer division at both extremities. Figure 3 presents the computed tug righting lever curve. The tug has a significant transversal stability, making possible to linearize the roll restoring term over more than 15 deg. roll angle.

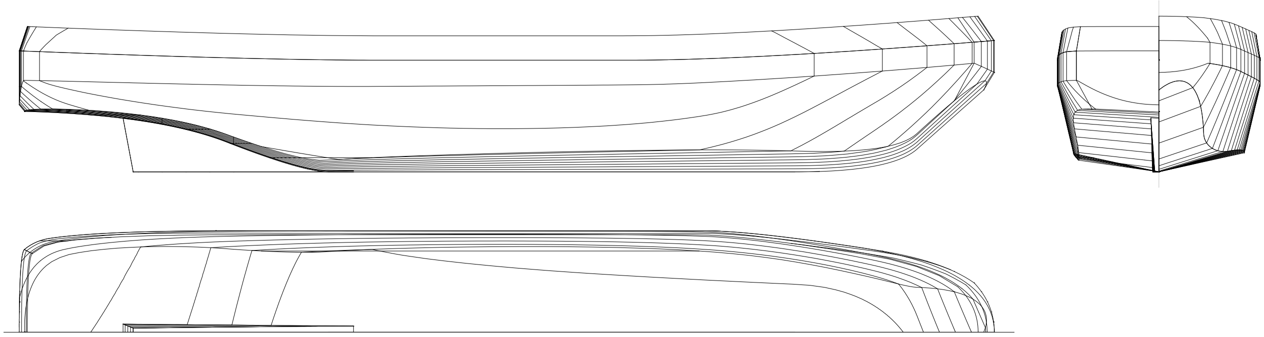

Fig. 2.
The offset-lines of the river-costal 4000 HP tug
Source: (Dragomir, 2014)

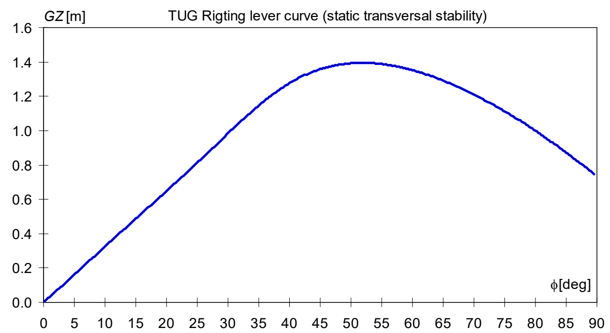

Fig. 3.
GZ[m] tug transversal stability diagram

Fig. 4.
Danube River and Black Sea Romanian harbours
Source: (http://ro.wikipedia.org)

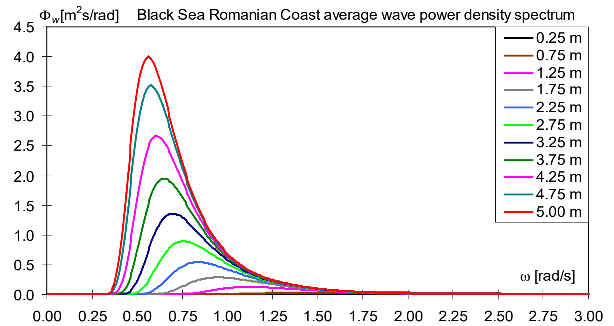

Fig. 5.
Black Sea Romanian Costal average wave spectrum $\Phi_w(\omega)$
Source: (Gasparotti, 2015)

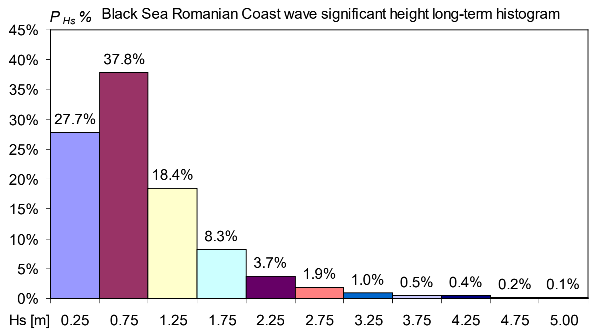

Fig. 6.
Black Sea Romanian Costal H_s long-term histogram $P_{Hs}\%$
Source: (Gasparotti, 2015)

Table 1
The main characteristics of the river-costal tug numerical model

Length overall*	L_{OA}[m]	48	Main propulsion*	MP[HP]	4000	Inertial mass moment	$J_x[tm^2]$	11102
Length of waterline*	L_{WL}[m]	47	Bollard pull*	BP[kN]	539	Metacentre height	GMT_0[m]	1.8385
Breadth maximum*	B[m]	10	Maximum speed*	v[km/h]	20	GZ max. ref. angle	φ_{GZ}[deg]	51
Breadth max of WL	B_{WL}[m]	9.604	Volumetric displacement	∇[m^3]	919.45	Heave natural period	T_ζ[s]	4.525
Height aft*	H_{aft}[m]	7.15	Long.centre gravity *(mid ref.)*	LCG[m]	1.1079	Pitch natural period	T_θ[s]	4.657
Height midship*	H_{mid}[m]	6.35	Vertical centre of gravity	KG[m]	3.35	Roll natural period	T_φ[s]	6.032
Height fore*	H_{fore}[m]	7.75	Long.centre of WL *(mid.ref.)*	LCF[m]	-1.447	Water density	ρ[t/m^3]	1-1.025
Free board safety**	F_s[m]	0.3	Vertical centre of buoyancy	KB[m]	2.1371	Number of elements	NEL	83
Draught aft,mid,fore	$T_{a,m,f}$[m]	3.5	Block coefficient	c_B	0.582	Average element size	d_x[m]	0.5875

*Source: *(Dragomir, 2014); **(DNVGL, 2018)*

4. The Response Amplitude Operators of the River-Costal Tug

For the river-costal tug (Figure 2, Table 1) the response amplitude operators on heave, pitch and roll motions are obtained, by program DYN (Figure 1) modules 2 and 3.

Figures 7.a,b and Figures 8.a,b present the heave and pitch *RAO* for the speed 0 and 20 km/h, heading angle 0, 45, 90, 135, 180 deg. Figures 7.c,d and Figures 8.c,d present the heave and pitch *RAO* for heading angle 90, 180 deg. and the full range of tug speed 0 – 20 km/h.

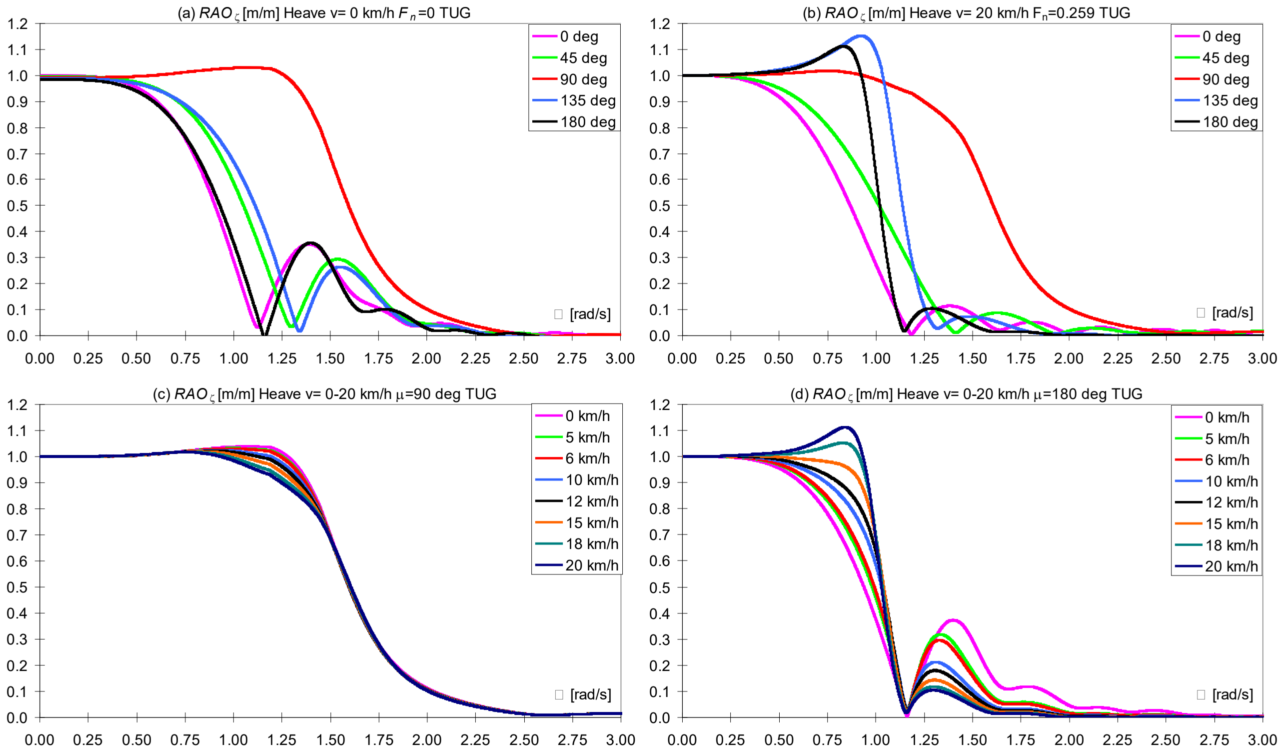

Fig. 7.

RAO_ζ[m/m] heave : a) v=0 km/h; b) v=20 km/h; c) v=0-20 km/h μ=90 deg; d) v=0-20 km/h μ=180 deg

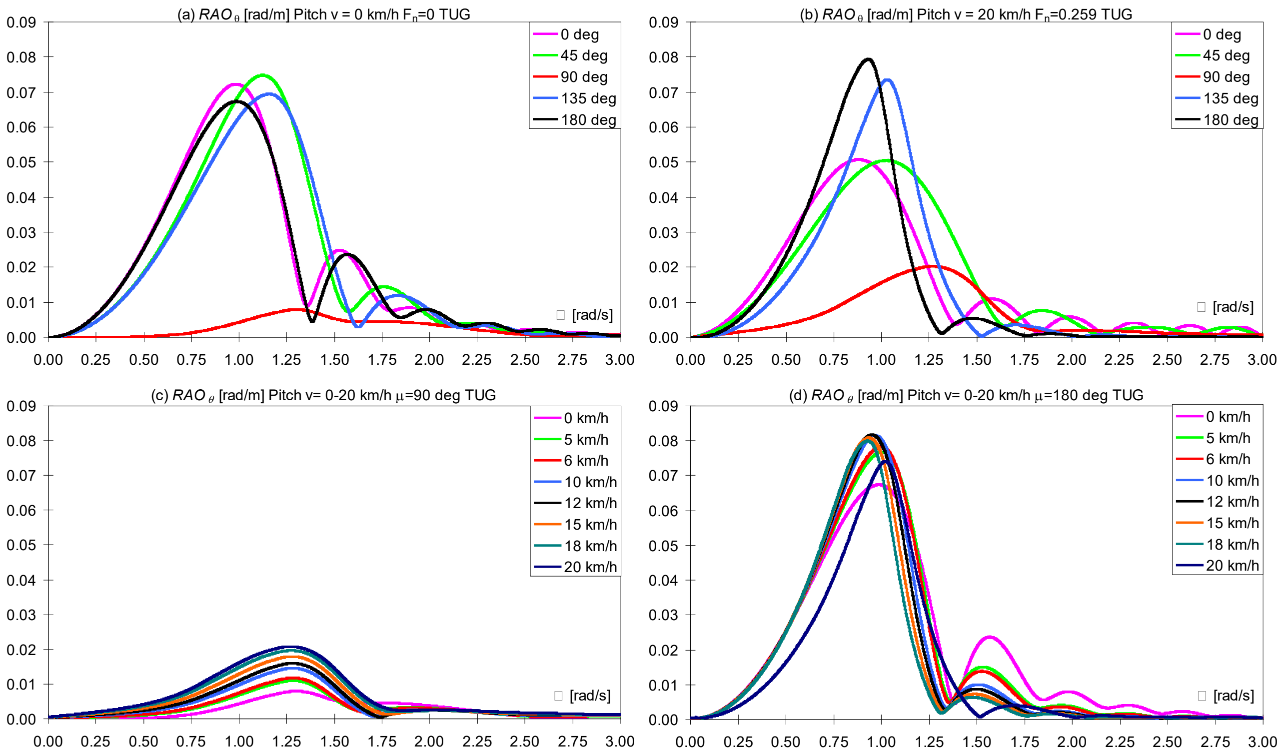

Fig. 8.

RAO_θ[rad/m] pitch : a) v=0 km/h; b) v=20 km/h; c) v=0-20 km/h μ=90 deg; d) v=0-20 km/h μ=180 deg

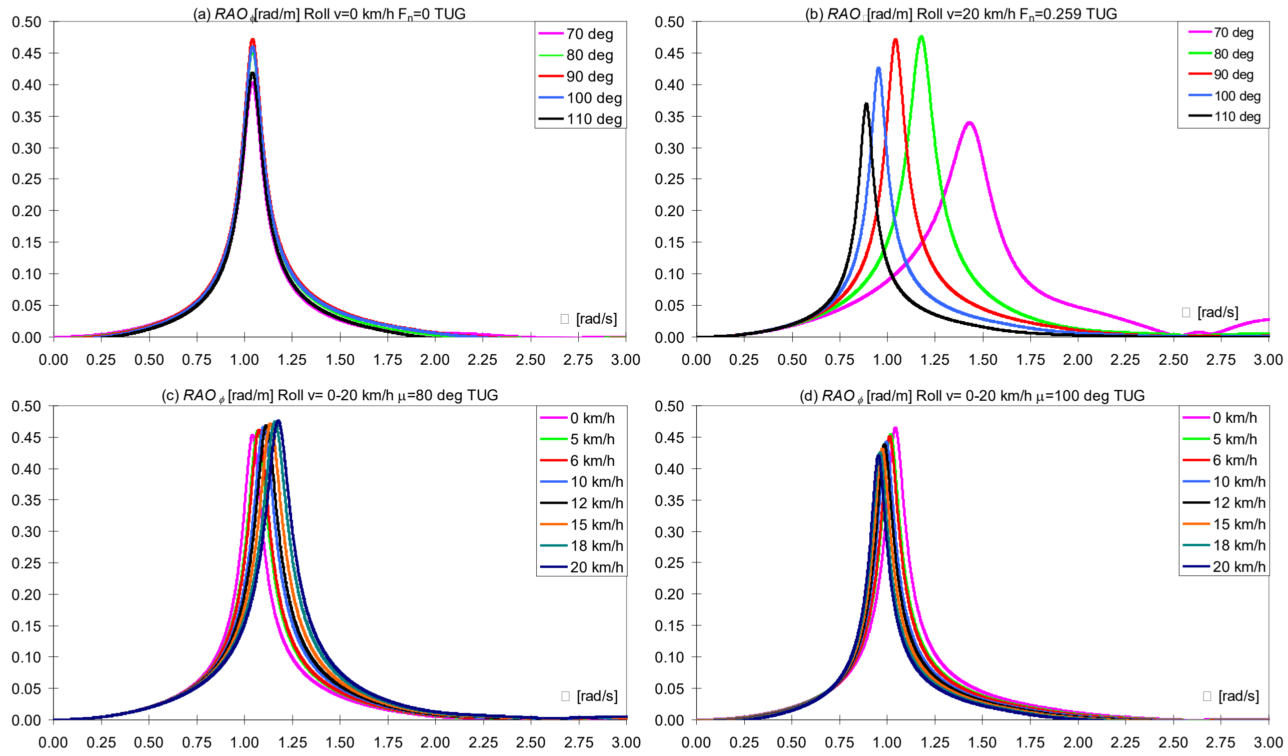

Fig. 9.

RAO_{φ}[rad/m] roll : a) v=0 km/h; b) v=20 km/h; c) v=0-20 km/h μ=80 deg; d) v=0-20 km/h μ=100 deg

For beam sea condition (90 deg.) the tug speed influence on heave and pitch *RAO*’s is very reduced. For head waves condition (180 deg.) the tug speed influence on heave and pitch *RAO*’s is significant.
Figures 9.a,b present the roll *RAO* for the speed 0 and 20 km/h, heading angle 70, 80, 90, 100, 110 deg. Figures 9.c,d present the roll *RAO* for heading angle 80, 100 deg. and the full range of tug speed 0 – 20 km/h.
Although for 90 deg. heading angle the tug speed has no influence on roll *RAO*, in the range of 70-110 deg. the speed influence occurs.

5. The Statistical Short-Term Response of the River-Costal Tug

For the river-costal tug (Figure 2, Table 1) the statistical most probable response *RMS* on heave, pitch, roll motions and accelerations are obtained, by DYN program (Figure 1) modules 4 and 5, using the *RAO’s* function from Section 4 and the irregular waves with the power density spectrum from Figure 5. Based on the significant wave height histogram (Figure 6), the waves' probability of occurrence and exceeding are predicted.
For the vertical motion there are considered three reference points, aft-side, mid-side, fore-side, so that a combined heave, pitch and roll motions criteria is applied. Due to the non-symmetric hull at amidships reference, we have considered the maximum between aft and fore vertical pitch induced accelerations.
Figures 10.a,b,c present the maximum statistical most probable response for combined vertical motions.
Figure 11.a and Figure 12.a present the maximum statistical most probable response for pitch and roll motions.
Figure 10.d, Figure 11.b and Figure 12.b present the maximum statistical most probable response for heave, pitch and roll accelerations.
Considering the tug speed 0 and 20 km/h, for the extreme sea state condition H_s=5m with 0.1% probability of occurrence (Figure 6), Table 2 presents the maximum maximorum most probable tug motions and accelerations. Also, the admissible values for the seakeeping criteria (Figure 1, module 5) of the river-costal tug are presented in Table 2.
The highest speed influence is on heave and pitch accelerations, medium on heave and pitch motions and very reduced on roll motions and accelerations. Vertical aft and fore motions, heave acceleration, pitch motion and acceleration have the maximum values in head waves conditions. Vertical midship motion, roll motion and accelerations have maximum values in beam sea conditions. The highest overcome is recorded on the pitch acceleration criteria, by 39.49%.
Figures 13.a,b and Figures 14.a,b present the polar diagrams for navigation safety in terms of wave significant height $H_{s\ limit}(v,\mu)$ and Beaufort level $B_{limit}(v,\mu)$ for the river-costal tug, by the seakeeping criteria from Figure 1, module 5.
Considering the main heading angles reference, follow and quarter-stern sea condition (0-45 deg), beam and quarter sea condition (70-110 deg.), head and quarter-bow sea condition (135-180 deg.), Table 3 presents the resulting sea state level limits for tug navigation safety and Table 4 presents the seakeeping criteria leading to restrictions. For the inland waterway there are no restrictions IN(2.0). For the coastal waterway, for the speed range 0-6 km/h the main restrictions occur at beam sea condition C(3.80) and in the speed range 10-20 km/h the main restrictions occur at head and quarter-bow sea condition C(3.67) – C(2.41).

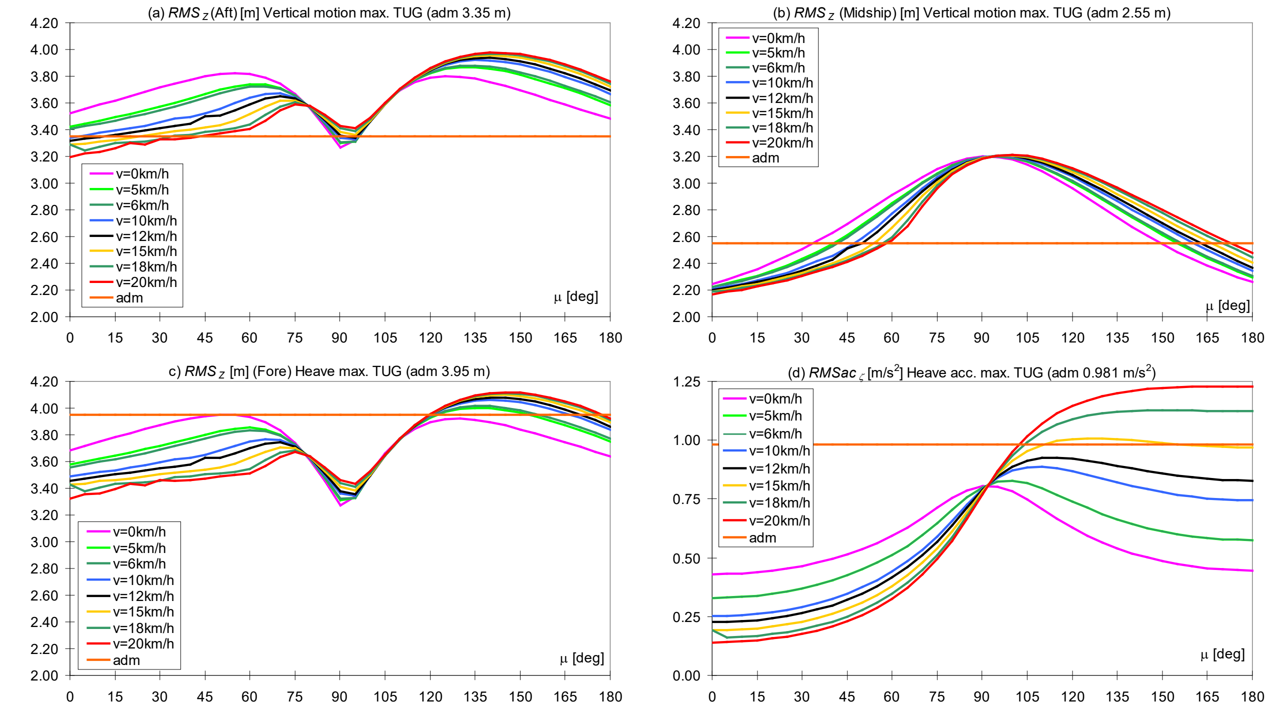

Fig. 10.

Maximum most probable RMS_z [m] vertical motion a) aft; b) midship; c) fore and d) $RMSac_\zeta$ [m/s^2] heave acceleration

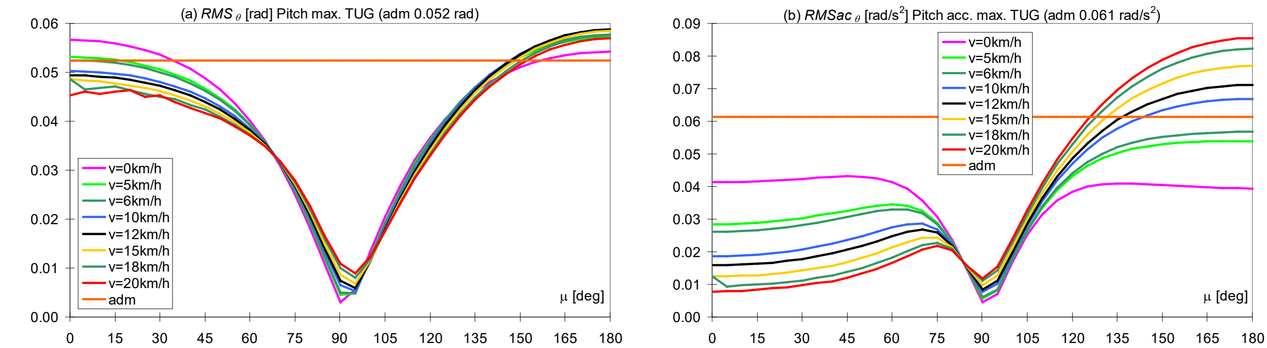

Fig. 11.

Maximum most probable a) RMS_θ [rad] pitch motion; b) $RMSac_\theta$ [rad/s^2] pitch acceleration

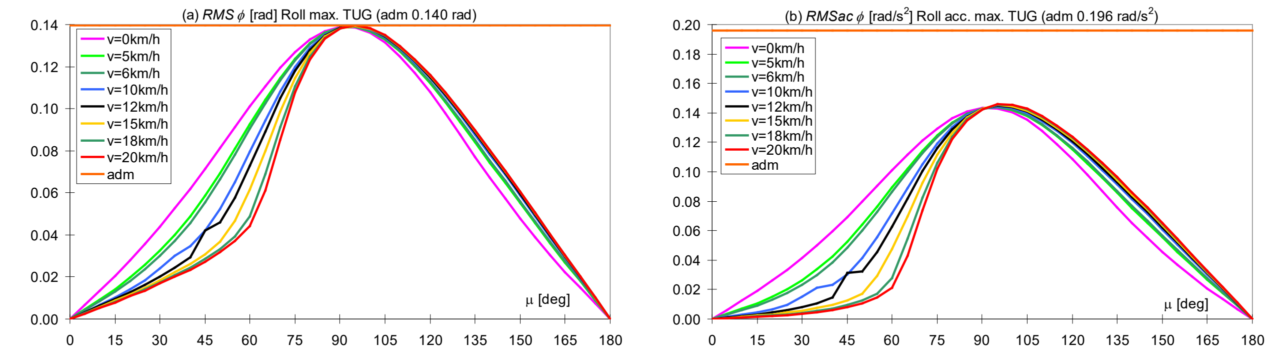

Fig. 12.

Maximum most probable a) RMS_φ [rad] roll motion; b) $RMSac_\varphi$ [rad/s^2] roll acceleration

Table 2

The maximum maximorum most probable values of the tug motions and accelerations, taking as reference H_s=5m

v[km/h]	$RMS_{z\,aft}$[m]	$RMS_{z\,mid}$[m]	$RMS_{z\,fore}$[m]	RMS_θ[rad]	RMS_φ[rad]	$RMSac_\zeta$[m/s^2]	$RMSac_\theta$[rad/s^2]	$RMSac_\varphi$[rad/s^2]
adm	3.350	2.550	3.950	0.052	0.140	0.981	0.061	0.196
0	3.822	3.199	3.949	0.0566	0.1388	0.804	0.043	0.143
	14.08%	25.44%	-0.03%	8.12%	-0.58%	-18.00%	-29.65%	-26.95%
20	3.976	3.214	4.118	0.0570	0.1397	1.229	0.086	0.146
	18.69%	26.03%	4.26%	8.79%	-0.002%	25.32%	39.49%	-25.68%

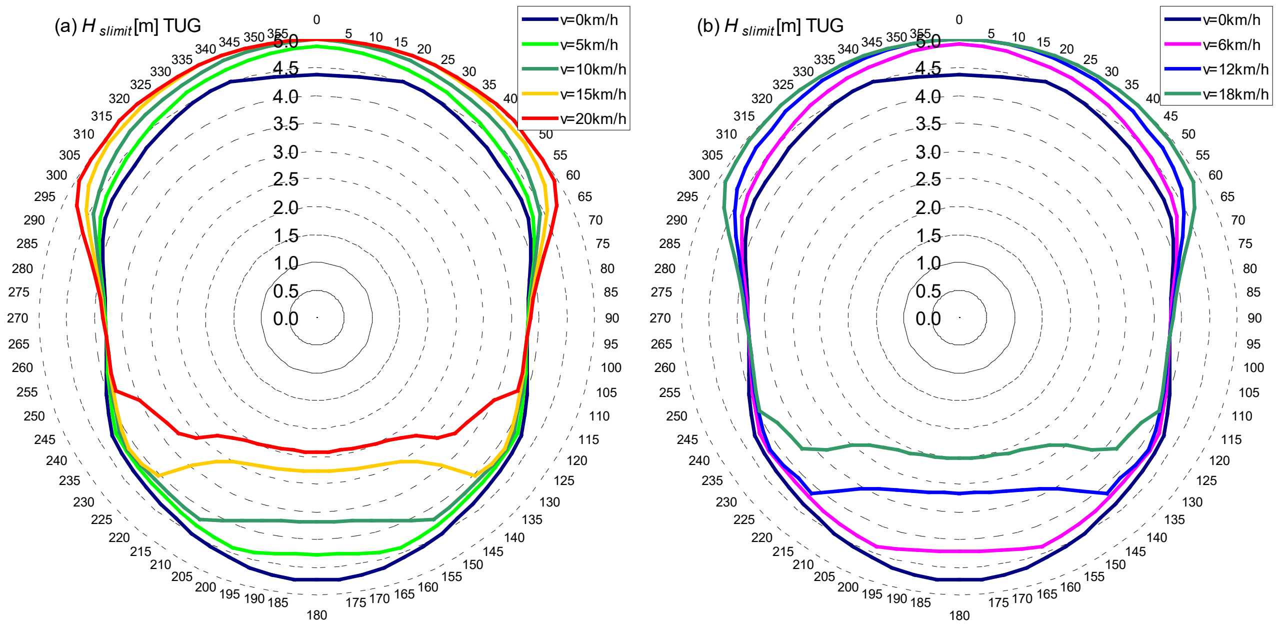

Fig. 13.
Polar diagrams on significant wave height $H_{s\,limit}(v,\mu)$ [m], μ=0-360 deg, a) v=0,5,10,15,20 km/h; b) v=0,6,12,18 km/h

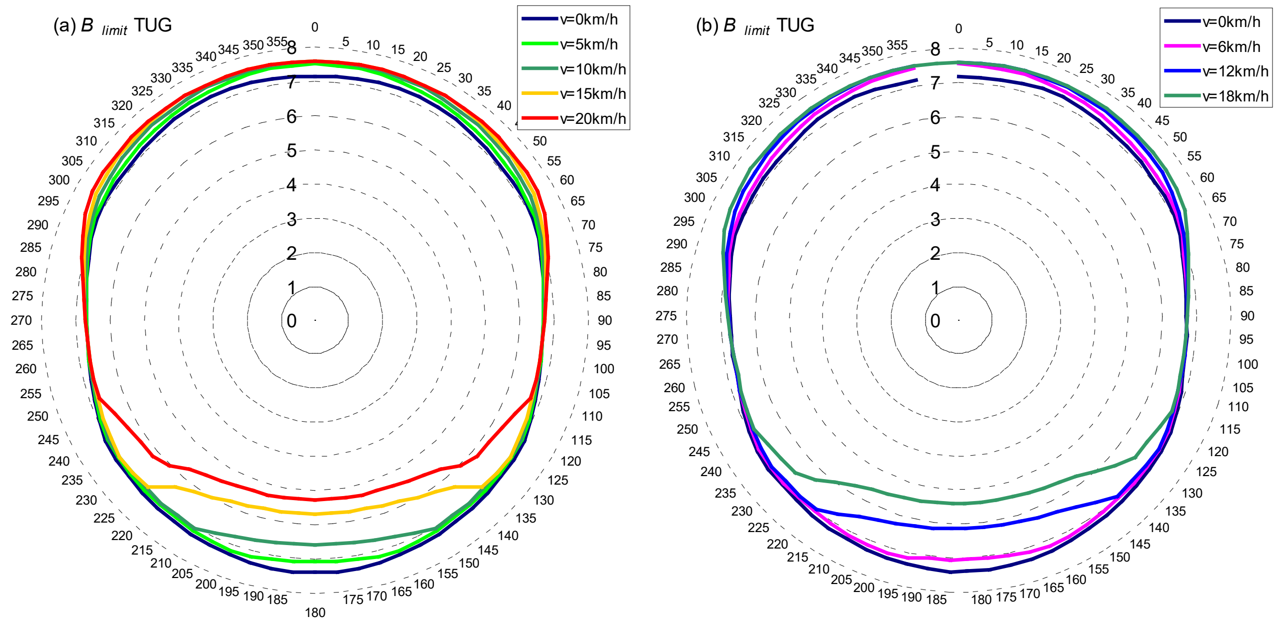

Fig. 14.
Polar diagrams on Beaufort level $B_{limit}(v,\mu)$, μ=0-360 deg, a) v=0,5,10,15,20 km/h; b) v=0,6,12,18 km/h

Table 3
The significant wave height $H_{s\,limit}$[m] and Beaufort level B_{limit} limits for the tug safety navigation

v[km/h]		**0**		**5**		**6**		**10**		**12**		**15**		**18**		**20**	
μ[deg]		$H_{s\,limit}$	B_{limit}	$H_{s\,limit}$	B_{limit}	$H_{s\,limit}$	B_{limit}	$H_{s\,limit}$	B_{limit}	$H_{s\,limit}$	B_{limit}	$H_{s\,limit}$	B_{limit}	$H_{s\,limit}$	B_{limit}	$H_{s\,limit}$	B_{limit}
0		4.356	7.15	4.878	7.51	4.916	7.53	5.000	7.59	5.000	7.59	5.000	7.59	5.000	7.59	5.000	7.59
45		4.296	7.11	4.497	7.25	4.542	7.28	4.725	7.40	4.760	7.43	4.897	7.52	4.951	7.56	4.995	7.59
70		4.079	6.95	4.145	7.00	4.159	7.01	4.225	7.06	4.263	7.08	4.329	7.13	4.410	7.19	4.473	7.23
90		3.789	6.69	3.799	6.70	3.800	6.70	3.807	6.70	3.811	6.71	3.817	6.71	3.825	6.72	3.830	6.73
110		3.994	6.87	3.948	6.83	3.940	6.82	3.910	6.80	3.897	6.78	3.881	6.77	3.867	6.76	3.838	6.73
135		4.317	7.12	4.188	7.03	4.170	7.02	4.113	6.98	4.095	6.96	4.031	6.90	3.343	6.29	3.049	6.03
180		4.705	7.39	4.257	7.08	4.196	7.04	3.675	6.59	3.159	6.13	2.752	5.68	2.521	5.39	2.413	5.26
limit	inland	IN(2.0)		IN(2.0)		IN(2.0)		IN(2.0)		IN(2.0)		IN(2.0)		IN(2.0)		IN(2.0)	
	0-45	C(4.29)		C(4.49)		C(4.54)		C(4.72)		C(4.76)		C(4.89)		C(4.95)		C(4.99)	
	70-110	**C(3.79)**		**C(3.80)**		**C(3.80)**		C(3.81)		C(3.81)		C(3.82)		C(3.82)		C(3.83)	
	135-180	C(4.32)		C(4.18)		C(4.17)		**C(3.67)**		**C(3.15)**		**C(2.75)**		**C(2.52)**		**C(2.41)**	

Table 4
The seakeeping criteria leading to navigation restrictions for the river-costal tug
F-Q follow and quarter-stern sea; B-Q beam and quarter sea; H-Q head and quarter-bow sea
v.a,m,f.m – vertical aft, midhsip, fore motion; p.m –pitch motion; h.a – heave acceleration; p.a – pitch acceleration

v[km/h]	F-Q	B-Q	H-Q	*v*[km/h]	F-Q	B-Q	H-Q
0	v.a.m ; p.m	v.a.m ; v.m.m	v.a.m ; p.m	12	v.a.m	v.a.m ; v.m.m	v.a.m; v.m.m; v.f.m; p.m; p.a
5	v.a.m ; p.m	v.a.m ; v.m.m	v.a.m ; p.m	15	v.a.m	v.a.m ; v.m.m	v.a.m; v.m.m;v.f.m; h.a; p.m; p.a
6	v.a.m ; p.m	v.a.m ; v.m.m	v.a.m ; p.m	18	v.a.m	v.a.m ; v.m.m	v.a.m; v.m.m;v.f.m; h.a; p.m; p.a
10	v.a.m	v.a.m ; v.m.m	v.a.m ; p.m; p.a	20	v.a.m	v.a.m ; v.m.m	v.a.m; v.m.m;v.f.m; h.a; p.m; p.a

6. Conclusion

The operation safety of a river-costal 4000 HP tug (Figure 2 and Figure 3, Table 1) has been analyzed by eigen program DYN (Figure 1), with seakeeping criteria formulated on the main motions and accelerations, heave, pitch and roll (module 5, Figure 1) and irregular waves specific to the river-costal navigation route (Figure 4), from the Danube River (H_s≤2m) to the Black Sea Coast (H_s≤5m), (Figure 5 and Figure 6).
The analysis of the response amplitude operators *RAO* (Figures 7,8,9.a,b,c,d) points out that the tug speed changes in the range of 0-20 km/h lead to the increase of the heave and pitch motions at head sea condition. At beam sea condition, for the tug main motions the speed influence becomes much reduced. Taking as reference the extreme condition of the irregular waves with significant height H_s=5m on the Black Sea Coast (Figures 5,6), for the tug speed changes in the range of 0-20 km/h, the maximum most probable *RMS* values (Figures 10,11,12) exceed the admissible seakeeping criteria (Table 2) as following: vertical combined motions aft 14.08-18.69%, midship 25.44-26.03%, fore max. 4.26%; pitch motion 8.12-8.79%; heave acceleration max. 25.32%; pitch acceleration 39.49%. The tug roll motion and acceleration are in the limits of the seakeeping criteria, due to the significant transversal stability (Figure 3). Based on the tug speed influence on *RAO*'s functions and the maximum statistical most probable responses, the seakeeping criteria that lead to restrictions for the river-costal tug navigations are indentified (Table 4). Taking as reference the navigation safety polar diagrams H_{slimit}, B_{limit} (Figure 13 and Figure 14, Table 3) for Danube River waterway the tug has no navigation restrictions, H_{slimit}=2m. For Black Sea Coast waterway, for the tug speed range 0-10 km/h the navigation restriction is H_{slimit}=3.67-3.80m, close to the H_s=4m limit, B_{limit}=6.70, with the exceeding probability $P[H_s>3.80\text{m}]\approx 0.9\%$, and for the tug speed range 12-20 km/h the restriction is H_{slimit}=2.41-3.15m, B_{limit}=5.26-6.13, with the exceeding probability $P[H_s>2.41\text{m}]\approx 4.8\%$. It results that in order to ensure the 4000 HP tug navigation safety on the costal waterways, the tug speed should be reduced bellow 10 km/h, according to the sea state conditions.

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AN APPROACH FOR OPTIMIZING FERRY PASSENGER FLEET SIZE

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Abstract: Passenger ports are providing maritime services that are necessary to satisfy the demands of the users and serve also to provide a direct service instead of using road connections in the narrow places. Here, a model for optimizing the size of a ferry fleet in a passenger port is proposed. The model is done in the case of the Boka Kotorska Bay where there is an intensive need to provide a ferry service of passengers at the proposed routes. The numerical experiment includes the heterogenous fleet in transport capacities. Here, the possibility to transfer passengers inside the bay is of utmost importance especially during the summer peak season. In addition, the analysis also reports the environmental aspects in the sense of emission estimation that affects the inhabitants located at the coast of the bay. However, this paper represents one of the initiatives to improve the ferry passenger service in the area.

Keywords: passenger port, analysis, model, ferry service.

1. Introduction and Related Literature

Investigations about the ship fleet size have been investigated a lot in the previous period. In this paper, we pay attention to the ferry passenger service necessary to transport local inhabitants and tourist to the appropriate locations similarly as done in Škurić and Maraš (2017). We combine the estimation of emission produced from the ferry ships and calculate the level of NO_X, SO_2 and PM that are recognized as ones of the biggest air pollutants. The investigation of emission inventories represents a very important aspect of the environmental protection of the coast. Generally, together with cruise ships, ferry ships are treated to be significant polluters in the passenger ports. To calculate the level of emissions, it is necessary to analyze the effects of the transport of ferry ships, which are primarily related to their engines. Despite the fact that diesel engines achieved fuel efficiency in consumption, they are still not insignificant source of emissions of NO_X, SO_2 and PM. By combining propulsion characteristics of ferry passenger ships, the aim is to point out their differences and the possibilities for reducing emissions through the optimal allocation of the fleet. Regarding the calculation of emission from ferry passenger ships, it should be noticed some assumptions regarding the navigational characteristics of the area. Winebrake et al. (2005) applied MIP in the case of New York and New Jersey passenger ports for calculating NO_X and PM. Some of the important investigations are done by Saxe and Larsen (2004) and De Meyer et al. (2008) that calculated emission for Dannish and Belgian ports. On the other hand, one of the most important studies for passenger ports are done by Cooper and Andreasson (1999), Cooper (2001), Corbett and Farrell (2002) and Tzannatos (2010a,b). Similar methodology has been used in Chang and Wang (2012) where authors compared the techno-economic effectivity of the ships at the Port of Kaohsiung. The cruise ship emission inventories are described and reported in Dragović et al. (2015) and the cases of Dubrovnik and Kotor cruise ports. Ship-activity phases in ports from the perspective of calculating emission inventories are presented in McArthur and Osland (2013), Castells Sanabra et al. (2014), Song (2014), Maragkogianni and Papaefthimiou (2015) and Tichavska and Tovar (2015a,b).
However, the analysis provided in this paper comprehends modeling the optimal ferry passenger fleet size in the case of minimizing the level of emission from the ferry ships. The structure of the paper is as follows. In Section 2 is provided the integer linear model formulation. Numerical experiment is described and validated in Section 3 while Section 4 reports the results obtained from the case study. Section 5 gives concluding remarks.

2. Model Description

In this section, we describe the model and input data for calculating emission level from ferry ships. It also includes the model formulation in the case of minimizing the emission inventories. Such study has been previously done in Dragović et al. (2015) for the cruise ships. The methodology provided in initial emission calculation is accepted from mentioned study.
Like in many other papers, in the case of ferry ships, the role of main and auxiliary engines is necessary to calculate the emission. These engines are characterized to be diesel and the load factor of auxiliary engines is accepted to be 43% according to the analyses provided by ENTEC (2002), CARB (2004) and ICF (2009). Additionally, the load factor of main engines is 45%. In the case of transporting passengers in Boka Kotorska Bay (Figure 1), ferry ships are passing through three different phases: reduced speed zone with the speed limit of 12 knots, maneuvering while approaching the port and berthing or anchoring. The data with regards to the load factor for each ship-activity phase are given in Table 1. Similarly, in Table 2 are given emission factors for each ship-activity phase and in accordance to the different air polluters (CARB, 2004).

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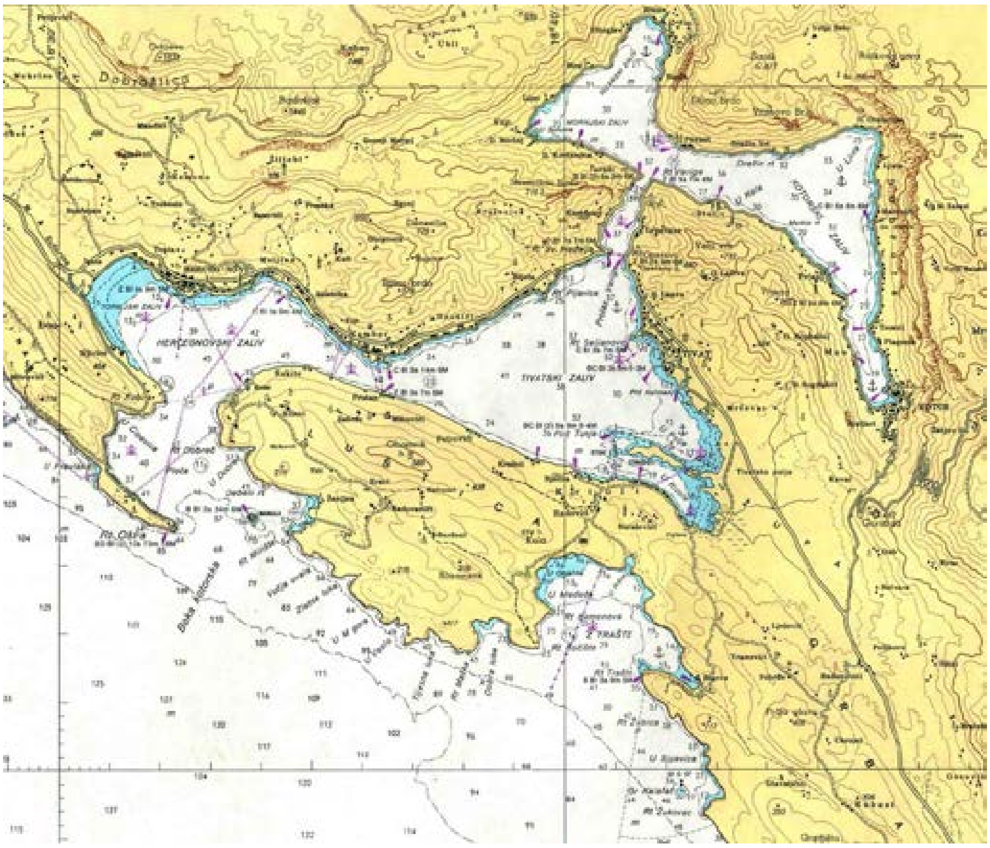

Fig. 1.
Boka Kotorska Bay: study area (PKAD, 2015)

Table 1
Load factors of ferry ships

	Reduced speed zone	Maneuvering	Berth/Anchor
Main engine (ME)	0.45	0.45	0.20
Auxiliary engine (AE)	0.43	0.43	0.20

Table 2
Emission factors of ferry ships

Emission factor (g/kWh)	**Ship's activity**	
	Reduced speed zone/ Maneuvering	**Berth/Anchor**
NO_X	5.10-15.34	11.6
SO_2	11.7-12.9	12.6
PM	0.20-0.70	0.08

The emission produced from the ferry ships can be calculated according to (1) and applied in the case of NO_X, SO_2, and PM.

$$E = E_{RB} + E_M + E_{V/S} \tag{1}$$

where E_{RB} represents the emission of ferry ships in the first activity phase (reduced speed zone), E_M is the emission of ferry ships during a maneuvering and $E_{V/S}$ represents the emission of ferry ships at berth or anchor. Based on the methodology applied in Dragović et al. (2015) and data from Tables 1 and 2, for each activity the emission is separately calculated (formulae (2-4)).

$$E_{RB} = [T_{RB} \cdot [(P_{ME} \cdot LF_{ME} \cdot \sum EF_{ME_e}) + (P_{AE} \cdot LF_{AE} \cdot \sum EF_{AE_e})]_{RB}] \cdot 10^{-6} \tag{2}$$

$$E_M = [T_M \cdot [(P_{ME} \cdot LF_{ME} \cdot \sum EF_{ME_e}) + (P_{AE} \cdot LF_{AE} \cdot \sum EF_{AE_e})]_M] \cdot 10^{-6} \tag{3}$$

$$E_{V/S} = [T_{V/S} \cdot [(P_{ME} \cdot LF_{ME} \cdot \sum EF_{ME_e}) + (P_{AE} \cdot LF_{AE} \cdot \sum EF_{AE_e})]_{V/S}] \cdot 10^{-6} \tag{4}$$

where T_{RB}, T_M and $T_{V/S}$ represents travel times of each activity in hours, P_{ME} and P_{AE} are main and auxiliary engines' power in kW, LF_{ME} and LF_{AE} are load factors of main and auxiliary engines while $\sum EF_{ME}$ and $\sum EF_{AE}$ indicate sum of all emission factors *e* for each polluters for main and auxiliary engines in g/kWh.

2.1. Formulation

After the calculation of total emission produced by ferry ships, we propose a model for minimizing the total ship emission and the allocation of the ferry fleet. The integer linear programming model is based on the supposed demand for transportation that is expressed as a number of passengers that need to be transported. Therefore, we have the following parameters and decision variables:

n – number of ferry ship types,
r – passengers' demand,
x_{ij} – number of ferry ship of *j* type that are assigned to the demand *i*,
e_{ij} – emission (in tons) per one ferry ship of *j* type that is available for demand *i*,
p_{ij} – capacity of ferry ship of *j* type in planning horizon available for demand *i*,
P_i – number of passengers that needs to be transported in planning horizon according to the demand *i*,
t_{ij} – operational time (in hours) of ferry ship of *j* type available for demand *i*,
T_i – maximal time (in hours) needed for passenger transportation by ferry ships according to the demand *i*.

The objective is to minimize the level of emission.

$$\min \sum_{i=1}^{r} \sum_{j=1}^{n} e_{ij} x_{ij} \tag{5}$$

s.t.

$$\sum_{i=1}^{r} \sum_{j=1}^{n} p_{ij} x_{ij} \geq P_i \tag{6}$$

$$\sum_{i=1}^{r} \sum_{j=1}^{n} t_{ij} x_{ij} \leq T_i \tag{7}$$

$$\sum_{i=1}^{r} x_{ij} \geq 1 \tag{8}$$

$$x_{ij} \in \{0,1\} \qquad i = 1,2,\ldots,r \qquad j = 1,2,\ldots,n \tag{9}$$

The objective (5) is related to minimization of total ferry ship emission. Constraint (6) represents the condition of available seats for passenger transportation onboard ferry ship that needs to be equal or greater the demand. Constraint (7) implies that the operational time of ferry ship cannot be greater than the service time (maximal time of passenger transportation). More than one ferry ship can be allocated to each demand as proposed in constraint (8). Constraint (9) implies the status of *n* and *r* as well as the binary status of x_{ij}.

3. Numerical Experiment

The numerical analysis is done for the Boka Kotorska Bay and the demand for passenger transportation during a specified time in September 2015. Applying formulae (1-4), the total emission per hour of ferry ships is calculated. After that, the integer linear programming model is applied and coded in MATLAB 7.12.0. The output results indicate the optimal allocation plan and assignment of ferry ship necessary for minimizing the level of emission for NO_X, SO_2 and PM. The input data for the model are given in Table 3 and according to the ferry ship data obtained from http://www.naviecapitani.it/. Here we propose the five types of ferry ships' capacity denoted as FT1, FT2, FT3, FT4 and FT5. The sum of available ships is 18. Their total capacity is 4275 passengers per day. The details for these ships are also provided in Table 3.

Table 3
Input data

	Number of ships	Total engine power (kW)	Ship's capacity	Total ships' capacity
FT1	3	820	499	1497

FT2	4	1402	134	536
FT3	3	2162	350	1050
FT4	4	162	48	192
FT5	4	1646	250	1000

The real-case emission and ferry ship assignment are provided in Table 4. Applying (1-4), in Table 4 are given the output results of the total emission per ferry ship type. The calculation is done for five days with specified operational time and supposed demand of transportation. The emission in tons per hour and total emission during a day is reported. The total emission for five days is 14.142 tons.

Table 4
Assigned ships

Date	Operational time (h)	Demand	Assigned ships					Emission (t/h)	Total emission (t/day)
			FT1	FT2	FT3	FT4	FT5		
1/9	5.66	335	0	0	3	0	4	0.144	1.852
	7.20	1511							
2/9	8.00	1742	0	0	3	0	4	0.144	1.843
	4.80	130							
3/9	8.00	696	2	0	0	0	0	0.015	0.336
	14.40	130							
4/9	7.20	1755	0	0	3	0	4	0.144	3.341
	16.00	34							
5/9	4.80	2023	3	4	3	0	4	0.217	6.770
	8.00	1325							
	8.80	172							
	9.60	135							

4. Model Application: Results

Using the integer linear model and formulae (5-9), the improved results about the total level of emission of ferry ships and their assignment per daily demand is reported in Table 5. As it can be noticed, the level of emission is drastically reduced to 7.7292 tons. The model reached to optimize the total emission (to minimize it) as to propose a new allocation of ferry ships to satisfy the passengers' demand.

Table 5
Results of a model

Date	Operational time (h)	Demand	Results of assigned ships					Emission (t/h)	Total emission (t/day)
			FT1	FT2	FT3	FT4	FT5		
1/9	5.66	335	3	0	0	3	1	0.044	0.5660
	7.20	1511							
2/9	8.00	1742	3	0	0	3	1	0.044	0.5632
	4.80	130							
3/9	8.00	696	2	0	0	0	0	0.014	0.3136
	14.40	130							
4/9	7.20	1755	3	0	0	1	1	0.041	0.9512
	16.00	34							
5/9	4.80	2023	3	0	3	3	4	0.171	5.3352
	8.00	1325							
	8.80	172							
	9.60	135							

It is interesting to note that in the first demand from the date 1/9, the model outputs seven ferry ships that are available to transfer 1891 passengers (45 more than the demanded number). Seven ferry ships are also allocated to the second demand that can transport 19 passengers more than requested. Third case includes two ferry ships and 173 extra seats for passengers, while five ferry ships with 1795 passenger seats are enough to satisfy the demand in fourth case. Regarding the fifth date, 13 ferry ships are allocated to transfer 36 passengers more than requested. Even though the model provided better results for the emission and allocation of ferry ships, there is a space for further improvement of the model that can be pointed out to its complexity.

5. Conclusion

The optimization of ferry passenger fleet size is analyzed in this paper. The numerical experiment is provided in the case of local ferry passenger transportation in Boka Kotorska Bay. The methodology is combined with the estimation and minimization of emission from ferry ships. The analysis included three polluters, namely: NO_X, SO_2 and PM. The optimal allocation of ferry ships is formulated by the integer linear programming model.
The obtained output results indicate that with the optimal assignment of ferry ships, the emission can be drastically reduced. The methodology for calculating emission is consisted of the data regarding the ship-activity phases. In addition, for this experimental analysis, statistical data had to be provided. Since the expectations are that the number of passengers i.e. local inhabitants and especially tourist will grow even more in the next period, this research can be improved in the sense of including some other parameters and work on its complexity. On the other hand, further research should be directed to the promotion of super-low-emission-ferries that can operate on the local level such as the area of Boka Kotorska Bay. This will affect the sustainable development of the whole area.

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COOPERATION AS A DRIVER FOR TRANSFORMATION OF THE MOBILITY SYSTEM IN THE CASE OF E-MOBILITY

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Abstract: High energy consumption, CO_2 and other emissions related to transport require a transformation of the mobility system. Although recently e-mobility is being discussed as a possible solution, neither a breakthrough of technology, nor market penetration happened so far. The approach of the multi-level perspective (Geels, 2012), which explains socio-technical system change, might be helpful to understand the barriers for a transformation of the system towards sustainable mobility based on technological innovation. The model describes how innovation is absorbed by and transforms an existing "regime", consisting of economy, society, politics, technology, etc. We used this approach to examine the potential of e-mobility for systemic change in a case study of Lake Constance region. The analysis focuses on cooperation between the stakeholders in e-mobility, illustrating the regime's response to the technology. Barriers and starting points to support a transformation process were identified. Even if electric mobility is not necessarily sustainable, the case study allows for general conclusions concerning the spread of new technologies and mobility concepts. Thus, findings may be applied to the change process of todays' fossil fuel driven mobility regime. Results reveal a fragmented e-mobility market with various technical standards, players and their offers. Information about services and accessibility is difficult to get for customers. Partially cooperation between operators of charging stations exists in roaming agreements, which allow customers to use charging stations independently of their original providers – but they do not cover the whole region. At the same time there is potential for joint mobility services, e.g. connecting public transport with e-bike rental. Although experts clearly see the need for joint mobility services, the interest of the relevant players is low. They wait for external actions rather than actively shaping the transformation towards e-mobility. Thus, a change of the current mobility regime requires coordination and cooperation within different fields, ranging from technical standards over information to interlinking different services, including existing public transport and active mobility modes.

Keywords: transformation, governance, e-mobility, stakeholders.

1. Introduction

In Europe, e-mobility is being forced in order to reduce greenhouse gas emissions and emissions of particles within cities. For example, the German government has been promoting electric mobility for years and 2016 even intensified related measures. The goal is to bring one million electric vehicles onto Germany's roads by 2020. The support programme focuses on temporary purchase incentives, the expansion of the charging infrastructure and public procurement of electric vehicles (BMWi, 2018). France also supports electric mobility with a purchase bonus and subsidises the construction of charging stations (Electrive, 2017). With these measures, France plans to terminate the sale of cars with internal combustion engines by 2040 (BBC, 2017). Although these policies are meant to increase sustainable mobility, it has to be mentioned that electric mobility is not synonymous with low CO_2-emissions and resource consumption in general. If driven by alternative energy electric mobility might contribute to lower such emissions (e.g. Van Mierlo, Messagie and Rangaraju, 2017; Hawkins *et al.,* 2013), but energy and resource consumption remains critical if mass production of electric vehicles takes place (Althaus *et al.,* 2010). The study reported here does not investigate the potential for emission savings, but the potential distribution of a new technology. Results should also allow to derive conclusions for other technologies or mobility concepts more clearly supporting a transformation of the transport system towards sustainable mobility.

2. Potential and Barriers for System Transformation in Mobility

2.1. System Change Through Technical Innovation

New technologies provide options to improve the mobility system but simply implementing them is not enough. Technologies would need to be integrated in the given system by both stakeholders and users. The approach of the multi-level perspective MLP provides a model to describe and analyse the comprehensive process of change as a socio-technical transformation, where the 'socio-technical regime' as a structure with its actors and their behaviour, thinking and interaction is being changed in interaction with innovation out of a 'socio-technical niche'. Push factors for this change arise from the 'socio-technical landscape', including trends or processes leading to pressure on a given system (Geels, 2002 & 2004; for mobility see also Geels and Kemp, 2012).

2.2. E-Mobility at Lake Constance Region

Within the framework of the project E-Destination e-mobility supply and infrastructure in the Lake Constance region were investigated. Related to system transformation and the model of the multi-level perspective the situation could be interpreted as a regional e-mobility niche. Thus, the potential and barriers for integration in the mobility regime shall be estimated based on this case study. The project focused on the examination of the existing interconnections between

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various stakeholders and the potential for cooperation in order to promote electric mobility. The analysis was limited to electric mobility services, i.e. rental and sharing of electric cars and electric bikes and the charging infrastructure.
The area under investigation was defined as the Swiss cantons of Thurgau and Schaffhausen, the district of Constance and the Lake Constance district in Germany, as well as all other municipal areas in Austria, Germany and Switzerland that are located within a 10 km radius around the shore of Lake Constance. The analysis was based on secondary research, a standardized stakeholder survey and an expert workshop. Existing rental, sharing and charging infrastructure was recorded. Since the survey took place in June 2016, the infrastructure that is shown below is based on this state of data. The cooperation between the stakeholders was analysed by a standardized stakeholder survey conducted with 73 regional stakeholders from mobility, e-mobility, administration and tourism. In particular, they were asked about the current and potential cooperation between the stakeholders. In a concluding expert workshop, we were able to deduce measures and recommendations for promoting electric mobility in the region.

3. Results

While landscape pressure for todays' mobility system can be found in trends of increasing pressure to react on climate change, the need to reduce local emissions and to reduce resource consumption for mobility might lead to the development of different niche innovations. As the impact of different technologies and mobility concepts on the regime would lead to specific changes, any innovation would need to be analyzed solely. Although, certain barriers for change as well as supporting factors might be similar. Thus, the following analysis of e-mobility and rental/shared mobility in a niche for Lake Constance region as well as their potential for regime transformation provide some general insights on systemic transformation.

3.1. E-mobility in a Niche in the Lake Constance Region

The mobility system in the region – as elsewhere – is dominated by the regime of individual motorised transport based on internal combustion engines complemented by public transportation, cycling and walking. The niche of e-mobility in the field of rental, sharing and charging within Lake Constance region can be characterised as follows.
The region offers a variety of electric bike rental stations, predominantly at the shores of Lake Constance and in the bigger communities (Fig. 1). The market is very heterogeneous and characterized by many different operators. *Rent a Bike* is the only larger provider, though its operation area is limited to Switzerland. In Germany two providers offer more than one rental station, while the majority of the rental stations is operated by individual providers. In most cases the rental of electric bikes is not the main business activity of these companies. With the exception of *Rent A Bike*, cooperation between the various providers is lacking.
Sharing or hiring opportunities of electrically powered cars are very limited in the region with only two larger car sharing providers offering electric cars (*Stadtwerk am See with emma/Caruso*). In addition, eight rental stations are run by various providers, such as municipalities, companies and individuals. There was no connection identified between the operators of rental stations for electric cars and those for electric bikes.
The large number of electric bike rental stations indicates a niche for e-mobility in the region. The availability of electric cars for rent or sharing is still very low. In this regard the niche is just about to emerge. However, the niche seems to be already embedded in the mobility regime, due to the integration of the rental services of one of the two large providers *(Stadtwerk am See*) within the car sharing service of *Deutsche Bahn*, an important player within the German mobility system.

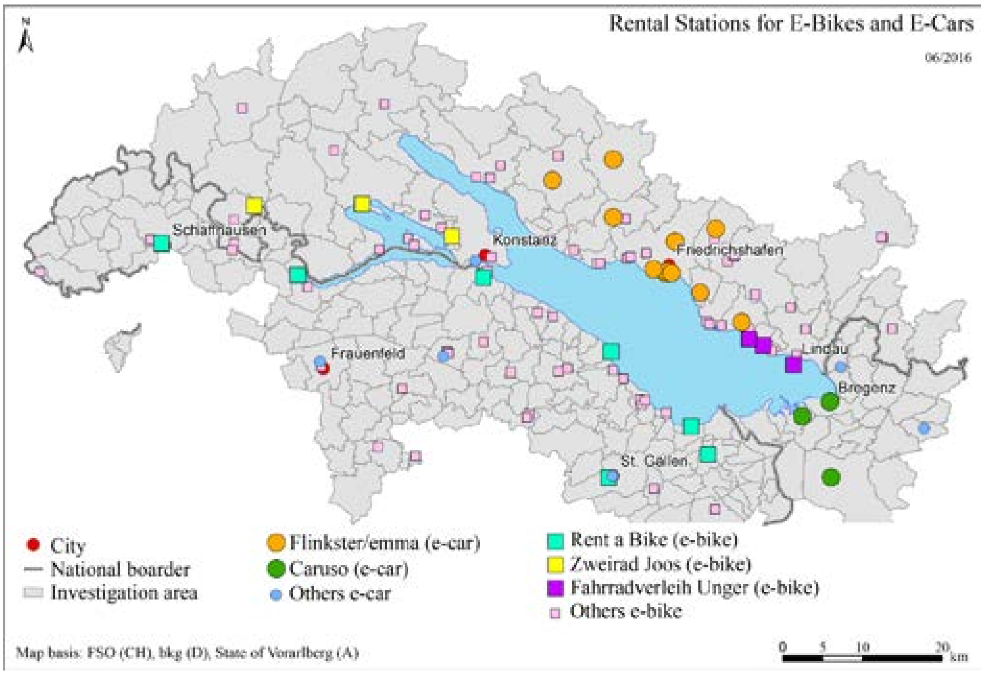

Fig. 1.
Rental Stations for E-Bikes and E-Cars

The charging infrastructure plays an important role in the establishment of e-mobility (Biresselioglu et al., 2018). Since e-bikes can be charged at any domestic power socket, the following results of the analysis refer to charging stations for electric cars. With around 300 recorded charging stations the density in the area is quite high, whereby the number of stations has grown since the investigation in 2016 (Chargemap, 2018). The stations are mainly located in cities, urban areas and in tourist destinations (Fig. 2). About 1/4 of these stations are domestic power outlets (SchuKo in Germany and Austria, SEV1011 T13 in Switzerland). Though these can in principle be used for charging electric cars, they are not designed for a permanent load with the usual maximum amperage and are therefore not suitable for long-term usage (e-Stations, 2016). However, from supply side the market is very fragmented. There are 18 players that operate more than one station and/or act regionally, nationally or internationally. These provide about half of the stations, the remaining stations are run by individual operators. Most of the providers of charging stations have limited market areas. Furthermore, with the exception of the Austrian *Vorarlberger Kraftwerke* no operator is active across borders. In the German and Austrian investigation area, the market areas are rather regionally limited. In Switzerland, on the other hand, several operators act nationally (e.g. *EVITE*, *MOVE*, *easy4you* and *swisscharge*).

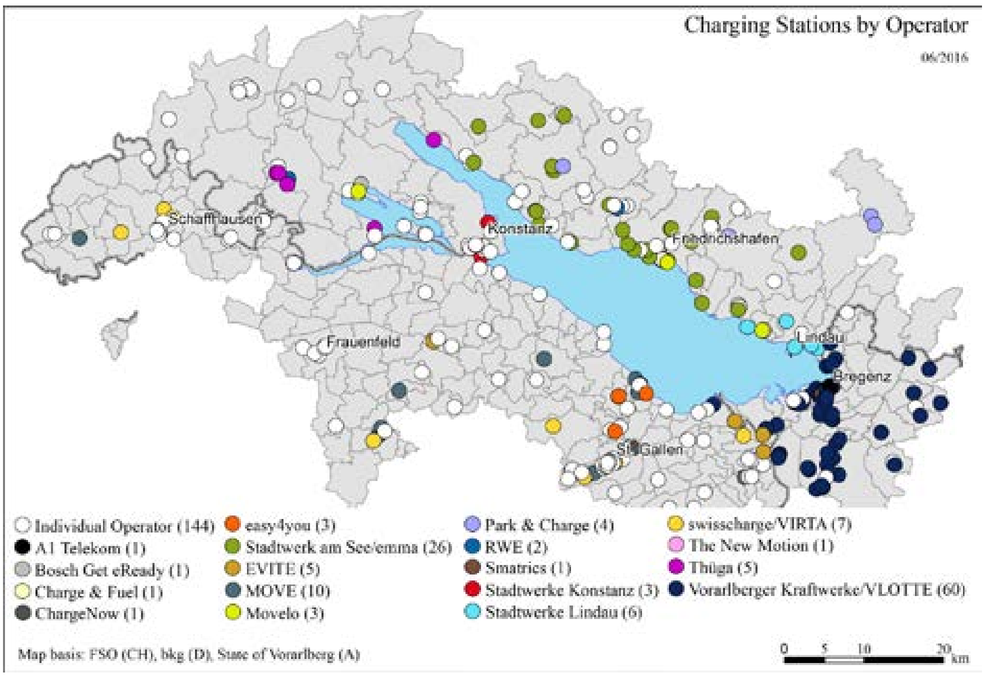

Fig.2.
Charging Stations by Operator

The problem arising with the large number of providers is that each of them uses its own access system for customers to use the charging stations. Depending on the provider, access and payment are carried out via RFID card, QR code, app, EC card, Credit Card etc. This diversity poses a barrier to the use and thus the establishment of electric mobility. Consequently, cooperation between charging station operators is of particular importance - e.g. by roaming agreements allowing the customers of a specific provider to use the stations of others. Figures 3 and 4 show the interconnection between charging station operators by country. The large dots represent "charging networks" including operators of charging stations as well as companies only integrating charging stations from operators and making them available to their customers. The small dots are charging stations and the connections between the dots show which charging network allows their customers to charge at which charging station.

The density of cooperation varies greatly between the three countries. The German part of the area is characterized by little cooperation between the operators, except for *Intercharge* and *Plugsurfing,* with many stations not integrated into a charging network. The situation in Austria is different: the market is dominated by one utility company *Vorarlberger Kraftwerke,* which is also very well connected to many other charging networks. In Switzerland, on the other hand, numerous charging stations are not part of a charging network. Similarly, there is hardly any collaboration between these charging networks - with the exception of two companies (*Intercharge* and *The New Motion*) having roaming agreements with other providers.

From the multi-level perspective on systemic change e-mobility developed in a niche within the Lake Constance region so far leading to a variety of players on the market, which is increasing complexity for users and thus preventing a development out of the niche for both, e-mobility and rental/shared mobility.

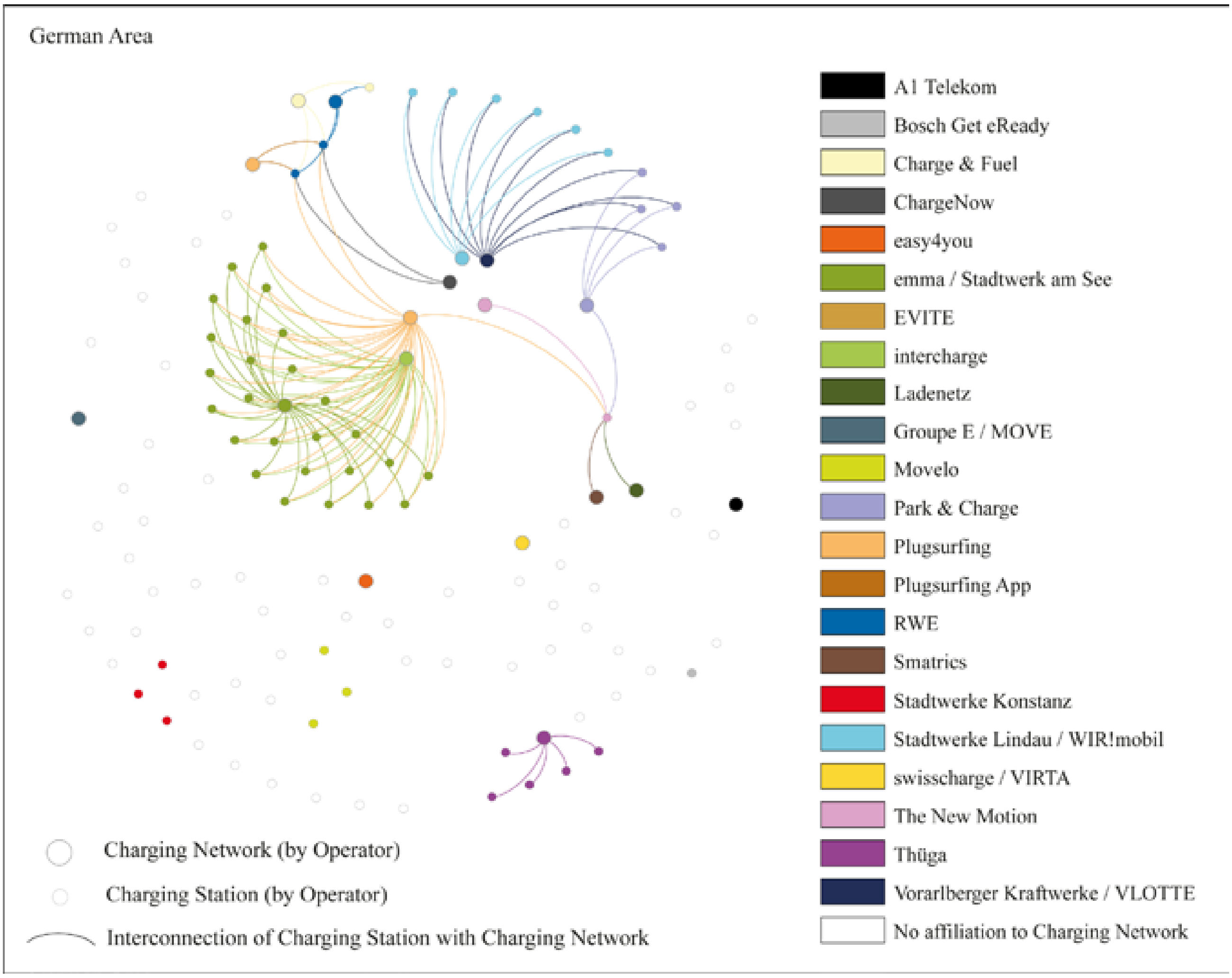

Fig. 3.
Interconnection between Charging Networks by Country, German Area

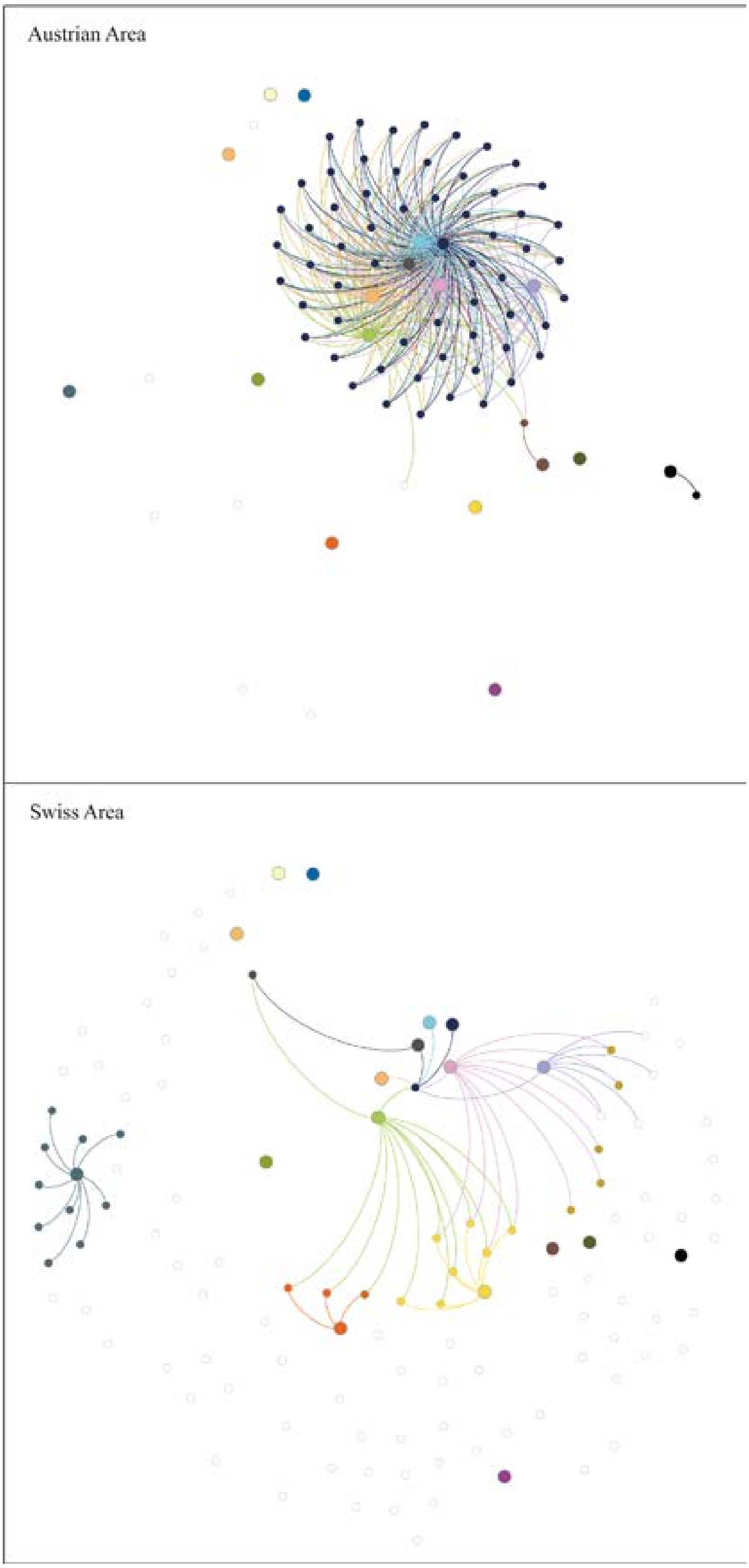

Fig. 4.
Interconnection between Charging Networks by Country, Austrian and Swiss Area

3.2. Potential of System Transformation at Regime Level Trough Cooperation

The analysis reveals the existence of an e-mobility niche in the region. However, system transformation at the regime level has not yet taken place. Lacking cooperation between the actors and low integration of services on the supply side have been identified as significant reasons. The stakeholder survey not only confirms the importance of more cooperation for the expansion of electric mobility but reflects stakeholders awareness about the topic. When asked about the importance of different aspects for the spread of electric mobility, stakeholders evaluate those aspects related to cooperation and greater networking throughout as more important than the further development of the charging and rental infrastructure.

One form of cooperation could be realised by joint mobility offers that integrate electric vehicle renting with existing mobility services such as public transportation. By this means, longer distances could be covered by public transport and the last mile by e-mobile vehicles. Such solutions could not only promote the use of public transport, but also reduce individual motorised transport and thus enhance system transformation at the regime level towards sustainable mobility. On the Swiss side such an intermodal service already exists with the cooperation of the (e-)bike rental company *Rent a Bike* with the Swiss Federal Railways, various private railways and other partners. However, there is a lack of such collaborations in the German and Austrian parts of the region. The stakeholder survey and discussions with industry representatives show limited interest in such collaborations, both from the side of public transport providers and rental companies. This is due to the fact, that the rental of e-bikes is usually not part of the core business of the rental companies. Another reason is the large number of providers, which makes it much more difficult to establish such collaborations.

In this context, greater cooperation between providers of electric vehicles would be even more important. Nevertheless, the stakeholder survey shows that the interviewed rental and sharing companies have a limited interest in a stronger cooperation with other rental or sharing operators. Only one of the participating 14 rental and sharing companies is interested in greater cooperation in the fields of "shared mobility services" and "booking and payment". Two of the respondents would like greater cooperation in the area of "advertising and communication". The rental and sharing companies are much more interested in cooperating with partners from tourism and charging station operators, especially regarding communication and advertising, but also in terms of joint mobility services.

As described in 3.1., cooperation among charging station operators is greater than among the rental and sharing companies of electric vehicles. However, there is still potential for greater collaboration, especially in Switzerland and Germany and on an international basis. In many cases, one reason for the lack of networking is due to the business models of the charging station operators. Most of the providers are regional (public) utility companies that offer the charging infrastructure for their customers and have no ambitions to operate beyond their regional market or internationally, with few exceptions. As a result, the supply side seems fragmented making it difficult for users to gain overview and access e-mobility, sharing/rental and charging opportunities; it is not a surprise that there is no market uptake of electric mobility technology and rental/sharing.

Some operators, which do not operate their own stations but base their business model on the connection and integration of the existing charging stations of other operators may help to solve the problem. These integrators (e.g. *Intercharge* and *Plugsurfing*) enable a barrier-free use of the charging infrastructure and thus of electric mobility; they serve as drivers for a system transformation at the regime level. At the same time, it is also noticeable that an increasing number of energy supply companies are discovering electric mobility as a new business area, thus also opening up opportunities for system transformation. Concerning the regime level, it can be concluded that one of the barriers for cooperation and coordination to a better integration of services is that some companies do not operate as part of the mobility system. If charging or mobility services are offered as an add-on to other businesses there is less interest of contributing to a better organized mobility system. Changing a regime means building a new regime – with all relevant stakeholders included; in this case alliances still have to be formed as well as ways of organizing the use of the new infrastructure and of cooperating to offer it to the users have to be set up.

3.3. Supportive Interventions and Measures

The analysis shows that there is a niche for e-mobility in the fields of rental/sharing and charging in the Lake Constance region and that it is gaining stability. In particular, the infrastructure is available and is being further expanded. However, in order to take the next step towards the integration into the recent mobility regime, there is a need for organization and collaboration within the niche, as well as with the existing regime. Obstacles for cooperation result from the large number of providers, their unwillingness to collaborate and the fact that cooperation in the region is constrained by national borders and corresponding legislation. These circumstances make a bottom-up transformation more difficult.

A common vision and strategy for e-mobility could help as a central element of a future development of e-mobility in the Lake Constance region. For instance, this could take place under the auspices of regional organisations (e.g. *Internationale Bodenseekonferenz, IBK*). The IBK is a cooperative association of the states and cantons around Lake Constance. It is a platform of governments and administrations for common topics regarding education, research, economy, environment and social affairs (IBK, 2018). Such a vision and strategy could, for example, be integrated into the IBK mission statement “Leitbild Bodensee 2030” and thus provide a framework for future regional and national decisions. An e-mobility strategy could promote different measures. An important step would be to bring the various actors together and facilitate an ongoing dialogue. An important field of action involves the promotion of joint mobility solutions such as the integration of public transport and e-mobility rental services. In this respect, the aim should be to collaborate with existing services, e.g. with mobility and tourism packages (e.g. *Bodenseeticket* or *Bodensee Erlebniskarte*). Another way of promoting cooperation between the various mobility services would be a coordinated creation of connected mobility hubs, for example at railway stations, tourist attractions or other important junctions. A

further aspect is the creation of a common data platform to ensure the communication of the various services - based on existing platforms and data sources instead of setting up new ones.
With regard to infrastructure, experts do not see a need to support a further expansion of the rental and charging infrastructure for e-bikes. In the case of rental, there is already a market sufficiently regulated by supply and demand; an expansion of the charging infrastructure for e-bikes is technically not required and is not profitable. Nevertheless, there are still no e-bike sharing systems in the region, the development of which could certainly be encouraged by the municipalities. In addition, the promotion of the increased use of electric cars should be considered. One possibility could be opening up commercial vehicle fleets to e-car sharing systems, whereby many organisational obstacles would have to be overcome. Furthermore, on the technical level standards and uniform modalities for the use of charging stations are necessary.

4. Conclusion

The analysis of the situation of e-mobility in terms of infrastructure, rental/sharing, stakeholders and cooperation showed that electric mobility has been developed within a technological niche in the Lake Constance region so far. Barriers, challenges and starting points to push the transformation of todays' mobility regime towards e-mobility have been identified.
While distribution of charging infrastructure within the region is good, supply side is suffering from fragmentation of technical standards, information about and accessibility of locations for charging and renting/sharing. Cooperation on the supply side as well as connectivity to the existing (public) transport system is underdeveloped. This situation leads to a lack of information for customers and to disorientation concerning available mobility services from the users' perspective preventing them to change their mobility mode. In order to support regional distribution of e-mobility, market uptake of the technology and new mobility concepts like renting/sharing – leading to a new mobility regime in the end – more coordination and cooperation is necessary. The case study also showed that technical, informational and organizational borders replace political and administrative ones. Thus, cooperation and coordination would need to be supported within this fields aiming to provide overall information and accessibility for users.
The results are not only relevant for the case study Lake Constance but serve as an example for barriers and challenges other regions, new technologies and mobility concepts have to face. Identifying relevant stakeholders, fields of cooperation and supply-demand fit are good starting points in order to support a regime change in mobility.

Acknowledgements

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EMERGING TRENDS IN TRANSPORT TECHNOLOGIES: THE POTENTIAL FOR TRANSFORMATION TOWARDS SUSTAINABLE MOBILITY

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Abstract: The global increase of CO_2 emissions requires a transformation of the transport system. This paper aims to provide an overview of emerging cutting-edge transport technologies and mobility services that may have the potential to enable a transformation of the transport system towards sustainability. Thus, innovative transport technologies and mobility services were identified, focussing on non-scientific literature to keep track on the latest developments. The future trends for four technology categories of vehicles, engines, materials and infrastructure/operating technologies were assessed concerning their potential for supporting a change of the mobility system towards sustainability. Based on this, gaps and blind spots in current transport research activities were revealed. Especially autonomous driving systems appeared as emerging trends in all modes of transport. Several prototypes of unmanned cargo ships and aircrafts are currently in trial operations and indicate a large-scale implementation of the technology first in the freight sector. The major breakthrough though is expected in passenger transportation, where besides prototypes of autonomous vehicles several other innovations such as autonomous passenger drones already exist. Results further indicate a trend towards new business models and mobility services (e.g. Mobility as a service or on-demand systems) as several cities already announced to ban cars from their urban centres through implementation of these new mobility solutions. Related to these developments, new stakeholders will enter the mobility market and realign the initial competitors' landscape. Finally, technological developments as part of the emerging Industry 4.0 (e.g. additive manufacturing) will significantly influence traditional manufacturing processes and lead to a fundamental reorganisation of the transport industry in the future. Results of the trend analysis show that many new mobility options are arising from innovation, providing the potential for system transformation towards sustainable transport and mobility. However, this potential will only be realized if guided into the right directions by stakeholders, regulation and society as the study further revealed that innovations imply the danger of accentuating today's problems. Thus, a focus on mobility paradigms, sufficiency principles and strategies in both transport research and policies are of crucial interest.

Keywords: Trends in transport technologies, system transformation, sustainable mobility.

1. Introduction

Climate change, and in particular its adverse effects on large parts of our society, is one of the major challenges facing humanity in the coming decades. One of the main contributors to climate change is the transport sector, which features with 27.9% the highest growth rates of CO_2 emissions in the European Union compared to any other industrial sector (EEA, 2016). This goes back to the development of the combustion engine, which - in combination with the growing prosperity in industrialized countries and a lack of covering the external costs of mobility - made individual motorized mobility accessible and popular to a broad public. Besides the increasing CO_2 emissions, congested roads, safety issues and an increasing loss of cultural landscape by expanding transport infrastructures are just a few of many other negative impacts. A transformation of the transport system towards sustainability is necessary to address these challenges as well as to ensure innovation, efficiency and long-term competitiveness of the transport sector in the future.

In this regard, technological progress is often seen as a panacea. However, some emerging technological innovations in the transport sector "at first glance" seem to be clean and sustainable but raise severe questions and doubts with regard to their overall eco balance. The aim of this paper is therefore to provide an overview of cutting-edge transport technologies and mobility services that are currently emerging and that may have the potential to enable a transformation of the transport system towards sustainability.

2. Methodology

As a starting point for the literature review underlying this work, a **model of a transport system** has been applied. The model was developed in the initial stage of the *Swiss Competence Center for Energy Research - Efficient Technologies and Systems for Mobility (SCCER Mobility)* research project. The main objective of *SCCER* is to develop the knowledge and technologies essential for a transition from the current fossil fuel based transportation system to a sustainable one, including minimal CO_2 output, primary energy demand as well as virtually zero-pollutant emissions (SCCER Mobility, 2018). As a theoretical foundation, the model draws on the multi-level perspective (MLP) introduced by Geels (2002), a framework to explain systemic transformation processes.

The structure of the model was elaborated through questioning experts from the transport sector on their perception of the mobility system and its constituents. This resulted in a systemic delineation of mobility that addresses the 'mobility system' through its holistic nature with mobility related aspects, drivers and transport-related fields. In addition, it provides a framework, to understand past and current developments in the different fields of the system, as well as to project possible pathways for a future transformation of the system. The model consists of six thematic fields: (1) Technology / R&D, (2) Policy, (3) Economy, (4) Society, (5) Transport sector and (6) Spatial order. Each of the six thematic fields consist in addition of various components that interact with each other or have an interrelationship. This

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results in a total of 14 components, which further subdivide the main thematic fields of the systemic model (Hoppe and Michl, 2018).
For the specific purpose of the present research project, the model of the transport system has been reduced to those system elements that are expected to play a major role in future transportation and that are reflecting promising research areas, especially with regard to a transformation of the system towards sustainability.

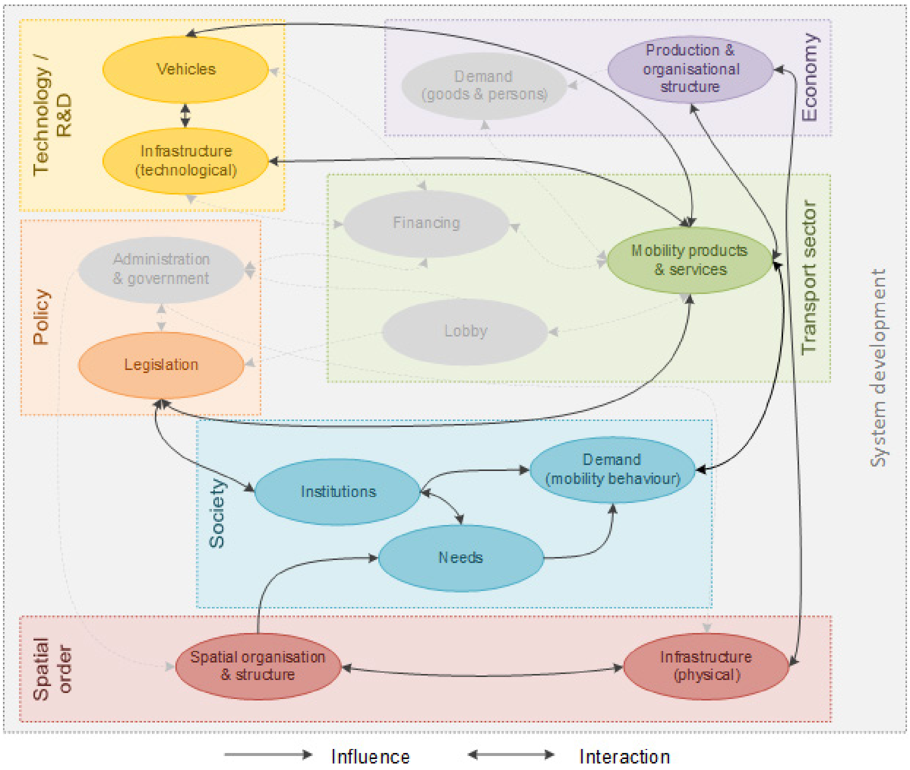

Fig. 1.
Model of the transport system
Source: Hoppe and Michl (2018)

According to this framework model of the transport system, current trends and developments in the mobility system were identified systematically in a broad-based **literature review**, collecting information from project reports, trend studies, transportation websites, future-oriented blogs, news reports and journal articles. Thereby the focus lied deliberately on non-scientific sources, to capture the latest trends in the various fields of research. In a final step, each identified trend was assigned to the corresponding system element within the underlying systemic framework model. This resulted in a detailed and extensive description of emerging trends and developments in the transport system, having the potential to significantly influence the current system and lead to a transformation in the future.

3. Large Scale Trends in Transport Technologies

The transport sector is currently changing through several emerging technological innovations. Some of these trend-technologies were newly developed; other technologies have existed for several years already, not able to exceed their current state as a niche technology yet. Aside from their current state of diffusion, the majority of today's trend studies assigns new technological developments a key role in the transformation process of the transport system. Whether it is about the reduction of CO_2 emissions through optimization of combustion engines, the electrification of propulsion systems or the development of new battery technologies, all these developments and forecasted trends have a major potential to change the mobility system towards sustainability in the future.

3.1. Trends in Vehicle Technologies

In the field of vehicle technologies, **autonomous driving systems** are one of the major trends emerging on a large scale. Over the past decades, cars have been equipped with all kinds of driving assistance systems like cruise control, collision warning and lane-keeping support and are gradually approaching full autonomy. Autonomous vehicles offer a great potential to change people's initial way of thinking about cars, resulting in a new perspective on mobility where commuters, for instance, make better use of time by preparing for work while travelling from A to B (Rauch, 2017). In addition, autonomous vehicles may provide greater safety, reduce emissions and increase road capacity through optimized traffic flows (Davies, 2016). Although an integration into the transport system would already be technically feasible, non-technical issues (e.g. consumer confidence and legal aspects) as well as difficulties involved in controlling a vehicle in unpredictable and challenging traffic conditions are some of the major constraints the transport industry is currently facing (Delle Site et al., 2012). Wadud et al. (2016) estimate a complete integration of autonomous vehicles into the transport system not before 2030.

Besides the automotive industry, the trend of autonomous driving systems is also taking place in the other modes of transport. In the **maritime industry**, northern European countries take a pioneering role in the transformation process towards autonomous shipping by aspiring to implement autonomous cargo vessels on coastal routes by 2019 (Birger, 2017). In the **aeronautical sector**, the two major global players *Boeing* and *Airbus* are both testing autonomous systems. While *Boeing* is pursuing concrete plans for autonomous aircrafts, its competitor *Airbus* is focusing on a concept of a self-driving vehicle that can be converted into a drone (Futurezone, 2017). In October 2017, the Chinese aircraft manufacturer *Longxing UAV Systems* performed a successful maiden flight of an unmanned cargo aerial vehicle that operates in both, autonomous and remote pilot modes and is particularly suitable for cargo operation in remote areas (Aerospace Technology, 2017). Ultimately, autonomous systems are also being tested in the **railway industry**. While there already exist a few prototypes for passenger transportation, the industry's focus lies mainly on autonomous systems for shunting and cargo operations. An Australian mining company, for example, runs the world's first fully autonomous freight train in operation since 2017 (Leary, 2017).

Another major trend in vehicle technologies are **drones**. Formerly mainly used in the military sector, drones are nowadays increasingly being tested in private and commercial applications. According to Dobie et al. (2016), 600'000 drones are currently in commercial use in the United States and about 1.9 million in private ownership and by 2020 these values are even expected to triple. Although numerous logistics companies are testing drones for goods and distribution logistics, legal framework conditions for regular commercial operations are still insufficiently worked out (Amazon, 2017). In addition, there are also several concepts for passenger transportation emerging. In 2016, the Chinese drone manufacturer *Ehang* presented its concept of a single-seater aircraft that claims to be the first of its kind to transport passengers autonomously (Cavanagh, 2017). First successful tests of this autonomous passenger drone have been carried out in Dubai in 2017. However, a mass production is not yet foreseeable and drones for passenger transportation remain a niche technology for now (Schmid, 2017).

3.2. Trends in Engine Technologies

In the field of engine technologies, one of the major trends currently influencing the industry is the **electrification** of conventional drivetrains. Already affordable middle class electric cars reach nowadays 300 kilometers and more with one single battery charge and the trend continues to improve (Cobb, 2016). However, there remain several constraints concerning the overall eco-balance of electric vehicles. According to Romare and Dahllöf (2017), the production of one single *Tesla* battery causes about 17.5 tons of CO_2. This equals emissions of about 150 to 200 kilograms CO_2 per kWh battery capacity. In addition, global production of cobalt and lithium would have to increase between twenty and thirty times to the present level to ensure a complete switch from conventional to electric drivetrains (DWN, 2017). Nevertheless, market shares of electric vehicles are constantly growing and are predicted to account for 25 to 40% of new vehicle registrations worldwide by 2030 (Arzt, 2017).

Besides the automotive industry, the trend of electrification is also taking place in the other modes of transport. In the **maritime industry**, Scandinavian countries again play a leading role in the transformation process towards electric drivetrains in Europe. A number of electric ferries are already in operation on local connections and several orders for new electric ferries have been placed recently (Feusi, 2017). In the **aviation industry**, a growing number of aviation companies are investigating the potential of hybrid-electric propulsion technologies. A cooperation between *Airbus*, *Rolls-Royce* and *Siemens* recently announced a maiden flight of a hybrid-electric aircraft by 2020 with the primary goal to provide a commercially viable hybrid passenger jet for regional air services by 2030 (Hollinger, 2017). Finally - against the common belief - electrification of drivetrains is still an important issue with regard to sustainable **rail transportation**. In Germany for example, only about 59% of all railroads are electrified and diesel-powered locomotives are still widely used, especially on peripheral railroads. Various research projects are therefore focusing on clean fuel technologies. However, the costs of an additional supply infrastructure as well as the conversion of the existing drive technologies are currently the biggest challenges (BMVI, 2017).

A further trend that is anticipated to take on major influence in the development of sustainable engine technologies is the **hydrogen fuel cell** technology. Although hydrogen propulsion shows a vehicle-side efficiency from around 45%, the production of hydrogen itself is still very energy-intensive. The International Energy Agency (IEA) estimates a fuel cell vehicle (FCV) market share of about 17% by 2050 with 35 million annual unit sales (Arena et al., 2017). Further trend studies estimate that hydrogen fuel cell technology could become the fastest growing propulsion technology in the automotive market by 2050 (Jaffery, 2016).

3.3. Trends in Material Technologies

In the field of material technologies, **additive manufacturing** is one of the major trends emerging on a large scale. Formerly mainly used for the production of prototypes, 3D printing is becoming increasingly important for industrial mass production of individual components in the course of the emerging Industry 4.0 (Richter and Wischmann, 2016). According to Wood (2016), 3D printing technology could substantially disrupt conventional manufacturing practices by offering modular production alternatives, onsite manufacturing, and the ability to create parts, tools and even complete

vehicles on-demand. In 2015, the world's first car - at least in parts - was produced using additive manufacturing technology (Schroeder, 2015).
Besides the automotive industry, 3D printing is also attracting more and more attention in the other modes of transport. In the **aerospace industry** for example, the world's most important manufacturer of aircraft engines, *GE Aviation*, uses already today more than 300 3D printers in its factories and aims to produce by 2020 about 100'000 additive parts per year (GE Reports Staff, 2017). In the European **railway industry**, the *Deutsche Bahn (DB)* - the largest railway operator in Europe – produces annually about 1'000 spare parts using 3D printers and in the future the company plans to extend its production capacity up to 15'000 spare parts per year (Global Rail News, 2017). Finally, in the **maritime industry**, Britain's royal navy plans to use 3D printed unmanned ships by 2030 (Hedstrom, 2015).
Another technology trend that is gaining increasing popularity in combination with 3D printing is **lightweight construction**. The main objective of lightweight construction in the transport industry is to save raw materials and energy due to lower vehicle weights (IAI, 2016). There have already been several concepts for lightweight vehicles emerging in recent years. In December 2017, the Swedish start-up *Uniti* presented a lightweight electric vehicle (about half a ton), which is specially designed for commuting in urban areas. Series production is scheduled for 2019 and with *Siemens* as one of the main partners, a fully automated version of the vehicle is expected to enter the automotive market in the near future (Schäfer, 2017).
Similar goals to those of lightweight construction - especially with regard to energy optimization - are pursued with **aerodynamic optimization**. The main objective of aerodynamic optimization is to design the form of vehicles and infrastructures (e.g. tunnels) in such a way that air resistance and consequently the energy required for locomotion declines. The *German Aerospace Center (DLR)* is investigating in this field of research with planning and construction of the *Next-Generation-Train* (DLR, 2013). Other examples of aerodynamic improvements are to be found in the Japanese high-speed train *Shinkansen* (Railway Technology, 2017) or the *Hyperloop One*, in which a transport capsule moves in an air-evacuated tube with considerably lower air resistance than conventional trains (Bradley, 2016).

3.4. Trends in Infrastructure and Operating Technologies

In the course of digitization and the advancing Smart City movement, **Intelligent Transport Systems (ITS)** are rapidly emerging. ITS-technologies optimize traffic flows and the use of infrastructure by intelligently managing and directing the different traffic elements. According to Kantowitz and Le-Blanc (2006), the following three types of communication can be differentiated within ITS-technologies: Vehicle-to-Infrastructure (V2I), Infrastructure-to-Vehicle (I2V) and Vehicle-to-Vehicle (V2V). Practical applications for V2I and I2V technologies can be found in car park management, traffic management, usage-based cost accounting or navigation applications. V2V communication technologies (e.g. adaptive cruise control, lane departure assistance or active brake assistance) have become widespread standard in all newer vehicle models, mainly due to the current developments in the automotive industry towards (partly) autonomous driving. V2V communication comprises a wireless network where vehicles send messages to each other with information about what they are doing right now. This data includes for example speed, location and direction of travel, which can be further processed - using complex algorithms - to alert drivers about hazardous situations ahead (Howard, 2014).
A further emerging trend in V2V technology is **Truck Platooning**, where trucks are connected with each other in such a way that they automatically move one after the other at a constant distance. This intends to relieve the drivers and save fuel by using slipstreams at reduced vehicle distances. Furthermore, Truck Platooning is also expected to induce road safety improvements. While a human driver has a reaction time of about 1 to 2 seconds, V2V communication can reduce the response time up to 0.2 seconds according to a study of the German vehicle manufacturer *Daimler* (Wilkens, 2017). After a successful multi-day test drive with six different truck manufacturers participating in 2016, Truck Platooning could be technically applicable in Europe by 2020 (Wilkens, 2016).
A final technology that needs to be mentioned in the context of V2V-technologies is the development of **swarm/collective intelligence**, which includes by definition that specific actions of individuals can evoke intelligent behaviours in the community through communication and networking activities (Dambeck, 2011). An example of an application relevant to mobility is the concept of community-based parking, which has been introduced by the German *Bosch Group* in 2016. The concept intends that a large number of vehicles participate simultaneously in the search of free parking spaces scattered throughout a city, thus making it much easier for the community to locate a free space than if each car had to search on its own. Once a "transmitter vehicle" detects a free parking space, this data is transmitted to a cloud where it is further aggregated and processed into a digital parking card. Based on this data, the "recipient vehicles" receive a precise indication, where free parking spaces are currently available (Greis, 2016).

3.5. Emerging New Mobility Products and Services

In the course of digitization and following the previously described technological developments, several **new mobility products and services** have emerged in recent years. According to Rauch (2017), digital networking does not only provide for more mobility offers. It creates rather a completely new layer on the mobility structures and the exchange of data between road users, vehicles and the surrounding infrastructure achieves the next level of mobility: a self-controlling system of real-time traffic planning, on-demand availability and smooth transitions from one mode of transport to another. According to a study of *Frost & Sullivan*, more than 20 million vehicles could be removed

annually on urban roads as a result of a further growth in new mobility services (ride-sharing, ride-on-demand services, etc.) as from 2025 (Briggs and Sundaram, 2016).
A major trend in the field of new mobility products and services are **sharing systems**, which originate from a fundamental rethinking in the ownership of mobility products, turning from ownership of transport modes to the use of transport modes (Delle Site et al., 2012). Especially in mature economies societies, a shift towards shared economies is currently evolving. However, this tendency is more evident for younger generations (Generation Y) and car ownership in general is highly affected by new attitudes and behaviors (Corwin et al., 2016).
Another important trend is a growing range of **mobility as a service (MaaS)** products evolving. MaaS organizes the entire transport chain for the mobility users, including planning, booking and accounting of trips in a mostly smartphone based system through all modes of transport. Several MaaS projects have emerged recently in Europe. The city of Helsinki for example has announced its intention to eliminate the need for privately owned cars by 2020 through the implementation of MaaS (Franckx, 2015).
A final trend in the field of new mobility products and services are **on-demand services** that are ordered individually and on-demand by the consumers. In particular, road-based services have established themselves recently on a large scale so far and further research is being intensified to achieve a complete autonomous operation of these systems (Dvorsky, 2017). As an example, the German car manufacturer *Volkswagen* presented its on-demand concept of a fully electric ride-pooling service called *MOIA* in 2017. Core of this concept is an electric vehicle with a capacity for six passengers that has been designed specifically for ride-pooling services in cities. Besides the vehicle, the concept also consists of a customer app, enabling passengers to book and pay for the ride on a smartphone based system. The main objective of this new mobility service uttered from the operator is to remove one million cars from the roads of major cities in Europe and the United States by 2025. In 2018, the service will be first launched in the city of Hamburg (Intelligent Transport, 2017).

4. System Transformation Towards Sustainability?

Besides effects of the single technologies on the transport system, general developments with their likely impacts on sustainability can be identified based on the trend overview:

1. Related to the **transport system** almost all new technologies and services create and require higher interconnectivity in terms of data and information exchange on different levels: Within vehicles, between vehicles and different modes, between vehicles and infrastructure as well as to transport system users. As a result, the transport system becomes more complex concerning data handling and system control on one side – allowing to optimizing the system in terms of resource consumption, energy efficiency and emissions on the other side.
2. On the **transport market**, the diversity of innovative solutions and new players is leading to higher complexity in the area of communication, coordination and use of new services and technologies. The transport market is about to be reorganized in terms of stakeholders, rules and supply-demand relations, which requires adaption to new frame conditions from both supply and demand side. This variety would allow for supporting the best solutions in terms of sustainability, in an ecological, social and economic sense.
3. As the implementation of technologies and services depends on user acceptance, **social and economic developments** are deciding factors for the direction of future development in transport. Innovation would only lead to fundamental change if they initiate a process of socio-technical development. In the past new options in mobility (as elsewhere) have promoted use of them and thus increased demand with the familiar effects of rebound in resource consumption and total of emissions in transport. Even if the potential of the described innovations contribute to sustainable mobility, the danger of reverse effects is high.
4. Regulation and **transport policies** will be crucial in this context setting the frame for implementation of technologies, success of related mobility services and the overall development of the transport system – especially when it comes to sustainability. Strategies of enabling what is possible would lead to increase of mobility options with strong rebound effects (as in the past), while transport policies aligned with European climate goals in combination with the described innovations have the power to push for a systemic transformation towards sustainable transport.

To conclude, results of the trend analysis reveal that innovation in technology and mobility services have the potential for both fundamental change of the transport system and a push for sustainable mobility. On the other side, they come with high uncertainty bearing the danger of negative side effects of the developments. As crucial factors within this context, decision making of stakeholders and users will play a major role and thus would need to be considered. Social and technological system development in interconnectivity will decide upon the future direction in terms of sustainability, which needs to be taken into account from a very early stage of innovation development.

5. Conclusion

The main objective of this paper is to provide an overview of cutting-edge transport technologies and mobility services concerning their potential to enable a transformation of the current transport system towards sustainability. In the field of transport technologies, results indicate that autonomous vehicles can be expected to have a strong disruptive effect on the transportation system and the current mobility behavior patterns and could lead to a substantial rethinking of established business and ownership models in the future. In addition, the expected increase in efficiency in traffic flows and a possible reduction in the number of vehicles through autonomous on-demand services could have a significant impact on the sustainability of the transport system in the future. However, it remains unclear how fast the technology will be able to establish in passenger transportation. Systemic effects of autonomous driving as well as of other technologies or services like MaaS will strongly depend on (political) frame conditions, user acceptance and transport market development.

When it comes to sustainability in transport, results concerning the likely future developments in transport reveal gaps in both perspective of research and policies. A variety of new mobility options are arising from innovation, providing the potential for system transformation towards sustainable transport and mobility. This potential would need to be guided into the right directions by stakeholders, regulation and society as innovations also imply the danger of accentuating today's problems by increasing demand of mobility with its side effects. Thus, a focus on new mobility paradigms, sufficiency principles and strategies in both transport research and policies are of crucial interest.

Within this context, the next step in the underlying research project will be to conduct qualitative interviews with experts from the transport sector. This will serve as a basis to formulate hypotheses concerning the evolutionary development of the transport system with a special focus on the aforementioned new paradigms, principles and strategies. The hypotheses will be validated in a subsequent online survey to ultimately identify gaps and blind spots in transport research.

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POLITICAL IMPERATIVES IN TRANSPORT A LONG-TERM VISION FOR THE DECISION MAKING PROCESS

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Abstract: This paper illustrates the findings regarding Political Imperatives, those influencing the future of the European transport sector. The identification of the European Political Imperatives in the transport sector is guided by the influence they can have in being 'game-changers' for the whole sector. This has led to analysis of 130+ Political Imperatives as produced both within and out of Europe, focusing on the different actors developing those Imperatives. Based on frequency and relevance, the report lists circa 60+ claims/demands and an equal number of Intentions as suggested by those Political Imperatives. As a final outcome, a comparison of formulated demands/ claims to and identified notices of intentions by the political sphere allows to identify those imperatives that are not yet part of the political agendas but might gain importance in the future. The core analysis shows which political imperatives are currently dominating the discourse and are thus important starting points for creating an image of the future transport sector. Imperatives that are amongst other aspects directly or indirectly having the goals of reducing GHG emissions by supporting modal shift, substituting the source of energy (EV's, alternative fuels) or using existing infrastructure more efficiently are making up the majority. Forward looking imperatives are especially touching urban transport and data issues. Here it can be stated that the imperatives coming from the European stakeholders were much more forward looking and that topics like intelligent transport systems, MaaS, green logistics have – although quite weak – already found entrance into some strategy papers. The deliverable has created an initial snapshot of the current state of imperatives with relation to the transport sector. However, it has to be expressed that a deeper and especially longer lasting assessment of the international sphere and national sphere also by integrating other methodological approaches like expert interviews into the research concept would have been able to create deeper insights or to validate the outcomes.

Keywords: Political imperative, transport policy, decision making, mobility future, transport sector.

1. Introduction

This paper is an outcome of INTEND, an H2020 project with the goal to deliver an elaborated study of the research needs and priorities in the transport sector. INTEND aims to develop a transport agenda to pave the way to an innovative and competitive European Transport sector. Three elements are considered relevant for assessing long- term strategies:

- Technological advances and forward-looking projects;
- Future transport concepts;
- Political imperatives.

This paper focuses on the Political Imperatives (hereafter PIs). PIs are relevant because policies are the direct and indirect result of political imperatives, and via direct regulation or via defining market rules, those policies address future transport concepts and technologies.
Considering INTEND goals and work-plan it is not the task to assess the identified Political Imperatives and their probability in developing real-world policy, or their importance for the future of the transport system. It is instead a central goal of this report to show a snapshot of predominant forward-looking Political Imperatives. This is done with relevance by type, spatial provenance, originator and addressee. They will moreover be clustered according to the dimension listed in the previous chapter.
In order to address this work, we identify four tasks:

1. Identification of relevant sector-specific Political Imperatives (hereafter PI) and visions in Europe;
2. Identification of relevant sector-specific PIs and visions outside of Europe;
3. Comparison of sector-specific European and non-European Imperatives and visions;
4. Identification of the most important ones to serve as an input for T 3.2.

It is important to clarify that a PI can be either the formulation of a demand/ claim or goal/ intention to reach a desired target state. But it can also be the formulation of a demand/ claim or goal/ intention to implement a certain policy or action in order to reach a previously defined target state.

2. Methodology

Considering the magnitude of the task, it is indeed necessary to develop an adequate approach and a sound methodology, those able to filter and structure the worldwide ensemble of existing PIs that are – at the moment – part of the political discourse or deemed as putatively relevant for the future development of the transport sector in , formulated by and to whom, are at the moment part of the worldwide political discourse or deemed as putatively relevant for the future development of the European transport sector?
The approach that has been developed to answer this question and therein included aspects is using Mayring's method of qualitative content analysis (Mayring, 2002). Seen before the background of a challenging timeframe and

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limited capacities, this method shall guarantee that:

- Relevant sources containing important PIs are being identified and scanned (efficiency and effectiveness),
- Relevant PIs can be extracted from the sources identified,
- Interrelations between content, addressee and originator are made visible in a best possible way.

Following Mayring (2002), the main basic concept of qualitative content analysis describes the process of "…analyzing texts [material] in a systematical manner, by using a category system that is being developed, based on the material given in a theory-based way" (Mayring, 2002; p. 114; see also Ramsenthaler, 2013; p. 23 [translated by the author]).
This means that this method's main purpose is to summarize text and therein included messages (content) that are being "translated" into categories organized in a specific system. The resulting "coded" and "categorized" text passages form the basis for further content-related analyses and the interpretation of the results in relation to the formulated problem (Ramsenthaler, 2013; p. 23).
For this reason, "Content analysis is not a standardized instrument that always remains the same; it must be fitted to suit the particular object or material in question and constructed especially for the issue at hand. This is defined in advance in a procedural model, which defines the individual steps of analysis and stipulates their order." (Mayring, 2014; p. 39).
Mayring differentiates four central characteristics of the approach. These are as follows (Ramsenthaler, 2013: 25 [translated by the author]):

- Assignment to a communication model,
- Adherence to a systematic analytical procedure,
- Category-centeredness,
- Quality criteria.

These characteristics find their expression in the procedural model, depicted in Figure 1.

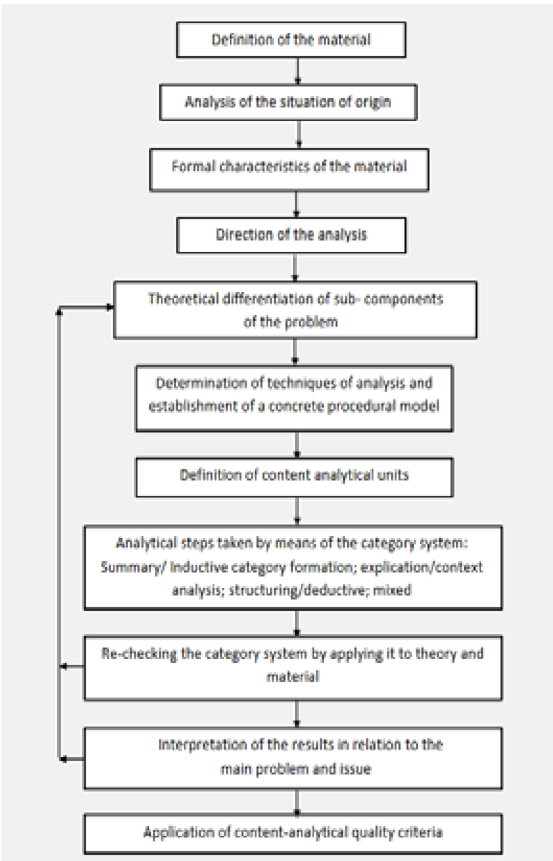

Fig. 1.
General content-analytical procedural model
Source: (Mayring, 2014; p54)

The model can again be summarized into four basic working steps:

- The first step comprehends a detailed examination of the research subject, the research question, the related material as well as of its communication model.
- The second step focuses on the determination of analytical techniques and the development of a concrete

procedural model for the analysis.

The third step consists of the actual analysis. Here the material is being reviewed based on an inductively, deductively, mixed form of both developed category systems. Thus, the content analysis can result in different kinds of outputs. These are as follows: summary, explication, structured material or mixed forms.
The fourth and last step aims at interpreting the results in relation to the main problem and issue.

2.1. Operationalization

As already mentioned in the preceding chapter, the content analysis is not a standardized instrument, hence its procedural model needs to be adapted to the specific analytical goal. In this specific case, we consider as first task to investigate define the research subject itself. This creates the main prerequisite for identifying adequate literature containing relevant PIs. Moreover, this very first step is – at the same time – delivering a part of the basic structure for building the before mentioned system of analytical categories.
Without wanting to anticipate the working definition of the term "Political Imperative" for INTEND, it is common understanding that imperatives are always target- or goal-oriented.
When a simplified communication model such as the one by Lagerberg (1975) – illustrated in Figure 2 below – is applied to the case of a PI, then it becomes clear that PIs can besides their main content distinguished by originator (source) and/ or recipient (addressee).

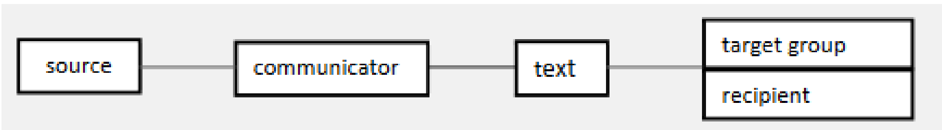

Fig. 2.
Simple content-analytical communication model (Lagerberg, 1975 cited by Mayring 2014:48)

Consequently, a reasonable approach for identifying relevant literature would be to investigate literature containing statements, declarations, demands, claims created by stakeholders having a relation to the transport sector.
An analysis of stakeholders that are influencing the discourse on transport related PIs – being originators, intensifiers and enunciators of PIs – has to be conducted. These stakeholders can be grouped in categories as follows:

- International non-governmental organizations (INGOs), Non-governmental organizations (NGOs),
- Important companies of the transport industry,
- Research institutions (in form of scientific publications),
- Supranational organizations, intergovernmental organizations,
- Governments/ ministries.

Although the European Economic Area is from an economic perspective the world's leading economic area, its future development is these days due to a further globalizing economy and emerging competitors more subject to external influences than ever before. This means that a stakeholder analysis and a search for adequate literature should also cover world regions beyond the European borders hence including also a spatial dimension.
As a result, we worked on a methodological model (see Figure 3).
After the finalization of step three – literature collection – the outcomes will be migrated to the Atlas.ti database. Atlas.ti is a scientific software for qualitative data analysis. With the help of this software, text passages containing transport related PIs can be coded (e.g. categorized according to Mayring). This is an approach that combines deductive and inductive category and it has been chosen in order to develop the category system. The deductive set of categories consists of the ones previously defined, namely geographic region of origin, kind of stakeholder being the originator, kind of stakeholder being addressed.

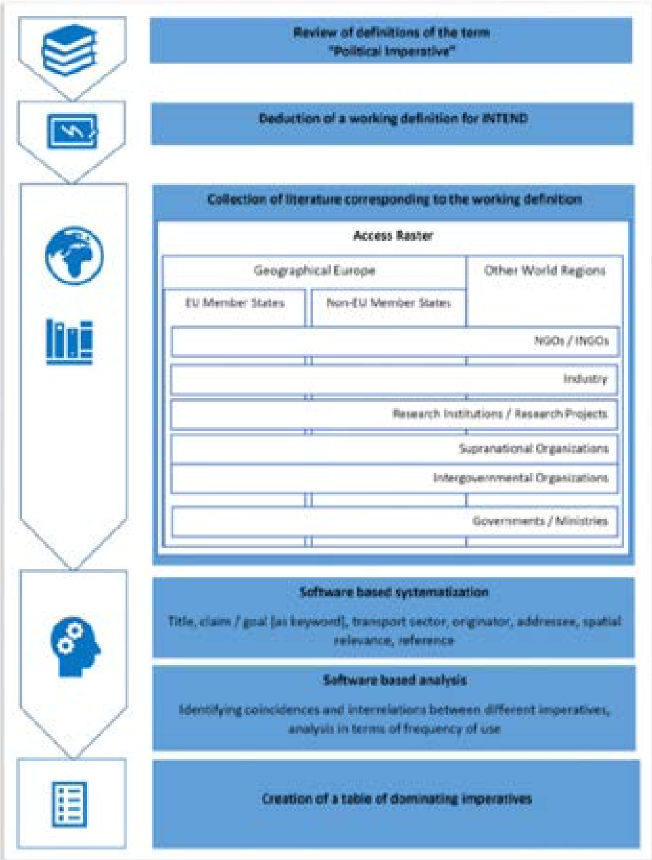

Fig. 3.
Methodological approach and research process for D 2.3

The inductive set of categories – the ones that are being developed during the literature review – consist of the content related ones, meaning the imperatives themselves (claim, formulated demand, notice of intention) and the part of the transport sector that is being addressed.
This asked for a reiteration of the research. In other words, after a first round of categorization, additional sources that may be relevant to the research subject and which have not yet been identified during the first step will also emerge. These texts are subsequently added to the collection of all sources and are also taken into account in the further procedure. Indeed, after approximately a third of the literature has been coded, the inductively developed set of categories – the content related ones – will have to be consolidated and reduced. This process is being performed by merging codes with the same meaning or generalization of existing ones in order to subsume a certain number of codes under a top-level code with a more generalized message.
The final product of this whole process is a database containing a huge amount of literature whose texts have been summarized and structured in form of codes. This allows to perform different kind of analyses in order to identify overlaps, as well as interrelations between different codes (categories). Moreover, the software also allowed to perform quantitative statistical analyses. This included analyses of appearance frequencies and overlaps with other codes (code-co-occurrence). In this way, the aforementioned category system can indicate which imperative was formulated in which region, how often by what kind of author to what kind of addressee.
These results will be summarized in form of table, and the identification of the more often appearing PIs. Since all the collected literature has been fully read, assessed and coded, the list will also contain PIs aside the mainstream, which let us to identify alternative paths that are not yet part of the political discourse. Here a comparative analysis will show which demands/ claims that have been formulated to the political sphere have found entrance to the discourse about the future transport system and are already part of the intentions formulated by the political sphere.
These working steps address the Objectives 1, 2, 3 as stated in Chapter 1. The final table will consist of the main columns, visible in Table 1.

Table 1
Column headers of the results table

Political Imperative Demand/ Claim, Intention (as keyword)	Origin	Frequency of Occurrence	Sector being addressed (Frequency)

Besides the development of the table comprising PIs as an input for Task 3.2, a sector-specific comparison regarding the European and Non-European imperatives and visions for the transports sector will be performed. This working step addresses the Objective 3, as stated in Chapter 1.

3. Defining the Term "Political Imperative"

It is not in the scope of INTEND to offer an in-depth and theoretical analysis of the term "Political imperative" (hereafter PI), nor to define its philosophical backgrounds in Western culture (which is mainly built after Kant´s deontological moral philosophy). Still it is useful to briefly assess the concept, so to better frame the activity of project and better address the H2020 call´s goals.

3.1. Semantic Change – A Review of Definition and Actual Use

In this regard a definition of what a PI has to be offered. Following Trebilcock, the variety of meanings about "normative" is "startling" (Trebilcock 2014, p. 9). Political imperative has been dubbed as political visions, or "political culture", "political agendas" or "political ends" (Savage and Kong 1993). In order to offer a common stand point, after Trebilcock´s suggestion, we assume that (political) imperatives are "perspectives or theories that purport to advise governments on what policies they should adopt in this context as a matter of efficiency, fairness, justice, or some other conception of right and wrong" (Trebilcock 2014, p. 9).

In this respect, Political Imperative looks like a very strong tool, which should address strategic view and public decision in every field of action of political actors. These PIs can be manifest or not. Some PIs don´t need any formulation, being part of a general political concept, universally accepted, which does not need to be explicit (for instance the idea of the state protecting its citizens, or the state´s monopoly in managing justice). This means we have no written PIs because around some arguments there is an unquestioned idem sentire de republica.

On the contrary, if PIs are manifest, this means that the value portrayed by the PI is not (yet) perceived as fully part of the political discourse. In these cases, the PI is the result of declining value previously given for granted, shifting perceptions, or new threat to social live. A pertinent example is the climate change, which asked a change in the existing policies and, thus, to reach new goals (as for Co2 emission reduction, energy saving etc.).

So, one manifest, the PI can have a variety of backgrounds and goals.

1. PIs are developed in order to enforce an idem sentire which is largely accepted, but still not fully in the political, social or economic debate and practise (e.g. Co2 reduction);
2. Explicit PIs are necessary in defining a sense of urgency and the need of action, which goes beyond the mere agreement on the issue (e.g. EU policy on climate change);
3. PIs can be a top-down action so to build an idem sentire on issue which are not yet portrait as crucial by a larger pool of stakeholders (e.g. industry competitiveness).

This let us to define the PI as a tool to shape the political debate and to inform consequently policies able to reach the designated goal.

It should thus be clear that PI´s goal - by its own nature – is addressing at large fundamental concepts, and "to advise governments on what policies they should adopt". In other words, a PI is an indication of a desired target. It is true that PI presents itself with very strong definitions, encompasses both the word "political" (e.g. the state monopoly of power) and the word "imperative" (e.g. something absolutely necessary or required; unavoidable), but the combination of the two into PI does not represent in se a policy. PIs are instrumental in nudging stakeholders and citizens to inform their actions towards desired goals. In this vein, a PI in se does not define (practical) action for the achieving of the portrayed goals, nor builds a roadmap.

In this regard, the concept of PI resembles normative scenarios, being the latter also used as a suggestion in formulating public policy able to reach a designed goal. This leads us to understand also why PIs and normative scenarios can overlap and how both can have strong value and clear target (e.g., 50% Co2 emission reduction for 2050), but they still have very vague strategy for the achievement of their targets.

Finally, PIs can vary according to time, geographies and "producers".

About time, if we focus on the transport field, it is interesting to remark how a (explicit) PI of the past was the motorisation of agricultural work and transport, with little or null awareness of the long-term consequences (Ladd 2008). The consciousness of externalities has changed this PI, and new PIs are now aiming to not-motorized transport solutions, especially in urban areas.

About geographies, PIs can vary, even dramatically, according to local characteristics and situations. Thus, PIs can be having divergent or even clashing goals. For instance, the role of climate change in formulating PIs is indeed crucial in many governmental circles, both in Europe and Asia, but is marginal (or even denied) in USA (at least at the federal level).

Indeed, the case of USA introduces to the question of the PI "producers". In that case, while the federal government is refusing to inform its policy and its PIs according to climate change and transition toward sustainability, several USA states still address their own PIs in line with those objectives. This leads us to define PIs as the result of national, international and supranational governmental bodies´ action. Just to add more complexity to the picture, also intergovernmental organizations are PIs producers. In this symphony of PIs, we can also aspect private actor's and stakeholder´s attempt to lobby their interests, and thus shape the debate and the PIs formulation.

3.2. Political Imperatives in Transport Research and Planning

Once we move to a more detailed understanding of PIs engaging the transport sector, still we realize the need of a preliminary and notional framing of the concept. We have seen as PIs are assuming the form of commendation in formulating public policy. But, often, and exactly because of their goals (large and general in the scope), not always PIs are precise in their devising. Some PIs are very clear and self-evident: EU´s PI of keeping European industry competitive in a global scale is a great example. Another good example is EU Co2 reduction goal: while many if not all of us can agree on this PI, it is also true that we need more information about the PIs, so to understand if they need to be part of our investigation about the transport sector. This is a slippery issue, because often PIs address issues which impact transport policy, though they don´t openly address topics or issues immediately linked to transport. PIs on Co2 emission reduction for instance deal with a more general environmental argument, but without doubt transport is of the main filed of implementation. Sometime the connection is less straightforward. Social inclusion is an important PI, with a growing relevance and here it comes the twist: the role of transport in shaping social exclusion (or vice versa to shape inclusion) is gaining traction…

This situation asks us to define two methodological line of action:

- In first place we need to identify those PIs which are really tied up with the transport sector, regardless of the definition of the topic;
- In second place, once the selection of those PIs is accomplished, we should consider and analyse only those PIs which are part of INTEND range of action and interpretation (e.g. "Identify the main transport research needs and priorities").

3.3. A practical Definition of PI

At this stage we can finally shape a practical definition of PI, one that fits the scope of the project and, more in detail, this deliverable.

We assume that, as Fig. 4 illustrates, PIs are of a dichotomous nature:

1. They are "…perspectives or theories that purport to advise governments on what policies they should adopt in this context as a matter of efficiency, fairness, justice, or some other conception of right and wrong" (Trebilcock 2014, p. 9).
2. In the context of specific perspectives and theories, Political Imperatives are notices of intention to implement specific policies/ to reach specific goals, in order to achieve efficiency, fairness, justice, or some other conception of right and wrong purported to be adequate.

This deliverable aims to identify PIs according to their actual field of engagement, regardless of their labelling or definition.

It, moreover, focuses on those major PIs affecting "economic efficiency, competitiveness, sustainability, user convenience and inclusiveness" (European Commission, 2015).

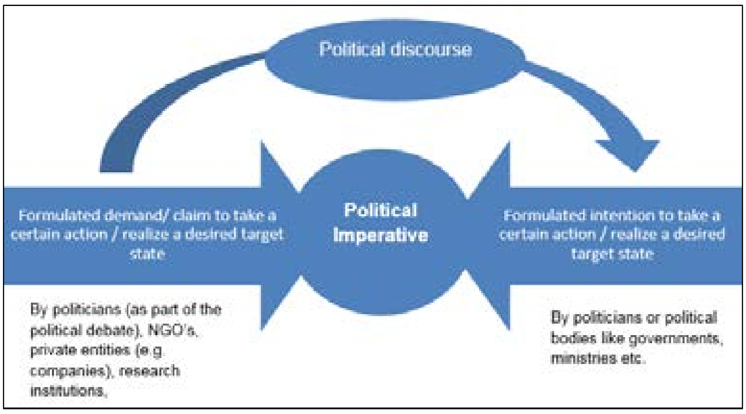

Fig. 4.
A practical definition of the term "Political Imperative" for INTEND

4. Stakeholder Analysis and Compilation of Political Imperatives in the Transport Sector

4.1. Stakeholder Analysis/ Collection of Literature

As described in Chapter 2, qualitative content analyses always bear the risk that the selection of adequate sources as well as the assessment of their contents are being influenced by subjective actions of the scientist/ person working on the analysis itself.

In order to minimize this risk Chapter 2.1 already underlined that clear criteria for literature selection and assessment have to be fixed right in the beginning. The involvement of more than one person, double-checking of the appliance of latter mentioned criteria as well as an intensive critical reflection of first results and a continuously critical reflection during the collection and assessment phase can also safeguard to keep the influence of bias as a result of subjectivity as minimal as possible.
During the phase of stakeholder analysis and literature collection, criteria have been applied as presented in Table 2 and Table 3
The global criteria were the guiding principles valid for the whole stakeholder analysis and collection of literature. The criteria presented in Table 3 have been applied stakeholder-type specific.

Table 2
Global criteria

Criterion	Description/ Explanation
Internet search engines	Google, Qwant, Yahoo, Bing
Search queries	For the literature research, the search terms were mostly entered directly into the search function on the websites of the specific stakeholders previously identified as relevant. The following search terms were used: 'future', 'transport', 'mobility', 'future of transport/mobility', 'transport strategy', 'transport policy', and 'infrastructure development plans'. Often it was also possible to get results through using the menu function on a certain webpage. When searching on research platforms, the terms were entered directly into the search engine of the specific scientific research platform.
Use of direct sources	• Only literature/ sources of information of the stakeholder itself or produced based on a subcontract have to be used. This shall safeguard capturing the intention/ demand that has been formulated by the stakeholder and not capturing the interpretation of another party that might be subject to influences of a third party. Example: Transport Strategy of a government instead of EC country reports. • Statements in press and media are not to be included for following reasons: 1. Statements in local/ regional/ national press and media are often depending on politics of the day and are thus seldom valid for a longer period of time. 2. Statements in press and media are often formulated in the respective national language. Thus they are seldom reaching the international discourse (only indirectly as an interpretation by international press agencies). Scanning national press and media as well as would have resulted in unpredictable additional efforts (language) and many uncertainties (gaining a balanced picture).
Actuality	• Only sources pointing to the near and far future have to be considered. This also includes statements regarding the assessment of the current • For transport strategies of governments/ ministries the year of this study (2018) had to fall into the period of validity of the concept/ strategy.
Language	• Only sources in English language have to be considered, for two reasons: • Publishing reports and statements in English language –especially via governmental/ ministerial channels – is an indicator that the publishing entity is actively participating in the international discourse. • Assessing reports and statements in other national languages would have been resulted in unpredictable efforts or resulted in an unbalanced picture of the discourse.

Table 3
Stakeholder-specific criteria

Stakeholder	Criterion
Websites and reports of International non-governmental organizations (INGOs)	• The reports and statements of interest should focus on a global scale or at least on one specific region covering more than one country.
Non-governmental organizations (NGOs)	• The reports and statements of interest should focus on a certain region or more than one country. • Reports and statements of national NGOs should not be included to avoid creating an unbalanced picture.

Important companies of the transport industry	• Companies of the transport industry have their headquarters in one country. In order to avoid creating an unbalanced picture only globally operating companies will be included. The sectors investigated are as follows: Consultants, Oil/ Gas Companies, Logistics Companies, Automobile Producers, Conglomerates, Maritime/ Shipping Companies • For the identification of the most important, globally operating enterprises in the field of transport, the ranking list of the business magazine Forbes was used, which can be found at the following address: https://www.forbes.com/global2000/list/. The first five
Supranational organizations, intergovernmental organizations	• Reports of supranational and intergovernmental organizations will be differentiated according to their spatial relevance: Global, Europe, Other world regions
Governments/ ministries	• State structures and ministerial organization/ responsibilities vary from country to country. • In order to include imperatives formulated by the political sphere of the most important economies official governmental websites of countries with the ten largest GDPs have been scanned. The underlying assumption was that these big economies with their huge transportation markets have an important influence on the direction of the discourse regarding the future transport system [science, research and development, production, consumption, implementation]. • Since Europe is the main focus of the Intend project, reports and statements by the political sphere in Europe are of special interest. • For the EU 28 governmental websites and websites of the respective ministries have to be scanned in order to extract relevant statements and reports. • Since countries of Geographical Europe have strong economic/ societal/ political/ scientific relations with EU member states or might be future member states reports or statements by their political sphere regarding the future of the transport system is of special interest as well. Therefore their governmental websites, independent from the country's size or economic power, have to be included in the scanning process.
Science	Research and science play a key role in developing concepts and scenarios for a future transport sector. Although the influence of third-party funded research is constantly rising – putting the research's independence at risk – publications in international journals have usually undergone profound review processes assuring that the results presented have been derived based on adequate research design. Therefore only peer-reviewed scientific articles will be included. The scientific search engines that will be used are: sciencedirect.com, scholar.google.com, and webofknowledge.com

In order to avoid bias resulting from subjective perceptions of the transport sector the internet has been scanned for potential sources by more than two researchers, possibly with different backgrounds. For each type of stakeholder group the results have been discussed afterwards before the respective stakeholder found its way onto the stakeholder map, presented in Annex 1 and before the related report/ statement became part of the literature list.

4.1.1. Results

As a result of the stakeholder analysis and literature collection altogether 135 sources for political imperatives have been collected. This material comprises around 7,920 pages of information. As stated before, the material identified can be based on the communication model assigned to certain groups of stakeholders.

With regard to these numbers it has to be sated that governmental reports are nearly forming a third of the material that has been identified as relevant. The reason for this is that this deliverable also tries to capture imperatives by the political sphere.

In order to guarantee a comprehensive snapshot of the "state of imperatives" in Europe as well as outside of Europe, governmental and ministerial homepages of all EU member states have been scanned for relevant sources. This also with the purpose of later associating the European "state of imperatives" with the context of the worldwide "state of imperatives".

Here, it has to be mentioned that for the different groups more material has been searched and initially assessed, but that only material of those stakeholders was finally included that fulfilled the global and stakeholder-specific criteria, that have initially been set. For stakeholders marked in "orange" no material in English language could be identified. Although French and German are also official European languages the international discourse is taking place in English. Therefore, it can be assumed that information that is not being provided in English especially by governments and ministries faces higher barriers to find entrance to the international – partly also European – discourse.

Moreover, some material has been produced/ published by the same stakeholder. This is for example the case concerning big organizations like the European Union or the World Bank.

The whole list of the collected material with clear references can be accessed via the publicly available INTEND deliverable D 2.3 under www.Intend-project.eu/publications.

4.2. Adding Literature to the Atlas.ti Database

The computer programme Atlas.ti offers the possibility to add different document types to the before created project and to use them for evaluation: not only text documents, but also web pages, geo data, audio and video files.
For this analysis text documents only e.g. PDF-files, HTML-files and doc-files were used, which were identified as suitable sources during the literature research. As described in Chapter 4.1., websites and reports of International Non-governmental organizations (INGOs), Non-governmental organizations (NGOs), important companies of the transport sector, supranational organizations and intergovernmental organizations, governments/ministries and scientific research were used. To prevent any interpretation by a third party, only sources directly from the respective stakeholder were used for the study.

4.2.1. Results

With regard to the imperatives themselves it can be stated that for each field – demand/ claim or intention – every time a relevant passage had been identified a new code was created or the passage was assigned to an already existing code. As a result, the huge number of imperatives had at the end of the assessment process a frequency of occurrence of "1", "2", or "3". Although most of the resulting imperatives could – during the phase of generalization/ merging – be assigned to a top-level code a huge number of imperatives only occurring once or twice could not been generalized respectively summarized with another code. Altogether the original amount of around 633 identified demands/ claims and around 847 identified intentions could be generalized to 137 demands/ claims and 149 intentions respectively. This results in higher frequencies of occurrence per imperative allowing to identify those that seem to be of more or less importance.
For the demands/ claims it can be stated that around two thirds of identified demands were less than four times found in the different sources that have been assessed and could not be further summarized respectively merged with higher frequency codes.
As a result, although demands/ claims with a frequency between 42 – 5 are only representing one third of the frequencies identified, they are representing 70% – around two thirds – of the marked passages in all sources.
For the intentions it can be stated that more than two thirds of identified demands/claims were less than four times found in the different sources that have been assessed and could not be further summarized respectively merged with higher frequency codes.
Although intentions with a frequency between 42 – 5 are only representing one third of the frequencies identified, they are representing 76% of the marked passages in all sources.
Again, it must be stated that also the process of generalization and merging is based on the interpretation of the content hence potentially subject to misinterpretation.
Moreover, naturally, imperatives vary with regard to their level of detail, why they are sometimes difficult to distinguish from each other what can sometimes result in overlapping.
For the demands/ claims the imperatives having the highest frequencies (7 – 45) of occurrence are shown in Table 4. Table 5 does moreover illustrate in what kind of source the respective demand/ claim has how often been spotted and what it is directed to.
Correspondingly, Table 6 and 7 illustrate the spotted formulated intentions, their origin and targets.
Demands/ claims and intentions with lower frequencies than 7 can be reviewed in the full INTEND Deliverable D 2.3. accessible via the website www.intend-project.eu/publications.

Table 4
Formulated demand/ claim to the Political Sphere - based on Atlas.ti Code (see results in Table 5)

No	Formulated demand/ claim to the Political Sphere - based on Atlas.ti Code (see results in Table 4)
1	Reducing climate related externalities (esp. GHG, noise emissions, land take of corridors/ hubs) by implementing different measures (climate action plans, sup. green private investments, enforcing cap trade etc.)
2	Supporting industries and science in developing and implementing innovative fuel technologies (battery technology, advanced bio-fuels), raising awareness for alternative fuels
3	Revision, enforcement of safety standards, industry-independent certifying organizations, integration of safety aspects in planning frameworks (SUMP), harmonization of regulations (speed limits, vehicle safety, zero alcohol tolerance, helmet wearing), European safety agency
4	Vehicle efficiency as a key factor to gain more energy efficiency/ reduce consumption
5	Closer public and private cooperation (private investments in the network need to become more attractive [incl. PPP])
6	Supporting modal shift (aviation to rail or inland waterway, motorized to public transport/active modes)
7	Modernizing/ extending (peak hours) Urban Mass Public Transport Systems (impr. energy efficiency, and marketing)
8	Raising investment in infrastructure development (modernization, capacity upgrade) in rural and urban areas

9	Standardization, harmonization,adaptation of regulations on EU level (cross-border road conventions, single European Sky Initiative)
10	Revision of fuel and power taxation as well as regulation standards (reducing subsidies, clear indexing [also of impacts] for comparability)
11	Reliable, economical, affordable and environmentally friendly energy supply
12	Combination of electricity, transport and heat sector based on renewable electricity, bio fuels (sector coupling)
13	Controlling or reducing travel demand
14	Further developments in technology necessary (also vehicle technology: EV's, modular vehicles, innovative materials)
15	Higher efficiency of transport systems
16	Incentives/ awareness raising campaigns for fleet electrification (buses, private vehicles, rail); public and commercial procurement
17	Increasing connectivity, intermodal access and fit-for-purpose network standards
18	Investments in research and development activities must be strengthened
19	Coherent EU framework for autonomous vehicles (infrastructure investments, safe deployment, regulations for the transitional phase, reform of vehicle safety approval regime, regulation, registration)
20	Digitization strategy/ regulations/ markets at national, European and international level (incl. transport sector)
21	Improving bulk transportation methods for long distance freight transport (rail/river)
22	Innovative research system (stronger evaluation and coordination of research policies and their impact, international research in strategic fields, long-term [basic] research, supporting side-paths
23	Political measures must be transparent and predictable
24	Exploitation, piloting of new technologies must be promoted/ regional test beds for experiments, failing should be part of the ecosystem
25	Harmonized development activities and systematically implement a comprehensive vision for a competitive and sustainable European transport system and industry
26	Higher rate of vehicle occupancy
27	Improved risk management (legislation, data and information sharing, risk quantification metrics, scenario planning, two way information sharing)
28	Increasing hub capacities (ports, airports, stations)
29	Market opening needs to go hand in hand with quality jobs and working conditions
30	Research and planning should follow a holistic perspective on transport and mobility (consumer preferences, perceptions, behavioral aspects)
31	Research related to autonomous vehicles (environmental impact, impact on mobility behavior, human-machine interfaces in vessels, cyber- and data security, infrastructure investments, planning policies)
32	Universal application and enforcement of high working standards (safety/security, environmental protection, working conditions, payment)

Table 5

Short-listed Demands/ Claims (Imperatives) to the political sphere

	Origin													Target										
	World			World Regions Outside Europe				Geographical Europe					Frequency	Traffic Carrier being addressed				Traffic Purpose		Spatial Dimension				
No. of Formulated demand/ claim to the Political Sphere - based on Atlas.ti Code	Companies related to transport (global players)	INGOs	Supra-, intergovernmental organizations - worldwide	Countries with ten biggest GDP's	NGOs - Other world regions	Supra-, intergovernmental organizations - other world regions	Research other world regions	EU 28	Non-EU countries	Research on European level	Supra-, intergovernmental organizations - European level	NGOs - European level		Air	Road	Rail	Water	Passenger transport	Freight transport	Urban transport systems	Rural transport systems	Physical transport infrastructure in general	Transport sector in general	Information technology - Transport related data
1	2	9	17	1	0	0	0	5	0	2	3	6	45	4	5	1	7	4	0	4	0	3	22	0
2	5	6	4	1	0	0	0	17	0	3	1	4	41	4	3	1	2	2	4	5	0	3	15	0
3	0	4	2	2	0	0	1	2	0	0	0	21	32	0	23	0	0	1	0	3	1	1	3	0
4	1	5	5	0	0	1	0	11	0	1	4	1	29	0	0	1	0	1	1	0	0	4	11	0
5	2	0	6	3	0	5	0	5	0	4	1	0	26	0	0	2	0	0	2	1	0	1	15	1
6	1	2	6	0	1	0	2	4	0	0	3	0	19	1	1	5	1	3	2	5	0	2	4	0
7	0	3	2	2	0	0	0	6	0	4	1	0	18	0	0	1	0	10	1	12	0	1	1	0
8	2	0	4	4	0	2	0	3	1	1	1	0	18	1	0	2	0	3	6	1	0	6	4	0
9	0	0	1	2	0	0	0	2	0	1	1	7	14	1	8	1	0	1	3	0	0	1	2	1
10	1	2	3	1	0	0	0	1	0	1	0	4	13	1	2	0	1	0	1	0	0	0	7	0
11	0	0	1	0	0	0	1	2	0	0	2	4	10	0	0	0	0	1	2	0	0	0	6	0
12	0	2	0	0	0	0	0	4	0	4	0	0	10	0	0	0	0	3	0	2	0	1	7	0
13	0	4	1	0	0	0	0	3	0	0	0	2	10	1	1	0	0	2	1	1	0	0	4	0
14	0	0	1	0	0	0	0	4	0	4	1	0	10	1	5	1	2	1	0	1	0	0	3	0
15	1	0	3	1	0	0	0	1	0	0	3	1	10	1	1	0	0	1	1	1	0	0	4	1
16	1	0	4	0	0	0	0	0	0	4	0	1	10	0	2	1	1	1	0	1	0	0	4	0
17	0	0	2	2	0	2	1	1	1	1	0	0	10	0	0	0	0	5	0	3	3	3	3	1
18	1	1	0	1	0	0	0	7	0	0	0	0	10	1	1	1	0	1	2	0	0	1	3	1
19	1	0	0	1	0	0	0	3	0	1	0	3	9	0	8	0	0	2	2	0	0	1	4	1
20	1	0	0	0	0	0	0	6	0	0	0	1	8	0	3	0	0	2	3	0	0	1	5	3
21	0	2	1	0	0	0	0	4	0	0	1	0	8	1	2	6	5	1	4	0	0	2	0	0
22	0	0	0	0	0	0	0	0	0	8	0	0	8	0	0	0	0	0	0	0	0	0	8	0
23	3	1	1	0	0	0	0	2	0	0	1	0	8	0	1	0	1	0	0	0	0	0	2	1
24	0	0	1	0	0	0	0	4	0	1	0	1	7	0	2	0	0	1	2	0	0	1	3	1
25	1	0	0	0	0	0	0	3	0	1	0	2	7	0	1	0	0	1	1	0	0	0	4	0
26	1	0	2	1	0	0	0	1	0	0	2	0	7	0	0	0	0	3	2	1	0	1	1	2
27	0	3	0	1	0	0	0	3	0	0	0	0	7	0	2	0	1	2	4	0	0	0	4	3
28	1	1	1	3	0	0	0	0	0	0	1	0	7	3	0	0	4	0	2	0	0	0	1	0
29	0	0	1	2	0	0	0	1	0	2	1	0	7	1	0	0	0	0	0	0	0	0	5	0
30	2	0	0	0	1	0	2	0	0	1	0	1	7	0	1	0	0	0	0	0	0	0	5	0
31	1	0	0	0	0	0	0	0	0	6	0	0	7	0	7	0	0	0	0	0	0	0	0	0

32	0	0	1	2	0	0	0	3	0	0	1	0	7	3	0	0	1	0	0	0	0	1	1	0

Table 6

Formulated intention by the Political Sphere - based on Atlas.ti Codes (see results in Table 7)

No	Formulated intention by the Political Sphere - based on Atlas.ti Codes (see results in Table 7)
1	Sustainable transition of energy supply and transport sector (low emissions, electrification, bio-fuels)
2	Improving safety standards (vehicles and infrastructures, incl. innovative technologies [C-IST]); safety training (emphasis on vulnerable groups)
3	Developing public transport systems (demand-responsive, comfortable, accessible, barrier-free, affordable, attractive, efficient, subsidized, innovative [mobility chains])
4	Improving connectivity within and of regions in a national and international (incl. European) context (incl. cross-border commuting)
5	Investments in transport infrastructure (arteries [incl. oil and gas distribution infrastructure] and gateways [airports, ports, train stations])
6	Improving intermodality
7	Increasing competitiveness and efficiency through organizational, management and functional optimization (incl. new
8	Implementation of intelligent transport systems (incl. autonomously driving vehicles)
9	Increasing efficiency and capacities (incl. elimination of bottlenecks)
10	Creating incentives for a modal shift, favoring environmentally-friendly modes
11	Fleet renewal and electrification
12	Supporting high speed connections, reducing travel times between cities
13	Strengthening national/ international competitiveness
14	Improving cost-effectiveness and sustainability of the financing system, developing innovative financing models
15	Reducing travel demand (e.g. by demand reducing land use structures, better communication infrastructures)
16	Improving security/ security training
17	Improving the quality of the railway infrastructure (TEN-T, freight corridors)
18	Minimization of negative impacts (externalities regarding health and climate) of transport and infrastructure
19	Improving accessibility (also for persons with reduced mobility)
20	Creating attractive infrastructures for slow modes
21	Research and development of new fuels and new transport technologies
22	Supporting ICT, open data
23	Development towards MaaS
24	Strategy development together with policy makers, science and industry
25	Improved connectivity to support growth of tourism industry
26	Increase competition in national rail market
27	Developing/ harmonizing rules concerning data collection (ownership, management etc. vehicle registration, road traffic crashes, drivers licenses, status of infrastructures), improving data quality, using innovative technologies for data collection
28	Transport sector should be privatized (passenger and freight)
29	Developing a climate change adaptation approach
30	Increasing capacities and qualities of airports
31	Creation of recharging and refueling infrastructure networks
32	Establishing a single African air transport market
33	Improving airport accessibility and predictability of first and last mile connections (passenger and freight)
34	Supporting local SMEs
35	Transport should promote environmental and urban sustainability

Table 7
Short-listed Intentions (Imperatives) by the political sphere

	Origin													Target										
	World			World Regions Outside Europe				Geographical						Traffic Carrier				Traffi c		Spatial dimensio				
No. of Formulated intention by the Political	Companies related to transport (global players)	INGOs	Supra-, intergovernmental organizations - worldwide	Countries with ten biggest GDP's	NGOs - Other world	Supra-, intergovernmental organizations - other world regions	Research other world regions	EU 28	Non-EU countries	Research on European level	Supra-, intergovernmental organizations - European level	NGOs - European level	Frequency	Air	Road	Rail	Water	Passenger transport	Freight transport	Urban transport systems	Rural transport systems	Physical transport infrastructure in general	Transport sector in general	Information technology - Transport related data
1	0	0	10	2	0	5	1	66	9	0	4	1	98	8	10	11	15	17	11	6	5	12	45	3
2	0	6	5	10	0	2	1	24	5	0	2	19	74	3	37	3	1	8	2	6	2	3	20	3
3	0	0	2	2	0	0	0	29	5	0	1	0	39	1	4	5	2	25	3	10	5	3	15	1
4	0	1	2	5	0	2	0	23	3	0	0	0	36	4	4	9	3	9	7	4	0	0	19	1
5	1	0	3	6	0	3	0	19	2	0	0	0	34	2	8	11	2	7	7	2	1	7	11	1
6	0	0	5	4	0	3	0	19	0	0	2	0	33	4	3	4	2	9	3	5	1	5	13	1
7	0	0	2	2	0	0	0	13	8	0	2	0	27	3	4	2	1	2	4	2	0	2	14	2
8	0	1	2	2	0	0	0	13	3	0	2	0	23	0	6	0	1	3	3	2	1	2	10	7
9	0	0	3	2	0	1	0	9	6	0	2	0	23	2	4	4	2	5	4	1	2	1	7	1
10	0	0	2	0	0	1	0	17	0	0	1	0	21	1	4	5	3	9	2	3	4	1	6	2
11	0	1	1	0	0	0	0	17	1	0	1	0	21	2	9	8	4	9	4	5	0	4	8	2
12	0	0	3	4	0	3	0	8	3	0	0	0	21	1	3	15	0	8	2	4	0	1	4	0
13	0	1	3	2	0	1	0	11	1	0	2	0	21	0	1	2	5	1	6	0	0	0	8	1
14	0	0	0	1	0	0	0	13	6	0	0	0	20	1	2	2	4	4	2	1	2	2	12	1
15	0	0	0	0	0	0	0	19	0	0	0	0	19	0	0	0	1	4	2	2	1	2	9	3
16	0	0	4	2	0	1	0	3	5	0	3	0	18	3	2	1	2	3	3	0	1	0	5	1
17	0	0	5	0	0	1	0	5	1	0	4	0	16	0	0	10	0	3	6	0	0	1	1	0
18	0	0	0	0	0	0	0	13	1	0	0	1	15	1	2	1	0	2	0	2	0	0	11	0
19	0	0	1	2	0	1	0	10	0	0	0	0	14	0	2	0	0	6	1	3	3	0	6	0
20	0	0	1	1	0	0	0	10	0	0	1	0	13	1	3	2	2	6	0	7	1	2	2	0
21	4	0	0	3	0	0	0	6	0	0	0	0	13	1	1	1	1	1	0	1	0	3	11	1
22	0	0	1	3	0	1	0	6	0	0	1	1	13	0	0	0	1	3	2	0	1	1	5	6
23	0	1	0	2	0	0	0	8	1	0	0	0	12	0	0	0	0	5	0	4	1	3	6	3
24	0	2	0	2	0	0	0	6	1	0	0	0	11	1	1	0	0	0	0	1	0	0	8	0
25	0	0	2	0	0	2	0	5	1	0	0	0	10	4	1	1	1	3	2	1	1	1	2	0
26	0	0	4	1	0	2	0	0	1	0	2	0	10	0	0	6	0	1	1	0	0	0	0	0
27	0	1	2	1	0	1	0	3	0	0	1	0	9	0	4	0	0	1	1	0	0	2	2	5
28	0	0	1	1	0	1	0	0	6	0	0	0	9	0	0	3	1	0	2	0	0	0	4	0
29	0	0	0	0	0	0	0	8	0	0	0	0	8	0	0	0	0	0	0	0	0	0	8	0
30	0	0	2	4	0	1	0	0	0	0	1	0	8	4	1	3	2	0	1	2	0	1	1	0
31	0	0	0	0	0	0	0	7	0	0	0	0	7	0	2	0	0	0	0	0	0	3	1	0
32	0	1	3	0	0	3	0	0	0	0	0	0	7	3	0	0	0	1	2	0	0	0	1	0
33	0	0	1	0	0	1	0	5	0	0	0	0	7	3	1	1	0	2	1	0	0	1	0	0
34	0	0	0	0	0	0	0	7	0	0	0	0	7	1	1	0	1	0	1	0	0	0	3	1
35	0	0	2	2	0	2	0	1	0	0	0	0	7	0	0	0	0	1	1	3	0	0	2	0

As a general outcome, it is remarkable that the imperatives with the highest frequencies are the ones that have the goals of making the transport sector more sustainable and safe and are thus targeting the whole sector. This includes PIs with goals of reducing GHG emissions by supporting modal shift, substituting the source of energy (EV's, alternative fuels) or using existing infrastructure more efficiently are making up the majority. For the demands/ claims 15 out of 32 imperatives are addressing this topic. For the intentions 13 out of 35 imperatives are addressing this topic.
On both lists the aspect of traffic safety received a quite high ranking (Demands/ Claims Rank 3, Intentions Rank 2) and the imperatives are over proportionally often targeting road transport.

4.3. Demands/ Claims

In general, it can be stated that the demands/ claims focus mainly on the creation and implementation of clear and reliable frameworks and regulations. This is the case for the demands/ claims 1, 2, 9, 10, 19, 20, 23, 25, 27 and 32 as shown in Table 5. Here an important point is especially the harmonization of standards, rules and regulations inside the European Union (e.g. soft-policy tools). Forward looking imperatives are especially touching urban transport and data issues. Here the imperatives are demanding:

- A standardized EU-wide framework for autonomous driving vehicles, including the transition phase;
- A digitization strategy for the transport sector (including clear and secure standards for data generation, management and privacy);
- Harmonized development activities and a systematically implementation of a comprehensive vision for a competitive and sustainable European transport system and industry (preserving the competitiveness of the fossil fuel industry).

According to the imperatives identified, the development and implementation of new technologies should be fostered by stronger financial commitment of the governments – also by regulatory measures like fair fuel taxes – but also by raising the attractiveness for private investors. Moreover, there are demands/ claims that are not exclusively targeting further growth, extensions of infrastructures. The imperatives 4, 12, 13, 15 and 26 are stressing the point of reducing the use of existing capacities, raise efficiency levels – e.g. by creating synergies via sector coupling – or increase levels of vehicle occupation.
Some demands are also stating that the costumer should be able to make informed decisions, as for example in the cases of mode choice, vehicle procurement, and fuel-consumption. According to the related imperatives this can be reached by implementing information campaigns, an implementation of transparent and comparable pricing standards, but also via an advance information tool (carbon footprints of possible mobility alternatives), as stated in the imperatives 2, 7, 10 and 30.

4.4. Intentions

The intentions are also mostly focused on the transport sector in general. The two most important targets are i) to realize the transition of the energy supply (electrification of the transport sector) and ii) to improve traffic safety. The latter imperative is mostly related to road transport. Altogether, 11 out of 35 imperatives formulated policy intentions to directly or indirectly reduce the negative impacts on the environment. In general, it can be stated that imperatives pointing to standardization, harmonization of regulations were in the short-list of the intentions – with one exception – completely missing.
Instead, the imperatives were more often pointing to a local, regional, national, international integration of physical networks to improve connectivity or accessibility and thus create a more attractive climate for enterprises. Here 8 out of 35 imperatives were directly or indirectly addressing this target. These were the intentions 4, 5, 12, 17, 19, 25, 32, 33. Another often mentioned topic was the one that targeted an optimization of existing networks (nodes and hubs) by reducing bottlenecks or extending existing capacities. This topic has been addressed by the imperatives 3, 5, 7, 9, 12, 30. A general observation that can already be made even by having a quick look of Table 6: the imperatives are in equal measure addressing most of the target sectors. While the demand/ claims were mostly focusing urban transport systems, it can be observed here that also rural transport seems to play an important role. Additionally, aspects like barrier-freedom or accessibility of vehicles and areas are more often mentioned. This is of course related to the kind of source and stakeholder.
So, the forward-looking intentions (imperatives) that have been mentioned are:

- Increasing competitiveness and efficiency through organizational, management and functional optimization (incl. new technological solutions);
- Implementation of intelligent transport systems (incl. autonomously driving vehicles);
- Improving cost-effectiveness and sustainability of the financing system, developing innovative financing models;
- Supporting ICT, open data;
- Development towards MaaS.

4.5. Demands/ Claims and Intentions with Relation to Research

Generally speaking, the sources used addressed more often demand and claim than intentions. Highest frequencies can be reported for the technology-based research, such as:

- Supporting industries and R&D in developing and implementing innovative fuel technologies (incl. battery technology, advanced bio-fuels), related infrastructure development as well as raising awareness for alternative [incl. electric] fuels;
- Research on traffic safety;
- Further developments in technology necessary (also vehicle technology: EV's, modular vehicles, innovative materials).

Other demands/ claims were formulating respectively suggesting a reform of the research environment itself or research on the impact of new technological solutions, transport systems:

- Investments in research and development activities must be strengthened;
- Innovative research system (stronger evaluation and coordination of research policies and their impact, international research in strategic fields, long-term [basic] research considering the innovation cycle, supporting side-paths in risky but promising research fields [where failing is too expensive for private research);
- Exploitation, piloting of new technologies must be promoted/ regional test beds for experiments, failing should be part of the ecosystem;
- Research and planning should be realized/ conducted following a holistic perspective of transport and mobility (consumer preferences, perceptions, mode choice, behavioral aspects);
- Research related to autonomous vehicles (environmental impact, impact on mobility behavior, human- machine interfaces in vessels, cyber- and data security, infrastructure investments, planning policies).

For the intentions only five imperatives related to research and development could be identified. These were more related to the development of strategic approaches or innovative policies:

- Improving cost-effectiveness and sustainability of the financing system, developing innovative financing models;
- Research and development of new fuels and new transport technologies;
- Strategy development together with policy makers, science and industry;
- Developing/ harmonizing rules concerning data collection;
- Developing a climate change adaptation approach.

5. Summary and Outlook

This meta-analysis has assessed altogether 135 different sources by stakeholders with relation to the European and global transport sector. A software supported qualitative content analysis of around 8,000 pages led to the result that altogether 286 political imperatives – 137 demands/ claims formulated to the political sphere and 149 intentions formulated by the political sphere– have been identified.

Imperatives that are amongst other aspects directly or indirectly having the goals of reducing GHG emissions by supporting modal shift, substituting the source of energy (EV's, alternative fuels) or using existing infrastructure more efficiently are making up the majority. For the demands/ claims 15 out of 32 shortlisted imperatives are addressing this topic. For the intentions 13 out of 35 shortlisted imperatives are addressing this topic.

Moreover, on both lists the aspect of traffic safety received a quite high ranking (Demands/ Claims Rank 3, Intentions Rank 2) and the imperatives are over proportionally often targeting road transport.

In general, it can be stated that the demands/ claims are rather focusing the creation/ implementation of clear and reliable frameworks and regulations. On the contrary imperatives pointing to standardization and harmonization of regulations were – with one exception – completely missing in the short-list of the intentions. Here, an important point is especially the harmonization of standards, rules and regulations inside the European Union.

Forward looking imperatives are especially touching urban transport and data issues. Here it can be stated that the imperatives coming from the European stakeholders were much more forward looking and that topics like intelligent transport systems, MaaS, green logistics have already – although quite weak – already found entrance into some strategy papers.

Nevertheless, there were still demands that might become more relevant in future and have yet not been sufficiently considered. These demands mostly relate to the development of long-term strategies in order to create also a reliable development for the economy. This touches topics like a digitization strategy for the transport sector, a strategy to apply and enforce high working standards also to safeguard a sufficient amount of workforce in the transport sector.

Other demands strongly point to research and development in sharing services, autonomous vehicles which are currently revolutionizing the transport sector. This requires innovative planning strategies and ways to regulate and develop new markets into the "right" direction, which opens-up another topic. Other demands/ claims were formulating respectively suggesting a reform of the research environment itself also by taking over a new rather holistic perspective on mobility and to orient research on societal needs. An interesting imperative that has been identified as a demand and intentions was to develop ways to reduce traffic demand and to escape from the growth-spiral.

Finally, the method chosen proofed to be adequate for delivering an initial snapshot of the current state of imperatives with relation to the transport sector. However, it has to be expressed that a deeper and especially longer lasting assessment of the international sphere and national sphere also by integrating other methodological approaches like expert interviews into the research concept would have been able to create deeper insights or to validate the outcomes. This was due to the limited amount of time not possible. This deliverable has, nevertheless, created a sufficient and most of all structured overview of the most important political imperatives can be valuable source for further analyses.

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SMART TRANSPORTATION PLATFORM FOR BIG DATA ANALYTICS AND INTERCONNECTIVITY

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Abstract: Innovations in Big Data Analytics and advances in Internet of Things have changed how we collect, interpret and analyses data from Smart City and Transportation environments. Advances in Fog Computing that suggests the extension of the Cloud to the Edge of the network using resources available to reduce latencies and improve reliability fit perfectly with concepts from autonomous and connected vehicles which have increasingly powerful processing capabilities. The use of such systems for congestion management, route planning, infrastructure management and other advances orchestration techniques requires the use of varying platform and technologies together. The existing proposals and platform are mostly designed to perform a fixed set of tasks, either purpose built or not generic enough to satisfy requirements from multiple use-cases. This paper analyses existing Fog Computing and Processing platforms characteristic data types and their brokers as well as existing Big Data cluster-computing frameworks like Apache Spark and Hadoop based on capabilities, data types and preferred use-cases. Supported by this analysis we propose a conceptual polyglot Fog Computing platform for Smart Transportation scenarios that can satisfy the needs of future smart city environments and can connect to multiple platforms and perform real-time, off line and hybrid processing of data as well. We provide a high-level framework for the integration of such platforms into collaborative clustering scenarios.

Keywords: smart transportation, fog computing, big data analytics.

1. Introduction

With rapid advances in autonomous vehicles and highly connected systems in the context of smart cities and transportation as well as the ubiquitous application of machine learning and data analytics in both local and cloud environments the field of future transportation and cities is rapidly expanding branching out into several research fields.
When considering Smart Transportation and smart, their interconnection in smart grid, opportunistic networks or clusters has become an increasingly appealing challenge. Especially with the introduction of concepts from Fog Computing with the local processing and decision making as an attempt to solve the scalability latency and some of the security issues inherent with cloud and centralized computing. This comes as there is an increased need for resource intensive processing and an increased concern over data-security and storage.
The recent Fog Computing framework proposals and IoT Middleware Reference architectures there is an increasingly clear consensus on the requirements of these gateways and of the use-cases in which they would be deployed. This makes possible the development of a system that can be can answer the required modularity, interconnectivity and lower level functionality abstraction to a degree where the development of management, control and analytics components for smart cities and vehicles becomes as trivial as mobile application development.
This paper proposes an IoT and Fog based Vehicle Centric Smart Transportation platform that look at the development of Smart Localities based on Wireless Sensor Networks (WSN) using Dynamic clusters based on fixed point gateways and mobile entities such as vehicles or other gateway enabled entities that cross these static regions and interact with them. Through this paper we will present a review of some of the existing middleware or gateway platforms, their advantages and drawbacks. Furthermore, we propose a dynamic application deployment and updating mechanism for these gateway for functionality extension as well as well as an experimental setup for the testing of the deployed systems.

2. State of the Art

When considering the background work that has been done for the development of these platforms there are several things that need to be considered. Concepts and Requirements need to be considered from the IoT domain that allow these gateways to be interconnected and for the connected devices or things to talk to each other in a protocol agnostic manner. Recent approaches require that the processing and other resources of the system be virtualizable and manageable to a level traditionally associated with Cloud computing. The paradigms and virtualization layers of new Fog computing approaches come into play in such systems, where some off the computational tasks can be offloaded to the edge, reducing costs and the strain on the network. These requirements and paradigms have led to several platforms being proposed that aim to solve portions of the problem. They range from Virtual Machine (VM), Container and shared environment solution, which offer varying levels of security and performance advantages.

2.1. Internet of Things

Internet of Things (IoT) is defined as the sensing analytics and visualization done anytime, anywhere and on anything (Gubbi et al., 2013) It can be considered the interconnected network of billions of devices as Gartner estimates at least

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26 billion devices connected by 2020 (Rivera et al., 2013). When considering the application of its concepts for Smart Cities its main advantage is the seamless integration of a large set of heterogenous devices and systems (Zanella et al., 2014).

There are several views when it comes to the tasks of IoT devices. Some see the role of edge devices and systems simply that of data whereas other proposals as in (Gaur et al., 2015) show the possibility of giving more agency to these edge devices by allowing decision making and connectivity tasks to be performed in a decentralized manor. The work in (Papadimitratos et al., 2009) looks at more complex vehicular networks where the vehicles are the network creating a large peer to peer network while (Verba et al., 2017) looks at their structure.

When considering the interconnectivity proposed by the Internet of Things, the field of Cyber-Physical Systems looks at how these systems should gather data, make decisions and interact with their environment. An overview of this can be seen in (Rawat et al., 2015) where they provide an overview of the impact of CPS on Smart vehicle systems and the impact of delays and latencies on these. The requirements of such systems can be seen in (Madakam et al., 2015) where a review of agent based systems is performed and a need for interoperability, flexibility and extensibility of such gateways which are in line with the IoT Requirements.

The processing, routing and mining of data for Traffic Monitoring, Management and Vehicle control is a crucial part of Smart Transportation systems as shown in (Chen et al., 2016), where the challenges of gathering and processing this data is mostly related to the quantity of messages and the semantics related to these sometimes, simple sensor messages.

When considering all the research, it can be said that future IoT systems will require decentralized control and analytics within highly interconnected vehicles or devices that can interact with their surroundings through some sort of local or peer networks.

2.2. Middleware and Gateway Platform Review

When considering gateways for smart city and transportation scenarios they need to satisfy the above-mentioned requirements and follow the existing directions if they are to be used as future platforms. An overview of some of the technologies and containers being used can be seen in (da Cruz et al., 2018) The overview of a few platforms implementing Fog Computing paradigms in the context of connected devices has be shown in Table 1. where they are analysed for their compliance based on the system requirements shown above.

Table 1
Overview of Fog Computing Platforms

Platform	Inter-operability	Abstraction	Container	Cooperative Behaviour	Load Distribution
(Hao, J., et. al., 2015)	✓				
(Rathore, M.M., et. al., 2016)	✓	✓			
(Chen, F., et. al.,2015)	✓	✓	✓		
(Sanchez, L., et. al.,2014)	✓		✓	✓	
(Verma, S., et. al., 2016)			✓	✓	✓
(Bittencourt, L.F., et. al. 2015)	✓	✓	✓		✓

The platform proposed in (Hao et al., 2015) provides a CoAP and generic HTML based IoT Environment for message routing with an analysis of acceptable delays in such systems, but fails to offer on gateway processing capability or any means of static or dynamic load distribution. The solution in (Rathore et al., 2016) provides a polyglot, layered and hierarchical system view where the gateway has only a broker role. The data mining platform from (Chen et al., 2015) provides a higher-level data analysis for metadata extraction and semantics based on their layered app based architecture. The platform from (Sanchez et al., 2014) provides a large scale implemented network that is designed to facilitate future tests on IoT Systems. The proposal in (Verma et al., 2016) provides a way of deploying and managing Virtual Machines in a fog Server Tier. A similar proposal is suggested in (Bittencourt et al., 2015) that looks at high interconnectivity and migration support with device and message abstraction but without a cooperation mechanism.

2.3. Fog Computing

Solving the problem of processing large data-sets on the edge while maintaining some of the capabilities and benefits of cloud systems was attempted by Cisco in (Bonomi et al., 2012) where they proposed the offloading of processing tasks to the edge of the network through Fog Computing. This approach aims to solve some of the latency, security and cost issues with using cloud systems, while improving on the scalability of a private clouds through the pre-processing of data locally.

The distributed control of such Smart Transportation systems has been proposed in (Banks et al., 2018) while (Hou et al., 2016) provides an overview of the addition of vehicles as system nodes forming the Vehicles as Infrastructure initiative. Proposals such as in (Hao et al., 2015) look at Urban planning based on big data management.

Considering these proposals, Fog computing paradigms and approaches are being used to tackle some of the challenges posed by big data management and processing. Furthermore, consideration of scalability and security as well as platform lock-in are also important in similar systems.

3. Vehicular Fog Computing Architecture

When formulating the components and choosing the protocols for the Vehicular Fog Architecture, the main directions, requirements and approaches that were used in the research reviewed in the previous sections need to be considered. One of the most important components that is most often noted in IoT systems is the capability to interconnect devices from different platforms and physical communication backgrounds. To do this our system needs to be able to allow components from different platform to interact using a common protocol or messaging service. The generated messages need to be translated or their protocol specific characteristics need to be abstracted away. These platforms need to be able to do local processing if the direction of Fog computing is to be followed and they need to be able to cooperate through service and resource sharing while allowing the use of these to be improved through either global or load balancing optimization.

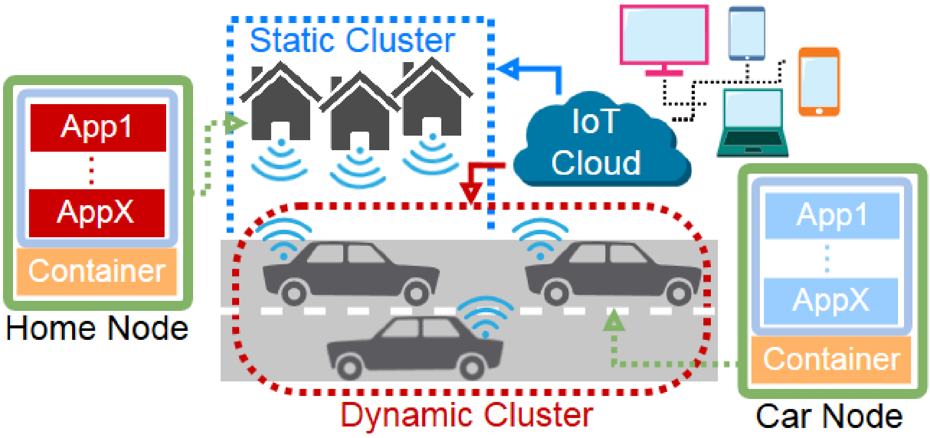

Fig. 1.
Overview of Smart Transportation Platform

Our approach is an extension of the work done in the PaaS approach from (Verba et al., 2017) for such a system that can be seen in Fig. 1. where a high-level view of the system is shown. Here we can see that the proposed Platform design is deployed on each Node on the system, which can be a Home based, Car based, Cloud based, Personal and other types of nodes. When these are considered the main difference between nodes is they mobility. Some nodes are static nodes that either don't or rarely change their location and peer group. The mobile or dynamic nodes change their location constantly as they could be a personal phone, a car, or other vehicles in the system. These varying characteristics are used to create clusters with different interdependencies and connectivity characteristics.
The IoT Cloud connection layer is available to all peers in the system and is designed to allow for higher level data analysis and processing tasks to be run where local information and data is not enough or higher-level decisions need to be made. The cloud layer is designed to incorporate different protocols and link them with the existing analysis and decision systems.

3.1. Fog Platform

The Fog Platform Deployed on all nodes, both static and dynamic have at their core the platform described in Fig. 2. This element relies on the fundamental idea that all components should be accessed in a unified way and the system needs to separate events and control commands that are crucial to transmit from data streams that require high bandwidth but where low reliability and higher latencies are acceptable.

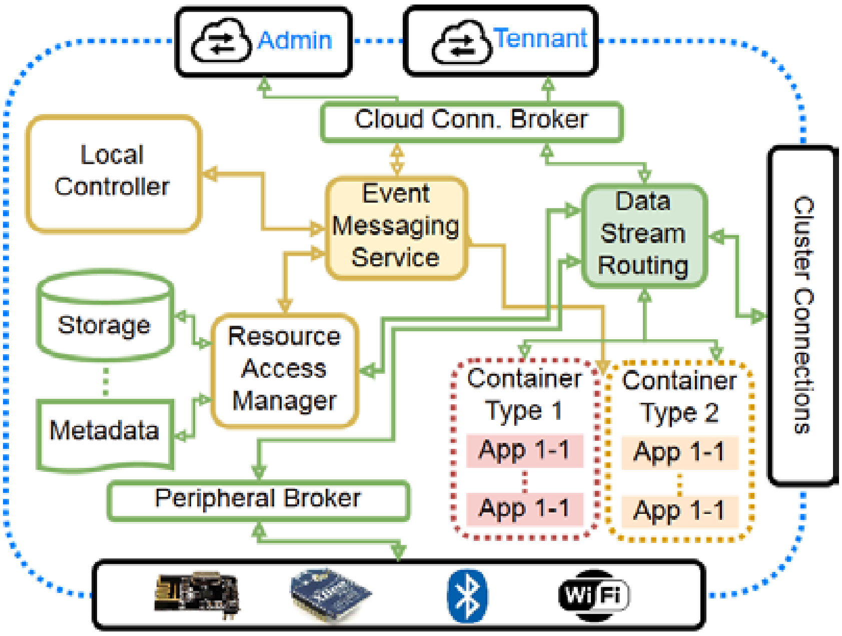

Fig. 2.
Overview of Smart Transportation Platform

The application containers on the system can vary based on use-case and requirements from, VM's to Docker images to Application deployed in shared environments. The main similarity between these is that they will have on message transmission system based on routing to send and receive information to peers. The same thing can be said for the peripheral, cloud and cluster brokers that take local events, messages and data then wrap these into the appropriate format for the sink they are sending it to. The Resource access manager controls the flow of information from apps and other peers to metadata information such as location, signal strengths etc. and varying storages. The local controller receives commands from on-site users and the administrative cloud which it uses to identify peers and control containers, the resource manager and the brokers.

3.2. Cloud Processing Layer

The Admin Cloud layer is tasked with performing centralized control commands on the deployed nodes and providing a user interface where the deployment schematics and system can be viewed. This layer is also tasked with authenticating nodes on the system and between each other. The management of users and region on these nodes is done locally. An overview of this and the tenant cloud layer can be seen in Fig .3.

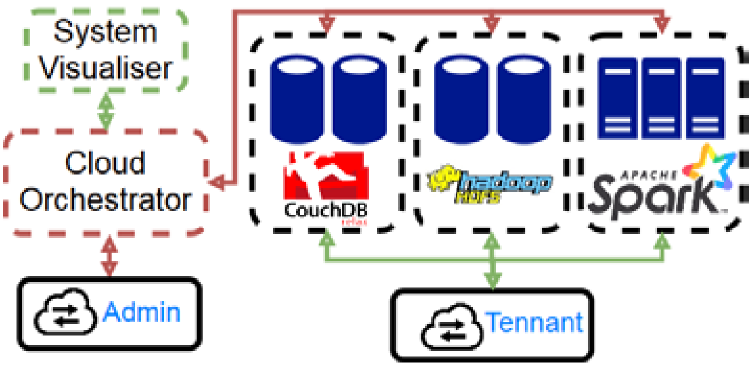

Fig. 3.
Cloud Orchestration and Processing Layer

The tenant cloud layer is designed to link the incoming data from application and nodes to the processing and storage units. The means and parameters of the storage are controlled by the cloud orchestrator which creates the databases and deployed the Hadoop or Spark tasks. This component is also responsible with configuring what happens to the resulting data.
The system visualizer or user interface allows managers and users of the system to have a graph based representation of the application deployed on the system and their interaction. This system aims to show at one time one node with all its applications and resources together with all the applications on other nodes it interacts with. This system aims to show all the apps that are deployed on other nodes but use information from the viewed node as well.

3.3. Clustering and Application Deployment

The creation of clusters and the temporary or permanent addition of peers is central to extending the functionality of IoT systems and realizing the requirements of Smart Cities and Transportation. The mechanism for clustering needs to be able to handle a highly heterogenous set of nodes and varying throughput of devices entering the system. For this to be achieved the authentication system needs to be able to gather information from the system and make decisions based on this. An overview of these phases can be seen in Fig.4.

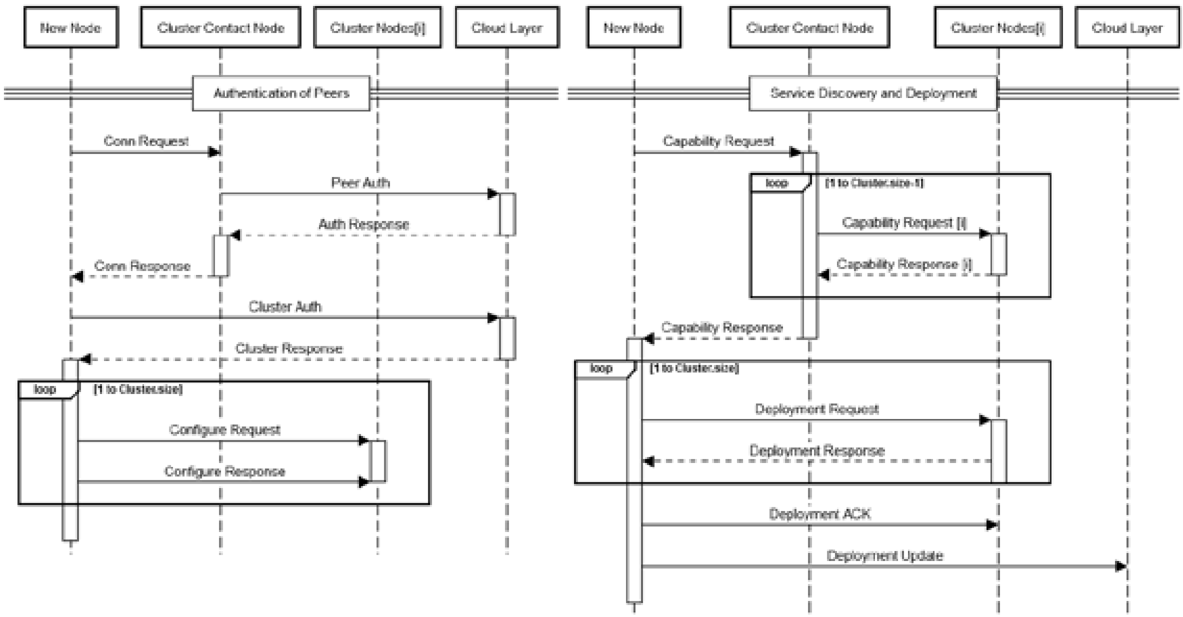

Fig. 4.
Authentication, Discovery and Deployment

The authentication process in based on simple two-way handshake between three entities where the cloud layer is the known and the safe one. The two entities verify each other in relation to the third one. This is done by the new node pushing a connection request to the first node in the cluster it discovered which is assigned a contact role. The contact node takes the information provided by the new node and verifies it through the cloud controller after which sends a response to the new node with the information it needs to authenticate the cluster and join. After the new node has then authenticated the cluster it joins in by sending the appropriate configuration requests to the new set of peers using the peer authentication parameters it received.
The Service Discovery and Deployment phase is designed for a new node to analyse the existing system and determine how it could extend the system functionality and how could the system extend the nodes functionality. The discovery is initiated by the new node by forwarding a request containing its own capabilities to the contact node which then queries the capabilities of its peers and responds to the new node by adding its own details as well. The new node than decides which apps it requires from the cluster and what endpoints and services it is interested in. It then sends the configuration request to each individual node, after which it configures itself. Finally, it sends a cluster wide acknowledgment to the nodes that it has successfully deployed everything after which it forwards and update of the system to the cloud layer.

4. Experimental Setup

The experimental setup is designed to test the functionality of the presented components and to allow us to evaluate how these behave in a real-life system. There were 7 types of devices used in the experimental setup in total. These range from the low capability Arduino and AtTiny based devices to the more powerful Nordic RF52 and to the Raspberry Pi Gateways carrying a varied set of sensors and actuators. An overview of these can be seen in Fig. 6.

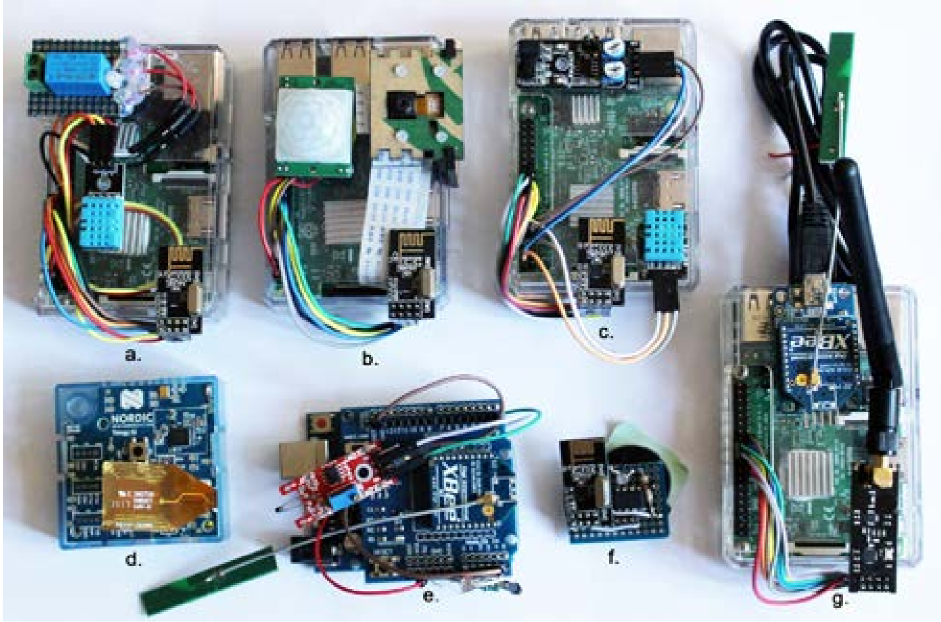

Fig. 6.
Experimental Devices

The Devices from Fig. 6 a,b,c and g are Raspberry pi 2 System on Chip Fog Nodes that have attached varying sensor that allow them to interact with their surroundings. Device a. has a relay, a temperature and humidity sensor and an RF24 wireless transmitter for communicating with peripheral devices. The Raspberry pi from b. is designed to be used with video surveillance, as it has attached a motion sensor and a Video Camera. The device c. has attached the temperature and humidity controller together with the RF24 module as well as a proximity sensor. The node in g. is designed to be a communication hub, as it can send and receive messages in all the testes technologies and has a higher range RF24 device. The device d. is a standard RF52 Thingy node that has a varying set of environmental sensors and communication devices but is used to tests the Low-Power Bluetooth connections with the Raspberry Pi. The XBee enabled Arduino board from e. has a light and temperature sensor for environmental monitoring attached to it. The AtTiny device from f. is designed to be a simple 3.3Volt powered monitoring device.

5. Conclusions and Future Work

The deployment of IoT systems for Smart City scenarios requires a platform that can deal with the scalability and interconnectivity challenges that come from these systems. They need to be able to allow highly heterogeneous application and devices to communicate seamlessly. Furthermore, due to the large computational requirements these systems need to be able to efficiently use the resources available at the edge of the network.
We have reviewed a significant section of the existing work that has been done in the field concluding the requirements and directions. Based on this review we propose a platform that aims to solve these issues using Dynamic and Static clusters based on node characteristics. Furthermore, we propose a dynamic application deployment and updating mechanism for these gateways and an experimental setup for the testing of the deployed systems. The proposed experimental setup looks at providing nodes with highly heterogeneous capabilities, both from the communication, sensor capabilities and use case perspectives.
Our future work will look at large scale deployments of such systems with several dynamic devices that can be attached to the system and evaluation of bottlenecks on the system, how these can be circumvented and the limitations of the clustering approaches. We will also consider the deployment of multiple containers and scenarios using characteristic models from the literature and the optimization of these deployments.

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OLDER PEOPLE AND SAFER MOBILITY: HOW CAN INDEPENDENT, MOBILE LIVES BE EXTENDED?

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Abstract: This paper brings together three major areas which are prone to be seen independently of one another. These are the wide-ranging, ubiquitous and rapidly advancing developments in transport technology; the impacts of a growing ageing population and urbanisation. The interaction between these megatrends forms the broad context against which developments in transport services and mobility must be planned and evaluated. This issue is explored through a consideration of the needs and preferences of older drivers who form a rapidly increasing proportion of the population.

Keywords: ageing society, extending mobility, ICT.

1. Introduction

This paper brings together three major areas which are prone to be seen independently of one another. These are the wide-ranging, ubiquitous and rapidly advancing developments in transport technology; the impacts of a growing ageing population and urbanisation. These "megatrends" are, of course, well known and have been much debated in applied research and policy contexts. However, little research has attempted to bring them together in specific application to older people and their mobility, rather than sustainable mobility in general, and the benefits of extending their active, independent and fulfilling lives through more sophisticated and integrated approaches which exploit new technologies in a targeted way. In particular, how do these trends interact to promote, or, alternatively, place barriers in the way of, extending the mobility of older travellers?

A major challenge will be to devise and implement policies which integrate public and private transport provision in ways which support the creation of portfolios of mobility services which will serve individual needs. The paper takes a broad view of private transport in that it includes private car ownership and use alongside other means of accessing transport and mobility services. The term "private" emphasises the type of access to the car, that is sole use by the owner driver (ownership being taken to cover a wide range of financial arrangements including, for example, leasing), rather than the physical nature of the vehicle itself. Among other sources of evidence, this paper draws on the outputs of recent EU projects where the authors have played significant roles.

2. Megatrends

Megatrends are long-term processes of transformation with a broad scope and a high impact (Georghiou et al., 2009). They are powerful factors which shape markets and drive social change. Megatrends have:

- Long time horizons and can be consistently observed over decades rather than months or years;
- Wide scope; their impact extends beyond geographical borders, and results in multidimensional, interconnected and major drivers for change in politics, society and the economy;
- Intensity of impact; all actors involved are affected robustly and comprehensively, this includes governments, individuals and businesses.

They also affect each other, which can make their impacts unclear and difficult to predict. Megatrends are, nevertheless, useful concepts when assessing the future developments and challenges which promoting mobility and developing the transport system call into play.

OPTIMISM identified megatrends through a comprehensive literature research of key-factors combined with expert knowledge. The identification of megatrends was central to an impact analysis of a wide range of factors influencing mobility and the future transport systems. Transport experts embracing a wide range of perspectives were asked to identify and rank the importance of megatrends as part of an extensive Delphi study. Eleven megatrends were identified. Urbanisation and the growth of cities was ranked as the most important factor influencing future transportation needs. Demographic and social change, including the growth of an ageing society, was ranked eighth and the shift to a knowledge society eleventh.

The INTEND project used a similar methodology to OPTIMISM. The main factors underpinning sustainable mobility were identified from a literature review. This was followed by a Delphi study to which fifty-nine experts drawn from the transport industry, policy makers and academic researchers contributed. Factors were ranked on a five-point Likert scale from 1, "Not at all important", to 5, "Extremely important". The highest scoring factor (mean = 4.41; SD = 0.9) was "Development of large metropolitan areas". The second highest scoring was "Ageing society" (mean = 4.3; SD = 0.79) and the third was "Urbanisation" (mean = 4.2; SD = 0.9). Further analysis of the Delphi questionnaire rankings using ANP (Analytic Network Process; see Saaty, 2001) methods revealed a strong degree of interconnectedness

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between the three factors. ICT developments were not included as a factor in the Delphi study since they did not feature strongly in the literature reviewed (Anoyrkati et al., 2016).

2.1. Ageing Societies

In industrialized countries, the number of older adults has increased and one quarter of the population will be aged 65 or older by 2050.The population share of the elderly over 80 years will be 13% by 2020 in Austria, Germany, Greece, Italy, the Netherlands, Portugal and Spain. In the UK the proportion of retired people is expected to be 23% by 2031. Eurostat statistics predict that the share of people above the age 65 in Europe will grow to 21% by 2020 and 28% by 2050. The impacts of a growing ageing population are raising major questions about how we might extend the active, independent and fulfilling lives of older people and the role of new technologies in helping realise this aim.

Current and future seniors, compared with previous generations, are healthier, wealthier and have a more active life style, including increased travelling and leisure mobility. However, ageing will still have a significant impact on mobility needs and services. Ageing reduces physical mobility and cognitive functions, slows reaction times and limits the capacity to process multiple sources of information simultaneously. The management of older peoples' safe mobility is becoming an increasingly important issue; mobility is vital for their quality of life. "Seniors" are becoming more mobile than in the past and the number of trips per year taken by the elderly has almost doubled (Dejoux V. et al., 2010). However, the older population is increasingly diverse and mobility needs and expectations vary across segments (Marin-Lamellet and Haustein, 2015).

2.2. The Growth of City Living

Approximately 50% of Europe's population lives in cities, and this is expected to rise to 70% by 2050. About half the urban population do not own their own car, but this is particularly marked in the under 30 age group. In addition, the proportion of men in this age group holding driving licenses is falling in many EU countries. The corollary of this observation is, of course, that older people are forming a growing proportion of car owners. Consumers of cars have been hardware-oriented, the physical product was the focus. There is now a growing trend towards a more service-oriented attitude to mobility needs with easy, timely, flexible on-demand access to a seamless provision of transport provision at the fore.

In Europe the level of urbanisation is expected to grow, although at a slower rate. The spatial structures created by urbanisation are determining factors for the mobility and transport sectors. A sufficient supply of mobility services is essential for these densely populated commercial centres with high production and service levels. Problems arise from the concentration of commuter flows during traffic peaks. Appropriate infrastructure also needs to be available, as well as good connections from the centres to the ever more sparsely populated peripheries. The trends of centralisation and the desertion of peripheries are leading to contradictions where the profitability, infrastructure and operations of transport need to fulfil conflicting requirements. Enabling economically affordable equality in accessibility is one of the main challenges.

Europe and Northern America has shown a demand for personal transport where individual mobility is an essential component of everyday life due to separated locations of residential, work and leisure activities (Rudinger et al., 2006). In Europe, at least, just over half of all car journeys are less than 8km in length and 80% are less than 16km. The vast majority of car journeys, over 90% begin and end in the same cities or towns.

The mobility sector will also be heavily influenced by changing household structure. Average household size has dropped by 10-15% and single person households make up a third of the total in many European countries. Again, demand for individual mobility services will increase. Life styles are becoming more versatile, leisure activities are gaining in importance and everyday life becomes more irregular and quickly changing.

2.3. New Technology and the Growth of the Knowledge Society

Knowledge acquisition and use, capacity for innovation and further development of products and services are characteristic of the knowledge economy. The emergence of the knowledge economy as a megatrend has made the acquisition and further development of knowledge necessary for corporations and individuals. The use of information and communication technologies (ICTs) to plan and facilitate the timing and location of day-to-day activities is a key component of emerging activity patterns, especially in urban mobility. One major driver for its development is the need to perceive mobility as a reflection of expanding spatial and temporal choice, and of "on demand" consumption. (Lee-Gosselin M. et al., 2009). According to Lee-Gosselin et al.*a key characteristic of this trend is a ``post-modern" complexity, in which mobility is a reflection of expanding spatial and temporal choice, and of "on demand" consumption.* The trend towards more cooperative transport systems and new types of mobility requires the development of new classes of ICT technologies and better ways to exploit existing ones.

IMTI (Integrated Multimodal Travel Information) applications have dominated transport ICT over the recent past. The main drivers of demand are time (travel and search time) and physical, cognitive, and affective effort savings. The most popular application relates to the pre-trip stage when planning multimodal travel. According to ERTRAC (2009), by 2030, a highly integrated and service driven information society will emerge in which the mobility consumer takes part actively and continuously regardless of his/her location and activity (home, work, commuting, leisure). In urban areas,

where by 2030, more than 80% of the European population is expected to be located, a wide variety of free or low-cost online services will bring on dramatic changes in consumer awareness, attitude and behaviour towards transport in general and personal mobility in particular.
Mobility operators will be able to use the same information services, for example to optimise the efficiency of the network infrastructure, or to limit the environmental impact of mobility patterns, by offering travel incentives to specific consumer groups or to customers on preferred travel modes and routes, or by implementing real-time traffic controls in specific locations. ICT developments will also contribute to the reduction of social exclusion by enabling travellers to have the same access to information and cost-effective mobility options, no matter where they live or how old they are.

3. Older Travellers

In industrialized countries, the number of older adults has increased and one quarter of the population will be aged 65 or older by 2050. In the UK, the number of people aged over 70 holding a driving licence now exceeds five million and, in Denmark, a much higher percentage of drivers aged over 70 intend to keep their licenses than in the past (Siren and Haustein, 2016). The older, affluent motorist sector is expected to grow by 35% between 2015 and 2020. Fourteen percent of the 55-64 age group in the UK have bought a new car in the last two years; the figure for the 65+ group is 11%. These groups have the highest rate of new car purchases in the UK; people over fifty currently buy 65% of all new cars. This demographic pattern is not peculiar to the UK, rather it is a feature of many developed economies.
Population ageing will be accompanied by an increase in the number of older drivers on the roads. Normal ageing results in a decrease in visual, psychomotor and cognitive abilities that are needed in driving. Moreover, older drivers are physically more fragile and vulnerable than younger ones and present a major risk of injury during a road accident. Several traffic situations, such as night driving, driving during rush hour, in bad weather, on motorways or in unfamiliar places, can be stressful or difficult for older drivers. In such cases they may be forced to give up driving or may (probably unwillingly) adopt driving avoidance behaviour triggering social isolation or increased risk of depression.
However, older drivers can adapt their driving behaviour to age-related functional and cognitive decline by avoiding difficult driving situations or by developing compensatory strategies, for example by increasing safety distances, reducing speed or reducing distances traveled. A study of the driving habits of Canadian seniors showed that they were significantly more likely to make social and entertainment trips on days with good weather and out-of-town trips on days with good road conditions (Myers et al., 2011). This behavioural adaptation reflects driving self-regulation, which allows the older driver to continue driving safely despite age-related changes. Of course, not all older drivers self-regulate their driving behaviour; many who do systematically over-estimate their own abilities, a phenomenon known as calibration bias. Drivers with poor cognitive performances and those who are not aware of their own abilities are less likely to avoid difficult driving situations than those with higher performances or have a more accurate view of their own abilities. New technologies can play a major role in mitigating these declining abilities, providing older drivers with tools which will help them drive more safely and longer.

4. The Preference for Cars

The importance of cars as a means of providing transport should not be underestimated. The continued dominance of private motoring for older travellers as a means of accessing mobility services needs to be fully taken into account in transport planning. A significant proportion of travellers prefer cars over public transport, even if public transport is potentially more attractive in terms of costs and travel time. The preference for private ownership is more marked among older drivers than younger ones; 83% of older (>60) drivers in a cross-section of developed countries wanted to own their car (Continental Ag, 2015).
Travellers' positive attitudes with respect to passenger cars are closely related to psychological factors such as feelings of freedom. As Marchetti (1994) put it, *the car has gradually evolved into a personal prosthesis, owning a car and freedom of movement can be considered anthropological invariants in travel behaviour.* Whilst there is significant evidence that this trend may be reversing in some demographic groups, notably younger people resident in cities, the preference for private car ownership is still very strong among older transport users. However, unpacking the Marchetti thesis may be productive. Two aspects may be of particular interest. Firstly, privacy and ownership need to be conceptually separated (Dutzik and Baxandall, 2013). Whilst private car ownership confers control over transport privacy, it may not be the only way of doing so, particularly in a technologically advanced society. For example, car-sharing and privacy may be much more compatible than they were in the past. Private ownership has also been the most effective way of providing personalisation of transport. Again, the development of more flexible, demand driven transport services may help to loosen this tie; mobility may become "smarter". New policies and strategies tailored to meeting the needs and wants of older travellers through the promotion of different private transport modalities are needed. The attractiveness of cars to older buyers needs to be based in driving features and not the form of ownership or access.

4.1. Connected Cars

What makes a car "connected" is the presence of devices in an automobile that connect the devices to other devices within the car/vehicles and or devices, networks and services outside the car including other cars, home, office or infrastructure. The important feature is connectedness. "Connected cars" includes autonomous ("driverless") vehicles (AVs) and ones employing Advanced Driver Assistance Systems (ADAS). The technology which is commonly associated with ADAS, for example parking assist systems and autonomous emergency braking (AEB), is already potentially able to prolong a safe driving career for older drivers. Automation can reduce human (driver) workload leaving more time and attention capacity for driving tasks such as monitoring the environment, identifying potential hazards and predicting changes in traffic. However, there is some evidence that higher levels of automation may be the source of falls in human performance, particularly if over-reliance on systems results in reduced driving skills over time.

Driving cessation provides an instructive and compelling example of the potential benefits of ADAS. Premature driving cessation occurs if driving activity is discontinued at an earlier stage than indicated given the driver's capabilities. There is significant evidence that premature driving cessation is particularly marked among women and that efforts to prevent this should focus on women's confidence and experience in driving (Siren and Haustein, 2016). Driving cessation can be either voluntary or involuntary, although the distinction is not always clear-cut. A study of Baltimore US seniors who had given up driving showed that 83% of respondents had stopped driving by their own decision (Choi et al., 2012), although some of these could also have been premature. A 2016 US review of 16 published studies showed that seniors who stopped driving were more likely to die within 3-5 years than those who did not (Chihuri et al., 2016).

Many driving aids are already familiar; for example:

- Improved safety through better road infrastructure, on-board safety systems, automatic "Smart SOS" emergency services calling (for example, eCall);
- Reduction in incidence and effects of vehicle crashes through collision protection systems;
- Improved vehicle security through more sophisticated access systems;
- Better use of road infrastructure to reduce congestion, enable smart parking and facilitating the spreading of journeys through time through vehicle mobility management systems;
- User and usage based, including driving style and habits, insurance premiums providing an incentive for safer driving;
- Operational assistance such as (adaptive) cruise control and autopilot, parking aids and visibility enhancement;
- Monitoring driver well-being through detecting tiredness and fatigue, contacting medical assistance when appropriate, and adjusting the car's internal environment to mitigate the effects of driver fatigue;
- Providing real-time feedback on driving performance to mitigate the incidence of calibration bias and improve the effectiveness of self-regulation.

Whilst connected cars have received a great deal of attention, we must be wary of concentrating on cars at the expense of people; we should focus on connecting travellers. What makes a traveller "connected" is having real time access to devices that connect to other devices and networks and so provide enhanced access to transport and mobility services, and the home, office or other infrastructure. Technological and other developments in the transport arena can, suitably applied, help older people travel more safely, confidently and securely, and for longer; connectedness enables and promotes different degrees and dimensions of travel autonomy. However, such benefits are not driven solely by technological development, but embrace the societal benefits which result from extending the safe and secure mobile life of an ever-expanding group of ageing travellers. Connectedness enables and promotes different degrees and dimensions of driving autonomy rather than the desire for autonomy in vehicles being the stimulus to develop connected cars.

5. Summary

Securing access to transport services through private ownership of a car is likely to remain the cornerstone of personal mobility for a long time to come. Arrangements such as car-sharing are of growing significance, but are based on a different model of access than private ownership per se. However, we must be wary of implementing change in an unconsidered way, avoiding the temptation of "doing things because we can". Travel-related ICTs are progressing very quickly, outstripping our abilities to keep up in associated ways.

The positive opportunities to improve accessibility and promote mobility for older drivers (Fagnant and Kockelman., 2015; Ticoll, 2015), the greater independence inherent in a longer driving career (Bohm and Häger, 2015) and wider travel horizons (McCarthy el al., 2015) have all been promoted as potential benefits of implementation of ADAS. However, this potential to improve the health and social wellbeing of older drivers is tempered by a possible lack of social acceptance of radical innovations, a lower capacity to accept and master new technologies and lack of capability to benefit from them (Anderson et al., 2014). Economic factors may play a regressive role in the adoption of new technology; those with the greatest need may be over-represented among lower income groups (Bierstedt et al., 2014). The societal, organisational, regulatory and business developments required for success may need to be as radical as the technological ones if we are all to benefit safely, securely and confidently. We must apply technology to mobility rather than simply putting travellers into new technology.

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THE FUTURE OF THE EUROPEAN TRANSPORT SECTOR: IDENTIFYING THE KEY TRENDS REGARDING THE TRANSPORT CONCEPTS OF THE FUTURE

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Abstract: The transport sector plays a significant role in ensuring the competitiveness and sustainable economic growth of Europe. The current transport system remains unsustainable while the EU will have to face major challenges in overcoming global socioeconomic megatrends, technology readiness and adaptation as well as new disruptive transport concepts. The aim of the current paper is to define the term future transport concepts and identify the latter within the context of passenger and freight transport with an outlook of 2020-2050. Thus, a literature review of forward-looking EU research projects and respective industry reports was carried out that identified 25 future transport concepts. Key trends of the aforementioned transport concepts have been identified while further analysis has been carried out to present the transport modes that these concepts are applicable to including their likely timeline of implementation based on the literature. Transport concepts such as automation, shared mobility, seamless transport, electrification, Superfast Ground and Underground Transportation, were found to be key trends among both transport sectors.

Keywords: future transport concepts, future of transport, mobility concepts, transport concepts.

1. Introduction

The transport sector plays a critical role in ensuring sustainable economic growth for Europe, offering jobs, better quality of life of the European citizens as well free movement of goods, services and individuals (EC, 2014). Within this context, the EU has recognised the importance of transport as a basic parameter for its future development and growth, which can provide a competitive advantage at a time of increasing global competition (EC, 2011; CEC, 2012). Despite the fact that, legislative progress is being made to decarbonise and make the European transport sector more efficient, the overall system remains unsustainable. The major challenges facing the European transport sector include traffic congestions, oil dependency, greenhouse gas emissions, infrastructure as well as growing competition from other transport markets (EC, 2014). Furthermore, the current and future global socio-economic megatrends, such as ageing population, urbanization and megacities, changing lifestyles, key resources scarcity, environmental challenges – climate change, will shape the European transportation system even further (Maraš et al., 2018).
In order for the European transport sector to face the current and future challenges, innovative transport solutions as well as research and innovation (R&I) support will be required. The EU considers R&I focused on sustainable, green and smart transport systems as a major and integral part of its transport policy and funds relevant research through various research funding programmes, aiming to keep Europe at the forefront of technological advances in transport (EC, 2014). To that end, a communication was published to provide guidelines for the development of a strategic plan for transport research, innovation and deployment (EC, 2012; Wiesenthal et al., 2015). According to the latest available data, the transport sector (automobiles and other transport) accounted for the largest share (29.8 percent) of EU companies' R&D investments, compared to 18.3 percent in a global scale (Hernández et al., 2017). Additionally, EU companies that reported R&D in the transport sector, provided employment to about 2.9 million people, regarding the aforementioned time period (Hernández et al., 2017).
The European transport sector is in a transitional period and in order to deal with the current and future challenges, a shift away from conventional thinking towards radically innovative ideas is needed (EC, 2012). Several pioneering transport concepts have already emerged and continue to emerge thus presenting a shift towards more disruptive mobility ideas. The latter will cause systemic changes to the transport system whether due to technological advances, political imperatives as well as new emerging transport concepts aiming to enable the European transport sector to effectively address the current and future mobility challenges. The main objective of this paper is to identify key trends regarding the transport concepts of the future in the literature, within a time horizon of 2020-2035 and beyond. The identification of the major trends in terms of future mobility concepts will enable a "sketching" of the way in which people and goods are likely to be transported in the future.

2. Research Gap & Methodology Followed

The methodology that was used to capture the key trends in terms of the future transport concepts involved desk research and specifically two main types of literature: a) forward-looking research projects (covering their project deliverables) and b) forward-looking reports from consultancy companies or industry related view reports including future transport-related technology-oriented websites and private/initiatives. In terms of research project, the literature review consisted of reviewing EU Framework Programme 7 (FP7) and Horizon 2020 funded projects that have already carried out their own analysis of future mobility concepts, to a certain extent (MOBILITY4EU, FUTRE, RACE2050, OPTIMISM, METRIC, iKNOW). For the online research key word terms were used such as "future mobility concepts",

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"transport concepts", "future X mode (X mode i.e. road, aviation, waterborne, rail) transport", "future of X mode", "innovation in X mode".
Based on the literature review, various transport concepts were identified with a time horizon of 2050. The results were divided into passenger and freight mode and the transport sector that they are applicable to (road, rail, aviation, waterborne). Similar transport concepts were labelled under wider categories that described the same notion. In addition some of the identified concepts were applicable to both passenger and freight sector. Furthermore, the analysis included the transport modes that each concept is applicable to and a timeline for their potential implementation, based on literature predictions and using Short (2020-2025), Medium (2025-2030) and Long term (2030-2035+) scale.
From the analysis of the transport concepts two main matrices (section 5.1 and 5.2) were build that present the key trends for passenger and freight transportation sectors, on the basis of highest number of citations in the literature. The key trends identification was based on the approach taken by the EU INTEND project and Tromaras et al. (2018) that defined a cut-off criterion of the seven top ranked concepts for each transport sector. The resulting key trends are to some extent expected to reflect those mobility concepts that are more likely to shape the future transport landscape. Finally, the concepts that form the key trends were further detailed for the purpose of presenting the level of maturity, the potential implications as well as the key considerations for the further development and adoption of each mobility concept. Fig. 1 presents the main methodology steps that were followed in the completion of the current study.

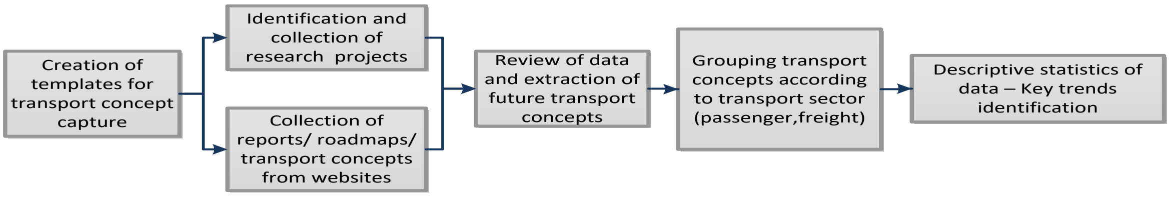

Fig. 1.
Methodology steps followed in the current study

2.1. Transport Concepts – Providing a Definition

Having identified a literature gap regarding the term "transport concept" or "mobility concept", a definition was given that described how mobility takes place between two places, referring to the movement of passengers or goods. It may describe the transportation mean and the way that transportation or mobility takes place. **Table 1** explains the total number of (25) future transport concepts that were captured by the literature review.

Table 1
Total number of future transport concepts captured by the literature review

Transport Concept – Code Name	Transport Concept – Context, Brief Description
Slow Travel / Slow Logistics	Reduced importance of time regarding both passenger and freight transport modern life
Superfast Ground and Underground	Hyperloops, Cargo Tubes, Underground Freight Pipelines (e.g. "CargoCaps")
Personal Rapid Transit (PRT)	Small automated pods or buses operating on designated rails (network of specially built guideways) or on streets, for either scheduled or individual destinations
Magnetic Mobility, Magnetic Levitation	Magnetic levitation technology for rail (maglevs), shopping carts / magnetic shoes sliding on / along magnetic tracks
Personal Air Transportation, "Flying	Urban air mobility; small personal aerial vehicles manually piloted, remotely piloted or fully autonomous
Seamless Transport Chains – Multimodality, Intermodality	Multimodal, intermodal or seamless transport chains for passenger and freight transport
Automation	Autonomous or automated driving for any transport mode for either passenger or freight transport
Noiseless Transport	Noiseless aviation – advanced low-noise aircrafts; reduction of noise and vibration in trains; comfort and noiseless shipping – low vibration vessels; reduction of noise of urban freight
Delivery Drones	Urban airspace utilization for deliveries of goods; delivery drones as a part of the supply chain
Electrification	Electrified transportation means for any mode using electricity, hydrogen fuel cells or hybrid propulsion
Small Vehicles Developed Fit-For-Urban-Purpose	Smaller vehicles, vehicle designs between e-bikes and e-cars, foldable city cars
Smart Use of Travel Time	Use of travel time made available because of vehicle automation; travel time as a usable timeslot for a wide range of activities
Shared Mobility, On-Demand Mobility, MaaS, FaaS, LaaS	Shared ownership models, on-demand mobility; Mobility as a Service – MaaS, Freight as a Service – FaaS, Logistics as a Service – LaaS

Transport Concept – Code	Transport Concept – Context, Brief Description
Private Car Ownership, Luxury Vehicles	Private car ownership remains the norm, continuing appreciation of status symbolism
Seamless Security Checks, Innovative Check - In Processes	Integrated security approach "No Borders"; seamless security checks at airports, innovative check - in processes
Blue Modal Shift	Bringing transport to inland waterways; Short Sea Shipping (SSS) promotion
Co-Modality	Efficient use of different modes on their own and in combination
Freight Consolidation Hubs, Freight Distribution Centres	Urban and peri –urban freight consolidation hub freight villages; multimodal settlements that provide access to different modes of transport as well as several inter-modal infrastructure facilities for logistics service providers.
Urban Cross-Modal Logistics	Urban cross-modal logistics utilizing all transport modes; deliveries with small electric vans, (electric) bikes or tricycles; small and flexible means for road freight transport
Personal Mobility Devices – Micro-mobility	Personal mobility devices, such as Segway, electric skateboards, etc.; reduced usage of traditional forms of mobility for short distances
High-Speed Rail	High-speed train technologies; high-speed rail for passenger transport
Crowd Delivery – Crowd-based City Logistics	Urban deliveries – crowd delivery; involvement of private individuals traveling on a particular route, in urban deliveries
Quite Night Urban Deliveries	Urban deliveries done at night when traffic is limited
Freight Shuttle Systems	Freight shuttle systems for high-volume freight containers; unmanned shuttles propelled by electric, linear induction motors, able to carry cargo on elevated, dedicated tracks (e.g. Freight Shuttle System – FSS initiated at Texas A&M Transportation Institute)
Smart, Dynamic and Interactive Highways	Safer and more sustainable roads; interactive lights; smart energy sources; adaptable to different conditions road signs; photo-luminescent road markings; temperature sensitive warning signs on the road; solar roadways containing heating elements, inductive charging capabilities for electric vehicles, etc.

3. Review of Selected Literature

The analysis of literature was performed in parallel for passenger and freight transport, since the majority of the literature sources dealt with transport concepts applicable to both sectors. Table 2 presents all the future transport concepts drawn, the number of citations in the literature review and their sources.

Table 2
Future transport concepts over literature sources

Future Transport Concepts	Literature Sources	Total Number of Citations
Automation - Autonomous Cars	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; Delle Site et al., 2013; Delle Site et al., 2012; Kompil et al., 2013; IKNOW, 2011; Manyika et al., 2013; Briggs and Sundaram, 2016; KPMG, 2017; D'Incà and Mentz, 2016; Arbib et al., 2017; Corwin et al., 2015; Corwin et al., 2016; Goodall et al., 2017; UKi Media & Events, 2018; Goulding and Butler, 2018; Morrell, 2017; Goulding and Morrell, 2014a; Dohna and Morrell, 2016; Otto, 2017; Lineberger et al., 2018; Sümmermann et al.,2017; Leech et al., 2015; Schmidt et al., 2018; Foulser, 2017; OECD/ITF, 2017; Rohr et al., 2016; Future Transport 2056, 2018; Mobility of the Future – Examining future changes in the transportation sector http://energy.mit.edu/research/mobility-future-study/; Project "Next" http://www.next-future-mobility.com; Marr, 2017; UITP, 2017	**32**
Shared Mobility, On-Demand Mobility, MaaS, FaaS, LaaS	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Delle Site et al., 2013; Delle Site et al., 2012; Kompil et al., 2013; IKNOW, 2011; Briggs and Sundaram, 2016; Winterhoff et al., 2009; KPMG, 2017; D'Incà and Mentz, 2016; Cornet et al., 2012; Arbib et al., 2017; Corwin et al., 2015; Corwin et al., 2016; Goodall et al., 2017; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014a; Dohna and Morrell, 2016; Otto, 2017; Lineberger et al., 2018; Sümmermann et al., 2017; Leech et al., 2015; Schmidt et al., 2018; Foulser, 2017; OECD/ITF, 2017; Future Transport 2056, 2018; Klingebiel and Wagenitz, 2013; Mobility of the Future – Examining future changes in the transportation sector, http://energy.mit.edu/research/mobility-future-study/; Grosse-Ophoff et al., 2017; UITP, 2017	**30**
Electrification - Electric Cars	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; Delle Site et al., 2013; Delle Site et al., 2012; Kompil et al., 2013; IKNOW, 2011; Briggs and Sundaram, 2016; Winterhoff et al., 2009; KPMG,	**24**

Future Transport Concepts	Literature Sources	Total Number of Citations
	2017; Cornet et al., 2012; Arbib et al., 2017; Corwin et al., 2015; Corwin et al., 2016; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014a; Dohna and Morrell, 2016; Otto, 2017; Lineberger et al., 2018; Leech et al., 2015; Foulser, 2017; OECD/ITF, 2017; Future Transport 2056, 2018; Mobility of the Future – Examining future changes in the transportation sector, http://energy.mit.edu/research/mobility-future-study/	
Seamless Transport Chains – Multimodality, Intermodality	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; Delle Site et al., 2013; Delle Site et al., 2012; Kompil et al., 2013; IKNOW, 2011; Briggs and Sundaram, 2016; Corwin et al., 2015; Corwin et al., 2016; Goodall et al., 2017; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014a; Goulding and Morrell, 2014b; Dohna and Morrell, 2016; Sümmermann et al., 2017; Foulser, 2017; Rohr et al., 2016; Future Transport 2056, 2018; Global Railway Review Vol. 24, Issue 2 (Young, 2018; Harnish, 2018; Sanguina et al., 2018); The World Bank, 2017	**20**
Automation - Autonomous Trucks	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; Manyika et al., 2013; D'Incà and Mentz, 2016; Corwin et al., 2015; Corwin et al., 2016; UKi Media & Events, 2018; Goulding and Butler, 2018; Morrell, 2017; Goulding and Morrell, 2014a; Dohna and Morrell, 2016; OECD/ITF, 2017; Future Transport 2056, 2018; Marr, 2017; Carey, 2017	**16**
Electrification - Electric Trucks	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; Delle Site et al., 2013; Delle Site et al., 2012; Kompil et al., 2013; KPMG, 2017; Arbib et al., 2017; Corwin et al., 2016; UKi Media & Events, 2018; Goulding and Butler, 2018; Dohna and Morrell, 2016; Lineberger et al., 2018; OECD/ITF, 2017; Future Transport 2056, 2018; Mobility of the Future – Examining future changes in the transportation sector, http://energy.mit.edu/research/mobility-future-study/	**15**
Personal Air Transportation, "Flying Cars", Flying Taxis	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; IKNOW, 2011; UKi Media & Events, 2018; Goulding and Butler, 2018; Morrell, 2017; Lineberger et al., 2018; Future Transport 2056, 2018; Cece, 2016; Marr, 2017; Overly, 2017; Tucker, 2018; Kotoky, 2018	**15**
Smart Use of Travel Time	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Manyika et al., 2013; Winterhoff et al., 2009; KPMG, 2017; Cornet et al., 2012; Arbib et al., 2017; Corwin et al., 2015; Corwin et al., 2016; UKi Media & Events, 2018; Dohna and Morrell, 2016; Otto, 2017	**13**
Delivery Drones	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Manyika et al., 2013; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014a; Dohna and Morrell, 2016; Rohr et al., 2016; Future Transport 2056, 2018; Marr, 2017	**10**
Superfast Ground & Underground Transportation	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; D'Incà and Mentz, 2016; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014b; OECD/ITF, 2017; Global Railway Review Vol. 24, Issue 2 (Young, 2018; Harnish, 2018; Sanguina et al., 2018)	**9**
High-Speed Rail	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014b; Dohna and Morrell, 2016; OECD/ITF, 2017; Global Railway Review Vol. 24, Issue 2 (Young, 2018; Harnish, 2018; Sanguina et al., 2018)	**9**
Automation - Automated Trains	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; D'Incà and Mentz, 2016; Corwin et al., 2016; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014b; Future Transport 2056, 2018; Global Railway Review Vol. 24, Issue 2 (Young, 2018; Harnish, 2018; Sanguina et al., 2018)	**8**
Personal Rapid Transit (PRT)	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Delle Site et al., 2013; Delle Site et al., 2012; Kompil et al., 2013; Corwin et al., 2016; UKi Media & Events, 2018; Goulding and Butler, 2018; Goulding and Morrell, 2014b; Project "Next", http://www.next-future-mobility.com	**8**
Small Vehicles Developed Fit-For-Urban-Purpose	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Briggs and Sundaram, 2016; Winterhoff et al., 2009; KPMG, 2017; Corwin et al., 2016	**7**

Future Transport Concepts	Literature Sources	Total Number of Citations
Freight Consolidation Hubs, Freight Distribution Centres	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; Goulding and Butler, 2018; Goulding and Morrell, 2014a; Dohna and Morrell, 2016, ERTRAC, 2014	**7**
Private Car Ownership, Luxury Vehicles	Winterhoff et al., 2009; Cornet et al., 2012; Arbib et al., 2017; Corwin et al., 2015; Corwin et al., 2016;	**5**
Automation - Autonomous Ferries & Vessels	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Manyika et al., 2013; Corwin et al., 2016; Marr, 2017	**5**
Urban Cross-Modal Logistics	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; UKi Media & Events, 2018, ERTRAC, 2014	**5**
Noiseless Transport	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Christodoulou et al., 2014; IKNOW, 2011; UKi Media & Events, 2018, ERTRAC, 2014	**5**
Electrification - Electric Aircrafts	Hauptman et al., 2014; MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; IKNOW, 2011	**4**
Blue Modal Shift	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Christodoulou et al., 2014; The World Bank, 2017	**4**
Personal Mobility Devices – Micro-mobility	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Future Transport 2056, 2018; Sachs, 2016	**4**
Automation - Autonomous Aircrafts	Christodoulou et al., 2014; IKNOW, 2011; Manyika et al., 2013	**3**
Electrification - Electric Trains/Hydrogen-Powered Trains	Goulding and Butler, 2018; Goulding and Morrell, 2014b; Global Railway Review Vol. 24, Issue 2 (Young, 2018; Harnish, 2018; Sanguina et al., 2018)	**3**
Crowd Delivery – Crowd-based City Logistics	Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; UKi Media & Events, 2018; Sampaio et al., 2017	**3**
Magnetic Mobility, Magnetic Levitation	Hauptman et al., 2014; UKi Media & Events, 2018; Goulding and Morrell, 2014b	**3**
Seamless Security Checks, Innovative Check - In Processes	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Christodoulou et al., 2014; Delle Site et al., 2013; Delle Site et al., 2012; Kompil et al., 2013	**3**
Co-Modality	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014; Goulding and Butler, 2018	**3**
Quite Night Urban Deliveries	Christodoulou et al., 2014; Goulding and Butler, 2018, ERTRAC, 2014	**3**
Electrification - Electrified Ferries and Vessels	MOBILITY4EU, 2016a; MOBILITY4EU, 2016b; MOBILITY4EU, 2016c; Keseru et al., 2016; Papanikolaou et al., 2014; Reichenbach et al., 2014; Aggelakakis et al., 2014	**2**
Slow Travel / Slow Logistics	Hauptman et al., 2014; IKNOW, 2011	**2**
Freight Shuttle Systems	Goulding and Morrell, 2014a; Goulding and Morrell, 2014b	**2**
Smart, Dynamic and Interactive Highways	Goulding and Morrell, 2014a; Future Transport 2056, 2018	**2**

4. Transport Concepts of the Future in Passenger and Freight Transportation

The following section contains the future transport concepts that were identified in the literature review and have been grouped into passenger or/and freight transport based on which of these categories they were applicable to, according to their source. In some cases these concepts were applicable to both categories. For example, the shared mobility concept was predominantly mentioned in the scope of passenger transportation. Nevertheless, shared mobility is also applicable to the freight transportation sector as well, with some of the literature sources having dealt with ideas such as last mile logistics using MaaS, FaaS and LaaS. In this context, the total number of citations referring to shared mobility concept were accounted to both passenger and freight transport sectors. On the other hand, transport concepts that were only applicable to one transport sector they were only accounted only once i.e. high-speed rail has only been mentioned in the literature within the context of passenger transport.

4.1. Transport Concepts of the Future in Passenger Transportation

Based on the reviewed literature, Table 3 presents the future transport concepts regarding passenger transportation and their total number of citations. The transport modes that each concept is applicable to and a timeline for each concept potential implementation are also presented, with the latter being based on the literature predictions.

Table 3
Future transport concepts for passenger transport

Passenger Transport-applicable Future Transport Concepts	Total Number of Citations	Road	Aviation	Rail	Waterborne	Timeline for Implementation
Automation – Passenger Transport	34	+	+	+	+	Medium term
Shared Mobility, On-Demand Mobility, MaaS	30	+	-	-	-	Medium term
Electrification – Passenger Transport	26	+	+	+	+	Medium term
Seamless Transport Chains – Multimodality, Intermodality	20	+	+	+	+	Long term
Personal Air Transportation, "Flying Cars", "Flying Taxis"	15	+	+	-	-	Medium term
Smart Use of Travel Time	13	+	-	-	-	Medium term
High-Speed Rail for Passenger Transport	9	-	-	+	-	Medium term
Superfast Ground and Underground Transportation, Hyperloops	9	-	-	+	-	Long term
Personal Rapid Transit (PRT)	8	+	-	+	-	Short term
Small Vehicles Developed Fit-For-Urban-Purpose	7	+	-	-	-	Short term
Private Car Ownership, Luxury Vehicles	5	+	-	-	-	Medium term
Noiseless Transport	5	+	+	+	+	Long term
Blue Modal Shift	4	-	-	-	+	Medium term
Personal Mobility Devices – Micro-mobility	4	+	-	-	-	Short term
Magnetic Mobility, Magnetic Levitation	3	+	-	+	-	Medium term
Seamless Security Checks, Innovative Check - In Processes	3	-	+	-	-	Medium term
Co-Modality	3	+	+	+	+	Long term
Slow Travel	2	+	-	+	+	Long term
Smart, Dynamic and Interactive Highways	2	+	-	-	-	Long term

4.2. Transport Concepts of the Future in Freight Transportation

The same principles with the previous section were applied for freight transport. The future transport concepts related to freight transportation, their total number of citations, the transport modes that these concepts are applicable to as well as a timeline for their potential implementation, are presented in the Table 4 below.

Table 4
Future transport concepts for freight transport

Freight Transport-applicable Future Transport Concepts	Total Number of Citations	Road	Aviation	Rail	Waterborne	Pipeline	Timeline for Implementation
Shared Mobility, On-Demand Mobility, MaaS, FaaS, LaaS	30	+	+	+	+	N/A	Medium term
Seamless Transport Chains – Multimodality, Intermodality	20	+	+	+	+	N/A	Long term

Automation – Freight Transport	18	+	+	+	+	N/A	Medium term
Electrification – Freight Transport	18	+	+	-	+	N/A	Medium term
Delivery Drones	10	-	+	-	-	N/A	Short term
Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines	9	+	-	+	-	+	Long term
Freight Consolidation Hubs, Freight Distribution Centres	7	+	+	+	+	N/A	Medium term
Urban Cross-Modal Logistics	5	+	-	-	-	N/A	Medium term
Noiseless Transport	5	+	+	+	+	N/A	Long term
Blue Modal Shift	4	-	-	-	+	N/A	Medium term
Crowd Delivery – Crowd-based City Logistics	3	+	-	-	-	N/A	Short term
Quite Night Urban Deliveries	3	+	-	-	-	N/A	Short term
Co-Modality	3	+	+	+	+	N/A	Medium term
Slow Logistics	2	+	-	+	+	N/A	Long term
Freight Shuttle Systems	2	+	-	+	-	N/A	Long term
Smart, Dynamic and Interactive Highways	2	+	-	-	-	N/A	Long term

5. Key Trends Identification and Further Analysis

For the identification of the key trends, a cut-off criterion was needed to be defined in order to reach a certain level of consensus to those concepts with a significant potential to be implemented and to drive disruption and reshaping of the future transport ecosystem. As stated in the methodology the seven top ranked concepts for each category have been identified as the key trends.

Based on the aforementioned principles, the key trend future transport concepts for passenger transport are: *1) automation, 2) shared mobility, on-demand mobility, MaaS, 3) electrification, 4) seamless transport chains – multimodality, intermodality, 4) personal air transportation, 5) smart use of travel time, 6) high-speed rail, 7) superfast ground and underground transportation*.

The respective key trends for freight transport are: *1) shared mobility, on-demand mobility, MaaS, FaaS, LaaS, 2) seamless transport chains – multimodality, intermodality, 3) automation, 4) electrification, 5) delivery drones, 6) superfast ground and underground transportation, 7) freight consolidation hubs, freight distribution centres*.

Automation has been identified as a key future transport concept that is expected to revolutionize transportation for both passenger and freight sectors. Many automakers are currently working on autonomous vehicles while low levels of automation has already been introduced into conventional vehicles. Fully autonomous cars are estimated to become commercially available in the market by 2025-2035 (ERTRAC, 2017). Similarly, in the road freight sector, highway platooning and highly automated trucks on open roads could become available with the aforementioned timeline (ERTRAC, 2017). In the rail sector, automation already exists in selected market segments, such as metro transport, with the example of Copenhagen's metro (Copenhagen metro, 2018) offering full autonomy over specific lines. However, automation remains rare for the main rail lines, while demonstrators are planned for 2020-2025 that will take the current system in Europe towards full autonomy (Shift2Rail, 2015). In the waterborne sector, ship autonomy is expected to reshape the sector with key driving factors being reduction of labour and operating costs, as well as optimized commercial flexibility as a result of big data (Lloyd's register, 2017). Smaller crewless vessels have already been developed and are currently in service, while larger vessels are under development and will potentially be in service between 2020 and 2025 (Paris, 2017; Rolls Royce, 2017). In the aviation sector automation technologies are already being introduced in conventional aviation and smarter avionics systems are being integrated in the cockpit. The main drivers for further automation include increased safety levels, increased throughput, effectiveness and cost efficiency (Voege, 2016).

Fuelled by the shared economy model and boosted by the availability of new communication technologies, shared mobility is rapidly gaining popularity, with several platforms globally being introduced (Whim, UbiGo, Qixxit, Moovel, Beeline, SMILE; Goodall et al., 2017). According to Schiller et al. (2017), Europe accounts for about 50 percent of the global car-sharing market, while the total number of car-sharing users is expected to rise up to 15 million by 2020. Taking into account the suggested rise of shared mobility schemes in the future, the next step will be their integration under one roof, a vision that essentially describes MaaS concept. The MaaS concept also extends to freight transport, with concepts of its use for last mile logistics or other variations such as FaaS or LaaS. Future Transport 2056 (2018) defined FaaS as "a business model whereby on-demand and ride-sharing concepts formulate different procedures for the supply of goods to customers, which is accessed through a single account and booking interface". Furthermore, based on the cooperation of shippers, retailers and delivery companies, LaaS "enables individuals to choose their own logistics service provider and bundle deliveries as they wish, instead of being delivered by the logistics service provider of their online retailer" (MOBILITY4EU, 2016b; Keseru et al, 2016).

Electrification is one of the most commonly referred transport concepts with a potential application across all the transport modes. Electromobility is considered a key enabler for decarbonisation and is in fact already being used and will continue to further penetrate each market at a different pace. For road passenger transport, the global number of electric vehicles (EVs) surpassed 2 million in 2016, with passenger cars, vans and buses already in service. The OECD/IEA (2017) forecasts projected EV car fleet growth to reach 9-20 million by 2020 and 40-70 million by 2025, based on automakers' production pledges. Furthermore, Fuel Cell Electric Vehicles (FCEVs) are expected to contribute to 30 percent of the vehicle mix by 2030 (IEA, 2010), with some models already available in the passenger transport market. Electric trucks and vans are being used by various companies for delivery, logistics and other purposes (Margaritis et al., 2016), while companies like Tesla (Tesla, 2018) and Cummins (Cummins, 2017) are working on heavy duty truck applications. In the rail transport sector, electrification has already penetrated to a great extent. In Europe, 60 percent of the main lines are already electrified and 80 percent of traffic is running on these lines (Meyer, 2016). Although, electrification can have environmental benefits, the cost of upgrading current infrastructure could be an obstacle. Additionally, hydrogen fuel cells have already been introduced in rail, with more recent examples of their usage by Alstom (Alstom, 2017) and Siemens (Railway Technology, 2018). ERRAC (2016) suggests that the use of hydrogen fuel cell electric propulsion in rail will require further development including hydrogen production and storage technologies with a timeline of implementation reaching beyond 2035.

In the waterborne sector, electrification of auxiliary systems or auxiliary electric propulsion is not uncommon. Around 2,500 ships in the world are powered by electric propulsion using diesel electric, hybrid systems or batteries (Meyer et al., 2016). Fully electric ships using batteries exist in small numbers, while recently the first all-electric cargo ship has been launched in China (Meyer et al., 2016; Leary, 2017). Similarly, Hydrogen Fuel Cells in the waterborne sector, can either find applications in providing power to auxiliary systems or to propel smaller as well as larger vessels. For the aviation sector, electric propulsion could be a viable option in the future although, only for short range (Meyer et al., 2016) and it is predicted to be applicable for aircrafts with less than 100 seats (Malkin et al., 2016). Various concepts of small electric or hybrid electric aircrafts are being developed by Airbus, Boeing, NASA, Rolls-Royce and Siemens as well as Embraer (AIRBUS, 2017; NASA, 2016; Embraer, 2018).

Seamless transport chains were identified as another key transport concept of the future, applicable to both passenger and freight transport. E.C. (2011) and OECD/ITF (2012) both highlighted the importance of seamless door-to-door mobility for passenger and freight and recognized seamless transport as a crucial and ambitious strategic vision for the future of transportation. The key topic areas for discussion about seamless transport chains concept implementation, are focused on seamless transport for trade and growth, new approaches for seamless logistics, connectivity enhancement across borders, integration of transport and communication systems to provide seamless services, the role of e-ticketing, smartphones and data sharing in seamless transport provision, etc. (OECD/ITF, 2012). From an IT point of view, ERRAC (2016) suggests that seamless transport travel will be enabled by 2025.

"Flying cars" or "passenger drones", seem to be concepts that are receiving a lot of attention, driven by the rapid technological advances on unmanned aerial vehicle (UAV) technologies. Some typical examples, include CityAirbus, Vahana, PopUp, Ehang 184, Volocopter 2X, Lilium and Uber Elevate (UKi Media & Events, 2018; Lineberger, 2018). Morrell (2017) considered that passenger drones are likely to reach the technology readiness levels of commercialization and adoption before 2030. Over the coming decades, delivery drones are also expected to become an integral part of the supply chain, covering delivery needs in urban and in rural – hard-to-reach areas, thus offering faster delivery times for consumers, less traffic congestion and emissions reduction and increased access of remote areas. Several companies, such as Amazon, Google, Alibaba, UPS, DHL and Wal-Mart have already started experimenting with such systems and the key considerations for the further development and adoption of this concept, include functionality, legislation, system integration into the existing urban infrastructure, safety, security and privacy related issues (Zickuhr et al. 2016, Gulden T. R., 2017). SESAR JU (2016) has forecasted that 70.000 drones could deliver about 200 million lightweight parcels across Europe in 2035.

Being inextricably linked to autonomous driving, smart use of travel time appeared to be among the key transport concepts of the future. In the future, travel time may be seen as a usable timeslot for a wide range of activities, from working, to online shopping, or other in-vehicle entertainment services. Significant revenue opportunities for companies operating in different sectors will emerge, such as services and product sales, on-board advertising, subscriptions, data monetization based on media consumption, (Manyika et al., 2013; Arbib et al., 2017; Corwin et al., 2015).

High-speed rail has also proven to be one of the key future transport concepts relevant to passenger transport that will allow medium-distance passengers to travel by rail offering a cheaper, greener and more sustainable alternative to air and road transport. Several European countries have already developed extensive high-speed rail networks, while some cross-border high-speed rail links also exist. According to EC (2011) a complete European high-speed rail network is expected by 2050 and a stepwise tripling of the length of the existing high-speed rail network by 2030 while connections between all core network airports to the rail network and preferably to high-speed rail will have to be prioritised.

Along the lines of new innovative concepts, superfast ground and underground transportation is likely to play a significant role for future passenger transport. Examples like Hyperloop have been proposed as a faster and more cost-

efficient transport alternative to air and high-speed rail transportation, in respect to distances up to 1.500 km (Musk, 2013; UKi Media & Events, 2018). Despite the main concerns regarding its technological and financial viability, experimentation and testing is underway with Virgin Hyperloop One that aims to provide Dubai with the first Hyperloop system by 2021 and TransPod that is focused on building a Toronto-Montreal hyperloop (UKi Media & Events, 2018). Respectively, underground freight pipelines form another innovative new type of transport infrastructure similar to hyperloop. This concept refers to the use of dedicated pipeline networks for transporting goods underground. Typical examples are the CargoCap and the Cargo sous terrain (CST) concepts, which entail the transport of goods in dense urban centres (CargoCap, 2018; Cargo sous terrain, 2018).
Infrastructures dedicated to freight deliveries in urban areas, namely freight consolidation hubs and freight distribution centres, were the final key transport concept that has been identified. Cities and private companies will have to establish consolidation and freight distribution centres in an effort to improve efficiency, shifting the distribution of freight to inner city utilizing greener and more efficient transport modes (Keseru et al., 2016). Future consolidation centres will bring together flows of goods for entire cities or regions, while different suppliers will have to cooperate and ship together their products via single shippers in an effort to make transport cheaper and more efficient and reduce number of deliveries (Siemens, 2011). IT systems and automation will play considerable role in this endeavor.

6. Conclusion

The current paper presented future transport concepts for passenger and freight transport that have been identified with an outlook of 2020- 2050 after a though review of pertinent literature covering forward-looking projects and industry reports. A literature gap has been identified thus leading to define the term future transport concepts, although the notion of the latter is not unknown when referring to how people or goods are transported. Some of these transport concepts could lead to systemic change of the current transport system and in many cases will cause disruptiveness. An extensive list of future transport concepts has been presented and a consensus was reached in order to identify the key transport concepts that have been cited the most across the literature and have the most potential of being implemented. While, specific concepts are more relevant to the passenger or freight sector, i.e. personal air transport or delivery drones, other concepts share common ground. Concepts such as automation, shared mobility, seamless transport, electrification, Superfast Ground and Underground Transportation, were found to be key trends for both sectors. The difference between them remains their context and how they will be implemented in each case. Compared to previous decades many new innovative transport concepts are being proposed and could potentially become commercially available in the distant future especially in the field of personalised transport.
As most of key aforementioned future transport concepts are already in development and to some extent their technologies are available although not matured enough, the EU will have to identify streams of research in order to prepare for their further development and potential adaptation. The latter does not only depend on technology readiness but also on socioeconomic megatrends as well as political incentives.

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EVALUATING MEGATREND IMPACT ON THE TRANSPORT CONCEPT OF THE FUTURE USING AN ANALYTIC NETWORK PROCESS

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Abstract: The motive of this research is the fact that until now no universal model for evaluation of megatrends, political imperatives, and technological advances impact on the transport concept of the future (TCF) has been defined. In the process of modeling, megatrends are one of the key elements for selection of the TCF. In this paper is proposed a model for selection of TCF based on the Analytic Network Process (ANP) approach. The developed model has allowed assessing the impact of the megatrends on the TCF and stability of the TCF ranking. It is developed ANP network for the passenger and freight transport separately. Based on the results of research, network structure of the ANP method can successfully resolve the dependence and conflicts among evaluation elements for TCF selection. The proposed ANP based model can become a tool for the evaluation of the TCF and for policy makers making decision. The paper is based on data from the INTEND project.

Keywords: megatrends, transport concept of the future, validation, making decision, ANP, research needs.

1. Introduction

In the last ten years there were huge advances in future studies and in detecting trends methodology, in particular in Europe. New scientific methods for strategic long term planning were developed in the context of long term political planning, participatory democracy and shaping the future with RTI policy initiatives. A trend is usually based on linear pattern, which only work in a specific context. Trends are usually described by time horizon, impact and geographical coverage.
But in reality it is needed to set up a comprehensive knowledge logistics process to integrate the knowledge derived from forward-looking projects have looked at the megatrends. Changes in climate and availability of strategic resources, as well as digitalization and globalization cause a need for proactive adoption and preventive innovation management. Global warming and the dependence on oil will induce revolutionary changes in the industry.
From the other side policies are shaping day-to-day and future mobility by impacting the transport system itself, or influencing mobility framework conditions. Policies and their imperatives are among the crucial factors shaping the transport market. Via direct regulation or via defining market rules, those policies address future transport concepts and technologies.
Having all this in mind the evaluations of the megatrend is challenging as transport itself is a complex environment. The results of the review of relevant and available literature for megatrends (Maras *et al.,* 2018), political imperatives (Doge *et al.,* 2018) technological advances (Tromaras *et al.,* 2018), showed that their number is significant and to assess their impact it is necessary to systematically approach the assessment of their effects on transport concepts of the future (TCF). The systemic approach also means taking into account the limitations of human reasoning. Human thinking has limitations regarding the simultaneous use of data, or when their number is significant. In cases where a significant amount of data is used in the assessment and evaluation process at the same time, due to the inability of the human brain to follow it simultaneously, it is possible not to make useful solutions and decisions (Saaty, 2001).
As megatrends, together with socio-technical shifts in the transport industry, are expected to change the whole sector fundamentally, they should be further validated in order to estimate their impact on defining the future transport concept as research priorities. The aim of the validation process is to determine the prioritized megatrends (as well as technological advances and political imperatives) for successful implementation and realization of key transport concepts of the future.
This paper presents one of the results of the H2020 project INTEND - Identify future Transport Research Needs (grant agreement No 769638, 2017-2018). The overall objective of the INTEND project is to deliver an elaborated study of the research needs and priorities in the transport sector utilizing a systematic data collection method. In this paper, the focus is on one of the project objectives such as to define the megatrends impact on research needs.
After the introduction, the ANP networks for TCF selection are presented in section 2. The numerical results and sensitivity analysis are shown in Section 3 and 4. The conclusion is given in the last chapter.

2. Modeling ANP Network for TCF Selection

The evaluation of megatrend impact is carried out through the application of the Analytic Network Process (ANP). The Analytic Network Process ANP (first papers Saaty, 1996, 1999), represents a decision-making method which enables to present the dependence and feedback between elements, analyze the interaction between them as well as to synthesize their mutual influences through a network structure. This is a method that is used to determine priorities based on the

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relative relationship between elements, which is a natural procedure for the human mind. ANP model combines advanced decision techniques and expert knowledge.

For the problem of estimation megatrends impact on the transport concepts of the future ANP method taking into account clusters of megatrends, political imperatives, technological advances and TCF. These clusters can be considered as drivers for the future development of both European and global transport system and therefore relevant for the identification of future transport research priorities. How the structure of the ANP network was developed?

First, a sophisticated Limesurvey was used for systematic data collection and define key elements in clusters and relationship between them. Experts were invited to participate in a survey session and ninety responses were received. Principal components analysis as a variable-reduction technique was used to reduce a broader set of proposed megatrends, political imperatives and technological advances (called as elements) into a smaller one, which accounts for most of the variance in the original set of elements. Finally, the 13 key elements which are most likely to impact the future research needs and priorities per transport sectors were identified (Table 1)

Table 1

Key elements that impacts on the future research needs and priorities

No	Passenger transport Sector		Freight transport sector	
	Cluster	**Element**	**Cluster**	**Element**
1	Megatrends	Environmental challenges – climate change	Megatrends	Environmental challenges – climate change
2	Megatrends	Urbanization and megacities	Megatrends	Urbanization and megacities
3	Megatrends	Ageing society	Political imperatives	Vehicle efficiency
4	Megatrends	Energy demand and sources	Megatrends	Bigger world economy
5	Political imperatives	Innovative research system	Megatrends	Energy demand and sources
6	Megatrends	Changing lifestyles	Megatrends	Ageing society
7	Technological advances	Infrastructure	Political imperatives	Innovative research system
8	Political imperatives	Vehicle efficiency	Technological advances	Infrastructure
9	Technological advances	Automation	Technological advances	Automation
10	Political imperatives	Increasing connectivity, intermodal access, and fit-for-purpose network standards	Megatrends	Changing lifestyles
11	Political imperatives	Closer public and private cooperation	Political imperatives	Raising investment in infrastructure development
12	Political imperatives	Supporting modal shift	Political imperatives	Digitisation strategy/regulations/markets
13	Technological advances	Electrified vehicles/vessels	Political imperatives	Closer public and private cooperation

The dominant TCF identified by the studies review (MOBILITY4EU, FUTRE, RACE2050, OPTIMISM and METRIC) are the elements of the TCF cluster. It is identified seven TCF for passenger and eight for freight transport. The TCF are ranked according to their frequency of occurrence in the reviewed literature. Elements in the clusters for TCF for passenger and freight transport are given in table 2.

Table 2

Dominant passenger and freight transport concepts of the future

Transport concept of the future	
Passenger transport sector	**Freight transport sector**

Automation – Passenger Transport (autonomous cars, aircraft, trains, vessels)	Shared Mobility, On-Demand Mobility, MaaS, FaaS, LaaS
Shared Mobility, On-Demand Mobility, MaaS	Seamless Transport Chains – Multimodality, Intermodality
Electrification – Passenger Transport (electric cars, trains, aircrafts, vessels)	Automation – Freight Transport (autonomous trucks, trains, vessels)
Seamless Transport Chains – Multimodality, Intermodality	Electrification – Freight Transport (electric trucks, trains, aircraft, vessels)
Personal Air Transportation, "Flying Cars," “Flying Taxis”	Delivery Drones
Smart Use of Travel Time	Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines
High-Speed Rail for Passenger Transport	Freight Consolidation Hubs, Freight Distribution Centres
Superfast Ground and Underground Transportation, Hyperloops	

Further, the analysis includes relationships among those key elements. Considering the equal number of identified key elements (13) in both transport sectors, there is an equal number of possible relationships among them (78 per transport sector). Forty-eight sets of judgments matrices were generated after the analyzing the relationships between key elements and selected transport concepts of the future. Two ANP networks were identified. The first one is the ANP network used to evaluate TCF in passenger transport and the second one is for the evaluation of TCF in freight transport (Figure 1 and 2).

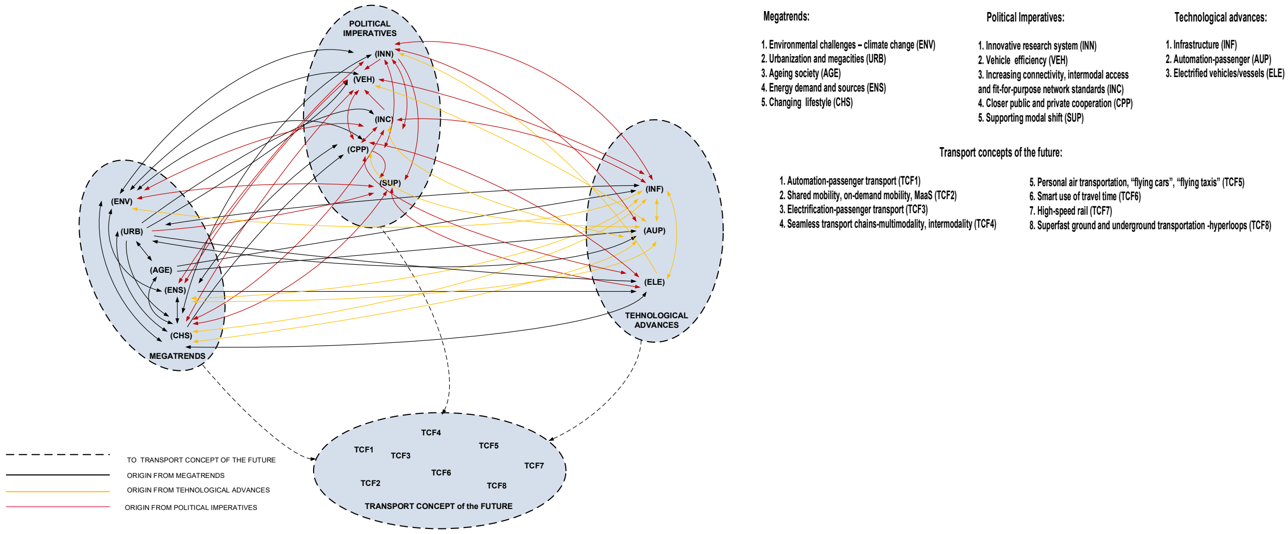

Fig. 1.
ANP network for passenger transport

The application of ANP also required estimation of relationships (weights) between all elements in clusters and between the clusters. Therefore, after the network model has been constructed, the elements in one cluster (e.g., megatrends or advances or imperatives) were evaluated according to their relative importance, through pair-wise comparison, with respect to the elements in other clusters. Further, cluster of key TCF was evaluated according to its relative importance by pair-wise comparison, with respect to other elements in the network.
An evaluation of these relationships was based on an ANP questionnaire survey. The obtained sets of judgments matrices were analyzed by using appropriate software developed by FTTE’s[2] on Python programming language and supported by the ANP Graphical user interface (GUI) application. Based on this analysis, the evaluation of key TCF was gained. It means that after the evaluation of preferences among the different megatrends, technological advances and political imperatives have been done and once the weights have been defined, we determined the prioritized elements (megatrends, technological advances, and political imperatives) in all clusters for successful implementation and realization of key TCF.

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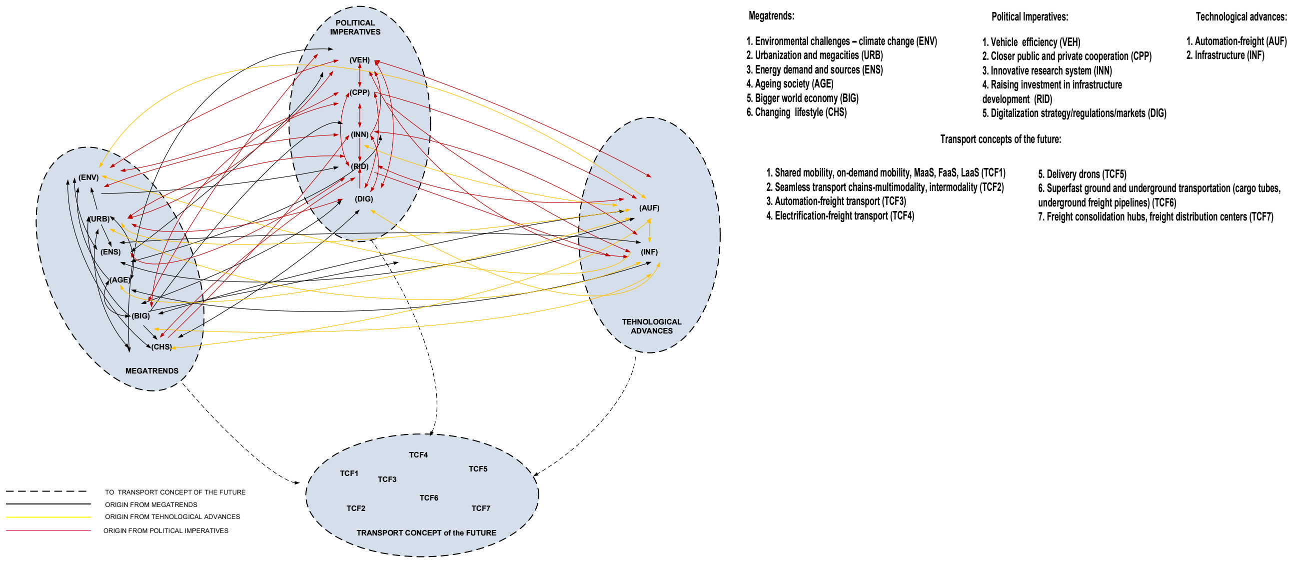


Fig. 2.
ANP network for freight transport

3. Results and Discussion

The megatrends validation has been carried out through the discussion of the results in two ways: (1) an analysis of the priorities of all elements within the TCF and (2) by analyzing the diversity and similarity of the priorities of the elements within the cluster megatrends, political imperatives, and technological advances. This is conducted for passenger and freight transport separately.

3.1. The Priorities of all Elements within the TCF and Megatrends for Passenger Transport

The final priorities for the passenger transport concept of the future (TCFPs) and the priorities of megatrends, political imperatives and technological advances are presented in Table 3. Outcomes are arranged in four groups. The first group of outcomes/results is the priorities of TCFPs. Then a set of priorities for megatrends, political imperatives and for technological advances are followed. For each of these groups is given, a rank in relation to the best-ranked element (Ideal), the normalized priority as a share of the element in relation to all elements in the group (Normalized by cluster), and the Score. It can be noticed that the elements with the highest priority are:

1. High-speed rail in the group of TCFP with 15.99% of overall priorities;
2. Changing lifestyle megatrend with 35 % influence on the TCFPs ranking;
3. Closer public and private cooperation, as political imperatives, with 23.42% influence;
4. Electrified vehicles/vessels, as technological advances, with 41.51% influence.

Looking in detailed we can see that the highest priority value of TCFP has High-speed rail. Looking ahead, the second, third and fourth TCFP is very close to the first one, and these are Personal air transportation, Automation, and Electrification. The other four TCPFs can be grouped into two groups, namely the fifth and the sixth TCFP respectively the seventh and eighth TCFPs. According to the differences between the priorities value of the first four TCFPs all of them can be taken into consideration in future research.
When it comes to elements influences within the cluster megatrends, political imperatives and technological advances all respondents estimate that the most important elements are: Changing lifestyle, Closer public and private cooperation and Electrified vehicles/vessels.
Significantly stands out the influence of the megatrends Changing lifestyle and Environmental Challenges compared to other megatrends. Impacts of these megatrends for the TCFPs are 35% and 30.1%. In contrast to them, the impact of megatrends Ageing society and Urbanization and megacities are smaller and similar values of priorities.

Table 3
The elements with their priorities and ranking for passenger transport

Elements	Ranking	Ideals	Normalized By Cluster	Score
TCFP				
Automation	3	0.8682	0.1388	0.0459
Electrification	4	0.8543	0.1366	0.0451
High speed rail	1	1.0000	0.1599	0.0528
Personal air transportation	2	0.8744	0.1398	0.0462
Seamless transport chains	6	0.7306	0.1168	0.0386

Elements	Ranking	Ideals	Normalized By Cluster	Score
Shared mobility	8	0.5553	0.0888	0.0293
Smart use of travel time	7	0.6313	0.1009	0.0334
Superfast ground	5	0.7416	0.1186	0.0392
Megatrends				
Ageing society	5	0.2063	0.0722	0.0188
Changing lifestyles	1	1.0000	0.3500	0.0911
Energy demand and sources	3	0.5326	0.1864	0.0485
Environmental challenges - climate change	2	0.8622	0.3018	0.0786
Urbanization and megacities	4	0.2561	0.0896	0.0233
Political imperatives				
Closer public and private cooperation	1	1.0000	0.2342	0.0454
Increasing connectivity, intermodal access and fit-for-purpose network standards	2	0.9952	0.2331	0.0452
Innovative research system	5	0.5780	0.1354	0.0263
Supporting modal shift	4	0.7856	0.1840	0.0357
Vehicle efficiency	3	0.9106	0.2133	0.0414
Technological advances				
Automation- passenger	3	0.5857	0.2432	0.0523
Electrified vehicles/vessels	1	1.0000	0.4151	0.0893
Infrastructure	2	0.8231	0.3417	0.0735

3.2. The Priorities of all Elements within the TCF and Megatrends for Freight Transport

The resulting final priorities (Table 4) for freight transport are obtained by estimation elements and relationships in ANP network for freight transport. The elements with the highest priority are:

1. Automation as TCFF with 20.87% normalized priority;
2. Changing lifestyle megatrend with 28.4% influence on TCFFs ranking;
3. Digitalization strategy/regulations/markets, as political imperatives, with 24% influence;
4. Automation in freight transport, as technological advances with, 60.6% influence.

Focusing on the priorities of TCFFs we can see that the Automation is dominant. TCFF Delivery drones and Shared mobility ranked second and third, are with a significant difference in priority value compared to Automation. All other TCPFs can be clustered into two groups, and the last group consists of Seamless transport chains and Superfast ground that representing business platforms.

When it comes to elements influences within the group's megatrends, political imperatives and technological advances the most important elements per groups are: Changing lifestyle, Digitalization strategy/regulations/markets and Automation in freight transport. The importance of Changing lifestyle megatrend suggests that the change in the lifestyle generates new and in the transport of goods different demands for transportation, or different supply and demand. In contrast to them, the impact of megatrends Bigger world economy and Ageing society are with small impact.

Table 4

The elements with their priorities and ranking for freight transport

Elements	Ranking	Ideals	Normalized By Cluster	Score
TCFF				
Automation	1	1.0000	0.2087	0.0744
Delivery drones	2	0.7635	0.1593	0.0568
Electrification	5	0.6468	0.1350	0.0481
Freight consolidation hubs	4	0.6592	0.1376	0.0490
Seamless transport chains	6	0.5669	0.1183	0.0422
Shared mobility	3	0.7186	0.1500	0.0535
Superfast ground and underground	7	0.4370	0.0912	0.0325
Megatrends				
Ageing society	6	0.3325	0.0943	0.0298
Bigger world economy	5	0.4063	0.1153	0.0364
Changing lifestyle	1	1.0000	0.2837	0.0896
Energy demand and sources	4	0.4997	0.1418	0.0448
Environmental challenges -climate change	3	0.6428	0.1824	0.0576

Elements	Ranking	Ideals	Normalized By Cluster	Score
Urbanization and megacities	2	0.6437	0.1826	0.0576
Political imperatives				
Closer public and private cooperation	5	0.7160	0.1714	0.0323
Digitalization strategy/regulations/markets	1	1.0000	0.2393	0.0451
Innovative research systems	3	0.8010	0.1917	0.0361
Raising investment in infrastructure development	2	0.9394	0.2248	0.0423
Vehicle efficiency	4	0.7219	0.1728	0.0325
Technological advances				
Automation-freight	1	1.0000	0.6062	0.0846
Infrastructure	2	0.6496	0.3938	0.0549

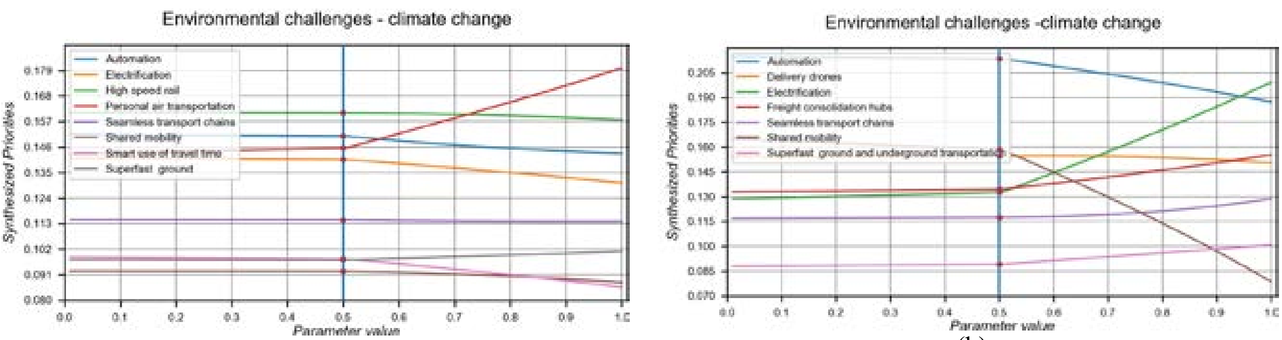
4. Sensitivity Analysis

Chapter 3 specifies the priorities of transport concepts of the future while the impacts of megatrends are validated. But how much stable is the result of megatrend validation? How sensitive are the transport concepts of the future priorities to the changes of the megatrends importance? The answer to these questions can be obtain by using the sensitivity analysis.

The sensitivity analysis is conducted to understand how the priorities of the TCF are robust and responding to the changes in megatrends, political imperatives and technological advances influence on the whole of the ANP network. The row sensitivity method has been used because this method enabled us to preserve the ANP structure (Adams, 2011). This implies following the change of the TCFs priorities in relation to the change in the importance of only one megatrend - the direct impact of megatrend (line charts). The moments of the TCF ranking changes when the megatrends importance is changed are shown as dots in cross-check of two lines. The change of the priority of all megatrends is shown on the spider graphs that define the stability of the first-ranked TCF solution. The space of the stability of the results is marked with transparent light green, and it indicates the stability of the best ranking TCF.

The example of the sensitivity of TCFs with respect to Environmental Challenges – climate change for the passenger and freight transportation is given in Figure 3(a) and 3(b). Normalized TCFs scores are displayed with the solid lines as a function of the parameter value. As can be seen in Figure 3(a) changes of megatrend Environmental changes - climate change importance is most reflected in the change of the Personal air transportation concept and Smart use of travel time. In the first case, we can say that the impact of the megatrend is direct and positive so that it quickly leads to a change in the Personal air transportation rank and it becomes the best ranked TCFP. In the case of TCFP Smart use of travel time, the impact of the megatrend is such that it loses its position and falls to the last position from the sixth place.

As can be noted from Figure 3(b), the initial rank of TCFFs obtained after the evaluation of all respondents is changed with the increase of the Environmental challenges – climate change megatrend impact. There are eight changes in the ranking of TCFFs. The rise of megatrend impact has mostly affected TCFFs Shared mobility and Electrification. Share mobility in the final ranking moves from the third place to the last position and Electrification from the fifth place moves to the first position. Therefore, it can be expected that with the increase of the Environmental challenges - climate change megatrend impact Electrification, a concept that characterizes the use of clean energy sources and environmental protection, will continue to penetrate each market at a different pace.

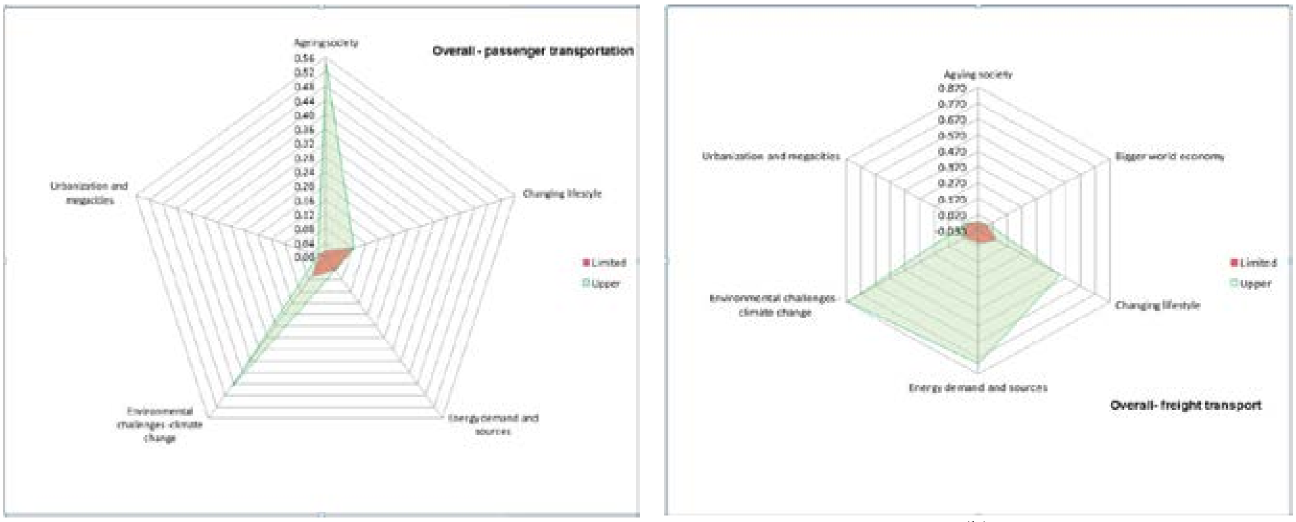


(a) (b)

Fig. 3.
Modifications of TCFPs scores with respect to Environmental challenges – climate change megatrend priority changing for passenger transport (a) and freight transport (b)

The impact of all megatrends is illustrated on the spider charts that define the stability of the best ranked TCF score. Spider chart is used for seeing how much the change of importance of a given megatrend causes a change in the first ranking TCF. Each megatrend is provided with the axis, and the same scale is between all axes. Each megatrend limited

and upper value is shown along with its own axis. Megatrends limited value are connected together and form one polygon (red color), and connected upper values form another polygon (light green color).
In the Figure 4(a) red color polygon illustrates the impacts of the megatrends on the TCFPs ranking. The light green color polygon represents the upper values of the megatrends at the moment when the best-ranking TCFP change its rank. For the outcomes for the passenger transport, megatrends Ageing society and Environmental challenges-climate change impact on the ranking of the High-speed train. The small change of the priority value for the Changing lifestyle, Energy demand and sources and Urbanization and megacities do not lead to the changes of the best-ranking TCFP. The space outside the cross-section of the two polygons represents the instability of the outcomes.
In the Figure 4(b) is presented the impact of the megatrends on the TCFFs ranking. Outcomes for the freight transport, megatrends priorities for Changing lifestyle, Energy demands and sources and Environmental challenges-climate change impact on the ranking of the TCFF Automation. In the long-term TCFF Automation will have a revolutionary impact on travel behavior that is confirmed with a high ranking influence on Changing lifestyle and the robustness of the solution. The small change of the priority value for the Ageing society, Bigger world economy, and Urbanization and megacities do not lead to the changes of the best-ranking TCFF.



(a) (b)

Fig. 4.
The impact of the megatrends on the best-ranking TCF for (a) passenger transport – (High-speed train) and (b) freight transport - (Automation)

5. Conclusion

The outcomes from the ANP network for passenger transport shows that the highest priority values of TCFPs has High-speed rail. Looking ahead, the second, third and fourth TCFP is very close to the first one, and these are Personal air transportation, Automation, and Electrification. According to the differences between the priorities value of the first four TCFPs all of them can be taken into consideration in future research.
It can be noticed that megatrends Changing lifestyle and Environmental challenges - climate change take an important first or second place so that they can be considered as the leading megatrends that influence the determination for future research needs.
Focusing on the priorities of TCFFs it shows that the Automation is dominant. TCFFs Delivery drones and Shared mobility ranked second and third, are with a significant difference in priority value compared to Automation. Significantly stands out the influence of the megatrends Changing lifestyle. The following megatrends have a slightly less impact: Urbanization and megacities, Energy demand and sources, Bigger world economy and finally Ageing society.
Looking at the similarities and differences between the results obtained for passenger and freight transport, it can be said that TCF Automation is the first ranked. This raises the question of what are the reasons for such a perception of the experts? The answer might lie with the fact that key megatrends for freight transport Changing lifestyle and Environmental changes – climate change and Urbanization and megacities are closely linked to Digitalization strategy/regulations /markets as key political imperatives and Automation freight transport as the first technological advances. All of these elements are in close interconnection so that it is not possible to precisely determine what the cause is and what is the consequence and to what extent this relationship is. Actually relations Automation-Changing lifestyle-Urbanization-Digitalization-Automation freight transport represent one loop or circle in which one another stimulates, causes, and in multiplication cooperate.
The outcomes from the sensitivity analysis illustrated that the most influential megatrends for passenger transport and for freight transport as well are: Energy demand and sources and Urbanization and megacities. Bearing in mind stability

of the ANP model outcomes Energy demand and sources megatrend is the megatrend with the biggest influence on best ranking TCFs priorities.

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A GAP ANALYSIS FOR TRANSPORT CONCEPTS OF THE FUTURE

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Abstract: The main objective of this paper is analysis and assessment of the realization of the defined transport concepts of the future. The advantages of each of the defined transport concepts of the future and the obstacles that could appear on the path of their realization have been analyzed. The idea is to define priority areas for future transport research programs by defining a list of priority gaps.

Keywords: transport concepts of the future, passenger transport, freight transport, gap analysis.

1. Introduction

Transport concept has been defined as a concept or idea that presents how mobility takes place between two places, referring to movement of passengers or freight (INTEND, 2018). It may describe the vehicle and the way that transportation or mobility takes place.
Eight top-cited concepts for passenger transport were identified in INTEND, 2018. The transport concepts presented here, are ranked according to their frequency of occurrence in the reviewed literature:

- **automation – passenger transport** (driverless vehicles, including autonomous cars, aircrafts, trains, vessels for passenger transportation).
- **shared mobility, on-demand mobility, MaaS** (shared mobility schemes, such as car-, bike- and ride-sharing, ride hailing, car-pooling, etc.; on demand mobility, demand-responsive mobility; MaaS – a single-digital service offering that integrates various public and private forms of transport and provides end-to-end journey planning, booking and payment options).
- **electrification – passenger transport** (electric-powered vehicles, including electric cars, trains, aircrafts and vessels/ferries for passenger transportation).
- **seamless transport chains – multimodality, intermodality** (seamless transport chains for passenger transport; seamless national and international travel for passengers; seamless passenger travel as a result of MaaS).
- **personal air transportation – "flying cars", "flying taxies"** (urban air mobility; passenger drones for urban passenger transport).
- **smart use of travel time** (time made available because of vehicles automation; travel time as a usable timeslot for leisure, socializing or work-related activities).
- **high-speed rail** (high-speed trains for passenger transport; high-speed rail networks as an attractive alternative to aviation).
- **superfast ground and underground transportation** (hyperloops for passenger transport; hyperloop for faster and more sustainable surface transportation).

In addition, seven transport concepts of the future related to freight transportation, presented below, are also ranked according to their frequency of occurrence in the reviewed literature:

- **shared mobility, on-demand mobility, MaaS, FaaS, LaaS** (mobility as a service – MaaS as last mile for freight transport; "freight as a service" – FaaS for more efficient goods shipping and delivery possibilities; "logistics as a service" – LaaS – to give consumers more control and flexibility over their home deliveries; LaaS to enable individuals to choose their own logistics service provider and bundle deliveries as they wish).
- **seamless transport chains – multimodality, intermodality** (seamless transport chains for freight transport; seamless logistics – smooth combination of different modes and minimization of delays / interruptions in the logistic chain; seamless multimodal freight transport services).
- **automation – freight transport** (driverless vehicles, including autonomous trucks, trains and vessels for freight transportation).
- **electrification – freight transport** (electrified vehicles, including electric trucks, aircrafts and vessels for freight transportation).
- **delivery drones** (small unmanned air vehicles supporting urban deliveries; delivery drones as an indivisible part of the supply chain; delivery drones to cater for hard-to-reach areas).
- **superfast ground and underground transportation** (cargo tubes; underground freight transportation pipelines in dense urban centres, as an alternative to the conventional transport systems; underground freight pipelines for moving goods within and between urban areas).
- **freight consolidation hubs, freight distribution centres** (multimodal settlements that provide access to different modes of transport for transport-oriented companies, logistic service providers and production enterprises; inter-modal infrastructure facilities provision; optimization of deliveries, efficiency increase and traffic/emissions reduction in city centres).

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2. Methodology

This chapter describes the approach for analysis and identification of existing gaps. The gaps, in this case, can be considered as the missing links between the strategic breakthroughs of transport concepts of the future and the major obstacles to their achievement.
Therefore, for the proposed key transport concepts of the future for freight and passenger transport, it is necessary to determine a list of breakthroughs and obstacles to their achievements. In this process, we consulted and reviewed previous transport related projects (both in passenger and freight transport), academic literature, reports from business sector and consultancy firms, relevant websites, synopsis tools and databases.
By crossing the breakthroughs and obstacles of the transport concepts of the future, we have identified existing gaps and consequently a proposal for their possible overcoming has been made (Figure 1).

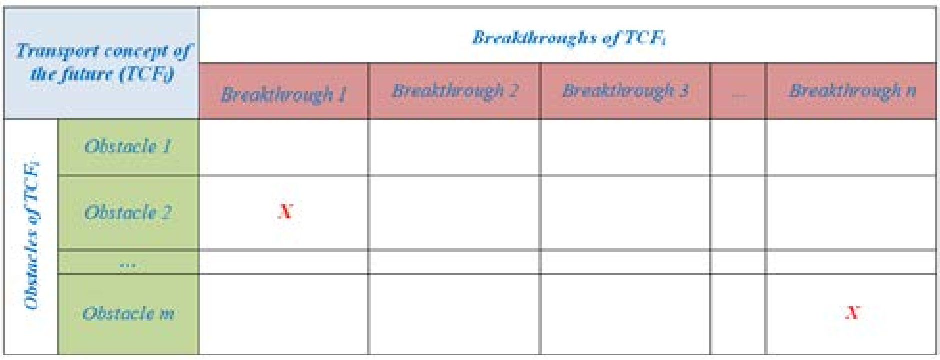

Fig. 1.
Example of gap analysis for TCF$_i$

Based on the defined list of gaps, we will analyze whether these gaps exist in the defined sketch of the transport system of the future.

3. Gap Analysis Results

In this part of the paper, an individual analysis of the proposed transport concepts of the future has been carried out and for each of them the breakthroughs and obstacles are presented. Their crossings enabled us to identify the gaps.

3.1. Transport Concept of the Future: Automation – Passenger and Freight Transport (Autonomous Cars, Trucks, Aircraft, Trains, Vessels)

INTEND, 2018 defines transport concept "Automation – Passenger and Freight Transport (autonomous cars, trucks, aircrafts, trains, and vessels)" as follows:
"*Autonomous – driverless vehicles operating with no need for any human intervention; autonomous cars; autonomous trucks, platooning technology for heavy duty vehicles, autonomous networks of long-haul trucks; autonomous passenger aircrafts; automated trains for passenger and freight transport; autonomous ferries and vessels for passenger and freight transport, automation – platooning of vessels/ferries*".
Further, it is possible to identify some specific characteristics of the breakthroughs and obstacles collected for this TC (Automation – Passenger and Freight Transport) in various transport modes. These are:

- Road transport – 11 breakthroughs and 17 obstacles (Table 1);
- Air transport – 3 breakthroughs and 8 obstacles (Table 2);
- Rail transport – 3 breakthroughs and 7 obstacles (Table 3);
- Water transport – 2 breakthroughs and 5 obstacles (Table 4).

Table 1
*Breakthroughs and obstacles of TC Automation – Passenger and Freight Transport - **Road transport***

TC Automation – Passenger and Freight Transport - Road transport	**Breakthroughs**										
	Increased safety	Better use of travel time	More efficient	Energy savings	Decreases in polluting emissions	Provision of mobility services to people currently unable to drive	Reduction in the need for parking space	The high cost of AVs may accelerate the move to shared mobility	Roadway infrastructure could be managed dynamically	Reduce the need for pedestrian areas	Predictable travel times

Obstacles	Increased congestion and pollution					**X**		**X**				
	A shift away - from public transit											
	Longer trips (especially commutes)											
	Repositioning				**X**							
	Security	**X**					**X**					
	Traffic management											
	City Infrastructure									**X**		
	Revenue								**X**			
	Liability insurance											
	Police and emergency response											
	Social justice and equity		**X**									
	Creating (and maintaining) maps for self-driving cars is difficult work											
	Driving requires many complex social interactions — which are still tough for robots											
	Bad weather makes everything trickier											
	Regulations											
	Cyber security	**X**										

Table 2
Breakthroughs and obstacles of TC Automation – Passenger and Freight Transport – ***Air transport***

TC Automation – Passenger and Freight Transport – Air transport		**Breakthroughs**		
		Low noise	Energy efficiency	Low engine power
Obstacles	Risk perceptions			
	Safety		**X**	
	Necessary "heterogeneous engineering"			
	Regulations			
	Technology maturity		**X**	**X**
	Infrastructure			**X**
	Air traffic management			
	Psychological barriers			

Table 3
Breakthroughs and obstacles of TC Automation – Passenger and Freight Transport – ***Rail transport***

TC Automation – Passenger and Freight Transport - Rail transport		**Breakthroughs**		
		Capacity	Costs and energy efficiency	Fully automated rail freight system
Obstacles	Infrastructure (in metro)	X		
	Public attitudes and staff opposition			
	System integration			X
	Software development			
	Functional safety		X	
	Sensor implementation			
	IT security		X	

Table 4
Breakthroughs and obstacles of TC Automation – Passenger and Freight Transport – ***Waterborne sector***

TC Automation – Passenger and Freight Transport – Waterborne sector		**Breakthroughs**	
		Advanced in modern ships	Safety and energy efficiency
Obstacles	Ship systems		
	Changes in the ports	X	
	Regulatory Framework		X
	Insurance		X
	Cyber Security		X

3.2. Transport Concept of the Future: Shared Mobility, On-demand Mobility, MaaS, TaaS, FaaS, LaaS

INTEND, 2018 defines transport concept "Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS" as follows: *"Shared ownership models, on-demand mobility; proliferation of car/ride/ fleet-sharing and ride-hailing; novel sharing concepts; Mobility as a Service – MaaS, Freight as a Service – FaaS, Logistics as a Service – LaaS".*
It is possible to identify some specific characteristics of the breakthroughs and obstacles collected for this *TC Shared mobility, on-demand mobility, MaaS* which allow the identification of 10 breakthrough and 5 obstacles (Table 5).

Table 5
Breakthroughs and obstacles of TC Shared mobility, on-demand mobility, MaaS

TC Shared mobility, on-demand mobility, MaaS		**Breakthroughs**									
		Integration of transport	Tariff option	One platform	Multiple actors	Use of technologies	Demand orientation	Registration requirement	Personalisation	Customisation	Discussion of MaaS's Roles in Future Mobility
Obstacles	Travel demand modelling for MaaS						X				
	Supply-Side Modelling										
	The benefits may be limited										
	MaaS can still face strong competition from existing travel applications	X									
	Policy Framework for Implementation of MaaS				X	X					

3.3. Transport Concept of the Future: Electrification – Passenger and Freight Transport (Electric Cars, Trucks, Aircrafts, Trains, Vessels)

Similarly, it is possible to identify some specific characteristics of the breakthroughs and obstacles collected from the literature for this *TC Electrification – Passenger and Freight Transport* for various transport modes, i.e.:

- *Road transport* – 3 breakthrough and 7 obstacles (Table 6);
- *Waterborne transport* – 6 breakthrough and 3 obstacles (Table 7);
- *Air transport* – 1 breakthrough and 3 obstacles (Table 8).

Table 6
Breakthroughs and obstacles of TC Electrification – Passenger and Freight Transport – ***Road transport***

TC Electrification – Passenger and Freight Transport - Road transport		**Breakthroughs**		
		Electricity Energy (efficient and utilize)	Improving local and regional air quality	Benefit for shareholders and owners of EVs
bs ta cle	Electric parking spaces	X		
	High costs			

	Uncomfortable and slow charging	X		
	Limited range	X		
	Availability			
	Accessibility and awareness		X	
	Space required for storing electricity (battery) in the vehicle	X		

Table 7
Breakthroughs and obstacles of TC Electrification – Passenger and Freight Transport – ***Waterborne transport***

TC Electrification – Passenger and Freight Transport - Waterborne transport		**Breakthroughs**					
		Flexibility of ship design	Flexibility of the ship's operation	Silencing the noise on the boat	Improved efficiency of fuel consumption	Effectively operated with On/Off technology	Powering the ship
Obstacles	Power solutions						X
	Higher initial cost				X		
	Adequate charging infrastructure						

Table 8
Breakthroughs and obstacles of TC Electrification – Passenger and Freight Transport – ***Air transport***

TC Electrification – Passenger and Freight Transport - Air transport		**Breakthroughs**
		Reduction in CO_2 emissions
Obstacles	Emerging challenges for the development of leading-edge need to be aligned with key principles	
	Management and standardization competencies	X
	Training workers	

3.4. Transport Concept of the Future: Seamless Transport Chains

Transport concept "Seamless transport chains" was described in INTEND, 2018 as follows:
"Seamless transport chains for both passenger and freight transport; seamless national and international travel for passengers; seamless logistics; seamless multimodal freight transport services; integration of all transport modes – multimodality, intermodality; seamless transport chains as a result of MaaS."
Genuine seamlessness is vital for the smooth transport of people, raw materials and products and thus is **central to economic growth** (ITR, International Transport Forum). **Seamless services save time, money and the environment.**
Some of the reviewed literature sources proposed seamless transport as a key future transport concept, in the scope of MaaS. That is why there is overlapping of the advantages and obstacles on the way of the rationalization of these two future transport concepts.
Table 9 identifies some specific characteristics of the breakthroughs and obstacles for *TC Seamless transport chains* collected from the literature. We identified in total three breakthroughs and eight obstacles.

Table 9
Breakthroughs and obstacles of TC Seamless transport chains

TC Seamless transport chains		**Breakthroughs**		
		Energy efficiency	Reduced emissions	Integration
Obstacles	Coordination and collaboration			X
	Adequate structure and the coherence system			
	Development of transhipment technology			
	Efficient management systems	X		
	Fast and low cost handling of loads			
	Work in the cross-border network			

	Electronics and business models			
	Regulations			X

3.5. Transport Concept of the Future: Personal Air Transportation – “Flying Cars”, “Flying Taxis”

INTEND, 2018 describes transport concept "Personal air transportation – flying cars, flying taxis" as follows: *"Urban air mobility; small personal aerial vehicles manually piloted, remotely piloted or fully autonomous; “Passenger Drones”, “Flying Cars”, “Flying Taxies”."*
Therefore, based on the literature, it is possible to identify some specific characteristics of the breakthroughs and obstacles related to this *TC Personal air transportation – “flying cars”, “flying taxis”*. In total, we have identified 4 breakthroughs and 6 obstacles (Table 10).

Table 10
Breakthroughs and obstacles of TC Personal air transportation – “flying cars”, “flying taxis”

TC Personal air transportation – “flying cars”, “flying taxis”		**Breakthroughs**			
		Avoid congestion on road	Enhance personal transportation, revolutionize the transportation industry, and improve the standard of living	Infrastructure	Reduced emissions, fuel use, and capital cost
Obstacles	Air traffic control and infrastructure			X	
	Cost and accessibility	X			X
	Safety		X		
	Charging				
	Regulation			X	
	Affects other sectors		X		

3.6. Transport Concept of the Future: Delivery Drones

Transport concept "Delivery Drones" can be described as follows (INTEND, 2018):
"Urban airspace utilization for goods deliveries; delivery drones as a part of the supply chain."
In addition, literature review allowed for the identification of 7 breakthrough and 47 obstacles related to this TC (Table 11).

Table 11
Breakthroughs and obstacles of TC Delivery Drones

TC Delivery Drones		**Breakthroughs**						
		Cost effective	Deliver Products	Improves Time Management	Conserves Energy	Saves Time	Promote Safety	Accuracy
Obstacles	Regulation			X				
	Safety						X	
	Order staging		X					
	Weight limit							
	Drop ship vendors							
	Distance limit							
	Requires investment	X						
	Shipping big-ticket items						X	
	Uninterrupted service							
	Designated delivery spots		X					
	Durability							
	Conditional awareness					X		
	Black boxes							
	Maintenance plans							
	Override kill switch						X	
	Classification system for drone and cargo		X					

	Drone insurance	X						
	Licensing (Vehicle, Pilot, Operator)			X				
	Weather contingency plans							
	Rules (Privacy, Security, Drone spam rules, Noise guidelines)							
	Automated here-to-there delivery							
	Grasp and release mechanisms							
	Aerodynamic packaging							
	Fly-drive capabilities							
	Systems (Collision avoidance, Crowded skies navigation system, Drone operating system)							
	Shot from the sky recourse							
	Political and consumer awareness							
	Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots			X				
	Drone financing	X						
	Flying drone bill of rights	X						
	Docking systems							X
	Better battery tech							
	Airbag crash protectors							
	Invisible fences							

3.7. Transport Concept of the Future: Smart Use of Travel Time

INTEND, 2018 defines the transport concept "Smart use of travel time" as follow:
"Use of travel time made available because of vehicle automation; travel time as a usable timeslot for a wide range of activities."
The same report (INTEND, 2018) recognizes that the smart use of travel time, as a transport concept of the future, is a direct consequence of the autonomous driving.
Accordingly, many of the obstacles that are present in autonomous driving and have been processed in Chapter 2.1.1 are also relevant for the transport concept “Smart use of travel time” and will not be considered again.

3.8. Transport Concept of the Future: High-Speed Rail

Transport concept "High-speed rail" was described in INTEND, 2018 as follows:
"High-speed train technologies; high-speed rail for passenger transport."
Based on the literature review, we were able to identify 3 breakthrough and 4 group of obstacles which are mostly relevant for this TC (Table 12).

Table 12
Breakthroughs and obstacles of TC High-speed rail

TC High-speed rail		**Breakthroughs**		
		Attractive alternative to aviation	High-speed rail as a cheaper, greener and more sustainable transport alternative	Need for a complete European high-speed rail network
Obstacles	Technical obstacles			
	Changes in environmental, human health, resource, and climate change impacts		X	
	Problems of the impact of rail development			
	Costs and challenges facing the HSR		X	

3.9. Transport Concept of the Future: Hyperloops

Transport concept "Hyperloops" was described in INTEND, 2018 as follow:

"*High-speed train technologies; high-speed rail for passenger transport*."
We have also identified some specific characteristics of the breakthroughs and obstacles collected from the literature and related to this *TC Hyperloops* which allow for the identification of 5 breakthroughs and 10 obstacles (Table 13).

Table 13
Breakthroughs and obstacles of TC Hyperloops

TC Hyperloops		Breakthroughs				
		Very fast	Power	Cheaper for travelers	Weather	The Hyperloop will arrive more frequently
Obstacles	Construction cost and Environmental impact			X		
	Construction material					
	Pressure					
	Spontaneous Decompression					
	Deadly Collisions	X				
	Acceleration of the capsule					
	The multi-ton capsules intended to carry passengers also pose as liabilities themselves					
	Too much air creates significant problems					
	Safety standards and security			X		
	New management challenges					X

3.10. Transport Concept of the Future: Freight Consolidation Hubs, Freight Distribution Centres

INTEND, 2018 describes transport concept "Freight consolidation hubs, Freight Distribution Centres" as follows: *"(Peri)-urban freight consolidation hubs; freight hubs located close to urban agglomerations, for goods consolidation between long distance hauls and short-distance inner-city transport; Freight distribution centres (freight villages); multimodal settlements that provide access to different modes of transport as well as several inter-modal infrastructure facilities, for transport-oriented companies, logistics service providers, etc."*
Literature review has allowed for identification of 8 breakthroughs and 9 obstacles (Table 14) relevant for this TC (*TC Freight consolidation hubs, Freight Distribution Centres*).

Table 14
Breakthroughs and obstacles of TC Freight consolidation hubs, Freight Distribution Centres

TC Freight consolidation hubs, Freight Distribution Centres		Breakthroughs							
		Environmental and social benefits resulting from more efficient and less intrusive transport operations within urban areas	Possible facilitate a switch from push to pull logistics through better control and visibility of the supply chain	Better inventory control, product availability and customer service	Potential to link in with wider policy and regulatory initiatives	Theoretical cost benefits from contracting out "last mile"	Public relations benefits for participants	Potential to allow better use of resources at delivery locations	Specific transport advantages opportunity for carrying out value-added activities
ta	Potentially high set up costs (and sometimes high operating costs) (Browne, et al., 2005)					X			

	Logistical zones in the area of the port have some disadvantages, especially because they involve higher land costs with potentially more restrictive labor regulations if they are under the jurisdiction of port workers. (Rodrigue, 2017)								
	Much urban freight is already consolidated at the intra-company level or by parcels carriers, so limited benefits (or even negative consequences) for trying to channel these flows through a consolidation centre. The potential scope for UCCs may therefore be limited. (Browne, et al., 2005)								
	Difficult for a single centre to be able to handle the wide range of goods moving in and out of an urban area, for example due to different handling and storage requirements. (Browne, et al., 2005)								
	Most studies report an increase in delivery costs due to an additional stage in supply chain which imposes a cost (and often a time) penalty, though this clearly depends on how well the centre is integrated into the supply chain and the extent to which all costs and benefits are considered. (Browne, et al., 2005)		X						
	Single consolidation centre for an urban area is unlikely to be attractive for many suppliers' flows due to the degree of diversion required from normal route (and may therefore negate transport savings for onward distribution). (Browne, et al., 2005)								
	Lack of enforcement of regulations for vehicles not included in the consolidation scheme. (Browne, et al., 2005)								
	Organizational and contractual problems often limit effectiveness. (Browne, et al., 2005)	X							
	Potential to create monopolistic situations, thus eliminating competition and perhaps leading to legal issues. (Browne, et al., 2005)								
	Loss of the direct interface between suppliers and customers. (Browne, et al., 2005)								

3.11. Transport Concept of the Future: Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines

INTEND, 2018 describes transport concept "Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines" as follows:
"Hyperloops, Cargo Tubes, Underground Freight Pipelines (e.g. "CargoCaps")"
For this TCF, we identified 5 breakthroughs and 6 obstacles from the relevant literature (Table 15).

Table 15
Breakthroughs and obstacles of TC Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines

TC Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines		Breakthroughs				
		Safety and security	Reliability	Environment	Delivery times	Transport Costs
Obstacles	Technology acceptance	X				
	Intermodal transfer with existing modes		X			
	Support for adoption					
	Costs and funding					X
	Design and construction					
	Competition					

4. Results

After overviewing all TCF breakthroughs and obstacles that are present on the realization path for each of them, Table 16 gives a summary of all identified gaps.

Table 16
List of TCF gaps

TCF		Breakthroughs	Gaps
TC1: Automation – Passenger and Freight Transport	**Road transport**	Increased safety; Provision of mobility services to people currently unable to drive	**1.Security, Cyber security**
		Better use of travel time	**2.Social justice and equity**
		Energy savings	**3.Repositioning**
		Decreases in polluting emissions; Reduction in the need for parking space	**4.Increased congestion and pollution**
		The high cost of AVs may accelerate the move to shared mobility	**5.Revenue for city**
		Roadway infrastructure could be managed dynamically	**6.City Infrastructure**
	Air transport	Energy efficiency	**7.Safety**
			8.Technology maturity
		Low engine power	**9.Infrastructure**
	Rail transport	Capacity	**10.Infrastructure (in metro)**
		Costs and energy efficiency	**11.Functional safety**
			12.IT security
		Fully automated rail freight system	**13.System integration**
	Waterborne sector	Advanced in modern ships	**14.Changes in the ports**
		Safety and energy efficiency	**15.Regulatory Framework**
			16.Insurance
			17.Cyber Security
TC2: Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS	**MaaS**	Integration of transport	**18.MaaS can still face strong competition from existing travel applications**
		Multiple actors	**19.Policy Framework for Implementation of MaaS**
		Use of technologies	
		Demand orientation	**20.Travel demand modelling for MaaS**
TC3: Electrification – Passenger and Freight Transport	**Road transport**	Electricity Energy (efficient and utilize)	**21.Electric parking spaces**
			22.Uncomfortable and slow charging
			23.Limited range
			24.Space required for storing electricity (battery) in the vehicle
		Improving local and regional air quality	**25.Accessibility and awareness**
	Waterborne sector	Improved efficiency of fuel consumption	**26.Higher initial cost**
		Powering the ship	**27.Power solutions**
	Air transport	Reduction in CO_2 emissions	**28.Management and standardization competencies**
TC4: Seamless transport chains		Energy efficiency	**29.Efficient management systems**
		Integration	**30.Coordination and collaboration**
			31.Regulations
TC5: Personal air transportation - "flying cars", "flying taxis"		Avoid congestion on road; Reduced emissions, fuel use, and capital cost	**32.Cost and accessibility**
		Enhance personal transportation, revolutionize the transportation industry, and improve the standard of living	**33.Safety**
			34.Affects other sectors
		Infrastructure	**35.Air traffic control and infrastructure**
			36.Regulation
TC 6: Delivery Drones		Cost effective	**37.Requires investment**
			38.Drone insurance

		39.Drone financing
		40.Flying drone bill of rights
	Deliver Products	**41.Order staging**
		42.Designated delivery spots
		43.Classification system for drone and cargo
	Improves Time Management	**44.Regulation**
		45.Licensing (Vehicle, Pilot, Operator)
		46.Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots
	Saves Time	**47.Conditional awareness**
	Promote Safety	**48.Safety**
		49.Shipping big-ticket items
		50.Override kill switch
	Accuracy	**51.Docking systems**
TC 8: High-speed rail	High-speed rail as a cheaper, greener and more sustainable transport alternative	**52.Changes in environmental, human health, resource, and climate change impacts**
		53.Costs and challenges facing the HSR
TC9: Hyperloops	Very fast	**54.Deadly Collisions**
	Cheaper for travelers	**55.Construction cost and Environmental impact**
		56.An easy terrorist target
	The Hyperloop will arrive more frequently	**57.New management challenges**
TC 10: Freight consolidation hubs, Freight Distribution Centres	Environmental and social benefits	**58.Organizational and contractual problems often limit effectiveness.**
	Possible facilitate a switch from push to pull logistics through better control and visibility of the supply chain”	**59.Increase in delivery costs**
	Theoretical cost benefits from contracting out “last mile	**60.Potentially high set up costs (and sometimes high operating costs)**
TC 11: Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines	Safety and security	**61.Technology acceptance**
	Reliability	**62.Intermodal transfer with existing modes**
	Transport Costs	**63.Costs and funding**

As we can see from the Table 16, we have identified 63 gaps in total. Clarification of identified gaps, i.e. an explanation of which obstacles should be overcome so as the TCF would function and come to life, is given in Table 17.

Table 17
Description of Gaps

Gaps
1.Security, Cyber security Automated vehicles could be used for terrorist attacks (as ar bomb for instance) without any physical risk and with much lower risks of detection for the terrorist. Moreover, automated vehicles could be hacked for malicious purposes. (Franckx, 2015) "Another question is cyber security", "How do you ensure that these cars cannot be hacked? How vehicles become smarter and connected, there are more ways to get in and disturb what they do." This should not be impossible to fix. Software companies have long been facing this problem. (Plumer, 2016)
2.Social justice and equity There is a risk that AV would benefit more from the rich and create a higher burden for low-income people. These without AV can be in a disadvantageous position when it comes to employment, because they can work with AV and respond to e-mail while travelling. (GovTech, 2017)
3.Repositioning After having dropped their passenger, the AVs will now have to drive to places where parking is available (or cheaper), or to catch other users (which could be other family members, or, in the case of shared cars, third parties); this “repositioning” could have an important impact on traffic flows. (Franckx, 2015)
4.Increased congestion and pollution Increased congestion and pollution caused by travel by those currently unable to drive, such as young people without

Gaps
driving license, the physically impaired, and elderly people. (Franckx, 2015) It is not clear to what extent autonomous cars will really lead to shorter headways -One should not compare the theoretical safety distance between AVs with the theoretical safety distance between vehicles driven by humans as a lot of people drive closer to the preceding car than is justified on safety grounds; (Franckx, 2015) Le Vine and at. 2016, examined the impact of the dynamics of driving autonomous vehicles on congestion in traffic. Autonomous vehicles which offer a comfortable ride similar to slowing down and acceleration on the rail, create more traffic congestion than a man behind the wheel. When driverless cars accelerated and decelerated in the style of light rail, the congestion deteriorated from 4 percent to 50 percent and the number of cars travelling through the intersection also fell between 4 percent and 21 percent. Going for high speed rail style of smoothness, those numbers got even worse: Delays increased from 36 percent to nearly 2,000 percent and intersection capacity fell between 18 percent and 53 percent. Only the vehicles with drivers and autonomous vehicles are included in simulation in study. There were no trucks, buses, or pedestrians
5.Revenue for city AVs will not go to red light, they will not accelerate to the highway over the permitted border or park outside the permitted parking space. This, however, will affect the city budget. In some cities, traffic fines make a significant percentage of the city's budget. Cities will need to generate new revenue streams to counter the loss of funds. (GovTech, 2017)
6.City Infrastructure Often, AVs require a clear striming stripe, storage locations for data collected during guidance, and a robust network of climbing if they are working on electricity. (GovTech, 2017)
7.Safety Obstacles to the advancement of automation depend on basic safety concerns (a key problem due to potential loss of life and poor publicity that may be the result of a collision of aircraft). (Spinardi, 2015) For the adoption of passenger drones and flying cars (especially fully autonomous), operators of these vehicles should show a safety record covering both mechanical integrity and safe operations. As has been shown in autonomous cars, any accidents can have considerable attention and can slow down the adoption of such a concept. (Lineberger et al., 2018)
8.Technology maturity Although GPS technology exists and is used in autonomous cars, it should be improved to provide remote sensing and recognition needed to deal with the multi-way and fast convergence associated with the autonomous flight. These vehicles would require advanced technologies, such as artificial intelligence, to allow advanced detection and avoidance capabilities. Machine learning can be essential since operations move from piloted to autonomous: the vehicle should learn from pilots on the basis of over a thousand working hours to become completely autonomous over time. Energy management is crucial: to have enough energy to transport passengers or cargo, to maintain a safety margin and reload for the next flight. Although the technology of using batteries as a source rapidly improves, in order to increase the capacity of passengers and cargo and extend the range of passenger drones, it is necessary to further improve or to find alternatives. (Lineberger et al., 2018)
9.Infrastructure In terms of infrastructure, it is necessary to provide the appropriate landing and landing zone, as well as the charging stations for the battery. A broad network requires new infrastructure or the conversion of existing infrastructure (such as helipads, roofs of large public buildings and unused land). In order to provide a unified traffic management system, additional infrastructure along the predefined flight corridors should be installed to help rapidly communicate data and geolocation. All these changes in infrastructure would require cooperation with commercial actors and local urban planning bodies. (Lineberger et al., 2018)
10.Infrastructure (in metro) Modification or replacement of vehicle fleet and signaling system and additional complexity can increase costs in comparison with other signaling and control systems. Closing an existing system over a longer conversion period is likely to be difficult and costly, as existing metro lines often represent vital links in the urban transport network. In order to ensure high levels of security, a greater degree of physical segregation from the environment will be required than for trains in which a driver can react to extraordinary or unexpected events such as collapse, burning trees or damage to the infrastructure. This is not so significant for underground lines as it is important when converting a surface infrastructure that was not originally designed for such a high degree of isolation. A very high percentage of runs on which trains are currently running without a driver are underground or raised. By contrast, most of the metro is at the ground level, and it is likely that the peripheral line should be upgraded, as the crossing is a daily problem on the metro paths. It is necessary to improve the system of communication and tracking for passengers throughout the system in order to provide functions that would otherwise be performed by a staff member. This also applies to remote monitoring and correction (where possible) of equipment faults by the remote control center. The equipment requires a high degree of reliability and availability to ensure the safety of passengers. Such systems would represent **additional capital and maintenance costs**. (Powell, 2016)

Gaps
11.Functional safety Higher system complexity increases potential error rates and demands new functional safety approaches. (Bosch, 2017)
12.IT security More digitised and interconnected systems are exposed to numerous hazards and vulnerabilities. (Bosch, 2017)
13.System integration Smart systems need to communicate across rail services, transport modes and infrastructure. (Bosch, 2017)
14.Changes in the ports Increased ships' automation will require some changes in the ports, e.g. for maintenance of ships, as well as for increased automation in both approaches and landing. (EU, 2018)
15.Regulatory Framework So far, the legislation governing autonomous ships is totally unclear. The main concern concerns the provisions on the number of crew members and safety, as well as the construction standards. According to IMO International rules, all ships should be employed with a minimum number of crew members in order to be able to navigate. This rulebook should be amended to include vessels with special characteristics that will allow them to sail with less or no crew on board. The same situation is with regard to the safety of the ship, where minimum standards regarding the conditions of vessels and equipment should be applied. Building and maintenance standards that classification societies also provide should be materially supplemented, and these societies will require people with expertise in autonomous technologies. Safety in navigation and responsibility: it is probably the main concern of people who are still cautious about autonomous ships. A boat sailing in the open sea faces many risks associated with weather, other hurdles, or even risking being threatened by a third party (e.g. pirates). So, such an autonomous ship should be very intelligent to be able to control any potential risk. (Jokioinen, 2017)
16.Insurance Existing insurance (..., war risks, piracy risks, cargo insurance...) should be available. However, premiums may vary depending on the level of actual risks in the navigation of these vessels. (Jokioinen, 2017)
17.Cyber Security The new risk that can arise using remote navigation is a cyber security. In this way, a new type of piracy can be developed. Therefore, the systems should be developed in such a way that they will exclude unauthorized access but also give the shore master overriding authority over any unauthorized instruction. Furthermore, a new insurance cover may be required which will cover such type of risks. (Jokioinen, 2017)
18.MaaS can still face strong competition from existing travel applications Even if Maas would aim at a pan-European or global market, MaaS can still face strong competition from existing travel applications that have already offered global services. Maas service will have to work with existing providers. It remains unclear whether such providers are willing to integrate their platforms with MaaS. (Li & Voege, 2017)
19.Policy Framework for Implementation of MaaS Implementation of MaaS in the city can face financial challenges. Many cities subsidize public transport services. If Maas had a profit from his monthly subscriptions, this does not necessarily mean that the sale of tickets for public transport was realized. Government policy will have to define the MaaS business model in terms of public transport services. Many employers offer free passes for public transport for their employees when traveling by public transport. Often employees can get a tax reduction for travel expenses. If an employee chooses Maas instead of public transport, an employee may not be able to receive the same subsidy or tax cuts. So, only when local governments identified MaaS as a type of sustainable transport system with the same state subsidy policy or tax cuts, MaaS can be applied in a city where subsidies and taxes are offered for those traveling by public transport. (Li & Voege, 2017)
20.Travel demand modelling for MaaS Providing innovative services such as MaaS requires the continuation of ongoing modeling of demand based on activities, given the more dynamic context of modern lifestyles, social impact, ICT, responses to travel recommendation systems, attitudes and subjective considerations, and an increasing degree of uncertainty. It is necessary to think critically about how to expand existing models based on activities and models of elections in order to better capture the overall nature of travel behavior and the decision-making process related to MaaS. (Jittrapirom et al., 2017)
21.Electric parking spaces In large cities, the use of electric vehicles would result in the need for millions of electric parking spaces, which is a real challenge for implementation. Implementation of the EV fleet would also require changes in infrastructure, to allow significantly higher power supplies to chargers than is currently available. (García-Olivares et al., 2018)
22.Uncomfortable and slow charging Convenient and reliable re-charging has already been identified as one of the most important aspects to increase user acceptance of electric vehicles, but is most often neglected. One clear challenge is to provide appropriate charging capabilities to urban dwellers that often have to rely on overnight street parking and limited garage spaces in high-density populated city areas. Municipalities aim long-term to reduce the number of vehicles in cities and are reluctant to electrify a high number of parking spaces with bulky or unsightly charging stations that often do not fit easily in the townscape. These users will have to rely on quick-charge capabilities or charging during the day at work. Additionally, there is the possibility to

Gaps
promote this means of charging with incentives due to the potential usage in vehicle-to-grid applications. (ERTRAC, 2017)
23.Limited range Increasing range capability of electric vehicles remains a high priority, as previously mentioned, in order to increase user acceptance and win the broad mainstream market especially in comparison to conventional vehicles and current existing usage models of these vehicles. It is important to keep in mind, however, that increasing driving range supplied by the electro-chemical energy stored in the battery can only be achieved directly by increasing the size of the battery. Increasing the size of the battery increases the "installed" energy storage capability at an increased cost and increased size and weight. (ERTRAC, 2017)
24.Space required for storing electricity (battery) in the vehicle These problems can be solved by supplying electricity directly to the cables while the vehicle is active. Losses are limited to the conventional distribution of electricity and the power of electronics on the vehicle, and the exceptional efficiency of the electrical machine can be used at full scale. This advantage in the efficiency of the system, turns into significant benefits in operating costs. (eHighway, 2017)
25.Accessibility and awareness Other incentives such as access to the driver and parking access are high value, low-cost incentives for adoption. Local competencies must also play a role, ensuring that the local location and the license for a new EV service are quickly terminated. (SCE, 2017)
26.Higher initial cost The main disadvantages of all electric drives are the higher initial cost compared to the propulsion systems based on internal combustion engines, the increase in losses in the conversion of energy from fuel to propulsion, the greater the volume of the system due to the large number of component parts, and the issue of energy density in vessels with batteries. (EC, 2017)
27.Power solutions Due to the diversity of ships and sailing (some boats spend a week at sea and only a few days in the port, while other vessels are regular vessels), the power solutions for one type of ship are not suitable for another ship. (EC, 2017)
28.Management and standardization competencies At present, there is no established access to standards, however, in order to make the supply chain efficient, specific standards, including the definition of components (e.g. an electric motor considered to be a drive engine?). (EC, 2017)
29.Efficient management systems Introducing more efficient management systems and cross-port operations in consolidation/distribution nodes close to cities, preserving the added value of long journeys; (Perkins, 2012)
30.Coordination and collaboration Need for intermediation and coordination to overcome the power imbalance and to reduce searching and transaction costs, and to avoid moral hazard and opportunism. •Fair gain sharing: the presence of conflict in co-modal initiatives is also connected to the perception of the unfair share of gain. Fair gain sharing is a proxy for horizontal collaboration. •Information sharing and visibility: shippers and carriers do not collaborate horizontally because of competition law, fear of losing competitive advantage, and a lack of cross network visibility, among others. •Risk allocation: The existing literature allocates the risk related to co-modality (unused capacity, disruptions, delays, etc.) to the carrier which is usually in charge of the consolidation of different flows from its clients. (CO^3, 2012)
31.Regulations Too many regulations that hinder innovation. Different standards, regulations and procedures in member states prevent impeccable cross-border transport operations, as well as synchronic transport when logistics chains involve several countries. (Perkins, 2012)
32.Cost and accessibility Flying costs are more than driving, and the same goes for drones. It is estimated that average driving costs are 12 times higher for flying vehicles than those left on the ground. As far as personal planes are concerned, their price remains surprising. *(*Dewost, 2018); (Krauth, 2018)
33.Safety Private planes may be the closest device to mobility in air traffic, and are much more dangerous than cars. The biggest obstacle seriously delaying the great development of air traffic in urban areas is perhaps security, reflecting highly mediated discussions about autonomous accidents in the vehicle. The survey found that more than half of the Americans surveyed said that their main concern was the safety of autonomous flying cars. *(*Dewost, 2018); (Krauth, 2018)
34.Affects other sectors • Necessary co-operation of city-transport operators on demand with regulators to understand and respond to key regulatory issues (airspace management, fully autonomous adoption path, licensing and certification, and air traffic management). • Education of urban planners in terms of infrastructure conditions that are necessary in urban areas for operations with passenger drones to begin to involve them in urban planning processes in local communities.

Gaps
• Manufacturers should consider improving their concepts, working with regulators, and cooperating with urban transport operators on demand, in order to establish a market for their aircraft. In addition, manufacturers should begin to plan reduced production and subsequent aircraft support. • Drone technology providers should consider cooperation with drone manufacturers in order to fully understand their needs and integrate technological software, sensors, materials, engines and energy management into vehicles. Air Traffic Management Providers should consider working with their national airspace management regulators (such as the FAA in the United States) to participate in early pilot programs, formulating regulatory and standard standards, and adapting hardware and software to meet major quantity, low altitude and fully automated unique air traffic management systems in the future. (Lineberger et al., 2018)
35.Air traffic control and infrastructure There are numerous practical challenges in the direction of creating a regulatory management system: small drones are more susceptible to changes in time; the need for a dynamic mapping system that is updated in real time; connection for tracking constant tracking of drones in flight; and even interoperability, including devices that do not fly. Also, the lack of available free space and the difficulty of accessing up-and-down infrastructure (for landing and landing and flight safety) are significant obstacles, and the construction and design a vast network of vertiports is a major urban planning job in itself. *(*Dewost, 2018)
36.Regulation The existing rules, updated by the FAA in August 2016, insist that drones must be in the line of sight and must always be controlled live by the operator. Rules suffocates new innovations (at least in the U.S.). Other countries were welcomed by autonomous drones with open arms. For example, Delft agreed to implement the first fully autonomous network of unmanned aerial vehicles, complete with docking stations and drone rentals. New Zealand has been selected as the first commercial service for the delivery of drones in the world due to friendly regulations in the country. (Blair, 2017)
37.Requires investment The introduction of drones as part of the delivery process requires greater investment. The impression is that the investment will be more burdensome for smaller traders - or use third-party services that utilize drones. (Mehra, 2015)
38.Drone insurance Drones, drone cargo, and drone businesses will soon become the largest new market for insurance companies. (Frey, 2015)
39.Drone financing As the need for instrumentation and safety equipment mushrooms, delivery drones will become far more expensive. As a result, drone financing will become a hot new area of business in the near future. (Frey, 2015)
40.Flying drone bill of rights Do people have the right to “keep and bear drones?” (Frey, 2015)
41.Order staging In unmanned flights, the existing allocation process will have to be redesigned to support drones, and employees will have to train for these new processes. (Mehra, 2015)
42.Designated delivery spots Drones will need designated places for package delivery. (Frey, 2015) So flight is the easy part. Dropping off the package is the problem. Others address the issue by creating special landing zones. (Kobie),(Nentwich & Hórvath, 2018).
43.Classification system for drone and cargo Drones are being created in thousands of different shapes and sizes with thousands of different capabilities. A comprehensive classification system will be needed to properly manage and regulate this industry. Cargo classification systems applied to ground-based shipping will need to be revised for the more volatile conditions associated with remote controlled airborne vehicles. (Frey, 2015)
44.Regulation The second big challenge is regulation, and as ever the law trails innovation(Kobie)
45.Licensing (Vehicle, Pilot, Operator) Every drone that falls within certain classification guidelines will need to be licensed and insured. (Frey, 2015); (Nentwich & Hórvath, 2018). People who load and unload cargo onto flying drones will also need to be licensed. Those who fly drones will need to be tested and licensed in a less rigorous but similar way that airplane pilots are tested today. (Frey, 2015)
46.Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots People who service and fix drones will be in hot demand in the near future. Drones will become one of the most highly regulated industries of all times. It is not too soon to start educating the influencers. With all their different configurations, styles, and function, drone pilots will require far different training than airline pilots do. Currently there are very few simulation programs available for practice. Police will not only employ drones to assist in managing public safety, they will also use drones to monitor other drones. Drones are far more versatile and faster to deploy than virtually all other options officers have at their disposal. (Frey, 2015)

Gaps
47.Conditional awareness Drones will invariable fly into unusual situations, and whether it’s swarms of bees, bird attacks, lightening strikes, or signal jammers, they will need to alert operators of problems as soon as they arise. (Frey, 2015)
48.Safety Safety is very important the question of the fall of the drone from the sky, either by mechanical error or by the devious hacker. (Kobie) Health and safety - injuries because of collisions; contamination with dangerous loads. (Nentwich & Hórvath, 2018).
49.Shipping big-ticket items The drones will become the target of thieves as they fly several hundred meters from the ground. Retailers will have to consider this before using drones to send big-ticket items. (Mehra, 2015)
50.Override kill switch Wireless signals are far from perfect. If a signal is lost, hacked, or hijacked, the drone must either return home or be removed from danger. (Frey, 2015)
51.Docking systems People will eventually not want packages delivered onto their driveways. For example, any pizza left on a driveway becomes an open invitation for cats, dogs, and other stray animals. A better option would be to have some sort of docking system that would allow the drone to land and deliver the package into a secure area. (Frey, 2015)
52.Changes in environmental, human health, resource, and climate change impacts • spatial incompatibility between HSR and other long-distance modes that is often ignored, • an environmental review process that obviates modal alternatives, • siloed interest in particular environmental impacts, • dearth of data on future vehicle and energy sources, • poor understanding of secondary impacts, particularly in land use. (Chester and Ryerson, 2014)
53.Costs and challenges facing the HSR • Total per mile costs of providing rail service increase significantly with increases in travel speed, but ridership also increases with faster speeds, albeit less dramatically. Hence, there is a “sweet spot” where ridership and costs are optimized. This sweet spot also varies from corridor to corridor. • The feasibility and benefits of higher and high speed rail investments depend primarily on ridership. Therefore, it is important to focus initially on connecting major mega-regions with proven demand. • Certain metropolitan regions are more conducive to high speed rail by virtue of existing land use patterns and complementary public transportation service. It is important to provide rail service where people and economic activity are already concentrated, but it is also important to plan ahead for growing cities and regions. (Metcalf et al., 2010)
54.Deadly Collisions Capsule capable of sustaining force in the event of decompression should be extremely difficult given the nature of the design. The capsule must be strong enough to withstand atmospheric pressure inside the cabin, but it must remain light enough to not destroy or compromise the tube while traveling. Assuming it does not immediately destroy itself in pieces in the event of decompression, the capsules will accelerate the path until they collide with each other with deadly force. (Interesting Engineering, 2017)
55.Construction cost and Environmental impact Land acquisition and building/tunnelling rights. (Krauth, 2018)
56. Safety standards and security People are more concerned than ever about the threats of a terrorist attack. Designing hundreds of kilometers of tube transported by hundreds of people at the same time brings the real possibility of a terrorist attack. (Interesting Engineering, 2017), (Krauth, 2018)
57.New management challenges The dispatch system must meet the increased requirements for speed and reliability. It should provide simultaneous activation and execution of command sequences in the presence of a large number of different dispersed objects. (Dudnikov, 2017)
58.Organizational and contractual problems often limit effectiveness
59.Increase in delivery costs Most studies report an increase in delivery costs due to an additional stage in supply chain which imposes a cost (and often a time) penalty, though this clearly depends on how well the centre is integrated into the supply chain and the extent to which all costs and benefits are considered. (Browne, et al., 2005)
60.Potentially high set up costs (and sometimes high operating costs) Potentially high set up costs (and sometimes high operating costs) (Browne, et al., 2005) Logistical zones in the area of the port have some disadvantages, especially because they involve higher land costs with potentially more restrictive labor regulations if they are under the jurisdiction of port workers. (Rodrigue, 2017)
61.Technology acceptance One of the challenges is the acceptance of the technology as a viable alternative to conventional transport modes. it is

Gaps
not envisaged that this technology will completely replace other forms of transport but work in tandem with them to best optimize the transportation network. While this optimization is necessary, certain challenges exist with the use of this technology. (Egbunike and Potter, 2011)
62.Intermodal transfer with existing modes Pipelines will have to be connected to other types of transport and that the design boundary of such a system must include this interface. Efficiency and flawless transfer of goods in data exchange facilities, as well as an increase in the number of items for handling products, are of concern. (Egbunike and Potter, 2011) There are special disadvantages of the pneumatic tube mail system which are the inability to carry special delivery parcels due to the size of the carriers and because of that can carry only five pounds of mails in each container. (Shibani et al., 2016)
63.Costs and funding Related to the acceptance issue is financing. Investment costs can be considered factors that influence the underground infrastructure planning. When making the pipeline network a capsule, it is necessary that the network offers a long-term transport solution. However, obtaining a financial asset will only be possible if the technology proves itself. Operating costs will then depend on maintaining a constant flow of products through the pipeline. (Egbunike and Potter, 2011) The cargo transportation prices are rising each year. The high cost of creating and maintaining the vacuum tube and the tracking pipeline itself. (Shibani et al., 2016)

5. Conclusion

By overviewing the list of gaps, it is evident that some of the gaps are present in more TCFs. This is the case, for example, with Safety (TCF1, TCF5, TCF6,), Regulations (TCF1, TCF4, TCF5, TCF6) and Costs (TCF3, TCF5, TCF8, TCF9, TCF10, TCF11). Their grouping would provide a general picture on the guidelines for research needs, investment priorities and regulation necessities for removing obstacles, which altogether represents the required further steps in this research.

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THE CAUSE-EFFECT METHOD USED IN HIGHLIGHTING THE MAIN CAUSES AND IMPLICATIONS OF MARITIME ACCIDENTS IN THE BLACK SEA

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Abstract: Maritime transportation is a complex activity both in terms of the volume and nature of the shipped goods, but mostly in terms of the particular operational conditions, as the seas and oceans impose special measures for the safety of the ships. In the field of the maritime transportation, people interact with technology, the environment and organizational factors, each of them has a determining role in the safety of the ship in the sea. As regards the Black Sea, this is a great inner, and the wave area is much smaller in terms of its extent than in the open ocean. As a consequence, the average wave conditions are generally less energetic. However, strong storms, which are characteristic of the region, can generate large waves in the Black Sea with high wave heights comparable to the ocean waves, which can lead to accidents on the sea. The causes of the marine casualties and their effects are constantly investigated by international organizations such as United Nations and European Comision, as well as by specialized agencies such as International Maritime Organization (IMO), International Labor Organization (ILO), which have developed a number of conventions, regulations, rules and international standards to reduce the frequency or even to eradicate the marine accidents in the future. Among the causes that can generate marine casualties, the following should be taken into account: high traffic density, bad weather conditions (storms, waves, precipitation, frost), navigation barriers, sea conditions (sea depth and seabed), low visibility, human errors, hidden ship vices, gas emissions in tanks, which may separately or occurring with other factors, result in shipwrecks. The present work aims to present how to use the cause-effect method can highlight the major causes and their secondary causes with disastrous effects in terms of loss of lives, material damages and environmental pollution.

Keywords: Black Sea, maritime transportation, marine casualties, cause-effect method, sea conditions.

1. Introduction

World economic growth in the recent years has led to an increase in the foreign trade and, implicitly, of the global maritime trade. Starting from the fact that the production of the accidents in the sea is inevitable and that they can cause pollution of the seas and oceans, the evolution of the maritime transport has been marked by a number of requirements in terms of the pollution prevention and increasing safety.

On the other hand, it should be mentioned that the maritime transport is a complex economic activity due to the particular environmental conditions in which it is carried out, which requires special safety measures, but also that the quantity of the goods shipped annually and the material value of them.

International organizations and institutions such as the UN, EC and specialized agencies such as the International Maritime Organization (IMO), International Labor Organization (ILO), which have authority with respect the regulations, procedures, techniques and materials in the shipping industry, have developed international conventions, regulations, rules, norms and international standards for safety in the sea and the prevention of the marine pollution.

The causes of the marine casualties and their effects are constantly investigated, classified, and concludes, which are then transformed into international norms or conventions to reduce or eliminate the naval accidents in the following periods (Vlasceanu, 2015; Omer, 2015).

One of the important conventions on the pollution prevention and control, which has been adopted under the aegis of the IMO, is the International Oil Pollution Response and Cooperation Convention (OPRC), which Romania has adopted in 2000 (IMO, 1994).

Another Convention on the Prevention of the Marine Pollution from Ships is the 1973 International Convention, to which Romania has joined since 1993, and which today is known as the Convention on the Prevention of the Pollution from Ships (MARPOL 73/78, 1997).

As a response to a series of major oil-related disasters, the SOLAS Conventions (SOLAS, 1974) have repeatedly changed the Conventions of the International Convention for the Safety of Life at Sea.

Also, as a result of the shipping disasters resulting in losses and severe contamination of the marine environment, the International Safety Management Code (ISM, 1993) was developed and adopted in 1993 as an integral part of the International Convention SOLAS (ISM Code, 2002; ISM Code, 2005).

Maritime safety and protection against maritime pollution are fundamental objectives which focus on a large number of programs aimed at the safe and unpolluted maritime transport.

This paper seeks to outline the main causes and sub-causes of the marine casualties in the Black Sea using the cause-effect method.

2. Types of Accidents and Categories of the Ships Involved in the Black Sea

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Accidents at sea can be very serious accidents involving total ship loss, loss of life and serious sea pollution, serious accidents involving fires, explosions, failure, collision, cracks in the ship's body, etc. and less serious that does not qualify as very serious or serious accidents (Antão, P et al., 2008).
Most accidents in the Black Sea occurred during the cold season (November-March), when the hydro meteorological conditions are the most unfavorable, the strong wind, the fog, the abundant snowfall, the low temperatures that produce ice deposits on the deck and on the superstructures of the ship affects the ship's buoyancy (Guedes Soares *et al.,* 2001).
During the cold season, wind frequencies at high speeds are higher than the rest of the year. Winds at speeds of 11 and 15 m/s reach 12-25% of the total in winter, and winds with speeds higher than 15 m/s reach 10%, compared to the annual average of 3-5%.
Often the strong winds are accompanied by the abundant rainfall, low visibility, situations that may last for 13 and 45 days, which accompanied by strong frosts, increase the likelihood of the shipwrecks (Gasparotti and Rusu, 2012; Ivan *et al.,* 2012).
In the winter and in the western and northwest part of the Black Sea, due to the specific aerospace situation, permanent conditions for the production of the storms are created (Rusu *et al.,* 2014; Butunoiu and Rusu*,* 2014).
Different types of the ships seem to have different types of accidents. Containers may overturn as a result of the coupled ship movements (pitch and roll). This is more likely to occur in the seas with hard waves conditions with moderate heights, while the port container ships accidents have also occurred at relatively low wave heights (less than 4 m) (Gasparotti and Rusu, 2012; Rusu *et al.,* 2014).
In the case of bulk carriers, the accidents have been recorded in severe sea states (wave heights> 4 m). These vessels are particularly vulnerable to the accidental water inclusion. The combined load of the loaded goods and water leads to the excessive stresses in the structure of the hull, with the consequence of cracking and rapid diving off the ship (Gasparotti *et al.,* 2013; Gasparotti *et al.,* 2014).
Most of the reported accidents occurred under relatively low sea conditions (Ivan and Rusu, 2012).
In the Black Sea, known as the sea of storms, there has been a relatively large number of the naval accidents that have had unfavorable hydro meteorological conditions as immediate cause, some of which are presented below.
On January 10th, 1982, around 14:45 hour, in the conditions of a strong storm in the Romanian Black Sea coastline, the wind having 9 on the Beaufort scale from the V-NV direction, the Continental Carrier, which was marching on the Anvers-Constanţa route failed. The event took place even though the storm warnings were transmitted by the Radio coast Constanţa as early as January 9th, the commander continuing the maneuvering of the ship to be housed in the port of Constanţa. The combined of the wind and wave action reduced the ship speed by up to 80% of its nominal value and the ship became very difficult to manage.
Although the commander and the marine officers intended to keep the ship as far away as possible from the coast, where the depths are small, the ship has moved over the bottom of the water just to those places that have posed a danger of failure. In spite of the orders given to avoid the failure, nothing could be done because the ship has moved away from the inertia a considerable amount of space. In less than an hour the ship has failed at a short distance from the entrance to Midia Harbor.
Another shipwreck occurred on the night of February 28, 1984, when the Indian VISHVA SHANTI cargo ship that headed forwards the Constanta port failed. The accident occurred in the conditions of the existence of a 8-9 strong wind storm on the Beaufort scale in the N-NE direction, in the Black Sea Romanian seashore, with high waves and abundant blizzard snow, which reduced the visibility considerably. In this hydro meteorological context, plus the non-use of the appropriate nautical documents, the stress due to the fatigue and adverse environmental conditions, the ship collided with the protective pier and failed, tilting 170 degrees to the horizontal plane in less than half an hour, due to the penetration of the water through the large holes produced in the hull of the ship.
The largest shipwrecks in the history of the Constanta harbor during the storm are those of the "Sadu" ship in December 1988 and of the "Paris" and "You Xiu" in January 1995, resulting in loss of lives (Cumpănă C and Cumpănă AD, 2008).
On December 2, 1988, in the northern area of the Constanta port, the Romanian ship "Sadu" sank near the northern pier. It carried a coal transport from Constanta port to Galati. Around 13:00 that day, the 4,800 tdw ship was caught by the storm, repeatedly hit the dikes, and finally sank.
On the evening of January 4, 1995, the two "Paris" and "You Xiu" ships were caught by a strong storm. The cargo ships were empty and could not be controlled. The wind and waves hit the northern pier of the port of Constanta. The dike broke and the ships sank.
Also, due to a storm on July 26, 2007, the MULTI TRADER under the Cambodian flag sank near Venus. A few hours after the event, fuel jets have appeared on a 10 km length.
Then, on October 10, 2007, the Romanian fisherman YLDIRIMLAR-1 sank in Midia harbor, due to the unfavorable weather conditions and technical problems. The ship, with a length of 19 m, was pushed by a storm during the night while making a march from the Sulina port to the port of Midia. The ship partially sank a few hundred meters from the northern dike in the conditions of a wind speed of over 60 km/h in N-E and 5-6 m wide waves.
On November 12, 2007, the VOLGA-NEFT ship carrying more than 4,000 tons of crude oil broke in two during a storm during a stopover in the port of Kavkaz. A few hours after the incident of the Russian oil tanker, two other carrier ships carrying sulfur were sinking near the port of Kavkaz. These two accidents have had serious consequences for the marine environment due to the Black Sea sulfur pollution, both at the surface of the water and in the coastal region.
A similar accident occurred in December 2009 when a Moldovan ship was carrying fuel was broken in two by a very strong storm, in the offshore of the Russian resort Sochi.

In March 2012, there was an accident in the offshore of the Black Sea coast when a Russian ship, was drifting, collided with the REXXON oil prospecting platform, causing a huge explosion. Also in 2012, on July 13, a commercial ship with the direction of travel to Istanbul exploded at 15Km from the port of Mangalia.
Another accident occurred in the Black Sea on April 30, 2013, when a fire produced on board of the GSP Bigfoot 1, resulting in damages of the diesel generators.
In 2014, on 17 May, due to the strong wind, the anchor line was broken, with damages to the Mare Nigrum research ship. In 2015, of the 5 accidents caused by the high waves and strong wind in the Black Sea, which resulted in great damages and loss of the cargo, one of the accidents led to the destruction of a fishing vessel.
These examples of the accidents occurring in the Black Sea, show that, not only there is a high incidence in terms of the occurrence of such marine casualties, but also the fact that it is a close sea, the impact of the pollution can be higher than in the oceans.
On the other hand, the Black Sea is an important route of the navigation, which through the European transport corridor number 7 (the Danube-Rhine-Main Canal) connects with the countries from the Central Europe to the Baltic Sea.
A substantial increase of shipping is also expected in the near future, in the Black Sea due to the increase of the offshore activities generated by the identification of major oil and gas fields in the offshore (Raileanu et al., 2015).
In this context, enhancing safer navigation and reducing the risk of the accidents in these areas, which are at high risk, as they are subject to the intense maritime traffic, it is a problem that needs to be thoroughly analyzed from the point of view of the main causes leading to the undesirable events such as pollution of the environment and loss of the human lives (Modiga *et al.,* 2016, Gasparotti *et al.,* 2016).
Figure 1 shows the number of the navigation events and their severity over the period 2013-2017.

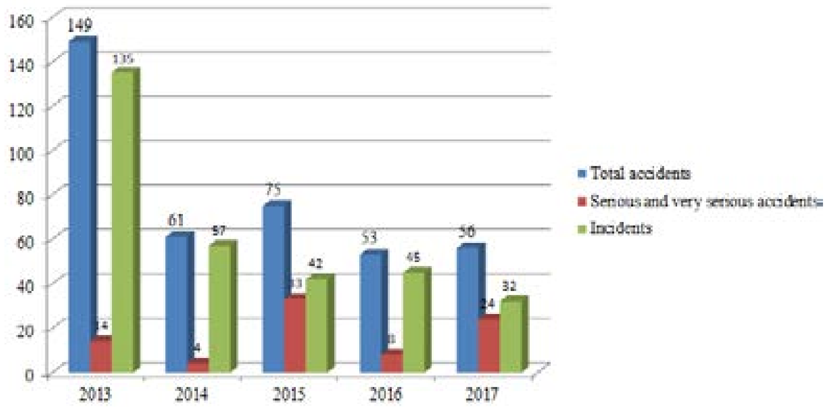

Fig. 1.
Total Number of Navigation Accidents and Their Severity Over the Period 2013-2017
Source:(Romanian Naval Authority, 2017)

Navigation accidents can occur through: collision or contact, fire or explosion, capsize, grounding, breakdown of the ship underway, stranding, and break up.
Figure 2 shows the types of the accidents that have taken place in the Black Sea between 2013 and 2017.

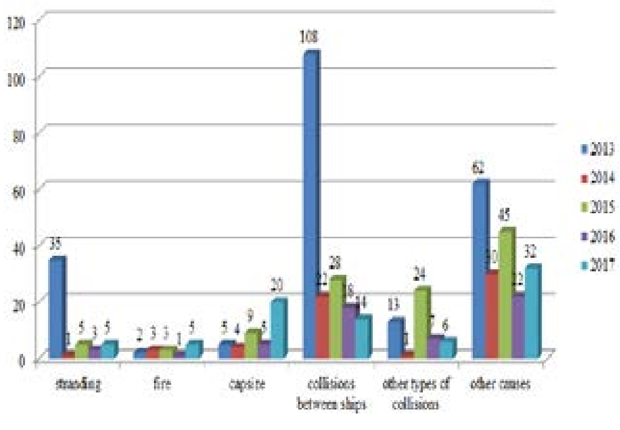

Fig. 2
Types of Marine Accidents in the Black Sea in the Period 2013-2017
Source:(Romanian Naval Authority, 2017)

Figure 2 shows that the collisions predominate and as time goes on, the number of the accidents is decreasing. Most accidents that have occurred in the Black Sea are minor accidents, sometimes accompanied by minor sea pollution.

3. Causes and Effects of the Marine Casualties in the Black Sea Basin Identified by the Cause-Effect Method

Statistical data show that the shipwrecks are caused by the sea conditions (depth of the sea and the seafloor relief on the seabed), navigation barriers, low visibility, human errors, hidden ship vices, complex technology, inappropriate operations and maintenance of the equipment, overheated machinery, inadequate spare parts, ships age, gas emissions in tanks and adverse hydro meteorological conditions(storms, waves, precipitation, frost), the latter being the second most frequent cause of the events (Toffoli *et al.,* 2005; Shuohui *et al.,* 2006). However, because there are no weather details in the databases, it is difficult to assess the exact cause of the accidents if they are caused by the fog, strong currents, high wave heights or other hydro meteorological aspects (Toffoli *et al.,* 2003). In a statistical analysis of the naval accidents in the Portuguese waters, (Gouveia *et al.,* 2007) concluded that the accidents due to the sea and hydro meteorological conditions have accounted for 23% of the total, being a major cause, after the technical failures (25%). However, the most accidents were due to the heavy hydro meteorological conditions and human errors (Milan and Gomoiu, 2008). When these two factors intertwine, the most dramatic situations occur, resulting in loss of lives, material damages and environmental pollution. Other causes may be: technological and organizational factors (Curry and McKinney, 2006). Of these other causes, according to the published statistical data, their share in producing of the marine disasters is the following: the complex technology 7%, inappropriate equipment exploitation 8%, out-dated equipment 3%, ships age 4%, human error 18%, collision with object 1%, fire/explosion 3%, cables/nets on propeller 3%, open water/cause unknown 5% (Figure 3). Referring to the human error, a study by the National Research Council of the United States (cited by Rothblum, 2006) speaks of the general technical knowledge as being the cause of 35% of the maritime accidents. In the same study, 78% of the seafarers have complained of the lack of the general understanding of the ships' system for which they work as a contributing factor to the accidents, as can be seen in the examples of the accidents in the Black Sea by not knowing the nautical and manouvring qualities of their own ship.

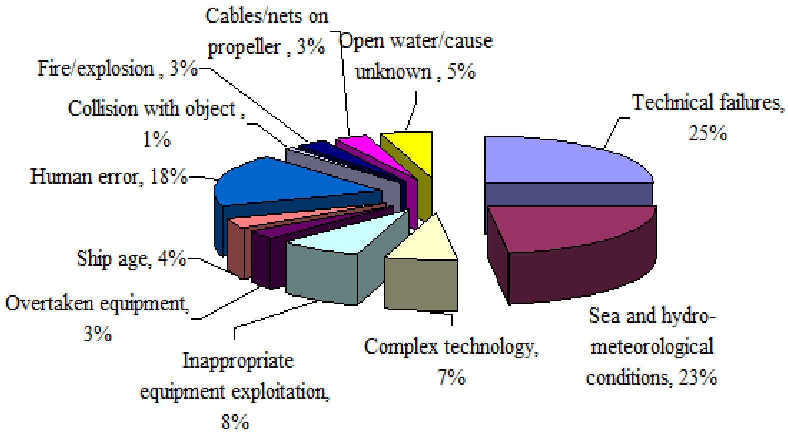

Fig.3.
The Influence of the Various Factors that Contributing to the Production of the Marine Accidents

All these causes can, individually or in combination, lead to the occurrence of the marine casualties (Milan and Gomoiu, 2008; Wayment and Wagstaff, 1999). Therefore, it can be said that the marine casualties are not produced by a single cause, but by a multitude of the causes.

Analyzing the causes of the Black Sea accidents, the main immediate cause is the unfavorable hydro meteorological conditions: storms, strong winds, high waves, often accompanied by the abundant blizzard snowfalls that considerably reduce the visibility (Rusu and Macuta, 2009). In some cases, the technical defects of the ship have been added to these harsh conditions. Alongside of these objective factors, a number of subjective factors have also emerged, which refer to the poor specialist training of the crew and commander, especially for the cases of crisis, stress and fatigue. In many of the accident cases cited, the commander did not receive or circumvent the storm warning transmitted by the Radio coast or did not use the navigation radar during the maneuvre and near the coast.

Overlapping of these categories of objective factors, mainly thunderstorms, strong winds and large waves, and subjective ones that correspond to the human errors have led to the serious naval accidents.

For the year 2017, the main causes of the marine casualties in the Black Sea were: hydro meteorological (21), technical (3), human error (22), immersing objects (13), and other causes (16). The share of these causes is shown in Figure 4.

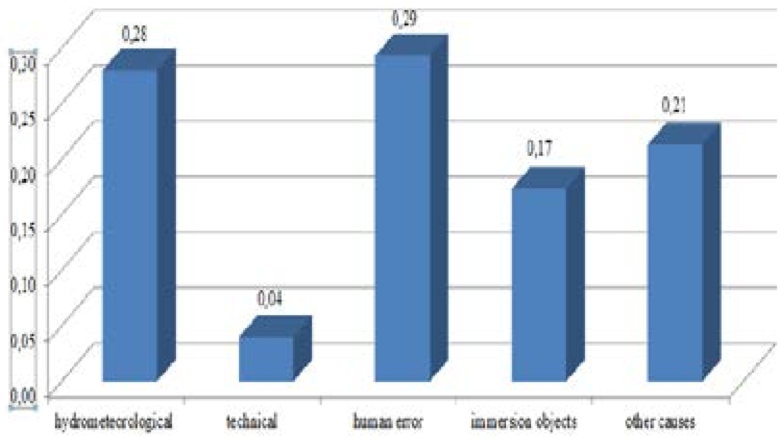

Fig. 4.
The Main Causes of Marine Casualties
Source:(Romanian Naval Authority, 2017)

In order to reduce the accidents at the sea, it is necessary to identify the causes that produced them. Starting from the causes that caused the accident, one can examine the entire chain of the events, determining the factors that contributed to its production or the underlying causes. By analyzing the underlying causes, it is attempted to understand why an accident has occurred and the circumstances of its occurrence ("what happened, how it happened", and "why it happened").
The cause-effect method provides the opportunity to identify the major causes and associated potential causes, so that the focus on the problem to be solved is done in a structured and systematic manner.
Starting from the analysis of the accidents produced in the Black Sea, an assessment can be made of the main causes and sub-causes, which have the effect of producing the marine casualties.
Considering the share of the causes leading to the marine casualties in the Black Sea, a cause-effect diagram (Figure 5) has been made, highlighting the major causes and their sub-causes.

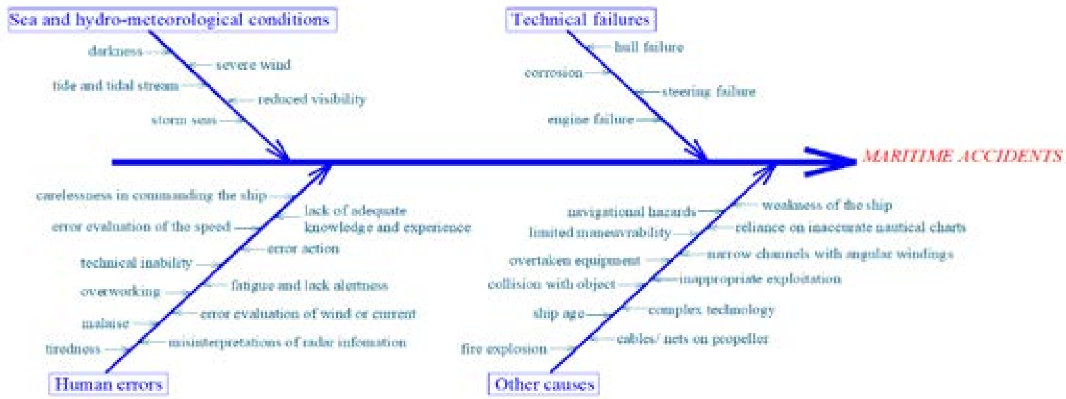

Fig. 5.
The Cause-Effect Diagram on the Maritime Accidents

The human factor is one of the main causes of the maritime accidents. Understanding the mechanism that causes the human error is the key to preventing the marine casualties.
Therefore, in order to make progress in reducing the maritime accidents, attention should be focused on the types of the human errors that lead to situations that can no longer be controlled. Identifying the types of the human errors can be done by analyzing the marine casualties and establishing how they occur.
Regarding the ship structure and naval system reliability, over the last 40 years the shipping industry has focused on improving them to reduce the accidents and increase the efficiency and productivity. Thus, a number of improvements have been made in the ship hull design, stability and propulsion systems, navigation equipment, all of which being currently highly technologically advanced and reliable. With all these advances, the rate of the maritime accidents is high, due to the fact that the structure of the ship and the reliability system are only a relatively small part of the security equation.

4. Conclusions

Marine accidents are unexpected events that may produce financial and property losses, damages, and loss of lives. The effects of these accidents can be disastrous, especially when they end with the loss of the human lives and the pollution of the marine environment.
Over time, a number of special measures have been established through the international conventions, regulations, rules, norms and international standards for the safety at the sea and the prevention of the marine pollution. Despite the international conventions and resolutions, aiming in improving the safety level, the maritime accidents remain a major concern.
The effects of these accidents adversely affect the environment, the people and shipboard activities, ranging from the minor injuries to deaths and insignificant damages to very serious damages on the environment and people's lives. The causes that can produce these marine accidents are multiple, and even if the statistics show a slow but steady decline over the last few years, they are inevitable.
The causes of the marine casualties in the Black Sea may be multiple: sea states and hydro-meteorological conditions, tide, tidal flow, strong wind, low visibility, technical defects (corrosion, steering faults, engine faults or ship's defect), conditions of the navigation routes (limited marine areas, navigation barriers, inaccurate nautical charts), age of the ship, small handling capacity, human errors (lack of adequate knowledge and experience, negligence in ordering a ship, technical inability, misconduct radar information, fatigue and lack of attention, overuse, fatigue), complex technology, etc.
All these causes, taken separately or in combination, can lead to real maritime disasters.
The cause-effect method is an analysis tool, being a suggestive model of the correlations between an effect and the causes that produced it. It provides a systematic way to look at the effects and their causes.
The problem analyzed in the method is an undesirable event (maritime accident), characterized by the risk of its occurrence, which must be diminished or eliminated, by determining the causes and sub-causes that determine it and their analysis.
The cause-effect method, based on the identification of the major causes and associated potential causes, provides an opportunity to understand how the accident occurred, what happened, how it happened and which are the main factors can be taken into account in avoiding the maritime accidents. In this way, it is possible to determine how these factors influence the occurrence of the accidents and at the same time to discover the links between the possible causes.
The advantages of using this method are: identifying the base causes, highlighting the cause and effect relationships, details about the factors that influence the production of the accident and the relationships between them, determining the areas requiring additional information that show what can be changed.

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ASSESSING THE TRAFFIC RISK ALONG THE MAIN BLACK SEA MARITIME ROUTES

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Abstract: Motivated by the fact that numerous maritime accidents have occurred in the Black Sea, the foundering of commercial ships, but not only, aims to assess the risks that may affect commercial traffic. Considering since 2001 to present, no less than 20 ships have shipwrecked in the Black Sea and five of them in 2017, a general analysis of the causes that have affected these undesirable events is required. In order to identify as accurately as possible the external factors which affected the vessels, the main wave parameters simulated by a wave modelling system implemented in the Black Sea are evaluated, together with the wind fields over the Black Sea basin provided by the U.S. National Centers for Environmental Prediction, Climate Forecast System Reanalysis (NCEP-CFSR). Thus, for the geographical area of the ship involved in a major incident, several sets of information that preceded the event, set during the event and another set a few hours after the catastrophe are identified. By studying external factors such as weather conditions, sea parameters, can lead to certain patterns that can be identified before they occur, and that in the future these disasters in the shipping industry are to be prevented. This study is designed to prevent the loss of human lives, commodities and ships in the future, risks in terms of environmental conservation.

Keywords: Black Sea, traffic risk, weather conditions, maritime accidents.

1. Introduction

Due to the phenomenon of globalization, commodity trade has witnessed spectacular growth over the past three decades, which has led to an equally spectacular growth of the commercial vessels number. The Black Sea region was not bypassed by this phenomenon of significant increase in the number of ships designed to support the demand of products and transport services. This phenomenon is favorable because it leads to the economic growth of the regions in which it develops. Less positive parts also appear; thus, the subject of this article addresses the risks posed by shipping in the Black Sea area. Maritime safety is a hotspot in any approach due to the socio-economic implications with which it often ends (Gasparotti and Rusu, 2012).

This study was designed to show that there are real concerns about maritime activity with its implications for the safety of human life at sea, the impact on the environment and the impact of maritime accidents on the industry's prestige. The availability of meteorological information can help the ship masters to decide where to sail, and which routes to plan for their ship in order to avoid dangerous situations (Ivan *et al.,* 2012; Rusu and Guedes Soares, 2014, Rusu *et al.,* 2014a).

At the same time, due to the increase in the world fleet, there is the presumption that, vessels that have exceeded a considerable period of years in service are intentionally withdrawn in certain geographical areas. Thus, as aging ships, outdated by the technical requirements and norms in force or showing fatigue, are operating in regions like the Black Sea to make way for new ships in Western Europe (Butt *et al.,* 2013; Weng and Yang, 2015). These claims are backed up by data and industry-specific figures showing that between 2001-2011 the number of ships registered above 100GT increased by 17,000.

2. Incidents in the Black Sea

To accomplish this study, all the serious incidents which ended as shipwrecks in the Black Sea geographic area have been identified. The area chosen for the study is bounded by the Marmara and Azov seas, with which it communicates through the Bosphorus and Kerch straits. For the period 2001-2017, there were 20 incidents that resulted in ship diving or shipwrecks, with only one ship having problems with the main engine and propulsion. A total of 21 records were collected in Table 1 (see Marine Traffic; BBC News, 2017; List_of_shipwrecks; The Telegraph News, 2017; Maritime Bulletine, 2017). All of these incidents were checked from various sources to confirm the facts for each ship.

Table 1
Incidents Occurred in the Black Sea, Between 2001-2017 resulting Foundered and Sank Vessels

No.	Vessel	Incident	Incident year	Incident month	Year Built	Flag	LxB	Type
1	Geroi Arsenala	Sank	2017	April	1980	Panama	114x13	Cargo
2	Liman	Sank	2017	April	1970	Russia	73x10	Navy
3	Anda	Sank	2017	July	1981	Togo	95x13	Cargo
4	Leonardo	Sank	2017	August	1975	Mongolia	114x13	Cargo
5	Bilal Bal	Foundered	2017	November	1974	Turkey	78x13	Cargo
6	Asptr-1	Sank	2016	October	1962	Russia	38x13	Floating Crane

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No.	Vessel	Incident	Incident year	Incident month	Year Built	Flag	LxB	Type
7	Fom	Engine fail	2016	October	1981	Panama	73x11	Cargo
8	Gulf Rio	Foundered	2015	January	1984	Kitts Nevis	89x12	Cargo
9	Fort Azov	Foundered	2015	February	1970	Kitts Nevis	114x13	Cargo
10	Akel	Sank	2015	July	1967	Liberia	58x9	Cargo
11	Elga-1	Sank	2014	December	1991	Russia	139x16	Cargo
12	Nikolay Bauman	Foundered	2013	March	1973	Moldova	113x13	Cargo
13	Vera	Sank	2012	January	1977	Cambodia	113x13	Cargo
14	Karam 1	Foundered	2010	November	1977	Sierra Leone	93x13	Cargo
15	Volgoneft-139	Sank	2007	November	1978	Russia	132x16	Cargo
16	Volnogorsk	Sank	2007	November	1970	Russia	123x14	Cargo
17	Nakhitchevan	Sank	2007	November	1966	Russia	103x12	Cargo
18	Kovel	Sank	2007	November	1958	Russia	104x14	Cargo
19	Hash Izmail	Sank	2007	November	-	Georgia	-	Cargo
20	Hera	Sank	2004	February	1984	Marshall Is	174x27	Bulk Carrier
21	Heng Shan	Foundered	2001	November	1980	Mongolia	175x26	Bulk Carrier

Source: original

Each ship involved in these incidents was identified, and more data were collected about it. In Table 1 are presented the ship's characteristics: ship's name, main dimensions, type of ship, year of construction and flag under which it operated as well as date at which the event took place.

3. Positioning Events on the Map

Geographic positions have been identified according to the reports of each event. Thus, the approximate locations where the events occurred are represented graphically on the map of the Black Sea (see Fig. 1.). The numbering in the first column of Table 1 was used to identify each event.

It is quite noticeable that most of these events took place near to the coast, and also that events took place in the proximity of areas with the highest density of Black Sea maritime traffic (Rata *et al.,* 2017). Only 3 of the 21 cases were the result of a collision with another ship, which in turn represents only 14%. Black Sea traffic density can be a cause of accidents because of the fairly high incidence rate of the total unfortunate incidents involving ships.

Analyzing the density of accidents and geographic areas where foundering and sinking accidents occurred in the Black Sea, we can identify two critical points in which ships appear to be prone to such events occurring with material damage and in the worst cases even with the loss of human lives. These are the proximity of the Bosphorus Straits and the Kerch Strait. Also, one cannot ignore the fact that the two critical points in terms of shipwreck and sinking events are similar with hot spots, as the density of the shipping in the Black Sea area (marinetraffic.com 2017).

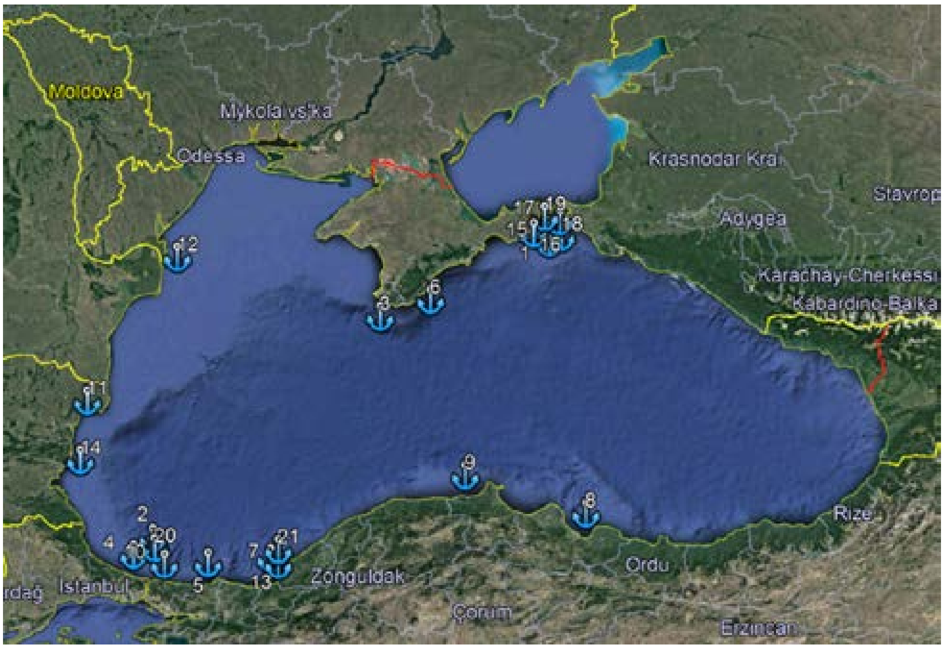

Fig. 1.
Black Sea Naval Incidents Representation From Period 2001-2017
Source: Original

4. Features of the Black Sea active fleet

It is found that ships carrying various activities in the Black Sea, especially shipping activities, are characterized as old ships. Concerned thing is that a considerable part of the ships that perform their service in this geographical area were built in the '80s,' 90s, but not only a few are built in the '70s, and even some of them were launched to the water by '60s (Rata, 2017).
The problem of these ships is a rather complex one, given the building criteria that are no longer up to date in many cases, the poor equipment of these ships due to the reduced operating budget, and last but not least the skill level of the ship's crew who often in these cases it is doubtful (Butt et al. 2013). All these things only come as a complement to the primordial factors, namely the technical and mechanical nature, the structural resistance of these ships being seriously affected during the 50 years of exploitation. Elements of maximum importance, reaching a degree of fatigue may endanger the safety of the ship at any time and to the most sensitive external factors: wave, wind, sea currents, but generally at wave that periodically apply mechanical stresses to the ship and she is acting like a metal beam under its own weight at the variable points indicated by the wave's peak (Domnisoru *et al.,* 2014).

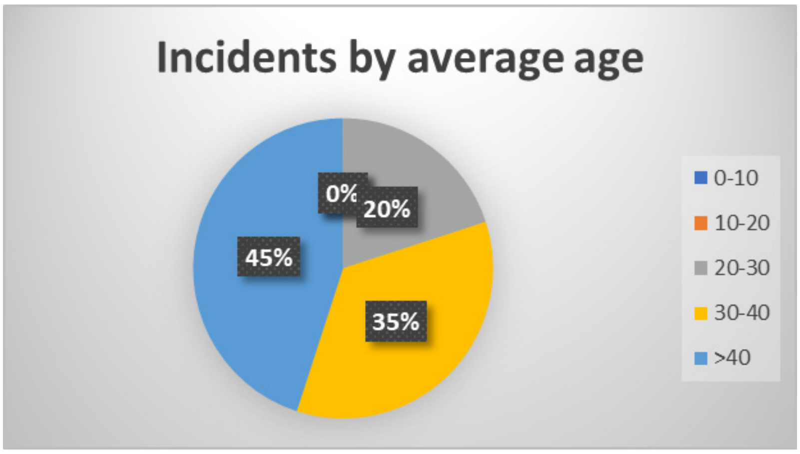

Fig. 2.
Percentage by Ships Age Intervals Involved in Naval Accidents 2001-2017, Black Sea
Source: Original

The risk according to the period when ships involved in serious shipwrecks was assessed and the results are presented in Fig. 2. It can be observed, at least in the case of the Black Sea, that the ships built no more than 20 years ago were not involved in the type of events studied in this study. Instead, the most impressive percentage, namely 45%, is represented by the ships built more than 40 years before the incident happened. Second place in this top is the range of 40-30 years

with an incidence of 35%, and the 3rd place of the podium is represented by the interval of 30-20 years with a percentage of 20%.
These results show that this causality is closely related to the time of ship build. Even the percentages thru their size show clearly the influence of the vessel's age on the possibility or risk of involving a ship in a severe naval event.
Figure 3 shows the evolution in time of the average age of vessels involved in naval accidents in the Black Sea perimeter, so we can see the increase of nearly 20 years in a period of 16 years, 2001-2017. This information leads to the idea that newly built ships are better suited to current safety requirements in operation, which is a gratifying thing. It is also underlined that in operation there are also a number of ships that were prone to a high accident risk since 2001, by a simple formula of calculation the difference of 16 years in time and the 20 years of increasing the age of ships involved in the latest accidents, leads to the idea that ships involved in accidents are largely part of the same build generation.

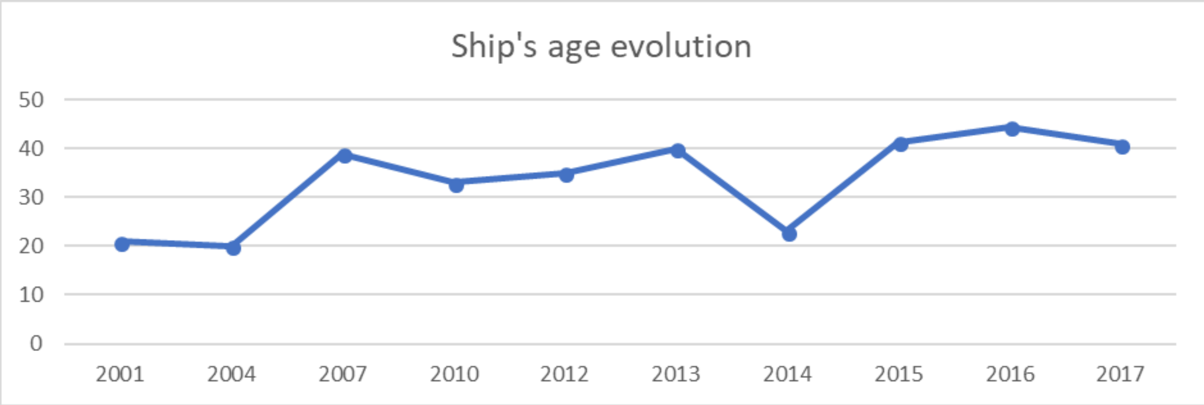

Fig. 3.
Average Age Evolution of Ships Involved in Naval Incidents 2001-2017, Black Sea
Source: Original

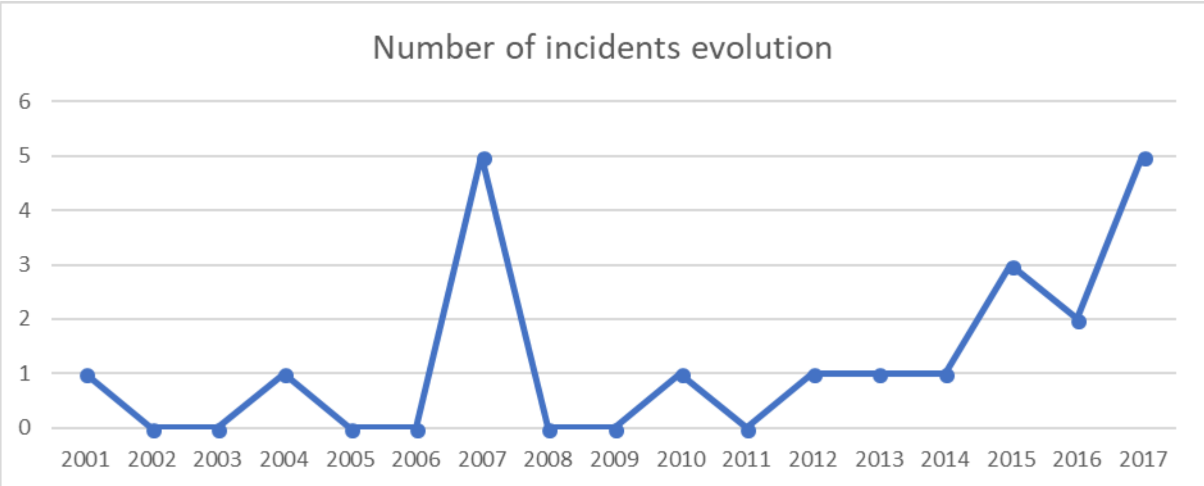

Fig. 4.
Annual Volume of Naval Incidents 2001-2017, Black Sea
Source: Original

Having reference information Fig. 3 and Fig 4., which show the evolution of the age of vessels involved in shipwrecks over time and the incidence of these undesirable events, it can be noticed that a growing number of ships built in the same generation, of the '80s, begin to emerge from use through a form that is not managed at all, and without attempting to limit the catastrophes that have resulted in human casualties, material damage and devastating impact on the environment.
Fig. 5. shows graphically the distribution of ships involved in the naval incidents listed in Table 1 by ship type. This graph shows that the most prone ships to be involved in an accident are the Cargo type. Cargo ships occupy the first place with over 80% of all ships involved in accidents during 2001-2017. Bulk carriers are ranked second with a smaller percentage of 9 percent, followed by technical and military vessels with 5 percent.

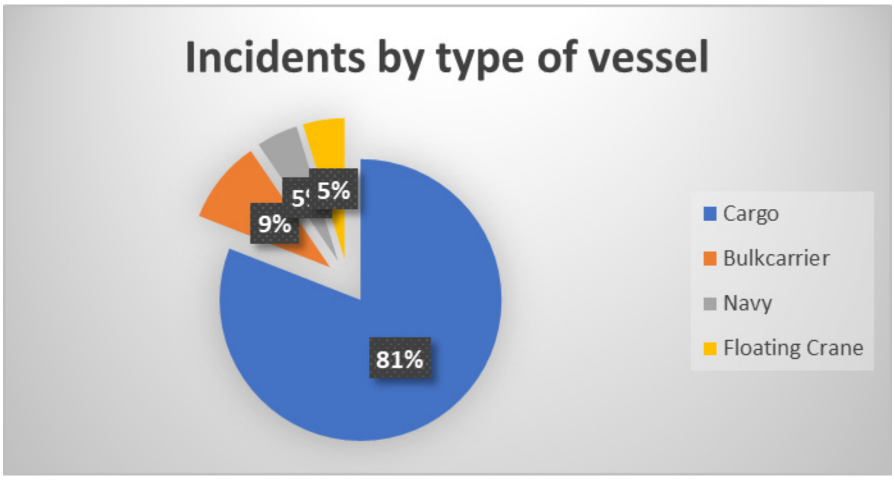

Fig. 5.
Percentage of Naval Incidents by Vessels Type 2001-2017, Black Sea
Source: Original

5. The Natural Factors That Lead to Accidents in the Black Sea

The vessel in the middle of the sea is affected by various external parameters, important forces that radically influence the ship's behavior on the water. The most important parameters developed by nature that have a direct influence on navigation are: wave height, wind speed, wave period, wave length, and the direction in which all these factors act on the ship.
The seasons generally dictate the average of the values of the external factors parameters, so we can observe the distribution of the accidents studied in the four seasons that take place over a calendar year. Thus, in December-February, in the winter season, it appears that occur 24% of the annual accidents, this value being reported over the entire 16-year period, 2001-2017.
In March-May, only 14% of the nautical accidents were recorded, leading to the remark that during the spring period, the density of marine accidents is reduced in the geographical area of the Pontic basin. Taking into account the values in the chart in Fig. 6. and in the summer season, the incidence rate is similar and reduced as in the spring season with a value of 14 percent.
In the case of the fall season, there are reported most of the incidents studied according to Table 1, so it can be seen how the percentage of 48% leads the autumn to first place between the four seasons that are highlighted in the climate of the region of the Sea Black.
At the same time, the results can be coupled with accident density, such as the autumn-winter seasons, resulting in a 72% accident risk, and the period with fewer number of accidents is spring-summer, adding up to a total of 28%.

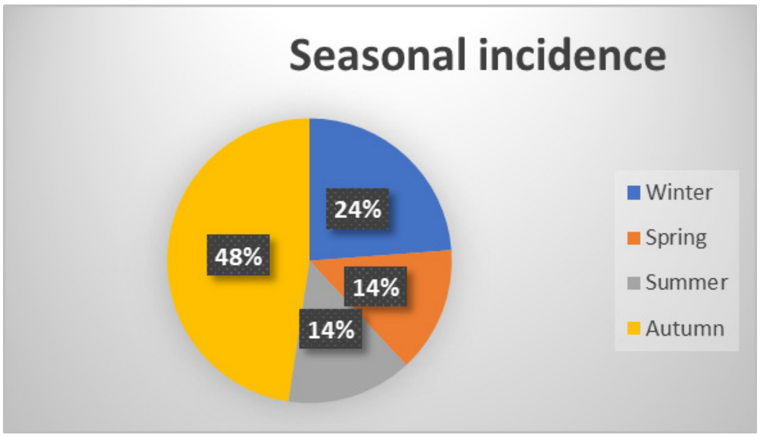

Fig. 6.
Seasonal Incidence in Percentage of Maritime Accidents 2001-2017, Black Sea
Source: Original

These things lead to the hypothesis that the sea is generally more violent by wave and wind parameters that act on sailing in the Black Sea region. In order to highlight the action of the parameters that influence the ship's behavior on water, in a rough sea, the wave conditions of the entire Black Sea basin were numerically simulated using wind re-analysis data provided by the United States National Centers for Environmental Prediction, Climate Forecast System Reanalysis (NEAP-CFSR) (Saha *et al.,* 2014). The wind fields were used to force the wave simulation model, SWAN (model of Simulating WAve Nearshore, Booij *et al.,* 1999). Thus, for each incident, the wind and wave conditions were

simulated for a period of 48 hours with a temporary increment of 3 hours. The wind speed is 10 meters above sea level and is marked with U10 (m / s). The other parameter of interest for this study is the significant height of the wave marked with Hs (m).
Thanks to the historical data base, the simulations could only be performed in the period 2001-2016, so of the 21 incidents mentioned in Table 1, only 16 events were checked for the condition of the sea, the ones which can be identified both in Table 1 and in Table 2 with numerical values ranging from 6 to 21.

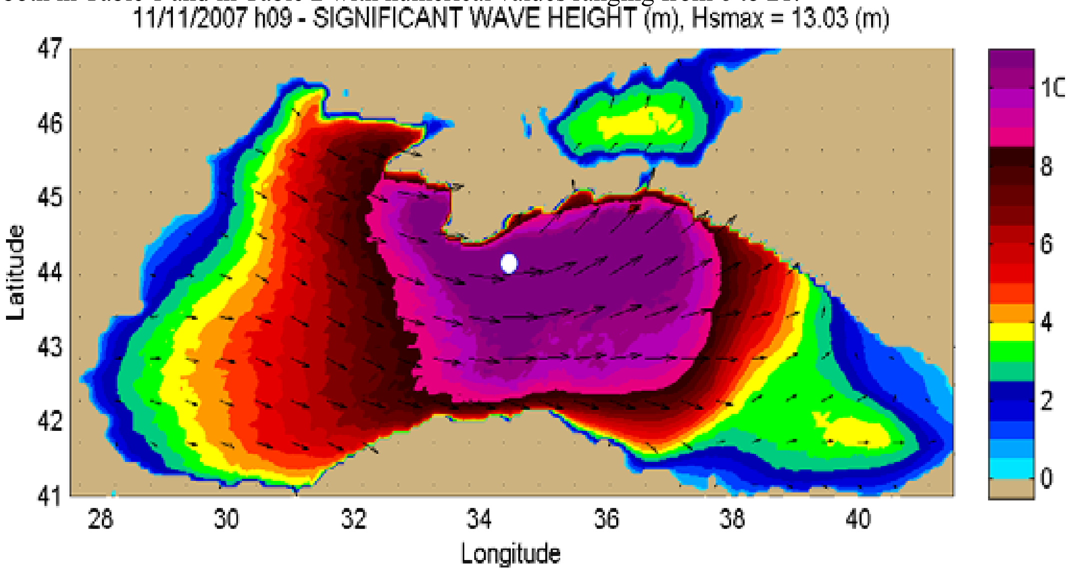

Fig. 7.
Spatial Distribution of the Mean Significant Wave Height Fields and the Mean Wave Direction in the Black Sea Basin (11.11.2017)
Source: Original

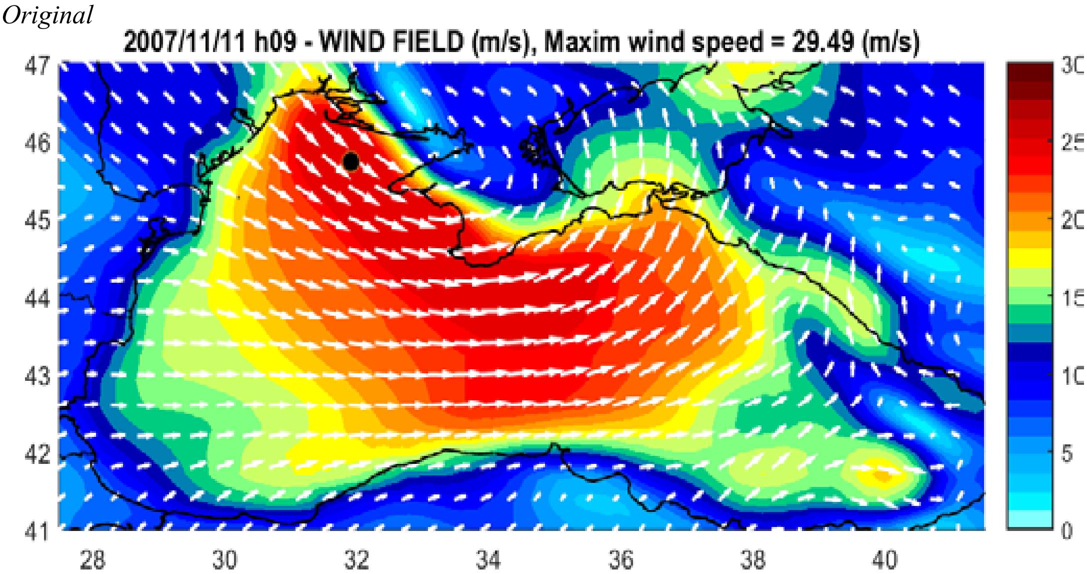

Fig. 8.
Spatial Distribution of the Wind Field and the Wind Direction Over the Black Sea (11.11.2017)
Source: Original

The results from the numerical simulation program were analyzed for each case, resulting in a series of graphical representations depending on the parameter chosen for the indicated time coordinate, as in Fig. 7. and Fig. 8.
They will be taken as an example of the embodiment of Table 2, a table in which the maximum value of the wave height was identified and noted on the second row, and the third the maximum value of the wind speed. The maximum values of these parameters were identified because it was considered the worst case, with the corresponding accidents being identified in Table 2 with values between 15 and 19.

Table 2
Wave and Wind Parameters of Black Sea in the Moment of Happening the Naval Accidents 2001-2016

No.	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Hs[m]	1.5	1.5	1.5	3.5	5.5	5	2.5	5	3	13	13	13	13	13	8.5	6
U10[m/s]	10	9	7.5	15	18	15	12	17	15	29	29	29	29	29	22	20

Source: Original

According to the data in Table 2 it follows that not all incidents were influenced to produce the sea state disaster, because for ships with length (L) higher than 60 meters in height, the 3 meters height of the wave is not a danger for a ship designed to navigate at least in the coastal area. Also, U10 wind speeds below 15 meters per second are not critical values that would normally disrupt sea navigation activity. Such levels of the two parameters could adversely affect the activity of a vessel for inland navigation, since design criteria were not designed to respond effectively to such conditions.
According to Fig. 9., result that only a part of the incidents, for which there existed data and where the numerical simulation of the sea conditions was done, were radically influenced by the state of the sea. Moreover, 62% is not a percentage to be ignored, being quite important. Only for 25% of the cases studied can be considered that the environment was not a decisive factor for the accident. Only 13% falls within the uncertainty range due to the boundary values of the wave and wind parameters studied.

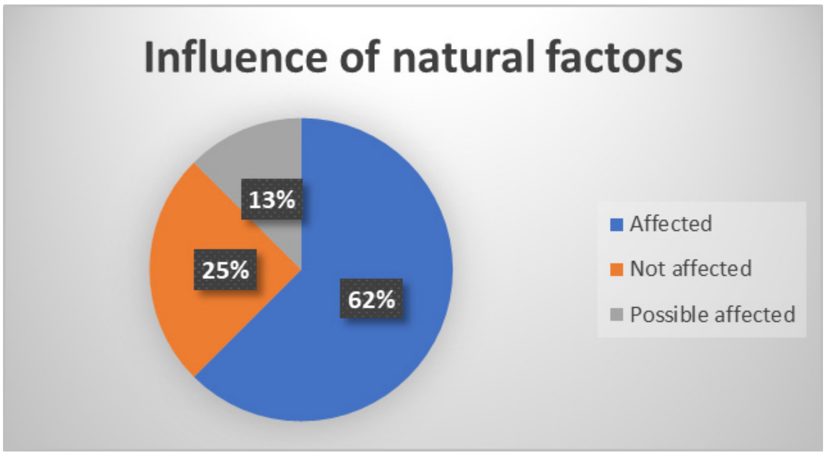

Fig. 9.
Influence of Natural Factors on Maritime Accidents 2001-2017, Black Sea
Source: Original

6. Conclusions

Due to the incidents that occurred during the period 2001-2017 in the Black Sea geographic area it was necessary to study the risk of occurrence of foundering and sinking events in order to identify the patterns that lead to the production of these tragic events. Such incidents are described as tragic events, because they often result in loss of human life, the effects of a shipwreck in addition to the economic ones that result from the loss of the ship or the cargo carried, it is also necessary to be mention those that negatively affect the environment. Following a shipwreck or sank, a number of pollutants result, which affect the natural ecosystem of the area through a series of polluting agents, among which can be remembered the ship's hydrocarbon spillage (Rusu, 2010) but also biological pollution with invasive organisms transported through of ballast tanks (Rata *et al.,* 2018).
An upsetting alarm signal may be drawn on the characteristics of the active Black Sea fleet that is already aged, and above all, there are prerequisites for greater aging from the perspective of migrating older ships to the East, creating space for world fleet growth, involve the introduction of new vessels in Western Europe into navigation. This factor, in an alarming way, dimension the risk of present and especially future shipwrecks occurring in the geographical area bounded by the Black Sea shores.
Complementary to natural conditions and characteristics of vessels operating in the Black Sea, human factors dictated by economic conditions imposed on these low-cost shipping services, as shipowners generally choose to use a very old ship, as example this study where the average age of ships involved in severe accidents is 37.3 years. As sum of the participating factors are considered the age of the ship, which brings with it problems of structural resistance due to the fatigue resulting from the use, the construction rules of the ship that are no longer topical, the systems that are not of the best quality and are not, an optimal state of operation, last but not least, the quality of crew skills that for various reasons fail to correctly interpret the data provided by the onboard systems.
There is an increasing trend over the past years in the number of maritime accidents.
A non-negligible factor is the new and continually changing conditions with which ships interact on established maritime routes due to climate change, which take place more often and are more pronounced in the last 30-40 years in the studied geographic area both through the duration and the intensity of the storms (Rusu *et al.,* 2014b, Lin-Ye *et al.,* 2018) that are born and developed in the Black Sea.

Acknowledgements

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THE FAILURE ANALYSIS OF HANDLING PROCESS IN MARITIME CONTAINER TERMINAL

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Abstract: The logistic chains used for supply activities in industrial processes use in most cases maritime containerized shipments. It is important to ensure a shorter transit through sea terminals. The waiting time is influenced by the movements of the means of transport (ships, trucks, trains, etc.), but also by the handling and storage capacity of the terminal. In the case of the last ones, the reliability of the handling equipment is extremely important in assessing the negative effects induced by the poor reliability of the handling equipment. Quantification of these can be done by using a simulation model. For the modeling of the containers flow in the terminal is suitable a discrete process model that allows the topological attributes of the terminal, the terminal's processes and to the capacity storage limitations to be modeled. A discrete simulation model adapted to a container terminal has been developed, based on which one can estimate the additional delays that occur in the case of a failure in the container handling process in the terminal area. Different scenarios for the moments of occurrence of malfunctions of equipments inside the terminal leading to a failure in the handling process are considered. The results are suitable for terminal administration in sustaining the acquisition of new equipment to support operations in the terminal.

Keywords: maritime container terminal, discrete simulation model, reliability.

1. Introduction

The most of the logistic chains with maritime components use containerized transport. In this case, the container terminals located inside the sea ports area ensure the transfer between the terrestrial network and the maritime transportation. The main operations performed inside of these are handling and storage processes. The proper functioning of handling equipment can influence the processes inside the terminal with effects on the entire logistic chain. Such an example can be represented by the failure of a quay crane which may lead to delays in the loading/unloading process of vessels, usually quantified in penalties paid by the terminal administration. Thus, it is important for the terminal administration to carry out an analysis of the probability of failure and of the impact induced by the unavailability of the handling equipment. According to (Steenken, 2005) the decision-making process in container terminals is carried out on three decision levels:

- Terminal design stage (terminal structure, connection with transport networks, selection and dimensioning of handling equipment, etc.);
- Operative planning stage (berth allocation, stowage planning, crane assignment, stowage area design, storage policies);
- Operative stage (internal transport in the terminal, allocation of containers in the storage area, scheduling of handling equipment).

In the case of the analysis of the reliability for a maritime container terminal, it is required to select the operative planning stage, because the consequences of under sizing the number of handling equipment in relation with the container flow size are always identified on the second decision level. The problem is caused by the lack of correct information about the situations that may occur in exploitation. Thus, the variation of the number of containers transiting through the terminal leads over time to non-uniform request of the handling equipment.
Also, the arrival of maritime ships is extremely difficult to predict, those being conditioned by a series of limitations that are not related with the activity of the administration of the container terminal.
To cope with such uncertainties, it is desirable to use a discrete event simulation software in which to build up the logical model of handling and storage activities inside the terminal (Rusca& all, 2016a). This is developed taking into consideration the topological attributes, the hierarchy of the processes within the terminal, respectively the capacity limitations of the handling equipment and storage area. In addition, for handling equipment, the mean time to failure and recovery required for handling process analysis can be modelled. The inbound and outbound container's flows in the terminal are dependent on the vessels' arrival times in the port, respectively on other transport means arrival' times from terrestrial network.
The inbound and outbound container's flows in the terminal are dependent on the vessels' arrival times in the port, respectively on other transport means from terrestrial network arrival times.

2. The Development of Approach for Failure Analyze

The paper presents the results of the research on the activity of container terminals located within the seaports. The measure of performance for the handling and storage processes are influenced both by the topological structure of the terminal and the non-uniformity of the inbound and outbound container flows from terminal as well as by the good

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functioning characteristics of handling equipments (cranes, transtainers, reach stackers, etc.). The malfunction of these equipments could influence the activity inside the terminal. The use of discrete modeling for maritime terminal activity represents an evaluation method of the critical areas inside the terminal (Angeloudis& Bell, 2011), (Kotachi& all, 2013), (Lin& all, 2014). The container terminal is considered to be a queuing system. Unlike the previous modelling models for bulk or RO-RO terminals, the present research has taken into account the logical hierarchy of the terminal operations, respectively pointed out the role of the storage area for the transit of containers from sea vessels to the terrestrial network (Dinu& all, 2017), (Ianone& all, 2016), (Özkan& all, 2016), (Rusca& all, 2016b).
The second stage of the research is represented by the assessment of the operational risks that may occur in the terminal activity. These are generated by a series of factors related to the sizing process of the storage area or handling equipment in relation with the size or the structure of the container flows (Rusca& all, 2015). Also, the failure of handling equipments causes a series of risks that may affect the operations that take place inside the terminal. A number of random functions were used to obtain possible values for reliability of handling equipment inside the terminal. Setting acceptable limits for risks, assessing actual risk levels and predicting the balance of cost/benefits for proposed safety measures are all meant to assist the risks management process (Monnier & Gheorghe, 1996).
Finally, using the simulation model developed at the first stage one has been analysed the impact of the failure for this kind of equipment on the terminal activity (fig. 1).

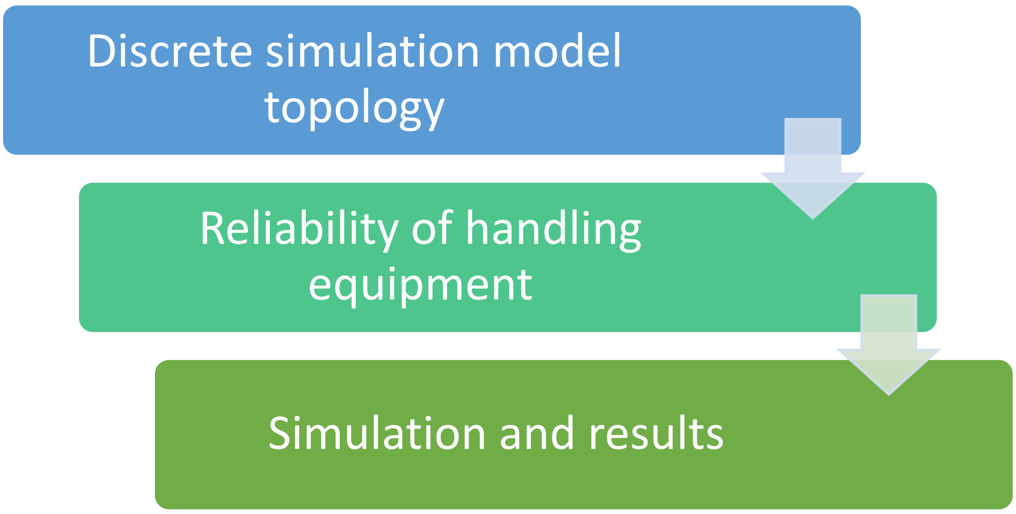

Fig. 1.
Approach used for failure analyse

3. The Simulation Model with Component for Malfunction Event and Repair Process

The discrete simulation model is made taking in consideration the topology of a Romanian Container Terminal (SOCEP SA). The simulation support is ARENA 12 simulation software. The model structure is organized in five sub-models:

- the arrival process of maritime vessels (Figure2),
- the arrival process of land vehicles (trucks) (Figure 3),
- the unload process of containers from vessel to the storage area (Figure 4),
- the load process of containers from storage area to vessels (Figure 5),
- the malfunction (failure) event and repair process (Figure 6).

In the first of them is simulated the arrival of vessels to quay. This is in accordance with a repartition function (Exponential, Poisson, Erlang, etc.) or may be according to a certain schedule of arrivals in the port, when the data could be provided. For every ship are generated two variables: first is the number of containers which will be unloaded, respectively the number of containers to be loaded on maritime ships. One ship occupies the quay and releases it when it receives a signal which confirms that the process of unload-load containers is finished.

- The arrival process of maritime vessels (Figure2).

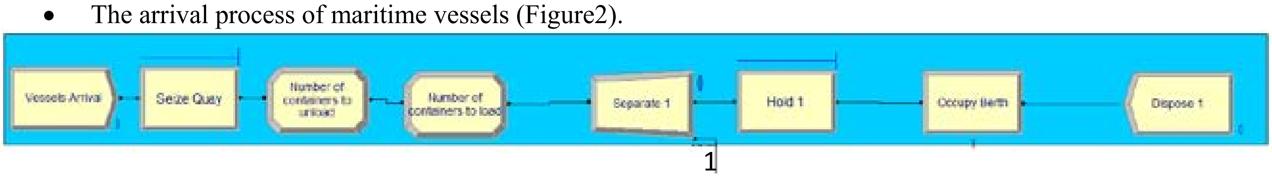

Fig. 2.
The sub-model for simulating vessels activities inside the terminal

In the second sub-model are simulated the activities of land vehicles. These can be trucks or trains. For the analyzed terminal, the rail network ensures a connection with the maritime container terminal, but the volume of inbound-outbound containers it is low, so the rail transportation is not considered hereby. But if it is necessary the model can be improved with a new module for this connection. For trucks one considers three possible situations: (i) unload a container; (ii) load a container or (iii) both of them.

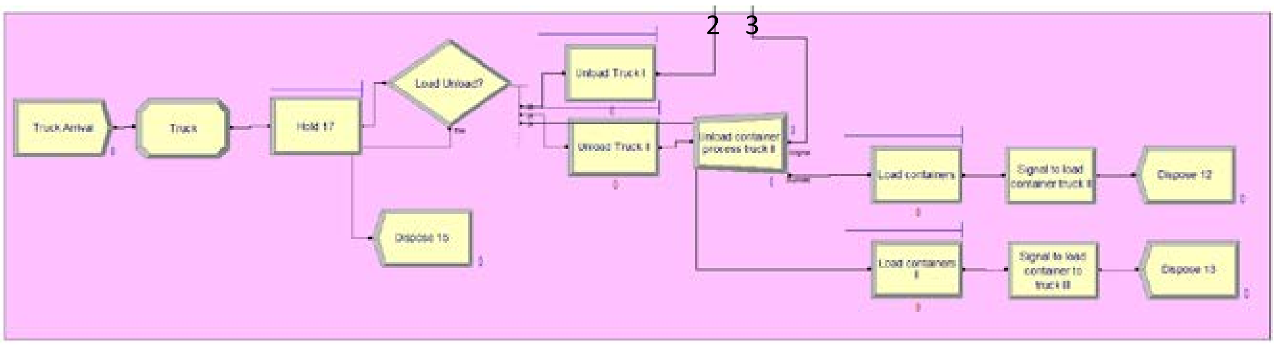

Fig. 3.
The sub-model for simulating trucks activities inside the terminal

In the third sub-model is simulated the unload process of containers from maritime vessel. This is made using one of the two existing quay cranes. For every container two proofs are made: if there are free slots in the storage area and if all the containers from the ship are unloaded. When the second the second condition is "TRUE", the unloading process is finished and the loading process can start. The containers unloaded from maritime vessels are separated in two parts: one contains the containers with destination in the hinterland and the other one contains containers which must be loaded on other maritime vessels. In some cases, the command of the ship can require the reorganization of the containers on the ship, but this is a particular case and it is not taken in consideration because data about the rhythmicity of these activities are not provided.

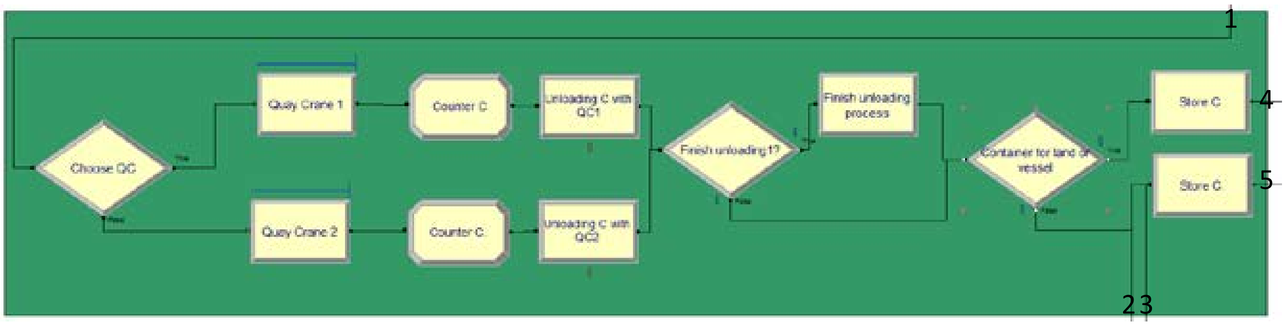

Fig. 4.
The sub-model for simulation of unload process of containers from maritime vessels

In the fourth sub-model is simulated the load process of containers from the storage area to maritime vessels. The same two quay cranes are used. If the number of containers loaded in the ship converges to the variable generated in the sub-model I, the process is finished and a signal it is sent to the vessel to release the quay for the next vessel. The number of containers in the storage area is increasing when we have the unload process from vessels or from trucks and is decreasing when we have the load process of vessels or trucks. In the storage area there are two separated zones, one is for containers from vessels with destination in hinterland and one is for containers unloaded from trucks which must be loaded to vessels. Also, in this last zone are found some containers unloaded from maritime vessels, but which must be loaded on other maritime vessels.

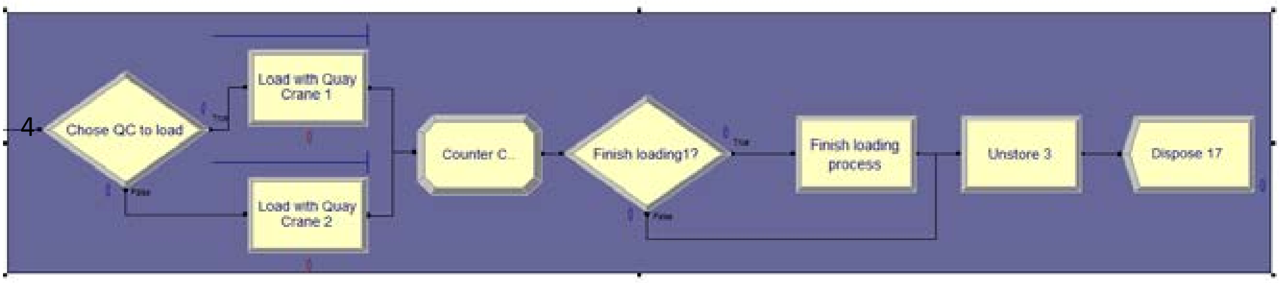

Fig. 5.
The sub-model for simulation of load process of containers to maritime vessels

The handling equipment failure is simulated in a separated model. Using a Weibul reliability function it is assigned a value for a malfunction test variable which is used in the main model to test if the quay crane is available. In case the test of malfunction return “FALSE” as value for availability of handling equipment, value 0 is assigned for malfunction test variable. After the period required for the repair process, the malfunction test variable will be associated again with the normal value 1.

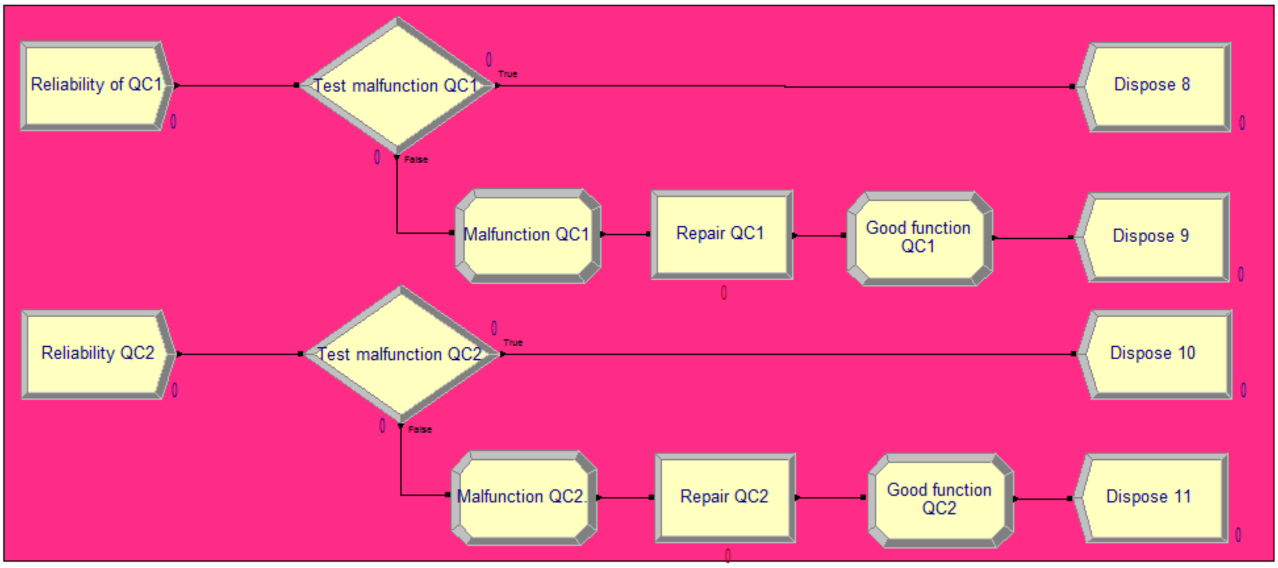

Fig. 6.
The malfunction event and repair process

4. The Failure Analyze of Handling Equipment Using Simulation Model

For the case of a Romanian maritime container terminal (SOCEP terminal from Constanta Port) the simulation model is used to evaluate the influence of malfunction of handling equipment over measure of performance for the activities carried out inside the terminal. The analyzed handling equipment is the quay crane used for unloading/loading the containers from/to maritime vessels. For the handling equipment different cases are defined, in correspondence with previous studies (Azimi& Ghanbari, 2011):

- idle time: the equipment has no demand (occurs frequently in the transitory regime at the beginning of the simulation),
- busy time: the equipment is used for containers unload or load activities,
- waiting time: the equipment is waiting for a free slot in storage area,
- down time: the equipment is out of service.

For the last case, in our simulation the mean time to failure of handling equipment follow a Weibull distribution $W(\beta,\alpha)$ where α is a shape parameter and takes the value 1, and also indicates a constant value in time for failure rate, respectively β represent a scale parameter and is used in two hypothesis (β=3 or 5 days).
The main run characteristics:

- the number of independent replications: 10,
- the warm period: 20 days,
- the simulated period: 6 months,
- the vessels arrival rate: exponential distribution ($E(\lambda)$) with λ=20, 25, 30 or 35 hours
- the capacity of storage area: 10000 TEU,
- the number of quay cranes: 2 cranes with serving time according to a triangular distribution with 3 minutes for lower limit, 4 minutes for mode and finally 5 minutes for upper time,
- the number of handling equipment inside the storage area: 10 reach stackers,
- the destination of containers from vessels: 90% to land network and 10% to other maritime vessels,
- the number of containers on vessels: normal distribution with μ=300 containers and σ=30 containers,
- mean time to repair quay crane: normal distribution with μ=6 hours and σ=0.5,
- the trucks arrival rate: constant 3 minutes,
- the trucks activities inside the terminal: 33% unload a container, 33% load a container, 34% first unload and after load a container.

Considering the hypothesis previously presented for input data, 12 scenarios are used for simulation model and the results are presented in Table 1. The simulation results provide a set of parameters useful for terminal administration in the decision making process. From these, in our research, we retain the following variables:

- number of vessels, trucks and containers used in simulation,
- occupancy ratio of quay,
- utilization ration for handling equipment,
- waiting time in queue for vessels to enter at berth,
- number of vessels in queue,
- the duration of unloading/loading process.

Table 1

The average value for exit data from simulation model

	Vessels arrival rate	**Failure distribution for Quay Cranes**	**Average number of vessels**	**Average number of trucks**	**Occupancy ratio of quay**	**Utilisation ratio of Quay Crane 1**	**Utilisation ratio of Quay Crane 2**
1	E(20)	No failure	198	106635	0.918	0.944	0.944
2	E(20)	W(5,1)	183	105140	0.898	0.887	0.892
3	E(20)	W(3,1)	186	105441	0.922	0.944	0.918
4	E(25)	No failure	173	108107	0.791	0.935	0.937
5	E(25)	W(5,1)	153	100568	0.926	0.944	0.922
6	E(25)	W(3,1)	144	102162	0.917	0.944	0.931
7	E(30)	No failure	139	108114	0.612	0.865	0.866
8	E(30)	W(5,1)	130	107407	0.727	0.936	0.925
9	E(30)	W(3,1)	140	101795	0.901	0.925	0.922
10	E(35)	No failure	114	108258	0.487	0.799	0.802
11	E(35)	W(5,1)	106	107395	0.582	0.935	0.847
12	E(35)	W(3,1)	130	106100	0.750	0.930	0.901

Table 1 (continuation)

The average value for exit data from simulation model

	Vessels arrival rate	**Failure distribution for Quay Cranes**	**Utilisation of reach stackers**	**Vessels waiting time to enter to berth [hours/vessel]**	**Unloading/loading process [hours/vessel]**	**Number of vessel in queue**
1	E(20)	No failure	5.84	64.9	18.78	3.08
2	E(20)	W(5,1)	5.41	126.5	19.43	6.54
3	E(20)	W(3,1)	5.40	236.3	26.73	11.68
4	E(25)	No failure	6.25	47.1	18.49	2.07
5	E(25)	W(5,1)	4.14	176.3	24.76	7.29
6	E(25)	W(3,1)	4.73	215.4	26.21	9.47
7	E(30)	No failure	6.25	20.1	17.88	0.66
8	E(30)	W(5,1)	6.19	39.8	23.08	1.20
9	E(30)	W(3,1)	4.41	81.5	27.21	4.66
10	E(35)	No failure	6.26	18.5	17.64	0.48
11	E(35)	W(5,1)	6.21	22.2	22.03	0.56
12	E(35)	W(3,1)	5.78	62.8	24.58	1.88

In the 12 scenarios for which the simulation was made, it was considered the impact assessment of the handling equipment failure over the measures of performance regarding the activities developed inside maritime container terminals. Thus, four hypotheses on the arrival of maritime vessels in the port area were analysed. These ones correspond to some exponential distribution functions with mean (20 hours, 25 hours, 30 hours and 35 hours. For each of these hypothesis, has been simulated the situation in which the quay cranes are operated without taking into account their probability of failure. In order to assess the influence of the failure of handling equipment was considered a failure rate following a Weibull distribution and a duration of the repair process according to a normal distribution.
The system is tested for the biggest values of vessels arrival rate. These are specifically chosen respecting our goals to evaluate the influence of malfunction of handling equipment when the maritime container terminal is facing with an intense activity. The results show an increase for number of vessels waiting in queue when the arrival rate λ decrease from λ=35 hours to 20 hours. This varies from a average value 0.48 (no failure of handling equipment and vessels arrival rate is Exponential with λ=35 hours) to 11.68 for average number of vessels in queue when for mean time to failure is taken W(3,1) distribution and vessels arrival rate is Exponential with λ=20 hours (Figure 7). The highest increase in the number of vessels in the queue is recorded when vessels arrival rate is Exponential with λ=30 hours and mean time to failure follow W(3,1) distribution, with an increase by six time of number of vessels in queue (Figure 8).

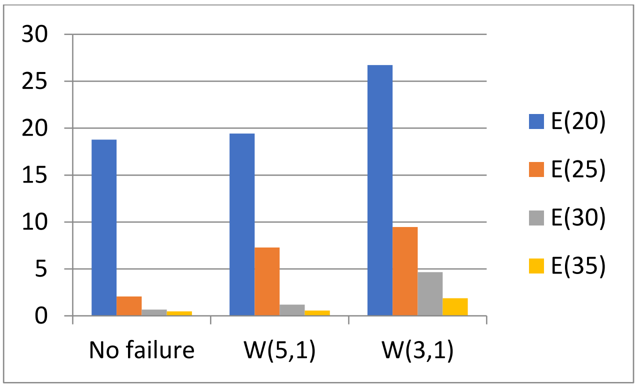

Fig. 7.
The number of vessels in queue

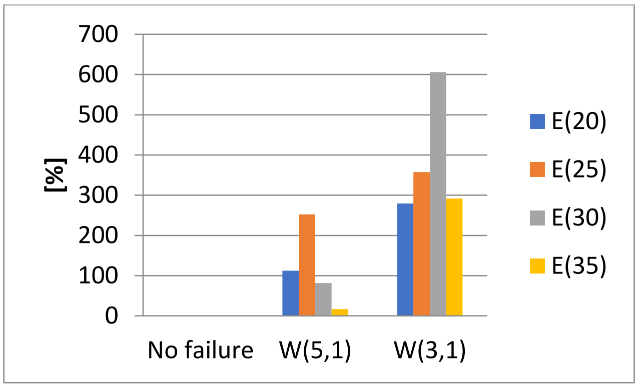

Fig. 8.
The variation of vessels number in queue

In case of average waiting time for vessels which enter at berth serving maritime containers terminal, the variation of values is between 230%-360% for all four input hypotheses when mean time to failure follow a W(3,1) distribution. A particular situation is recorded for malfunction according to a W(5,1) distribution when for a vessels arrival rate according to Exponential distribution function with λ=25 hours, waiting time have an increase with 273%, more larger in comparison with other results, which are approximatively 90-100% (Figure 9). The duration of process for unloading/loading containers on vessel is also influenced by malfunction of handling equipment, so as in case when the simulation does not include a down time for equipment, the vessels waiting time is 17-18 hours/vessel, in case of a mean time to failure according to W(3,1) distribution, they raise approximatively with 40-50% (Figure 10).

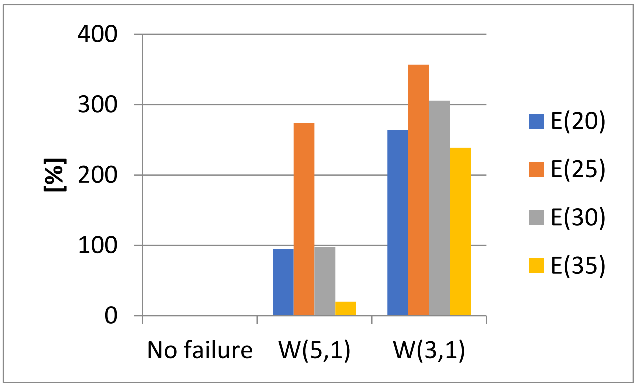

Fig. 9.
The variation of waiting time of vessels in queue

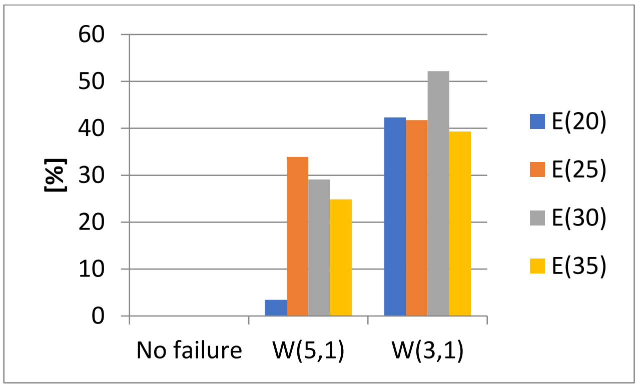

Fig. 10.
The variation of duration of vessels unloading/ loading process

3. Conclusion

The simulation model is developed using the topology, the number of equipment and the storage capacity from a real maritime container terminal. The simulation hypotheses are chosen to identify the critical thresholds when the quality parameters of the activities developed inside the terminal are influenced by the malfunction of handling equipment. The hazard event for handling equipment is estimated according to a Weibull distribution and for repair period of time is used a Normal distribution. If the duration of vessels unloading/loading process does not have a large variation (only 40-50%), the waiting time of vessels in queue for free berth have a large variation to approximately 200-300%. This variation is also influenced by the increase of the arrival rate corresponding to a time interval of 35 hours to only 20 hours between vessels according to Exponential distribution.
These results are useful for terminal administration to evaluate the importance of handling equipment replacement process when the reliability function reaches a low value with influence over the quality parameters of the activities developed inside the terminal. The simulation model can be adapted to all kind of container terminals and used together with predicted vessel traffic in the decision making process at design or operative planning stage.

Acknowledgements

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ENVIRONMENTAL REGULATIONS ON AIR POLLUTION AS A DRIVER OF INNOVATIONS IN SHIPPING

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Abstract: The dynamic increase in maritime trade during the last few decades caused a significant growth in air emissions from global shipping. In order to address this negative impact on the environment, a range of regulations governing the shipping industry's environmental performance have been developed in recent years at the international and regional levels. Relying on a desk study research, this paper aims to present the relationship between these new, strict emission requirements and the emerging innovativeness in shipping industry. Indeed, the shipping industry responded with new, innovative technologies (e.g. exhaust gas cleaning systems, alternative energy sources, including LNG propulsion systems), which are briefly elaborated. It is believed that in a long term these innovations are essential for achieving more rigorous environmental goals in the future, minimising the cost of compliance and thereby delivering competitive benefits. The background to these considerations consists of: a) a general introduction to the problem of air pollution from maritime transport and their influence on human health and life as well as the environment; b) a short review of literature concerning the impact of environmental policy instruments on companies' innovation-driven activities and competitiveness; c) a characterisation of the environmental regulations on air pollution from ships, mainly sulphur oxides, nitrogen oxides and carbon dioxide.

Keywords: green innovation in shipping, green shipping, environmental regulations in shipping, shipping and the environment.

1. General Introduction

1.1. The International Shipping at a Glance

The maritime transport is the backbone of international trade and globalisation. At the beginning of 2017 the world merchant fleet consisted of about 93.000 ships of a total capacity of 1.86 billion DWT. (UNCTAD, 2017) All these ships served world seaborne trade, which volumes surpassed, for the first time in history, 10 billion tonnes in 2015. Since 1980 the international seaborne trade has almost trebled (from 3.704 millions of tons to more than 10.287 millions of tons in 2016). Although the pace of recent developments in maritime trade is not as dynamic as in the previous years (as it reflects the slowdown in world economy and weaker GDP growth), seaborne trade accounted for over 80% of total merchandise trade in terms of volume. In value terms the share was estimated at about 70 % (UNCTAD, 2017).

1.2. The Impact of Air Emissions From Shipping on Humans and the Environment

Shipping is the most environmentally friendly mode of transport when we refer to the emissions per one tonne-kilometre. Nevertheless, it exerts a huge impact on the environment and is the source of negative externalities.
Shipping generates pollutions of different kinds. These include a range of air pollutants such as Sulphur oxides (SOx), Nitrogen oxides (NOx), particulate matters (PM), volatile organic compounds (VOC), greenhouse gases (GHG), and black carbon (BC), as well as sewage, ballast water, underwater noise, just to mention those which have attracted a special attention in recent years.
The primary source of air pollution is the process of fossil fuel combustion. According to various estimations ships generate approximately 5–12% of all SO_2 and 10–15% of the global anthropogenic NOx emissions from fuels (Eyring et al., 2005; Merk 2014). The reason for this quite considerable share is that shipping still uses the fuel of a quality that is no longer available and allowed in other transport modes. The share of shipping sector in global CO_2 emissions from the combustion of fossil fuels is not so spectacular, estimated at 3.1 %; however, it is projected to increase by 50% to 250% until 2050 if no additional policy instruments are implemented (IMO, 2013).
There is a lot of evidence of considerable negative impact of air emission on human health and life as well as on the environment. Sulphur dioxide and nitrogen oxides emitted into the atmosphere may react with water, oxygen and other chemical molecules and form, among others, acids and particulate matters, as well as contribute to the formation of ground level ozone. These pollutions have a strong influence on human life and health and may cause different serious health problems, including asthma, lung cancer, cardiovascular and pulmonary diseases or heart attacks, just to name a few. Corbett et al. (2007) have estimated that because the vast majority (70%) of these emissions occur within 400 km of coastal communities, around 60,000 premature deaths each year are attributed to shipping emissions, mainly in the seaside areas of East Asia, South Asia and Europe. They are also very harmful to the natural environment, contribute to seas eutrophication, affect sensitive vegetation and ecosystems, as well as have a climate-forcing impact.
All these external negative effects translate into costs (e.g. costs of illness, hospitals' admissions, premature death, degradation of environment, loss of productivity etc.), which lead to market failure. The proper response to such a phenomenon is internalization of external costs, thus various environmental policy instruments have been developed to address this complex issue.

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2. Instruments of Environmental Policy and Their Impact on Innovations

Market forces alone would not encourage companies to improve their eco-performance and would not lead to the development of green technologies, thus public intervention in the form of environmental policy instruments is crucial. Governments have a wide array of policy instruments at their disposal to combat pollution and incentivise innovations (Barde 1995; OECD, 2010; Mgiler and Vincent, 2013):

- Regulatory instruments ("command and control"), the most prevalent of which are technology- and performance-based standards; they allow relatively little flexibility with regard to the measures enabling achieving goals. (Barde, 1995; Mgiler and Vincent, 2013)
- Market-based (economic) instruments, that encourage behaviour through market signals rather than through explicit directives regarding pollution control levels or methods (Mgiler and Vincent, 2013); these include taxes, charges and tradable permits; in comparison with regulatory instruments they are considered to better address the problem of pollution by encouraging lower cost abatement across polluters (OECD, 2010).
- Subsidies, which can, under certain conditions, stimulate innovations, when we define them as "financial aid for research, development and investments in clean technology" (Georg *et al.,* 1992).
- Voluntary agreements and informative instruments (e.g. awareness raising, knowledge transfer, best practices).

Regulatory instruments are treated by the neoclassical economics as a burden for companies, but necessary for the society. However, they can also be perceived as means for improvement of companies' performance by accelerating the innovation-driven activities. This relationship between environmental regulation and economic performance is commonly known as the Porter hypothesis. The Porter hypothesis (Porter and van der Linde, 1995) stands that environmental regulations (market-based instruments in particular) can "trigger innovation that may partially or more than fully offset the costs of complying with them". Environmental regulations are therefore promoted as a "win-win" strategy, leading to better environmental quality and better economic performance and competitiveness of companies.

There are many studies attempting at investigating this hypothesis (e.g. Ambec *et al.,* 2013; Rubaschkina *et al.,* 2015); however, they bring ambiguous results. Dechezlepretre and Sato (2014) states that there is plenty evidence that environmental regulations foster innovation in clean technologies and discourage R&D in polluting technologies. Generally, most of the literature confirms the positive relationship between the number of green patents and environmental regulation, so called weak Porter hypothesis (Rubashkina et al., 2015 refers to many of them). On the other hand, Jaffe and Palmer (1997) in their study did not find a statistically significant link between regulatory compliance expenditures and patenting activity. Nevertheless, they discovered a significant positive correlation between pollution control expenditures and R&D undertaken by the regulated industry, although the scale of this effect was small. These findings were not confirmed by the study of Rubashkina et al. (2015), in which the manufacturing sectors of 17 European countries between 1997 and 2009 were analysed. The authors revealed that environmental regulation leads to an increase in patent applications but has no impact on R&D expenditures. Furthermore, they have a negligible influence on companies' productivity, despite the undertaken abatement measures and environmental control, what means that the win-win situation (also called the strong Porter hypothesis) has not been proven. The positive influence of environmental regulations on companies' innovations was also confirmed in recent studies from China (Zao and Sun, 2016), in which authors investigated Chinese pollution-intensive corporations panel data samples during 2007–2012. However, they also disclosed negative, although insignificant, effect of environmental regulatory measures on competitiveness. Ramanathan et al. (2017), after conducting nine case studies among UK and Chinese companies, argued that those, which choose a proactive approach towards the requirements imposed by environmental regulations and adapt innovatively, are "better able to reap the private benefits of sustainability".

The discrepancies between research outcomes may be attributable to the way in which the regulatory instruments are designed and if they are appropriately tailored to the particular problem that needs to be tackled. Some authors claim that regulations should be "innovation friendly" i.e. they should give the flexibility with regard to measures undertaken and specify only the desire outcome (Majumdar and Marcus, 2001). The same feature of regulatory measures is also emphasized in more recent studies (e.g. Ramanathan *et al.,* 2017). There are also other factors determining the involvement of the company in innovative solutions that should not be overlooked. These include: a firm's resources and capabilities (Ramanathan et al., 2017); managerial attitude and perception (Lopez-Gamero, 2010); business environment and market vulnerability; company size, its competitive position and financial stability; profile of business (sector); model of ownership.

3. Recent Environmental Regulations in Shipping

Increasing concerns over the impact of shipping air pollution on people and the environment have encouraged policy makers to deal with this complex issue. So far no internationally recognized market based instruments have been introduced with regard to shipping air emissions. However, a wide range of regulatory instruments aiming at the reduction of the negative external effects from shipping as well as associated external costs have been developed both on the international and regional levels. The leading role in the development of global regulations aiming at minimizing the negative impact of shipping belongs to the International Maritime Organization. Its flagship MARPOL 73/78 Convention supported by six annexes governing different aspects of shipping pollution, e.g. air emissions, sewage,

garbage or oils and oily water. Apart from the IMO, other organization such as HELCOM), OSPAR or the European Commission have also introduced their own regulations but on a regional scale.
A wide range of regulatory measures that address air emissions from ships, SOx and NOx in particular, have been adopted in recent years. They are governed by the Annex VI of MARPOL (entered into force in 2005) and its revised version with significantly tightened emissions limits adopted in 2008 (entered into force in 2010). Moreover, they introduced emission control areas for SOx (SECA) and NOx (NECA) with more stringent control of the emission of these gases (e.g. the Baltic Sea and the North Sea). These regulations are performance-based standards setting the particular level of emissions that needs to be achieved, which differ among different regions in the world.

3.1. Sulphur Dioxide

There are currently three standards of Sulphur emission on international seas (Tab. 1): 0.1% S m/m, 1.5% S m/m and 3.5% S m/m. However, the whole shipping industry will soon face a remarkable challenge as the global cap of 0.5% limit for Sulphur emission from ships will come into force in 2020.

Table 1
Limits for Sulphur emissions from the international shipping

Outside SECA	Inside SECA	EU special requirements
4.5% m/m/ prior to 1 January 2012	1.5% m/m prior to 1 January 2010	0.1% m/m vessel in berth in all EU ports from 1 January 2010
3.5% m/m on or after 1 January 2012	1.00% m/m on or after 1 January 2010	Inland waterways - max 0.1% S from 1 January 2010
0.5% m/m on or after 1 January 2020	0.1% on or after 1 January 2015	1.5% m/m for passenger ships operating on regular basis outside SECAs

Source: own elaboration

The regulation contains also the elements of technological based standards, as it refers to different technologies that may be used to meet these requirements. However, ship-owners still have a flexibility with regard to the measures intended to achieve the desired outcome. Therefore, instead of switching to low sulphur fuels, which price is considerably higher than that of conventional fuels, the regulation allows shipowners to utilize other compliance methods:

- using alternative fuel types such as LNG, methanol etc.;
- operating on high sulphur fuel oil after installation of exhaust gas cleaning systems (EGCS) on the ship board; this system must be designed according to the guidelines and approved by the IMO and ensure that the sulphur content in the exhaust is 6.0 g SOx/kWh or less;
- utilising any other technological method that is verifiable and enforceable to limit SOx emissions to the appropriate level; these methods should be also approved by the IMO.

3.2. NOx Emissions

NO_x emissions are addressed by the MARPOL Convention and its Annex VI, in Regulation 13, that provides for the control of NO_x emissions from marine diesel engines of over 130 kW output power (excluding ships used solely for emergency purposes). Different levels (tiers) of control apply based on, for example, the ship's construction date. Within each tier the engine's rated speed determines the actual limit. (Tab. 2) NO_x Tier III applies only to specified ships operating in areas designated as Emission Control Areas (e.g. the Baltic Sea and the North Sea). Tier I and Tier II limits apply globally regardless of ECAs for NO_x being established or not.

Table2
MARPOL 73/78, Annex VI NOx Emission Limits

Tier	Total weighted cycle NOx emission limit [g/kWh]			Ship construction date on or after
	n<130	130≤n<2000	n≥2000	
I	17	$45 * n^{(-0.2)}$	9.8	1 January 2000
II	14,4	$44 *n^{(-0.23)}$	7.7	1 January 2011
III	3,4	$9*n^{(-0.2)}$	2.0	1 January 2016 or later

n- engine's rated speed (rpm)
Source: MARPOL 73/78, Annex VI.

3.3. CO_2 Emissions

CO_2 emissions from shipping due to problems with allocating the ownership of these emission, have not been included in the international climate agreements (e.g. Kyoto Protocol, the Paris Agreement). Therefore, the global approach to CO_2 reduction falls to the IMO, which has developed a set of mandatory measures to reduce GHG emissions from shipping. In 2011 the "Regulations on energy efficiency for ships" was adopted as the new chapter to Annex VI of MARPOL. This annex introduced, among others, obligatory technical and operational measures such as the Energy Efficiency Design Index (EEDI), which sets compulsory energy efficiency standards for new ships. They aim at enhancing ships' efficiency and require that all ships constructed from 2025 must be at least 30% more efficient compared to those from the reference line (the average efficiency of ships built between 1999-2009).
In April 2018, the IMO adopted an „Initial IMO Strategy on reduction of GHG emissions from ships", being a milestone in the process of combating GHG emissions. The Strategy outlines a target to reduce GHG emissions by at least 50% by 2050 compared to 2008, with the overall aim of phasing them out (IMO, 2018). Moreover, the IMO has introduced Data Collection System, starting on 1 January 2019, which will oblige ship-owners to monitor and report data concerning fuel consumption and CO_2 emissions. It will be the parallel monitoring regime to that created at the EU level, i.e. EU MRV regulation (Monitoring, Reporting and Verification), which has already commenced at the beginning of 2018. The main purpose of those systems is to gather information needed for further discussion on emission targets and reduction measures, including market-based instruments.

4. Innovations in Shipping as a Response to Environmental Regulations on Air Emissions

It is quite challenging for ship-operators to conform to the strict environmental regulations, while remaining profitable at the same time. However, these environmental regulations affect not only ship-owners, but the whole shipping industry, including shipbuilders, manufactures of ship components (e.g. engines), seaports, ship fuel providers, etc. There have been and still are many worries that they will place an excessive burden on the industry and cause a distortion to the market and competitiveness. On the other hand, they may offer a chance to escape from "a polluting economic trajectory and move to a 'clean' one" (Dechezlepretre and Sato, 2014) and serve as a trigger for innovations, as there are still a lot of inefficiencies in shipping and thereby areas for improvements.
Consequently, companies involved in shipping are now diverting considerable resources to the search for viable solutions. Indeed, we can observe a surge of activity in R&D, resulting in an array of innovative solutions aiming at reducing the air emission from ships that have started to penetrate the market. Some R&D activities are undertaken by the private sector with their own funds, some are collaborative R&D programmes among shipping industry, governments, institutions, and research entities, financed by various sources (e.g. the EU funds under HORIZON 2020 programme). Particularly active in R&D and dissemination of its results are engine manufacturers, for example Rolls-Royce (UK), Wärtsilä (Finland), Mitsubishi Marine Engines (Japan), MAN and MTU (Germany), Caterpillar and Cummins (US), and shipbuilding companies, mainly from Asia (e.g. Hyundai Heavy Industries and Samsung Heavy Industries (Korea), Mitsubishi Heavy Industries and Kawasaki Heavy Industries (Japan), COSCO Shipyard Group (China)). The demand for new green innovative technologies and solutions becomes even more crucial now in the light of the introduction of a new, global cap for SOx emission from shipping in 2020 (i.e. 0.5% S in mass) as well as the ambitious CO_2 emission reduction target. Therefore, it is not surprising that R&D efforts are intensified and innovation is stimulated, in three areas in particular:

- exhaust gas cleaning systems,
- alternative fuels and new energy sources,
- energy efficient merchant vessels.

4.1. Exhaust Gas Cleaning Systems

Exhaust gas cleaning system (EGCS, commonly known as scrubber) is the technology in which ship-owners have invested to comply with SECA limits. It allows removal of sulphur oxides from ship's engine and boiler exhaust gases without switching to the considerably more expensive low-sulphur fuels. (Fig. 1)
Currently there are two main types of sulphur scrubbers: dry and wet, although the use of dry scrubbers is marginal (only one ship equipped with this solution). Moreover, dry scrubber's technology can not be considered innovative as it is already widely used in land-based industries. The most popular and innovative in the shipping industry are wet scrubbers: open loop scrubbers, closed loop scrubbers, and hybrid scrubbers having the flexibility to operate in both open and closed loop (Klopott, 2015). In *open loop scrubbers*, seawater is pumped from the sea through the EGCS, cleaned and then discharged back to the sea and the washwater is not recirculated (Lloyd's Register, 2012), whereas in c*losed loop scrubbers* the fresh or sea water that is chemically treated (usually by caustic soda injection) is used to effect exhaust cleaning. Most of the scrubbing agent is re-circulated with only minimal water intake and effluent discharge (Bureau Veritas, n.d, Wärtsila, 2017).
Despite some limitations (technological, operational, safety-related) of the scrubber technology, it is spreading throughout the industry and an increasing number of ships (mainly ro-ro and ferries) are now equipped with this kind of EGCSs. Their number is systematically increasing. For example, in the North and the Baltic Seas in 2000 there was only a single scrubber-equipped ship in operation, whereas at the beginning of 2017 nearly 100. Worldwide, the number

of vessels fitted with scrubber has reached 240 as of December 2017 (Springer, 2017). Reflecting latest IMO decision to lower the cap to 0.5% sulphur content from 2020, according to some scrubber manufacturers (e.g. DuPont Clean Technologies) up to 25% of global fleet will be fitted with this abatement technology by 2025 (Seatrade, 2016).

Fig. 1.
The scrubber and its installation on a board of ro-ro vessel
Source: author's photo

4.2. Alternative Fuels and Energy Sources for Ships

In the case when ship-owners do not prefer to operate the vessel using the more expensive low sulphur fuel or are reluctant to scrubbers, they may choose the alternative fuel path. Searching for viable alternative energy sources would not only satisfy the growing environmental demands but may also foster more efficient operation of ships. The most promising fuels such as LNG, biofuel, methanol as well as hydrogen, have already been widely researched and tested.

The innovative technology of utilizing LNG as a ship's fuel, pioneered by Norway, attracts special attention of the shipping industry both for economic (the price of LNG is much lower that of traditional fuels) and environmental reasons (considerable reduction of air emissions). This technology is powered by numerous innovative solutions (adopted by both ships and land-based facilities), ranging from the construction of LNG storage tanks and engines to the LNG bunkering facilities. Moreover, some obstacles to the use of LNG related to international legislation have already been overcome, making it all the more attractive and viable alternative, resulting in an increasing number of LNG-fuelled ships. At the beginning of May 2018 there were 121 LNG-fuelled ships in operation (17 % growth over the past 12 month) and the next 132 have been ordered (36% growth) (Corkhill, 2018). The latter includes nine LNG-powered containerships of 22,000 TEU capacity, ordered by one of the biggest container line, CMA CGM Group; the first is expected to be delivered in January 2020 (Hand, 2018).

The use of methanol as as an alternative fuel is also receiving increased attention. So far, there are seven methanol-fuelled ocean-going vessels of about 50,000 DWT, and in 2019 another four vessel of similar capacity will join this group. All of them are (will be) equipped with very innovative MAN B&W ME-LGI 2-stroke dual fuel engines that can run on methanol, fuel oil, marine diesel oil or gas oil (Methanex, n.d.). Another example of the use of methanol in shipping is the world's first methanol powered ferry *Stena Germanica*, launched in 2015 and operated by Stena Line. (Ship2Shore, 2015)

Yet another promising innovative and alternative fuel that could play a role in the future is hydrogen, particularly for use in fuel cells technology. Fuel cells convert chemical energy of hydrogen into electricity and can be used as auxiliary power or as supplementary propulsion power in hybrid ships (DNV, 2014). Fuel cells for maritime use are more commercially available now and some ship-owners (e.g. Royal Caribbean) intend to invest in this technology. (Royal Caribbean Cruises, 2016)

In addition to fuel cell systems, battery systems and wind-assisted propulsion are also considered and tested. Although speaking of wind powered ships in the context of innovations may be surprising, various sail arrangements, fixed wings and Flettner rotors have been already developed and tried on merchant vessels. One the concepts put forward is the B9 ship with a sail-based propulsion that aims to deliver 60% of ship's power, the rest coming from biofuels (B9 Energy Group, 2015).

Another technology that utilizes wind energy is the Flettner rotor (Fig. 2) – vertical cylinders which spin and develop lift due to the Magnus effect as the wind blows across them. Depending on vessel characteristic and voyage conditions, it enables to cut the main engine fuel consumption by 3% - 15% (GLoMEEP, n.d.) Recently (April 2018) Viking Line has put into operation the LNG-fuelled ferry *Viking Grace* with an installed rotor sail, making it the first passenger ship in the world equipped with a rotor for wind-assisted propulsion. The project has received funding from the EU's Horizon 2020 research and innovation programme. (Norsepower, 2018)

Even higher reduction potential has the SkySail technology (Fig. 2), combining expertise of cofounders (SkySails, DSM Dyneema and Gleistein) in kite technology, synthetic fibres and rope construction. (SkySail, n.d.) The ship's regular propulsion is aided by towing kites, which, depending on the prevailing wind condition, can result in reduction of ship's emission by 10-35 %. (DSM, 2011)

As far as battery powered propulsion systems are concerned, this is a technology already available for small ships, but cannot power large, deep-sea vessels and so far cannot be treated as a substitution for fuel. (DNV, 2014)

Fig. 2.
Flettner rotor on a board of ferry "Viking Grace" and SkySail
Source: Norsepower (2018) and SkySail (n.d.)

4.3. Energy Efficient Merchant Ships

A wide array of technological innovations is available to enhance energy efficiency of ships and thereby meet the regulatory requirements with regard to air emission as well as EEDI. These technologies mainly concern ship design, propulsion and machinery. As far as ship design is concerned innovative modifications of hull shape that minimize the hull resistance are of particular importance. For example, the resistance between the water and the hull can be reduced by introducing a layer of air bubbles under the hull (air lubrication/air cushion) (Wärtsilä, 2009 and 2016). Modification to the aft-body of a ship (e.g. ducktail waterline extension) additionally combined with interceptor planes (that are fitted vertically to the transom of a ship) also have a positive effect on the resistance of the ship as they create a kind of lift effect. Moreover, lighter and stronger materials can be used to reduce ship weight and thereby fuel consumption and emissions.
Various innovation with regard to ship's propulsion are also available or tested. The propeller blade design as well as optimization of propeller-hull interaction may improve considerably the performance of a ship. For example, an innovative contra-rotating propeller, replacing the end-plated propeller and rudder bulb, has one of the highest efficiencies. (Wärtsilä, 2009 and 2016; DNV, 2013)
In the area of ship's machinery there are also many innovations, especially in the main and auxiliary engines construction as well as in energy recovery and storage on a ship board. Hybrid auxiliary power system is a good example of innovation of that kind. It consists of a fuel cell, diesel generating set and batteries, which can storage the energy surplus. In order to achieve maximum efficiency, the loading of each component is managed by an intelligent control system. The very promising in terms of energy management on the ship board is the waste heat recovery system, that enables to recover the thermal energy from the exhaust gas and turned it into electric power. It can provide up to 15% of the engine power. (Wärtsilä, 2009 and 2016; DNV, 2013)
Taking into account possible innovative solutions, which can be combined together to enhance ship energy efficiency, several green ship ideas, sometimes futuristic, have been already developed. One of the extraordinary concept of zero-emission ship called Eco-ship 2030 was designed by NYK – one of leading ship operators (Fig. 3) Although it has not been put into practice yet, it employs some distinctive, innovative solutions enabling the reduction of CO_2 emission by 69%, such as weight reducing ship structure, optimized hull form, solar and wind energy harvesting as well as fuel cells to power the ship. (NYK Group, 2017)

Fig. 3.
NYK Super Eco Ship 2030
Source: Elomatic Oy (n.d.)

5. Conclusion

Following the green activities that are undertaken now by the shipping industry, the vast majority of innovations sprout from regulatory instruments of environmental policy. The IMO regulations are an example of well-designed instruments of that kind, which could more than offset the additional regulatory costs. Although they are not as flexible as market-based measures, they allow ship-owners to choose a technology pathway which suits their needs and capabilities. There are many prerogatives and real evidence from the shipping industry that they consequently may contribute to increasing efficiency and competitiveness in the long-term, leading in the future to emission neutral shipping.

Nevertheless, it should not be neglected that companies involved in the shipping sector have different capacities to deal with the challenges posed by eco regulation. There is a need for adequate financial and technical resources and support to meet the new requirements; sometimes a wide-scale collaboration is crucial, sometimes the state aid as well.

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IBERIAN MOTORWAYS OF THE SEA. AN OVERVIEW AFTER 15 YEARS OF VAN MIERT REPORT

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Abstract: After 15 years of the Van Miert report proposing to include the Motorways of the Sea in the TEN-T schema, an overview wants to be done in the Iberian Peninsula scenario. In 2015 the Intra European trade (Eurostat, 2017) supposed around 11,263.4 millions of tons, being through Short Sea Shipping (SSS) up to 1.808,5 millions of tons and only the 13.6 % on Ro/Ro trades (246.04 millions of tons or the 2.2 % over the total volumes). In the case of Spanish Short Sea Shipping traffics raised to 196.668 millions of tons (234.7 millions of tons in 2016 from www.spc-spain.es) being only 15.33 millions of tonnes or 7.8 % under Ro/Ro schema. Keeping in mind these figures, it is asked which rate of success should be acquired with the maritime transport promotion policies in European Union. The proposed paper wants to analyse in deep, which reasons could explain the low volumes that still Intra European Short Sea Shipping gets. The analysis will begin with a review of the SSS and Motor Ways of the Sea official definition and after having a complete overview of traffic figures, to propose a model to analyse the best mode to connect different Iberian destinations offered to Consignors, in an attempt to transfer part of the cargo from road to sea option.

Keywords: motor ways of the sea, short sea shipping, Western Mediterranean.

1. Introduction

Motorways of the Sea (MoS) concept was officially mentioned for first time in the White Paper of Transport (EC, 2001) with the main objective to reduce the existing and future bottlenecks in Trans European transport Networks (TEN-T) and additionally to improve the logistic integration of short sea shipping (ANAVE, 2004). From the beginning there was the thought that the building of links under 500 km. of distance, would require initial support to be developed like a quality stamp or distinctive or specifically financial aid from European funds like (in fact has been) FEDER or Marco Polo programs inter alia.

Coming back, among first initiatives to shift road transport to the sea representing the concept of MoS, was the action known as *Autostrade del Mare* carried out by Viamare S.p.A. in 1992 (Beškovnik, 2013). Further attempts to draw a definition or operational frame to the MoS concept are identified from the year 2002 (Ministry of Transport of Finland 2002, Gijón declaration 2002, Van Miert report 2003). A tentative definition suggested them as any multimodal service that includes a maritime leg with minima standards of quality that elevates them over the general concept of services understood as Short Sea Shipping (ANAVE 2004) that supposed a real alternative to road transport and contributed to the reduction of congestion, the environment conservation and the economic growth.

From an academic point of view, different proposals of definition were provided (Baird, 2007; Paixão, 2008). However, some authors were of the opinion that never has given a precise definition of a MoS (nor SSS) (Douet & Capuccilli, 2011). MoS can be deducted that are door to door regular services, serving with high frequency, including a short sea leg allowing a significant modal shift. Also they are called floating infrastructures, that move goods by sea from one member to another and aims to substitute land motorways to avoid congestion and give access to countries separated from the mainland and enable better integration of waterborne with surface, modes. (Paixao 2008). From these last definitions it seems that MoS should be limited to short sea services using Ro/Ro ships among member states so few potential for modal shift seems to be as most of them are operating in captive markets.

More recent information from EU web site established as main objectives of MoS, the concentration of freight flows on sea based logistical routes to improve existing or new maritime links being viable, regular and frequent to reduce road congestion and/or improve access to peripheral and island regions and States. So as to provide more efficient, commercially viable and sustainable alternatives to road-only transport.

Even that SSS traffics increased 12% between 2001 and 2010 (Ng 2013). However, SSS in general has not improved as expected because seems that its definition not fit with potential impact Ro/Ro services that are mostly captive and only a few remove trucks from roads. Additionally, shore infrastructures are subsidized, being the opposite scenario in maritime sector.

2. Spanish Scenario

During the year 2017, SSS services reached 248 millions of tons, supposing an increase of 6% from 2016, being split in 19% national coastwise and 81% of external traffics. But due to a reduction in the number of ships, the overall connections increased mainly when referred to SSS as alternative to road around 42% in the Atlantic basin and 25% in the Mediterranean one. The number of MoS in the Atlantic side was 2 and in the Mediterranean were 3. The mean occupation with respect to offer was 73.1% decreasing from 2016 when reached 80.1%, in both basins the offer increased and demand didn't follow this tendency being the overall figure of occupancy lower. From a global perspective the SSS share in the rolling traffic passed from 10% in 2014, to 9.7% in 2015 and to 9.1% in 2016 (SPC Spain 2018).

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Table 1
Share of SSS on the overall rolling flows in different countries

Countries and year	Share
Italy, 2016	46.8%
Belgium, 2016	4.4%
United Kingdom, 2016	21.8%
France, 2016	0.8%
Spain, 2016	9.1%

Source: Own based on SSS Statistic Observatory. SPC Spain 2018

2.1. The Offer of MoS Lines in Spain

During the second semester of the year 2017, in the Atlantic basin operated 50 SSS services being up to 32 (64%) a real alternative to road, having 2 more than 3 calls per week and thus considered as MoS. During the same period in the Mediterranean up to 38 (28%) services were considered an alternative to road out of 135 lines and only 3 considered MoS (SPC Spain 2018).
As it has been mentioned before, the total number of MoS in Spain has been in 2017 of 5 lines operated by 2 shipping companies, linking 8 international ports and served by up to 12 ships. Considering the two basins, in the Atlantic case we find 2 shipping companies in 2 MoS with 4 Ro/Ro ships linking 2 ports. In the meanwhile, in the Mediterranean there were 3 MoS served by only 1 shipping company, linking 6 ports and using 8 Ro/Pax ships. Being the average frequencies of call of 3.1 and 5 times per week, respectively.

Table 2
Detail of motorways of the sea in the Mediterranean and Atlantic basin. Year 2017

Mediterranean MoS	Frequency	Atlantic MoS	Frequency
Barcelona Civitavecchia	Daily	Algeciras Vigo Saint Nazaire Le Havre	3 x week
Barcelona Livorno Barcelona Savona	4 x week Daily	Santander Le Havre	3 x week
Valencia Livorno Valencia Savona	Daily		

Source: Own based on SPC Spain web site http://www.shortsea.es/index.php/simulador/lineas and Grimaldi web site www.cargo.grimaldi-lines.com (consultation date June 2018)

2.1. Evolution of the SSS Traffics in Spain

In January 2004, Spanish government established in Algeciras a position in order to promote SSS services. In that year, the short sea services apart from feeder connections existing nowadays there were up to 24 services running.
During the year 2004, 12 companies were linking 8 Spanish ports with other European destinations (see Table 3).

Table 3
Detail of Spanish SSS services. Year 2004

Company	Frequency	Route	Type of ship
Med Seaways	2 x week	Tarragona and Savona	Ro/Ro
Cía. Trasatlántica Española	every 2 weeks	Valencia, Barcelona, Piraeus, Istanbul and Izmir	Containers
Cía. Trasmediterránea	2 per week	Vigo and Saint Nazaire	Ro/Ro
Geest North Sea Lina / Naviera del Odiel	weekly	Bilbao, Rotterdam and Tilbury	Containers
Grandi Navi Veloci	weekly	Barcelona and Genoa	Ro/Ro
Naviera Pinillos	weekly	Bilbao, Southampton, Felixstowe and Thamesport Bilbao, Dublin, Liverpool and Greemock	Containers
Transmed	2 x week	Tarragona, Genoa and Salerno	Containers
UECC	2 x week	Bilbao, Pasajes, Portbury Santander, Pasajes, Vlissingen, Sheerness and Zeebrugge Vigo, Le Havre, Zeebrugge, Sheerness and Bremerhaven	Ro/Ro
Xpress Container Lines	weekly	Vigo, Le Havre, Thamesport, Rotterdam and Vigo Barcelona, Genoa, Livorno and Fos Gijón, Rotterdam, Bilbao, Gijón Vigo, Leixoes, Rotterdam and Vigo	Containers

Company	Frequency	Route	Type of ship
Grimaldi Napoli	3 x week	Valencia, Livorno, Salerno, Tunis, Malta	Ro/Ro
	daily	Barcelona and Civitavecchia	
OPDR Hamburg	Every 2 weeks	Hamburg, Bremen, Antwerp, Le Havre, Felixstowe, Southampton, Rotterdam, Lisboa, Leixoes and Vigo	Containers
	weekly	Rotterdam, Bilbao and Le Havre	
Flota Suardíaz	weekly	Bilbao, Zeebrugge, Vlissingen, Southampton, Vlissingen, Zeebrugge and Santander. Gijón, Saint Nazaire, Southampton, Vigo and Setúbal. Setúbal, Vigo, Gijón and Vlissingen.	Ro/Ro
	2 per week	Tarragona and Livorno Tarragona, Civitavecchia and Salerno	

Source: Own based on SPC Spain web site http://www.shortsea.es (consultation date June 2018)

As it can be seen only two services in Mediterranean basin had 3 or more calls per week and then could be considered as MoS and the actual Atlantic services then had only two calls per week. Also during the year 2007, two new services were opened in each basin. One carried out between Bilbao and Zeebrugge with three sailings per week that definitely left the Spanish port in 2015. And a second service in the Mediterranean between Barcelona and Livorno, still in force.

3. Case Study

This section identifies main Spanish ports involved in Short Sea Shipping and proposes new Motorways of the Seas. Main Spanish cities are connected with the most important Spanish ports and, on the other hand, connected to most important European ports and cities. Up to 54165 links between Spain and European countries were studied, based on time and costs. Moreover, three different types of ships are considered, namely, conventional ships (23 knots); fast ships (23 to 30 knots) and High Speed Crafts. For time and cost calculation purposes representative ships are used (Table 4).

Table 4
Detail of main characteristics of the considered ships

Particulars	Conventional Eurocargo Istanbul	Fast ship Superfast Galicia	High Speed Craft Millenium 3
Length	195	160	96
Beam	25.2	23.2	26
Draught	7.8	6.8	3.3
Power (kW)	12510	34300	38501
Speed (knots)	20	23.2	42
Gross Tonnage (GT)	20775	14560	6360

Source: Own based on www.equasis.org. (consultation date june 2018)

Travelled distance and speed are factors closely related to engine consumption and then conditioned by the fuel costs. Capital costs, crew costs and RMIA (i.e. repairs, maintenance, insurance and administrative) costs are considered. These costs are limited to the navigation phase, considering only the ship in open seas. Port costs like taxes, fees, discharge operation or demurrages are not considered. The method used is based on Stopford (1997); however different authors have proposed alternative methods to calculate them (Anderson and Ivehammar, 2016; Tzannatos, 2005; Tzannatos *et al.,* 2014; Mulligan and Lombardo, 2006 or Martínez de Osés and Castells, 2009).
Capital costs dependent on an additional time unit at sea, are assessed based on Gross Tonnage (GT). The capital cost per day is based on the Compensated Gross Tonnage (CGT) factor. The formula used is taken from the Compensated Gross Ton (CGT) System, from OECD Directorate for Science Technology and Industry in its Council Working Party on Ship building (OECD 2007):

$$CGT = A \cdot GT^{B} \qquad (1)$$

Being the factors A and B obtained from OECD (2007). From equation (1) applied to the price of all ships, the daily capital cost is obtained considering a credit at an interest of 5% and a useful and repayment life of 25 years (Tzannatos *et al.,* 2014).

$$\text{Capital cost} = 14.014 \cdot GT0.63\ €/\text{day} \qquad (2)$$

Regarding the group of repairs, maintenance, insurance and administrative costs, Jansson & Shneerson (1987) suggest that this should be around 3.5% of the daily capital costs. General formula to calculate RMIA costs is shown below:

RMIA = 0.4905·GT0.63 €/day (3)

Crew cost, this unitary value is difficult to estimate due to the variability if passenger and non-passenger ships are considered. The resultant formula of the crew costs is given by:

Crew Costs = [2.1(Officers·Wage) + 1.5(Mates·Wage)/30]·Sailing time/24 (4)

Based on Anderson and Ivehammar (2016, 2017) and Larsson (2010), fuel consumption for a specific journey is calculated considering the hull resistance as:

$$C = \frac{R_T \cdot D}{E_{MGO} \cdot \eta_T} \tag{5}$$

Where
C fuel consumption, in kilogram (kg)
R_T vessel resistance, in kilo newton (kN)
D sailed distance (meters)
EMGO the specific energy of Marine Gas Oil, 42700 MJ/kg is considered
η_T thermal engine efficiency

The total resistance of the vessel is calculated by a model for hull resistance (Larson and Raven, 2010):

$$R_T = \frac{1}{2} \cdot \rho \cdot V_S^2 \cdot (B + 2 \cdot d) \cdot L \cdot C_B \cdot C_{TS} \tag{6}$$

Where
ρ water density, in kg/m3
Vs speed, in m/s
B beam, in m
d draught of ship, in m
L length of ship, in m
C_B block coefficient, 0.67 is used
C_{TS} resistance constant, 0.0022 is used

4. Results

The main objective of this contribution is preselect the Spanish ports susceptible to belong to a Motorway of the Sea and find suitable routes in the European framework. Figures 5 and 6 show the most viable routes in terms of time and cost, respectively.

Fig. 1.
SSS Suitable routes in terms of time
Source: Own based on internet caught picture

Fig. 2.
SSS Suitable routes in terms of cost
Source: Own based on internet caught picture

Finally, based on proposed model explained in the above section, table 5 shows the final suitable routes connecting different European destination (one of them is one Spanish port) considering time, cost and type of ship.

Table 5
Proposed routes in terms of time, cost and type of ship

Country	Route	Type of ship
Germany	Bilbao-Bremen	Fast
	Bilbao-Koln	Fast
	Pasajes-Bremen	Fast
Belgium	Bilbao-Antwerpen	Fast
	Pasajes-Antwerpen	Fast
Croatia	Valencia-Rijeka Bakar	Fast
Denmark	Bilbao-Esbjerg	Conventional
France	Bilbao-Rouen	Fast
Poland	Bilbao-Gdansk .	Fast
	Pasajes-Gdansk	Fast
Greece	Valencia-Igoumenitsa	Conventional
	Valencia-Thessaloniki	Conventional
The Netherlands	Bilbao- Nijmegen	Fast
	Bilbao-Den Helder	Conventional
	Pasajes-Nijmegen	Fast
	Pasajes-Den Helder	Fast
Italy	Valencia - Livorno	Conventional
	Valencia-La Spezia	Conventional

Source: Own based on detailed calculations

5. Conclusion

Final calculations have been carried out, considering different goals to be accomplished. Keeping in mind the results showed in the previous section, the first conclusion is that HSC ships due to the cost of consumption are skipped from the first assessment. The selection between fast or conventional Ro/Ro ships depends on the possible competence with only road transport chains. Time is a factor to be considered but for certain type of goods, frequency is another factor to be considered by final costumers and also reliability or consistency along the time or influence of the seasonality. It is

also considered that higher speeds supposes higher consumptions and then pollutant emissions; however there combinations of routes with faster speeds where time makes them competent against only road transport chains.
As a suggestion to shipping companies, and of course subjected to further checking we propose different short sea links that can be real alternatives to only road transport chains with different European countries. Existing MoS are not considered in the proposal as they are at least at this moment reliable and efficient transport alternatives. Some of them get the geographical advantage that some combinations have, like is the case among Italy and Spain. Some others are relying in an advantage on only time or cost and a few on both; but they are.
As a concluding idea, it is left still a proper definition of SSS and MoS for exactly define them and make a clear frame of what are the links susceptible to get consideration and funding from EU.

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EFFECT OF MULTICULTURAL AWARENESS AND COMMUNICATION ON SAFETY ONBOARD A VESSEL

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Abstract: The need for people to be able to talk to each other without prejudice comes with globalization. Maritime safety is largely dependant on adequate communication and mutual understanding of persons onboard vessels. Although maritime technology evolved, there is still a large number of maritime accidents. Inadequate communication and misunderstandings are one of the factors that can lead to human error, that in return can cause accident. Human relations onboard are also dependant on communication, especially in cases of multicultural crews. In order to understand each other and create safe working and living environment, adequate communication is essential. But, adequate communication is not always sufficient to overcome cultural differences between cewmembers. Answer to that issue could be multicultural training for all crewmembers on board vessels. Questionnaire with title: ″Multicultural awareness and communication on board a vessel″ was given to experienced seamen in order to uncover their opinion on adequacy of communication and human relations on vessels with multicultural crews.

Keywords: multicultural, communication, human relations.

1. Introduction

Maritime safety is still largely affected by human factor, since about 80% of maritime accidents are caused by human error (Hanzu-Pazara *et al.,* 2014). Inadequate communication and poor human relations in certain conditions are recognized as contributing factors to human error. In order to reduce human error and improve maritime safety, adequate communication and human relations needs to be implemented on board ships. International Maritime Organization (IMO) addressed that problem and implemented IMO Model Courses. English is internationally accepted as language that is to be used for emergency situations, and as such, good knowledge of English is essential in order to safely complete voyage between two ports. But, accidents due to inadequate communication between crewmembers, or lack of same still happen. Maritime industry must find solution and reduce such accidents to minimum. Seafarers should have adequate education and trainings ashore, what should be supplemented with trainings on board ships. Many shipping companies are doing their best in order to get best possible education and trainings for their employees, but there are some companies that are focused on profit and don't look into safety. A sound knowledge of English is precondition for making a good career at sea, what is commonly known by seafarers around the world.

Ships' crews are nowadays made of persons from different countires and continents, and as such there are many differences between them. As per Trenkner and Cole (2003) 80% of the world’s merchant ships have become multilingual and multiethnic in crew composition. One in ten ships operates with crews composed of five or more nationalities (Badawi and Halawa, 2003). Seafarers should learn cultural differences in order to understand and appreciate each other more. Multiculturality courses are improving teamwork on board ships and increase safety performance. Again, sound knowledge of English is essential for that.

2. Importance of Adequate Communication in Maritime Industry

One of the essential elements for strong organization is consistent and direct communication because it leads to trust between all parties (Vredenburgh, 2002). Communication can be divided into two categories, communication on safety issues and clear two-way communication. Communication on safety issues is considered as integral part of Safety Culture, and it comes in various forms, like policies and procedures, incidents reports, performance statistics and workplace inductions (Vecchio-Sadus, 2007). Safety communication in organization is achieved by two methods, internal and external communication. Internal communication includes different types of presentation for all staff and management, team meetings, notice boards, e-mails or even videos. Delivering annual reports, publications or telephone enquiries are usual methods for external communication (Vecchio-Sadus & Griffiths, 2004).

Researches in the past showed that poor communication was main reason for low safety performance to low productivity and morale (Hofmann &Morgeson, 1999; Alexander *et al.,* 1989, Michael *et al.,* 2006). According to Vredenburgh (2002), regular and direct communication should be promoted to increase safety performance.

In constructive and open communication atmosphere all team members would freely discuss problems, ranging from routine to non-routine issues, and jointly engage in problem solving (Fairhurst, 1993; Hoffman *et al.,* 2003).Those members who have high collective orientation are more likely to have increased attention to task and are willing to help other team members during task performance. Therefore, this attribute will facilitate process of coordination and communication inside the team (Salas *et al.,* 2008).

In recent years shipping industry has experienced a numerous incidents and accidents caused by human factor, explained by three elements: ergonometric constraints, human fatigue and inter-relation between people, i.e. their communication skills (Horck, 2010; 2006).

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In order to fulfill crewing requirements and cut labor costs shipping companies usually employ multinational crews. A study carried by Seafarers International Research Centre, which included 10, 958 ships, shows that only one third of the ships have single nationality crews (Kahveci & Sampson, 2001; Hetherington *et al.,* 2006).
Presence of multinational crew implies a different language and culture background which is transmitted to the ship's complement. In cases when communication fails damages to property, environment, or loss of lives is possible.
According to Horck (2010) people from the same culture have to be able to communicate and language is basic facilitator of communication. In maritime industry English is standard language and proper knowledge leads to accident avoidance. Besides difficulties mastering a common language, misunderstanding and lack of communication has also been reported as common problem on ships (Hetherington *et al.,* 2006).
While the ship is in open waters navigation is usually performed by certified deck officer who is working alone on the navigational bridge. In cases when the ship encounters areas with congested traffic, when maneuverability is restricted, or ship is about to enter or leave port, navigation is carried out by a bridge team which work together. Also, in most ports of the world pilotage is compulsory and is common for a pilot to work together with ship bridge team, giving advices for actions to be performed during navigation and mooring operations. In all cases effective communication in common language is essential.
Some part of communication is so called non-verbal communication (Horck, 2010). Non-verbal communication can be explained as actions people do not say because they expect to be understood from manners and facial expression of other people. Culture constraints have an impact in understanding non-verbal communication (Storgard *et al.,* 2013).
Accident reports caused by communication failures are numerous. Horck (2006) presented accidents caused by lack of language constraints: the collision between Fu *Shan Hai* and *Gdynia* in 2004, collision between ships *Tricolor* and *Karibian* 2003, and the collision of *Silja Opera* in 2003. Besides accidents caused by language constraints, cultural constraints caused grounding of *Domiat* in 2004, and explosion on *Bow Mariner* in 2004.
Pyne and Koester (2005) summarized those related to different language, between bridge team and the pilot, crew and passengers, and those related to external communication and VHF communication with other ships. According to them, accident could be avoided with proper knowledge of English language. Besides language barriers, cases of misunderstanding where reported between crewmembers who speak same language. They summarized with the conclusion that adding people using English as second language and cultural differences between them, in the bridge team, can increase risk of miscommunication.

3. Multiculturality in Working Environment on Board Ships

The basic skill for surviving in a multicultural world, as has been argued, is understanding first one's own cultural values and next the cultural values of the others with whom one has to cooperate (Hofstede, 1997).
Language and culture is challenge in many maritime operations. Even persons who speak the same language can have a misunderstanding (Adams, 2010). Adequate communication is essential skill during maritime operations, especially in the crisis and crowd management, where team members should quickly understood each other. Different social groups or team members with different cultures may respond in own ways to similar situations (Maritime and Coastguard Agency, 2014). Ethnocentrism and prejudices about other cultures in maritime operations can make poor comunication among team members and can leed in catastrophic situation.
Everyone should understand that it does not matter from where you are coming or what cultural, ethnic or religious background you have, experienced or with no experience, there are, at all times, the possibilities to be successful. Dangerous tunnel vision could be always present for anyone and there is always possibility to change decision considering you have the right attitude and understanding of the value of a certain improvement. Understanding fellow crewmembers (knowing that people from different countires can behave differently) will lead to a positive outcome (Horck, 2004).
The communication is succesfull when the information is exchanged by all team members or everyone concerned with, it doesn't matter wich culture background team members belong. Accurate, clear and accepted communication leads to success. Anything less is failed communication and will lead to trouble (Adams, 2010).
According to UK Maritime and Coastguard Agency (2010), the work place is influenced by two different sets of cultural issues, related to differences due to a person's cultural background and organizational culture. Cultural differences increase the likelihood of different interpretations of the same event. A person's ethnicity may also make them more or less sensitive to the demands of the second set of cultural issues – the organizational culture in which the decision makers are embedded.
In order to reduce maritime accidents caused by human error, International Maritime Organization (IMO) implemented model courses, which are "*meant to suggest and help professors, lecturers and instructors in their teaching*" (Horck, 2003).
Among many learning objectives of IMO Model Courses 1.22, 2.07 and 1.39, particular attention is pointed on Cultural Awareness and Communication. As per training objectives the trainees should be able to explain the need of cultural awareness (sensitivity of cultural differences, methods for dealing with cultural differences, cross-cultural communication and effective communication on board and ashore) in duration of no more than one hour (IMO, 2002a, IMO, 2002b, IMO, 2014). After implementation of 2010 Manila Amendments as a part of additional requirement for Certificate of Competence (CoC) certification those courses are obligatory for all ship leaders (deck and engine

officers). But, just attending IMO model courses for officers is not precondition for safe working environment on board a ship.

4. Analysis of Present Situation in Maritime Industry

Authors conducted a survey in order to determine present situation regarding communications and multiculturality in maritime industry with title: "*Multicultural awareness and communication on board a vessel*". Tool for the above mentioned survey was questionnaire based on literature review and authors' expertise. Survey involved 70 seafarers of different nationalities and ranks. For all seafarers which had direct online access questionnaire was available online. For those which did not have that opportunity it was available in paper form.
Authors tried to poll seafarers of different nationalities and ranks in order to get perception about multiculturality and communication on board ships.
Nationalities of seafarers involved in questionnaire were: Croatian (59%), Filipino (16%), Indonesian (16%), Ukrainian (4%), Russian (3%), Indian (1%) and Montenegrin (1%).
Seafarers of all ranks were polled (Figure 1).

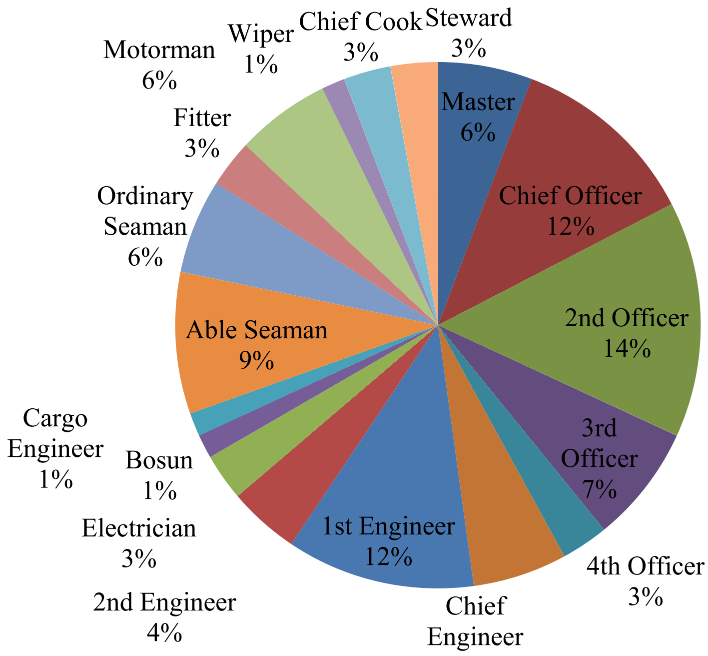

Fig. 1.
Ranks of polled seafarers
Source: Authors' own construction

Out of 70 respondents, 47% were working aboard crude oil tankers, 43% on LNG tankers, 9% aboard cruise ships/passenger vessels, 4% and 1% on bulk carriers (Fig 2).

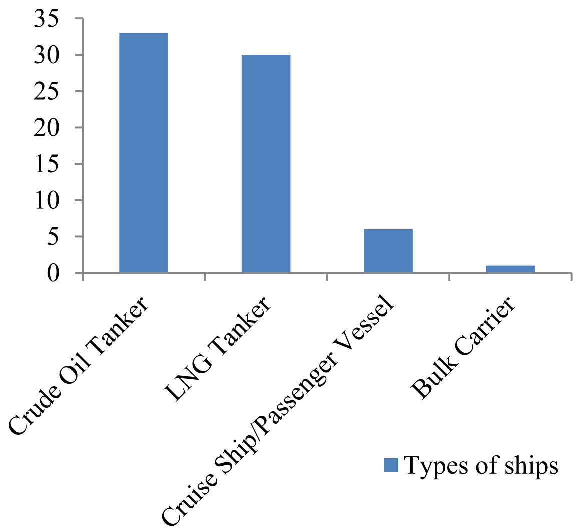

Fig. 2.
Types of ships on which respondents sail
Source: Authors' own construction

All age groups are represented in survey, majority being between 30 and 40 years old.
When asked are they or have they sailed with multicultural crew before, 99% of polled seafarers answered affirmatively.
English was official language on board all respondents ships.
When asked how well do they speak and understand the official language on board their vessels, 12% of respondents answered excellent, 40% very good, 42% good and 6 % average.
Polled seafarers answers on questions regarding attending formal Maritime English Course, Multiculturality Training and opinion about having those courses mandatory can be seen in Table 1.

Table 1
Seafarers opinion about Maritime English and Multiculturality course

Question/Answer(percentage)	Yes	No	I don't know
Have you attended Maritime English Course?	56%	44%	0%
Do you think that Maritime English course should be mandatory?	84%	10%	6%
Have you attended Multiculturality training?	41%	59%	0%
Do you think that Multiculturality training should be mandatory?	64%	32%	4%

Source: Authors' own construction

Sailing with multicultural crew is easier for 80% of polled seafarers, 9% find it more difficult than sailing with crewmembers only from their country, and 11% answered that they don't know what is easier for them.
88% of respondents answered that they don't have any difficulties understanding fellow crewmembers of different nationalities.
When asked have they experienced any accident, incident or near-miss on board their ships due to lack of communication or misunderstanding, half of respondants answered affirmatively.
When asked what do they think about multicultural understanding on board their vessel, could it be improved and how, seafarers answered variosly. Some were satisfied with present situation on board their vessels and some stated that there is always room for improvement. Few answers given by seafarers are cited below.
Seafarer 1: „Cross-cultural understanding onboard vessel is settled up by management philosophy and works well. Improvements always welcomed and should be in way of additional crew trainings given by company maritime superintendents who are in charge for management ISM."
Seafarer 2: „On this vessel cross-cultural understanding is very good. However, on my previous vessels I've experienced accidents that happened due to misunderstandings."
Seafarer 3: „It's simple give and take relationship so that we can be together with harmony."
Seafarer 4: „I believe that we understand each other very well considering the differences. Of course, there is always place for improvement. I believe that the implementation of cross-cultural training would be useful probably, however I am not sure what would be the best way for it to be the most efficient and most successful way of improving mutual understanding."
Seafarer 5: „Even though we have nine different cultures onboard we never had a cross-cultural incident, there could be improvements, in my opinion best are social gatherings and sport activities."

5. Conclusion

Influence of English on maritime industry is vast. Adequate communication in official language (English) is essential since there are more and more multicultural crews on ships. International Maritime Organization realized that and introduced standards for knowledge of English for individual ranks in their recommendations and guidelines. Inadequate knowledge of official language on board a ship can easily lead to human error that can result in an accident. Shipping companies and agencies for employement of seafarers should pay attention how their employment candidates understand English. Shore personnel that is in contact with shipboard personnel must also have adequate knowledge of official language in order to avoid communication problems and misunderstandings. According to polled seafarers, misunderstandings and inadequate communication is still factor that causes accidents. Adequate education ashore and trainings on board are essential for Maritime Safety. Multiculturality and English courses should be available for all seafarers and shore personnel. Currently available multiculturality trainings as per IMO are included in IMO Model Courses 1.22 (Ship simulator and Bridge teamwork), 2.07 (Engine-room simulator) and 1.39 (Leadership and teamwork) and they are not sufficient for fully understanding different cultures and adequate communication on board. Authors' opinion is that training about multiculturality should be standalone course.

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A VISCOUS FLOW SIMULATION AROUND A FULLY APPENDED SHIP HULL BY USING A FINITE VOLUME TECHNIQUE

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Abstract: The present study is concerned with predicting the total resistance of the fully appended surface combatant DTMB5415 ship model. The study dually stands as a further step for a previous investigation of the bare-hull ship resistance that was carried out by the author, as well as an incipient investigation for the maneuvering performance prediction which is going to be carried out in the very near future. A set of computations are performed to predict the total resistance at different free stream velocities. The computations are performed by making use of the ISIS-CFD solver of the Fine^{TM}/Marine package. The solver is based on finite volume method to build the spatial discretization for solving the Reynolds-Averaged Navier-Stokes equation in a global approach. The turbulence is modeled by making use of the *k-ω SST* and EASM models. Verification and validation of the numerical solution are performed based on a grid convergence study. Computed results are compared to the towing tank measurements and show a satisfactory agreement. A dedicated investigation is based on subdividing the computational domain into its particulars to check the influence of each appendage on the total resistance of the ship. A special focus on the free-surface prediction and the local flow is also included.

Keywords: CFD, DTMB, RANS, ship resistance, viscous flow.

1. Introduction

The power required to drive the ship depends upon the resistance induced by water and air. Predicting this total resistance is one of the first steps conducted by a naval architect during the primary design stage. Obviously, accurate prediction of the total resistance is crucially important to obtain the optimum power that can satisfy the energy efficiency criteria for the proposed design. For example, merchant ships are dictated by the optimum voyage speed which can result in the highest profit for the owner on one hand, on the other hand, fuel consumption should be carefully taken into consideration, bearing in mind the fact that fuel cost is significant, while in case of warships, they are designed based their operational requirements which definitely must include high speed and optimum maneuverability. Generally, the power required for ship operations should be reduced to an optimum level by means of hull form optimization, light weight adaptation for structure and machinery, increasing fuel efficiency and/or recovering the power losses in the propeller wake region by means of energy saving devices. Clearly, implementation of one or more of these solutions can result in a significant enhancement of ship performance. Yet, it remains the challenge for the design engineer to predict the total resistance, based on which one or more of these solutions can be implemented. This returns us to the major problem in this paper, which is the prediction of the total ship drag. This requires an effective and reliable tool to predict accurately the total resistance. Formerly, reliance on model test, empirical formulas or even build and try concept was the basic method to solve this problem. Apparently, by that time these methods were considered reliable and sufficient; yet, nowadays they are completely out of fashion. Recently, Computational Fluid Dynamics (CFD hereafter) has become a very powerful tool used by researchers and designers to solve marine hydrodynamic problems. The method is also flexible for all types and sizes of ships; model or full scale, merchant or special purpose. CFD is not just suitable for predicting forces acting on the hull; it can recently be used to give clear details of local flows and free-surface, thanks to the development in viscous flow solvers and free-surface capturing techniques, which usually in a classic tank testing requires very expensive and sophisticated tools.
Investigating the capability of CFD to predict a complicated ship resistance problem, the case study in this paper is applied on the fully appended DTMB 5415 model. Taking into consideration the fact that ship is always fully appended in the normal operating conditions, investigating the total resistance for the fully appended hull is crucially important to avoid any misleading during the power computations. The DTMB hull was conceived as a preliminary design for a Navy surface combatant (SIMMAN, 2008). The bare hull geometry includes both a sonar dome and transom stern, while the appended hull includes two bilge keels, twin screw propeller shafting system supported by shaft brackets and two rudders. No full-scale ship exists, however, several tank tests were performed on this particular model and included different test cases; the bare hull was tested and presented in (Olivieri et al., 2001) and (Longo et al., 2007), besides other several investigations for seakeeping and maneuvering are also tested and presented in (IIHR, 2015). The fully appended hull is depicted in Fig. 1, while the main particulars are tabulated in table 1.

Fig. 1.

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The bottom view of the fully appended DTMB 5415 model

Table 1
The DTMB 5415 ship model particulars

Main Particulars	Value
Length between perpendiculars, L_{pp} [m]	5.719
Length of water line, L_{wl} [m]	5.726
Breadth Molded, B_m [m]	0.768
Draft, undisturbed free-surface elevation from base line, T_s [m]	0.248
Displacement [m^3]	0.554
Block Coefficient C_B	0.507

Several numerical simulation of the fully appended DTMB hull was also reported in the literature. For instance, a simulation for the free-surface and flow configuration around the fully appended model without the bilge keel is presented by (Lungu and Pacuraru, 2010). Another analysis for fully appended ship which included resistance and powering estimation in different advance velocities has been reported in (Voxakis, 2012). Another nonlinear study concerned with the prediction of the free-surface of the fully appended ship during self-propulsion condition was conducted by (Burg et al, 2002). In the present research a CFD technique is employed to predict the total ship resistance of the fully appended surface combatant DTMB ship model based on viscous flow simulation. Investigation of ship resistance components induced by every appendage is also presented. The free-surface configuration in different advance velocities is included and finally, the flow configuration around the hull is analyzed based on the local streamwise velocity and turbulent kinetic energy. This study stands as a second step for the bare hull ship resistance computation previously reported by the authors (Bekhit and Lungu, 2017).

2. Numerical Approach

The numerical simulation is performed by making use of the ISIS-CFD solver of the commercial software Fine^{TM}/Marine available under the NUMECA suite. The solver is based on finite volume method to build the spatial discretization for the governing equation to solve the incompressible steady Reynolds-Averaged Navier-Stokes Equation (RANSE hereafter) in a global approach (Guilmineau et al., 2015). Closure to the turbulence is achieved by making use of either the *k-ω SST* model or EASM model.

2.1. Governing Equation

For incompressible flows, if there are external forces, the averaged continuity and momentum equations are given in tensor form in the Cartesian coordinate system by

$$\frac{\partial(\rho\bar{u}_i)}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial(\rho\bar{u}_i)}{\partial t} + \frac{\partial}{\partial x_j}\left(\rho\bar{u}_i\bar{u}_j + \rho\overline{u_i'u_j'}\right) = -\frac{\partial\bar{p}}{\partial x_i} + \frac{\partial\bar{\tau}_{ij}}{\partial x_j} \tag{2}$$

where $\bar{u}_i$ is the relative averaged velocity vector of flow between the fluid and the control volume, $\overline{u_i'u_j'}$ is the Reynolds stresses, $\bar{p}$ is the mean pressure and τ_{ij} is the mean viscous stress tensor components for Newtonian fluid under incompressible flow assumption, and it can be expressed as

$$\bar{\tau}_{ij} = \mu\left(\frac{\partial\bar{u}_i}{\partial x_j} + \frac{\partial\bar{u}_j}{\partial x_i}\right) \tag{3}$$

The system of equations is closed by imposing the turbulence closure equations whether in *k-ω SST* or EASM models. More details about both turbulent modeling can be found in (Menter, 1994) and (Gatski, 1993), respectively. Pressure-velocity coupling is enforced through a Rhie & Chow SIMPLE like method: at each time step, the velocity updates come from the momentum equation and the pressure is extracted from the mass conservation constraints transformed into pressure equation (Vissoneau et al., 2016). Convection and diffusion terms in the RANSE are discretized by a second-order upwind scheme and a central difference scheme, respectively. The flow is accelerated through a steady quasi-static approach within a time-span corresponding to the relationship between the length of the ship and the inflow velocity such that $T_{acc}=2.0L_{pp}/U_\infty$. Computations are performed for 30 seconds using 10 iterations per time step, while the time step is chosen with respect to the equation $\Delta t=0.005L_{pp}/U_\infty$ for *k-ω SST* model and $\Delta t=0.001L_{pp}/U_\infty$ for EASM model as it is suggested by the ITTC recommended procedures for CFD (ITTC, 2014). The free-surface is captured in an air-water interface based on volume of fluid (VOF) method. All the computations are performed with respect to an earth-fixed Cartesian reference frame with only two degrees of freedom including heave and pitch.

2.2. Computational Domain and Discretization Grid

The computational domain is having a rectangular configuration. Dimensions of the computational domain in (x– y– z) direction are ($5.0L_{pp}$–$1.5L_{pp}$–$2.0L_{pp}$) distributed as $1.0L_{pp}$ upstream, $3.0L_{pp}$ downstream, $1.5L_{pp}$ on the side, $1.5L_{pp}$ underneath the undisturbed free-surface and 0.5 above the undisturbed free-surface level. Taking into account the symmetry of the hull and neglecting all the lateral motions, only half ship is introduced in this computation to simplify the problem and reduce the number of grid cells required. Boundary conditions are applied on the ship hull and domain boundaries as follows:

- Top and bottom: prescribed pressure, updating the hydrodynamic pressure during simulation,
- Inlet, outlet and side: far field,
- Centerline plane: symmetry,
- Ship hull and appendages: No-slip,
- Deck: slip condition, assuming that the deck will remain in the air during the computation, where viscous effect can be neglected.

Figure 2 depicts the computational domain dimensions and boundary conditions.

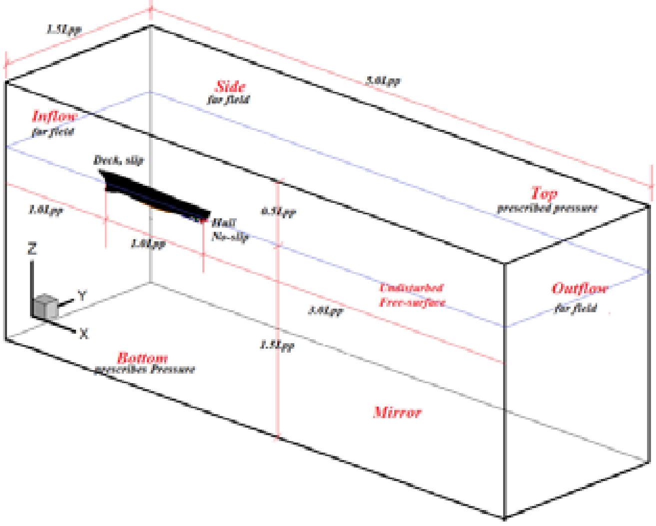


Fig. 2.
Computational domain dimensions and boundary conditions

Three computational grids are generated by making use of the unstructured automatic grid generator HEXPRESS available in the Fine^{TM}/Marine package. Table 2 summarizes the total number of grid cells for the discretization grids based on the wall treatment condition.

Table 2
Discretization grids number of cells depending on the wall treatment

Discretization Grid		Fine	Medium	Coarse
Wall treatment	Wall Modeled	2.669M	5.667M	8.958M
	Wall resolved	3.634M	9.022M	16.605M

Ensuring the grid similarity is quite difficult for such a ship due to the complicated geometry and the existence of the appendages. However, this problem is solved by imposing similar grid generation parameters and similar refinement ratios. The free-surface is refined, for medium and fine grids, in x- and y-direction according to the equation $\Delta x=\Delta y=2\pi Fr^2L_{pp}/50$, while $\Delta z= L_{pp}/1000$; where the Froude number is defined by $Fr=V/(gL_{pp})^{0.5}$. The distance to the wall is treated with two different approaches, wall modeled imposing y^+=32 and wall resolved having y^+ less than unity. The computational grid for the medium mesh is depicted in Fig. 3 highlighting the bow, stern and free-surface refinement.

3. Results and Discussion

Basically, the numerical solutions of the present paper are targeted in three main directions, namely verification and validation, velocity dependent results, free-surface and local flow solutions. In the first one, the ship velocity is set to the design velocity corresponding to *Fr*=0.28. The solution is presented for twelve sets of computations; six for *k-ω SST* model, three for wall modeled and three for wall resolved and similar for EASM for the same conditions.

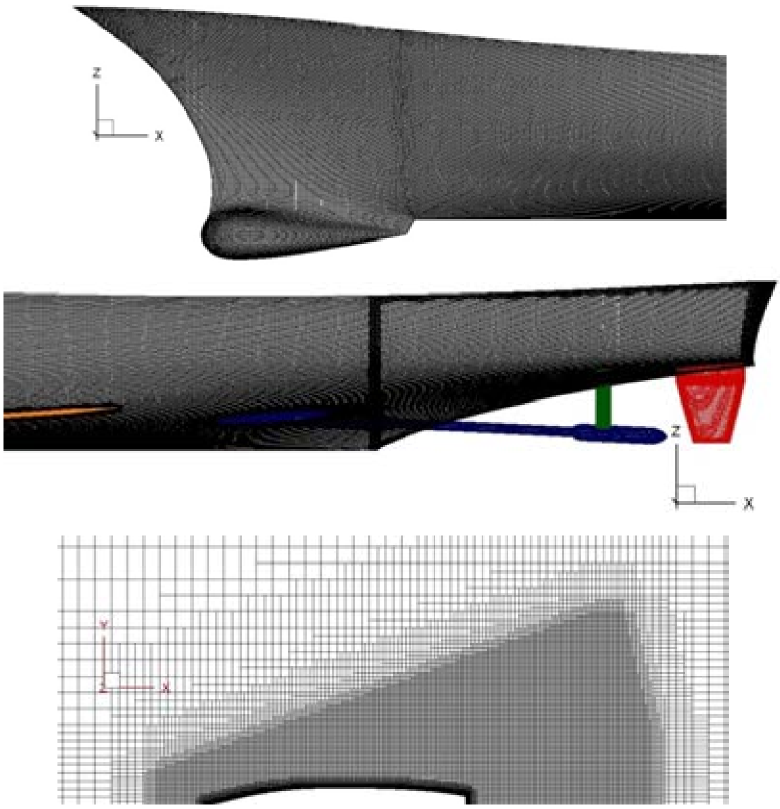


Fig. 3.
Discretization grid; bow (top), stern (middle) and free-surface (bottom)

3.1. Verification and Validation Results

Table 3 tabulates the comparison between computed and measured results, where WM is referring to wall modeled, WR is referring to wall resolved, while ε is referring the percentage relative difference between computed and measured results according to the relation: $\varepsilon=(100(CFD\text{-}EFD))/EFD$, where EFD is referring to the experimental results. M1, M2 and M3 indicate the fine, medium and coarse meshes, respectively. During the computation the hull is subdivided into its six main components: global appended hull, bare hull, bilge keel, shaft, brackets and rudders. The drag value is computed for every component individually. It is worth mentioning that the verification and validation is made based on the available bare hull results in (Olivieri et al, 2001), (Longo et al, 2007) and (Larsson et al, 2013).

Table 3
Total ship resistance coefficient C_T computed for the bare hull compared to the experimental results

Results	C_T EFD	C_T (WM), CFD		C_T (WR), CFD	
		k-ω SST	EASM	*k-ω SST*	EASM
M1	4.23×10^{-3}	4.415×10^{-3}	4.359×10^{-3}	4.057×10^{-3}	4.098×10^{-3}
ε		4.37%	3.05%	-4.09%	-3.12%
M2		4.545×10^{-3}	4.513×10^{-3}	4.293×10^{-3}	4.275×10^{-3}
ε		7.44%	6.69%	1.49%	1.06%
M3		4.561	4.551×10^{-3}	4.363×10^{-3}	4.334×10^{-3}
ε		7.82%	7.59%	3.14%	2.45%

The computed solutions show a reasonable agreement with the experimental results. The relative error range for wall modeled is varying between 4.37 and 7.82% for *k-ω SST*, while for EASM the error is between 3.05 and 7.59%, a fact that shows that for the coarsest mesh, the error is relatively significant. On the other hand, the error for the wall resolved model shows an under predicted value for the total resistance coefficient computed on the finest mesh whereas, on the opposite, the coefficient is over predicted for the other meshes. Yet, the absolute range of error remains between 1.06 and 4.09%, which can be considered as acceptable.
From the verification of results point of view, all the results are showing a monotonic convergence. However, the difference between fine and medium grid is significant compared to the difference between medium and coarse grids.

This might require an investigation of an extra grid, preferably with a density between the fine and medium grid to perform accurately the Richardson Extrapolation verification test.

3.2. Velocity Effect

For this case, the Froude number is chosen for three working conditions *Fr*=0.1, 0.28 and 0.41. These cases are computed only for the wall resolved on the medium mesh, considering the fact that the computed results showed a good agreement with the experimental results. The results also include a detailed definition for the drag force produced by hull components separately. Table 4 summarizes the resistance forces produced by the fully appended hull and hull components.

Table 4
Resistance results for the fully appended hull and for hull components individually

Fr	Turbulence Model	Hull Component Force [N]					
		Fully appended	Bare Hull	Bilge Keel	Shaft	Shaft Brackets	Rudder
0.1	*k-ω SST*	6.108	5.292	0.088	0.266	0.232	0.23
	EASM	7.184	5.402	0.112	0.302	0.15	0.21
0.28	*k-ω SST*	56.878	45.654	1.62	3.63	2.624	3.35
	EASM	55.728	45.458	1.658	3.556	2.02	3.036
0.41	*k-ω SST*	176.776	151.872	4.506	5.98	5.706	8.712
	EASM	178.528	154.156	4.586	5.654	5.748	8.384

It can be noticed from Table 4 that the bare hull ship resistance value is having a good match with the EFD results for both turbulence models. Error values, computed for bare hull as previously explained, for *Fr*=0.1 is 3.32% for *k-ω* SST and 1.31% for EASM, while at *Fr*=0.28 is 1.49% and 1.06% for *k-ω SST* and EASM, respectively and finally for *Fr*=0.41 the error values are 0.55% and 0.95% for *k-ω SST* and EASM, respectively.

Similarly, the sinkage value computed after 30 seconds for *k-ω SST* and EASM at different Froude number is tabulated in Table 5 and compared to the towing tank experimental data for the bare hull ship resistance found in (Olivieri et al, 2001). The relative sinkage error between computed and experimental results at *Fr*=0.1 is 14.9% and 14.32% for *k-ω SST* and EASM, respectively. This value is considered significant compared to the other errors obtained so far. This might be due to the poor grid quality. The other values for sinkage and trim errors at higher Froude numbers show a reasonable agreement with the computed results.

Table 4.
Sinkage and trim values computed for the fully appended hull compared to the measured value in (Olivieri et al, 2001)

Fr	Sinkage EFD	CFD		Trim EFD	CFD	
		k-ω SST	EASM		k-ω SST	EASM
0.1	0.174×10^{-3}	0.148×10^{-3}	0.149×10^{-3}	0.018	0.0192	0.0192
ε		14.9%	14.32%		6.67%	6.67%
0.28	1.82×10^{-3}	1.892×10^{-3}	1.891×10^{-3}	0.108	0.1073	0.1107
ε		3.96%	3.95%		0.65%	2.5%
0.41	4.7×10^{-3}	4.635×10^{-3}	4.642×10^{-3}	0.421	0.441	0.439
ε		1.38%	1.23%		4.75%	4.27%

3.3. Free-Surface and Local Flow Analysis

The free-surface is then computed for the three different Froude numbers for 30 seconds of simulation. Since the free-surface elevation for the fully appended ship is not provided, the comparison of the free-surface topology for a validation purpose will be made for the numerical solution in this simulation of the fully appended ship and the experimental results for the bare hull ship, assuming that, the appendages located at a sufficiently far distance from the free-surface should not have a significant effect on the free-surface topology. The comparison of the free-surface results at *Fr*=0.28 is brought into attention in Fig. 4 where the computed results are plotted versus the experimental results obtained in (Longo et al., 2007).The comparison shows a reasonable agreement with the experimental data, especially in the fore part of the ship where the appendages should have no effect on the free-surface. Heading more downstream, one can distinguish a slight difference between the computed free-surface and the measured one nearby and past the aft shoulders.

Figure 5 depicts the development of the free-surface topology corresponding to the change in the Froude number. The results reveals the aforementioned problem regarding to the cell size chosen for the *Fr*=0.1 which shows a noticeable under prediction for the free-surface around the ship. This might require an extra refinement for the free-surface grid to enhance the results. The free-surface for the other Froude numbers seems to be well developed seemingly due to a more accurate meshing in respect to the wave length. It is worth mentioning that the undisturbed free-surface is positioned at z=0.248m.

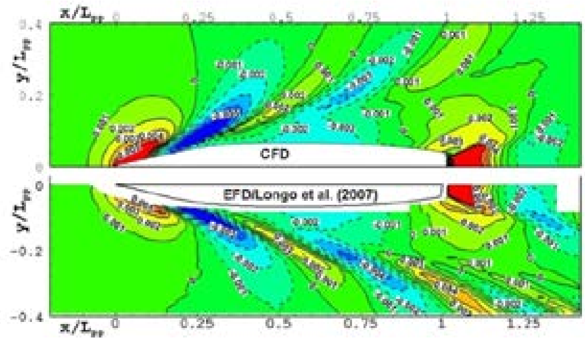


Fig. 4.
Comparison between computed free-surface at T=30 seconds for the fully appended ship and measured Free-surface for bare hull (Longo et al, 2007)

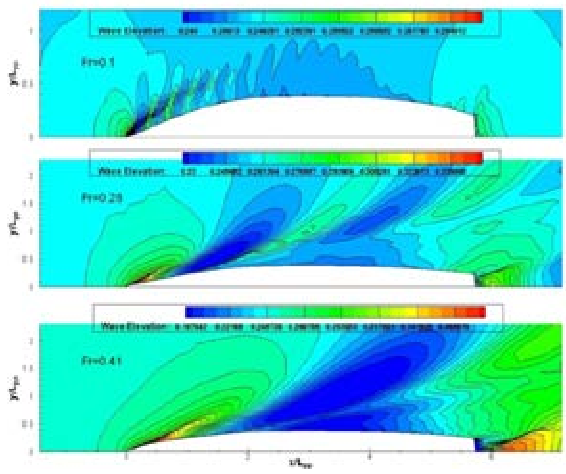
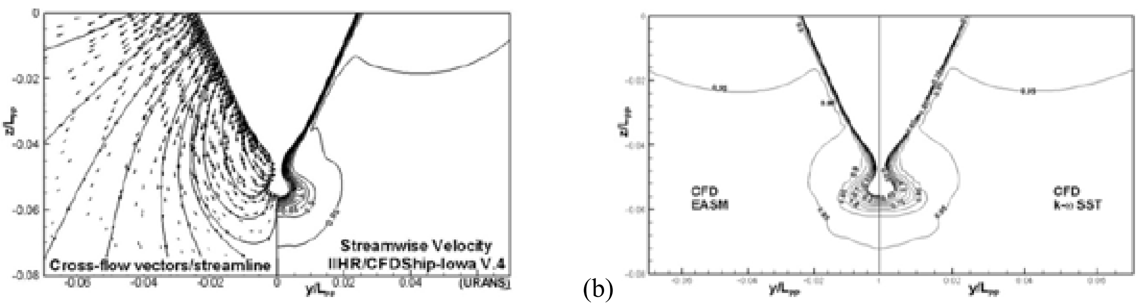


Fig. 5.
Free-surface topology computed at T=30 seconds at Fr=0.1, 0.28 and 0.41

Local flow prediction around the hull represents a significant challenge due to its complicated geometry and the existence of the appendages which tend to change dramatically the flow configuration around the hull. For a validation reason, the streamwise velocity contours are drawn in a plane distanced from the forward perpendicular at x/L_{pp}=0.1. The CFD solutions are compared with the data obtained for the bare hull in (Larsson et al, 2013), assuming that the flow before the appendages should not be significantly affected.



(a) (b)

Fig. 6.
Comparison between streamwise velocity computed at T=30 seconds k-ω SST and EASM models compared to other computed results by IIHR/CFD ship-Iowa V4
Source: (a) Gothenburg workshop on CFD in ship hydrodynamics (Larsson et al, 2013)

As it is obviously shown in Fig. 6, the agreement between the current simulation and the data provided in *(Larsson et al, 2013)* is allowing the authors to assume that the results for the rest of the wake flow should be within an acceptable level of accuracy. For this reason, three different cuts are presented in Fig. 7 for every appendage to show the flow distribution around the appendage. The distance for these sections are x/L_{pp}=0.6818, 0.9327 and 0.9948 from the forward perpendicular, respectively. The streamwise velocity contours plotted for these sections are showing the viscous effect and vortex development from the shaft as it can be seen in Fig. 7.c.

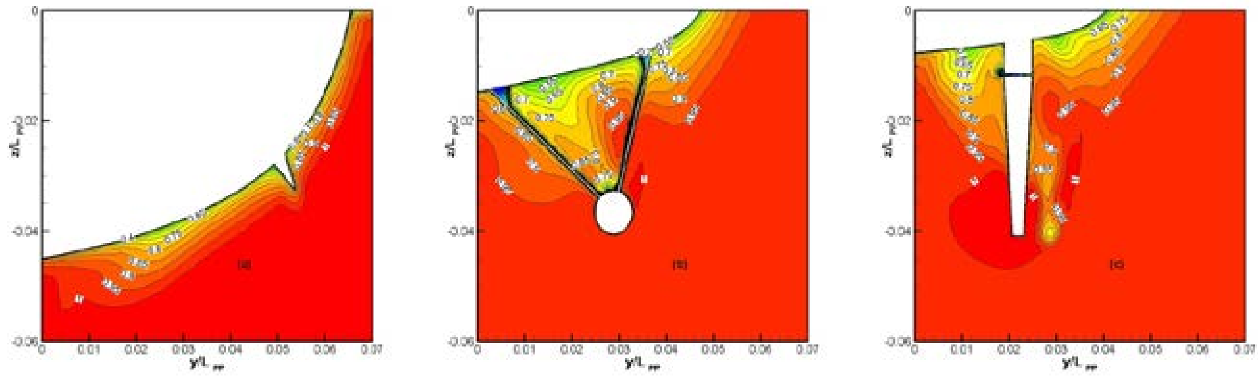


Fig. 7.
Streamwise velocity contours computed at T=30 seconds around the appendages: (a) bilge keel, (b) shaft and shaft brackets and (c) rudder

Figure 8 bears the comparison between the *k-ω* SST and EASM solutions used to predict the streamwise velocity contours and turbulent kinetic energy contours along the hull at 11 different sections distanced $\Delta x/L_{pp}$=0.1. The comparison shows the capability of both turbulence models to predict, at least at a qualitative level, the flow development around the hull. It can be noticed that the sonar dome produces a vortical structure pattern around the hull which tends to vanish in the downstream due to the viscous interaction. One more vortical configuration can be seen in the last cross-section, which is produced by the cap of the propeller shaft. The computed solutions reported in here are in a good agreement with the results previously reported (Lungu and Pacuraru, 2010).

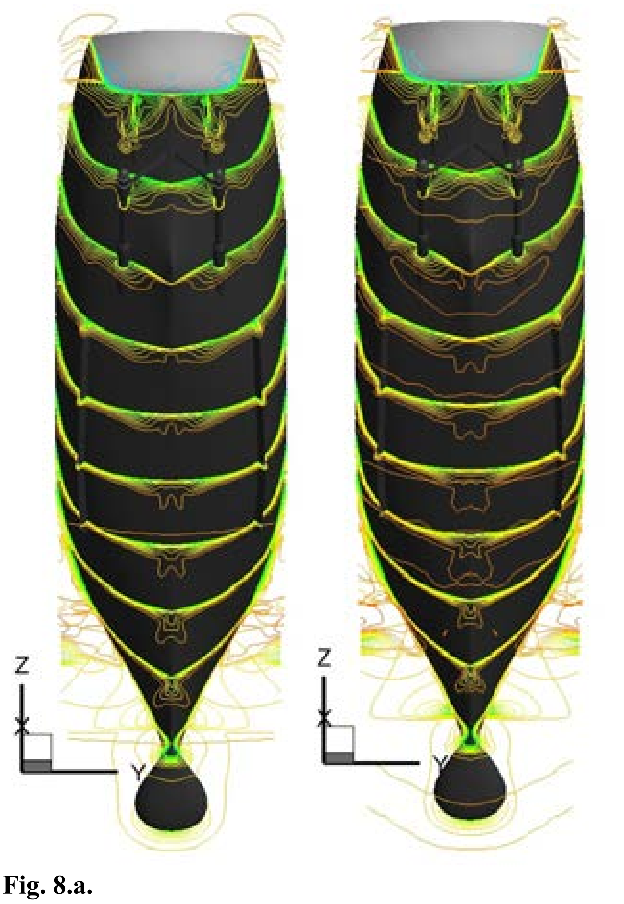


Fig. 8.a.
Comparison between streamwise velocity contours computed at T=30 seconds using k-ω SST (left) and EASM (right)

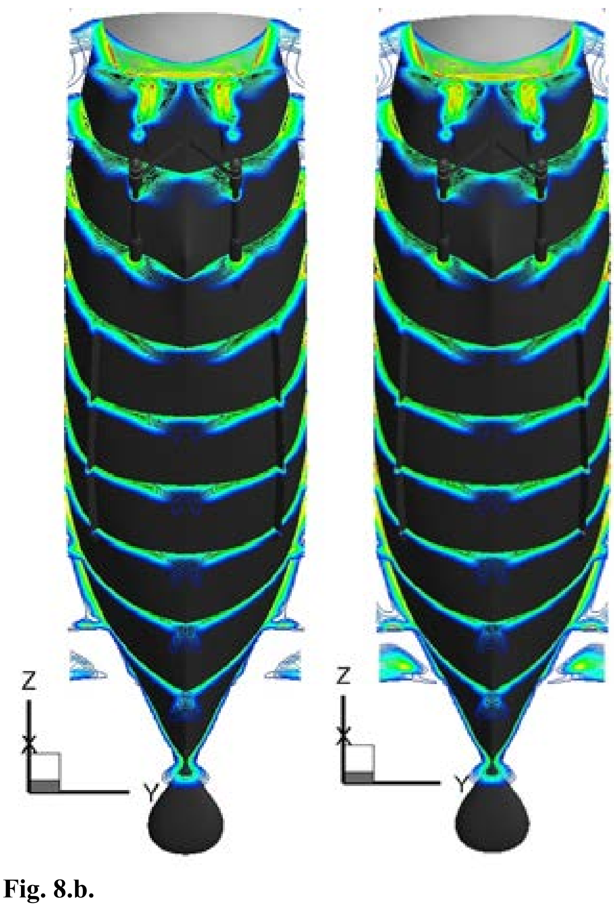


Fig. 8.b.
Comparison between turbulent kinetic energy contours computed at T=30 seconds using k-ω SST (left) and EASM (right)

4. Concluding Remarks

The study presented the total ship resistance prediction of the fully appended DTMB 5415 ship model. Different sets of CFD simulations were performed based on a viscous flow solver of the RANS equation where the turbulence was modeled based on *k-ω* SST and EASM models. The computed results were validated based on comparisons with the experimental results showing an encouraging agreement for ship resistance, sinkage and trim, free-surface and local flow prediction. Summing up the details presented in this study, the following concluding remarks can be drawn:

- For the total resistance prediction, the verification and validation study showed a reasonable agreement with the experimental results for the design speed and also for the different velocities; however, the verification study showed the need to analyze one more grid to enhance the results;
- The results for ship motion including sinkage and trim were well predicted except for the lowest velocity due to the fact that the refinement criteria were implied for a higher velocity, showing the need for extra refinement;
- The free-surface prediction was encouraging, except for the lowest Froude number, where the previously mentioned problem still exists;
- Local flow analysis showed a relative success in predicting the streamwise velocity contours and turbulent kinetic energy around the hull compared to experimental and previous simulations presented in the literature. The vortical structure of the sonar dome and the shaft cap were well predicted. Nevertheless, the overall accuracy of the local flow prediction can be enhanced by using local refinement nearby the hull;
- Finally, more rigorous investigation is required to enhance the overall results accuracy.

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NUMERICAL STUDY OF THE RESISTANCE, FREE-SURFACE AND SELF-PROPULSION PREDICTION OF THE KVLCC2 SHIP MODEL

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Abstract: The paper proposes an alternative method totally dependent on the use of CFD simulation to solve ship hydrodynamic problems as an alternative to the classical tank tests. The case study for this paper is the modified ship model of the Kriso Very Large Crude Carrier (KVLCC2). A series of numerical investigations are performed including: ship resistance computations with and without rudder, free-surface flow prediction for the design speed, wake flow structure investigation in the stern, propeller open water simulation and finally the self-propulsion prediction for ship with and without the rudder. Results are presented and compared with the available tank test results provided in the Gothenburg 2010 Workshop on CFD in Ship Hydrodynamics to investigate the accuracy of numerical simulation in comparison with the classical methods. A comprehensive study is brought into focus for clarifying various issues such as the wake flow structure, propeller open water test, self-propulsion with and without the rudder, all aimed at achieving a better understanding of the interaction between the ship hull, propeller and rudder. The results show an encouraging overall agreement with the available experimental data.

Keywords: Free-surface flow, POW, RANS, self-propulsion, ship resistance.

1. Introduction

There is a wide range of ship hydrodynamic problems a naval architect has to deal with, starting from the fundamental ship resistance and powering problems, heading through free-surface, self-propulsion, seakeeping and maneuvering. A need for an easy, quick and reliable tool is essential for primary design stage. Traditionally, the reliance on the experimental tests was the trend until the mid-nineteenth century. In fact, the method is well recognized as the most accurate and reliable; yet, it is still very expensive and complicated. The other alternative is the theoretical based method, which can provide a quick solution for predicting ship resistance and powering based on empirical equations and formulas deducted for specific types of ships. This method is very cheap and simple to use; unfortunately, it is restricted to the ship type and sometimes dimensions. Besides, there are no details at all regarding the flow configuration around the hull or at the free-surface. Since 1960s, the computational fluid dynamics (CFD hereafter) has shown a great progress that made the CFD one of the most recognized tools nowadays used for ship design and optimization, due to its flexibility and capability to provide very good details for the flow around the ship hull. The turning point in CFD simulations started in the 1980s when the Reynolds-Averaged Navier-Stokes Equation (RANSE hereafter) method was conceived to solve the wake flow of the stern. A rigorous investigation and development started in the 1990s regarding the turbulence modeling to provide more accuracy in predicting the bilge vortices in the stern wake at the propeller. The development in the RANS solvers since that time has reached a remarkable level. Recently, the CFD method reached a top level of accuracy that encouraged the researchers to think of what so called "Simulation Based Design, SBD" techniques to replace the classical method based on experimental or theoretical based design (Stern et al, 2003).

In this paper, a CFD technique is used to solve some of the ship hydrodynamic problems including ship resistance, free-surface, wake flow prediction, propeller open water (POW, hereafter) and finally self-propulsion. The case study for this paper is the modified hull of the Kriso Very Large Crude Carrier (KVLCC2 hereafter). The ship was conceived to provide data for both explication of flow physics and CFD validation for a modern tanker ship with bulb bow and stern. The full scale ship does not exist; however, several models were built and tested by various international well recognized towing tank organizations in the world such as NMRI in Japan, INSEAN in Italy and HMRI in Korea. Several experiments were performed, including ship resistance and free-surface, seakeeping, and maneuverability. In this case study, the INSEAN ship model is used for validating this simulation which has a length between perpendiculars of 7.0m and a draft of 0.455m, while the propeller diameter is 0.204m. Full details of the ship characteristics are tabulated in Table 1, as the geometry of the ship including propeller and rudder is depicted in Fig.1.

A set of test cases is chosen in respect to the Gothenburg 2010 (Larsson et al, 2013) test cases, which comprises ship resistance of the fixed hull without the propeller or rudder, free-surface, flow configuration around the hull, ship resistance with rudder including sinkage and trim. The other set of computations includes POW simulations carried

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out for the same conditions as those provided in SIMMAN 2008 (Stern et al, 2011) and (SIMMAN, 2014) workshops.

Table 1
Particulars of the KVLCC2 ship model, rudder and propeller.

Ship		Propeller		Rudder	
Parameter	**Value**	**Parameter**	**Value**	**Parameter**	**Value**
Length between Perpendiculars, L_{pp} [m]	7.0	Diameter, D_p [m]	0.204	Rudder type	Horn
Beam, B [m]	1.1688	Boss ratio, D_h/D_p	0.165	Rudder area, S_R [m^2]	0.1308
Depth, D [m]	0.6563	Pitch ratio, P/D_p	0.808		
Draft, T, [m]	0.4550	Expanded area ratio, A_E/A_0	0.448		
Block Coefficient, C_B	0.8098	Number of blades, Z	4		
Displacement, [m^3]	3.2724	Direction of rotation	clockwise		

Fig.1.
3-D geometry of the KVLCC2 ship model with propeller and rudder

2. Numerical Approach

The numerical simulation is performed by making use of the ISIS-CFD solver of the commercial software Fine^{TM}/Marine of NUMECA. The solver is based on finite volume method to build the spatial discretization for the governing equation to solve the incompressible steady RANSE in a global approach (Guilmineau et al, 2015). Closure to the turbulence is achieved by making use of either the *k-ω SST* model or EASM model. Pressure-velocity coupling is enforced through a Rhie & Chow SIMPLE method where the velocity updates come from the momentum equation and the pressure is extracted from the mass conservation constraints transformed into a pressure equation. Convection and diffusion terms in the RANSE are discretized by a second-order upwind scheme and a central difference scheme, respectively.

2.1. Governing Equations

For incompressible flows, if there are external forces, the averaged continuity and momentum equations are given in tensor form in the Cartesian coordinate system by:

$$\frac{\partial(\rho \bar{u}_i)}{\partial x_i} = 0 \quad (1)$$

$$\frac{\partial(\rho \bar{u}_i)}{\partial t} + \frac{\partial}{\partial x_j}\left(\rho \bar{u}_i \bar{u}_j + \rho \overline{u_i' u_j'}\right) = -\frac{\partial \bar{p}}{\partial x_i} + \frac{\partial \bar{\tau}_{ij}}{\partial x_j} \quad (2)$$

where $\bar{u}_i$ is the relative averaged velocity vector of flow between the fluid and the control volume, $\overline{u_i' u_j'}$ is the Reynolds stresses, $\bar{p}$ is the mean pressure and τ_{ij} is the mean viscous stress tensor components for Newtonian fluid under incompressible flow assumption, and it can be expressed as

$$\bar{\tau}_{ij} = \mu\left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right) \tag{3}$$

For resistance and self-propulsion computations, the flow is accelerated through a steady quasi-static approach within a time-span corresponding to the relationship between the length of the ship and the inflow velocity such that $T_{acc}=2.0L_{pp}/U_\infty$. Computations are performed for 30 seconds using 10 iterations per time step, while the time step is chosen with respect to the equation $\Delta t=0.005L_{pp}/U_\infty$ for *k-ω SST* model and $\Delta t=0.001L_{pp}/U_\infty$ for EASM model as it is suggested by the ITTC recommended procedures for CFD (ITTC, 2014). The free-surface is captured in an air-water interface based on volume of fluid (VOF) method. On the other hand, for the POW simulation, the solution is based on an unsteady RANSE. The flow is accelerated within 200 time steps, while the time step is chosen to provide 100 time steps per propeller complete rotation based on the rotating frame method. Only EASM is used for the POW computation, which can provide better results for the propeller wake based on the previous experience from previous simulations (Lungu, 2018). All the computations are performed in respect to an earth-fixed Cartesian reference frame.

2.2. Computational Domain and Discretization Grid

For resistance and self-propulsion simulations, the computational domain is having a rectangular configuration. Dimensions of the computational domain in (*x*–*y*–*z*) direction are ($5.0L_{pp}$–$2.0L_{pp}$–$2.0L_{pp}$) distributed as $1.0L_{pp}$ upstream, $3.0L_{pp}$ downstream, $2.0L_{pp}$ on the side, $1.5L_{pp}$ underneath the undisturbed free-surface and 0.5 above the undisturbed free-surface level. Taking into account the symmetry of the hull and neglecting all the lateral motions, only half ship is used in the ship resistance simulation to simplify the problem and reduce the number of grid cells required, while for the self-propulsion simulation, the entire ship hull is used.

The computational domain dimensions and boundary conditions for self-propulsion and POW are depicted in Fig. 2. Worth noticing the computational domain for the ship resistance computation is similar to the self-propulsion domain, except it has half the domain size in *y*-direction with a symmetry boundary condition applied on the ship centerline plan.

For POW simulation, the domain is of a cylindrical shape whose diameter is 6.0 times the propeller diameter D_p, and length is extended over $8.0D_p$. An isotropic refinement cylinder is applied in the propeller vicinity having a diameter $1.2D_p$ and extended downstream for $4.0D_p$, as described in Fig. 2. The boundary conditions applied on the boundaries are: for the inflow and cylinder side, a far field with the free stream velocity imposed, while the pressure is imposed on the outlet boundary. No slip condition is applied on the propeller solid wall, and a slip condition is applied on the propeller shaft.

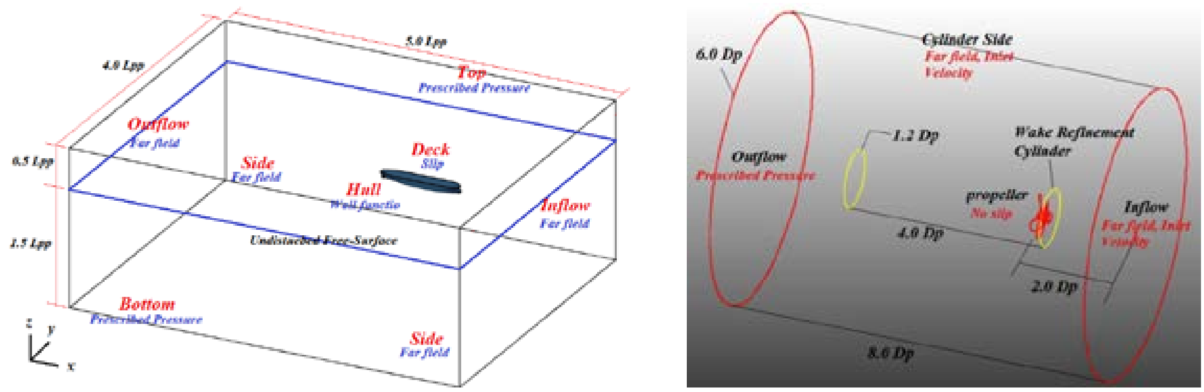

Fig. 2
Computational domain dimensions and boundary conditions: self-propulsion (left) and POW (right)

2.3. Discretization Grid

The computational grids are generated by making use of the automatic unstructured grid generator HEXPRESS available in the NUMECA software. Several sets of grids are generated and tested for bare hull, ship with rudder, POW and self-propulsion test. A local isotropic refinement is applied for the zones of interest to predict the flow characteristics, such as the wake flow region of the hull with and without rudder, the wake region of the propeller working in open water and finally for the actuator disk zone in self-propulsion simulation. Two different approaches are used to model the rudder; the real rudder modeling, which includes the semi-suspended rudder configuration with the actual stator and rotor parts and the simplified rudder which is used to eliminate the gaps between the stator and the rotor parts of the rudder to reduce the total number of grid cells during the simulation. Both methods are used to compute the solution for the design speed and shows being in a close agreement. For that, the analysis of resistance for the case of rudder is used based on the simplified rudder approach and it shows to have a good agreement with the experimental results. However, for the wake flow details, the actual rudder is used to simulate the real case problem. Details for the discretization grids are tabulated in Table 2, while the grid configuration for the ship with rudder and for the propeller in POW simulation is depicted in Fig. 3.

Table 2
Number of cells used for discretization grids

Computational Grid	Ship Resistance		POW	Self-propulsion		
	Bare hull	with simplified Rudder		Bare Hull	Simplified rudder	Actual Rudder
Number of grid cells	20.33 M	4.75 M	10.67 M	17.78 M	20.21 M	21.58 M

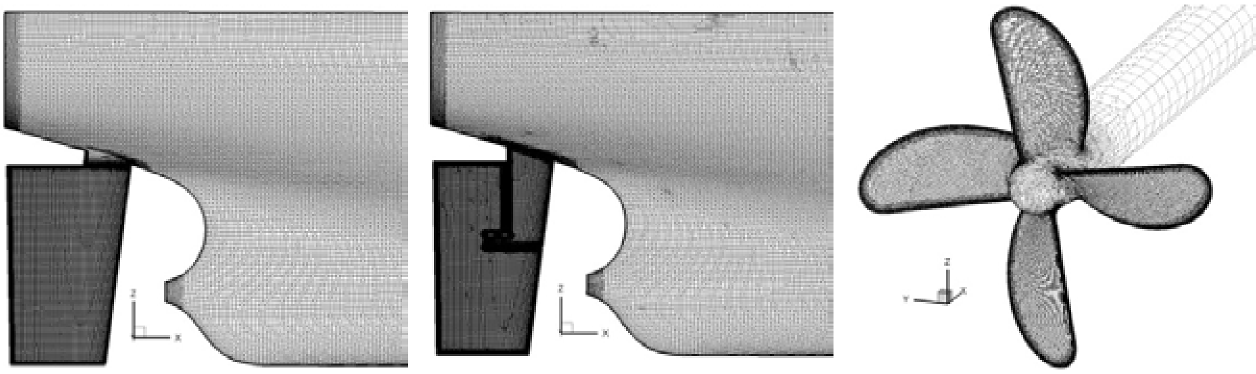

Fig. 3.
Discretization grid for ship with; simplified rudder (left) and actual rudder (mid) and propeller for POW test (right)

3. Results and Discussion

3.1. Resistance, Free Surface and Wake Flow

The results for resistance simulations are computed for ship with rudder including two degrees of freedom motion for sinkage and trim. The results are tabulated in Table 3 and compared to the experimental results showing a good agreement especially for case when turbulence is modeled using EASM. The relative error is computed based on the equation $\varepsilon = (100(EFD\text{-}CFD))/EFD$, where EFD refers to the experimental results while CFD refers to the computed ones. The maximum error in case for *k-ω* is within 7.5% while for EASM is about 4%. The results for sinkage and trim showed a relative similarity for both turbulence models; hence, the results are presented only for EASM results. The errors for sinkage and trim are significantly higher for lower ship velocities while it is within an acceptable range for higher velocities. This might be due to the fact that the free-surface refinement is chosen for a higher Froude number which tends to act as a wave damper wherever the velocity gets smaller, a fact that might change the water elevation around the hull, which leads to this increment in sinkage and trim errors. The Froude number is defined by $Fr=V/(gL_{pp})^{0.5}$.
The free surface results can be visualized in Fig. 4. The qualitative comparison for the free-surface topology is presented in Fig. 4a and compared to the EFD results provided in (Kim et al, 2001), while the quantitative results are plotted in Fig. 4b comparing the wave elevation at different cuts in the lateral direction distanced at y/L_{pp}=-0.0964 and -0.1581 from the hull. It can be clearly noticed that the computed results qualitatively and quantitatively are in a satisfying agreement with the EFD results.

Table 3
Resistance, sinkage and trim results compared to experimental results in (Larsson et al., 2013)

Fr		0.101	0.1194	0.1377	0.1423	0.1469	0.1515
Resistance C_T x10^3	**EFD**	4.237	4.146	4.071	4.056	4.046	4.037
	k-ω SST	3.937	3.838	3.786	3.797	3.744	3.937
	ε	7.1%	7.4%	6.9%	6.4%	7.5%	7.3%
	EASM	4.072	3.984	3.908	3.971	3.931	3.916
	ε	3.9%	3.9%	4.01%	2.1%	2.9%	3.0%
Sinkage σ×10-^{2} (m)	**EFD**	-0.147	-0.281	-0.409	-0.437	-0.472	-0.499
	CFD	-0.124	-0.251	-0.46	-0.461	-0.464	-0.485
	ε	-15.7%	10.7%	-12.4%	-5.4%	-1.6%	-2.8%
Trim τ°	**EFD**	-0.075	-0.1	-0.124	-0.132	-0.138	-0.154
	CFD	0.0651	0.089	0.117	0.126	0.134	0.15
	ε	13.2%	10.3%	6.1%	4.9%	3.1%	2.5%

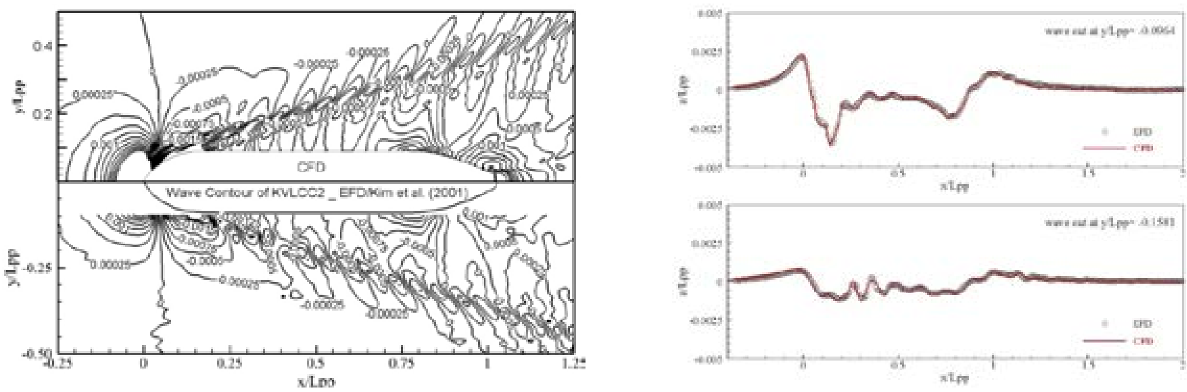

Fig. 4.
Free surface topology (left), and wave cuts at y/L_{pp}=-0.0964 and -0.1581(right)

Studying the stern wake flow can be very effective in enhancing the quality of the propeller design. The wake flow for this ship is characterized by the large distortion of the axial flow velocity contours caused by the stern vortices of the bilge resulting in the so-called “hook shape”. For a validation purpose, the development of the wake in the stern of the ship is compared with the experimental results at two different locations before and at the propeller plane placed at *x/L_{pp}*=0.85 and *x/Lpp*=0.9825, respectively. Though the contours are showing a slight under prediction of the streamwise velocity, the overall accuracy is satisfactory.

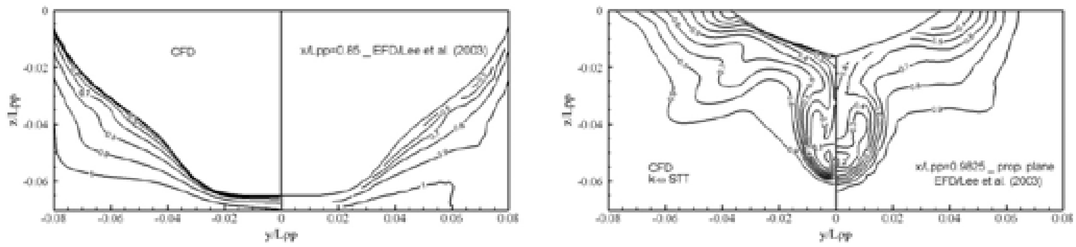

Fig. 5.
Streamwise velocity contours in x-direction at x/L_{pp}=0.85 and 0.9825 compared to EFD results

For the sake of getting a better insight into the wake flow, more details of the wake development in the stern is drawn in Fig. 6 for the locations chosen before and after the propeller for the velocity contours and the turbulent kinetic energy. The development of the vortices can be clearly seen in Fig. 6, where the first core of vortices structure starts at the stern bilge, a second vortical structure rises from the flow separation at the ship boss. Later, the two vortices are combined together and dissipate downstream due to the viscous diffusion.

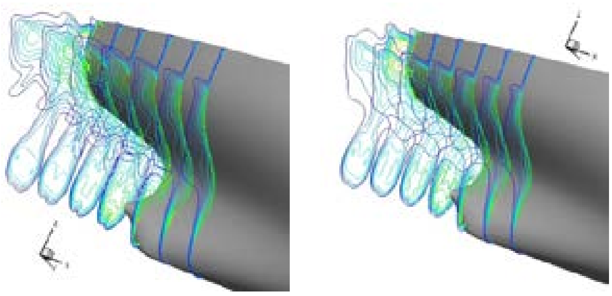

Fig. 6a.
Streamwise velocity contours at the stern using k-ω SST (left) and EASM (right)

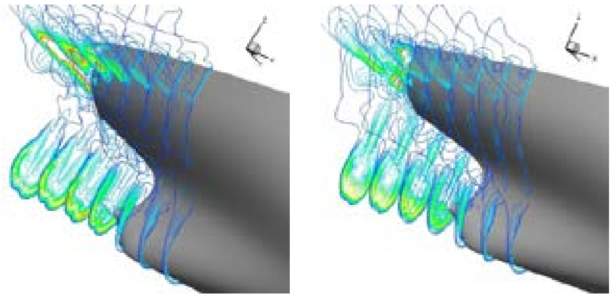

Fig. 6b.
Turbulent kinetic energy contours at the stern using k-ω SST (left) and EASM (right)

3.2 POW

The propeller model E689 is used for this study. The inflow velocity is kept constant, while the propeller rotation was changed accordingly to provide seven different values for the advance coefficient from J =0.1 to 0.7. The simulation is performed for 5 seconds and the thrust and torque coefficient K_T and K_Q are computed and compared to the experimental results. The comparison between the propeller performance curves can be visualized in Fig. 7. The average error for the thrust coefficient K_T is about 2.83% compared to the experimental results, while the average error for the torque coefficient K_Q is about 6.87%. The CFD results are in a reasonable agreement with the EFD except for the lower values of the advance coefficient where the slope of the K_Q noticeably differs.

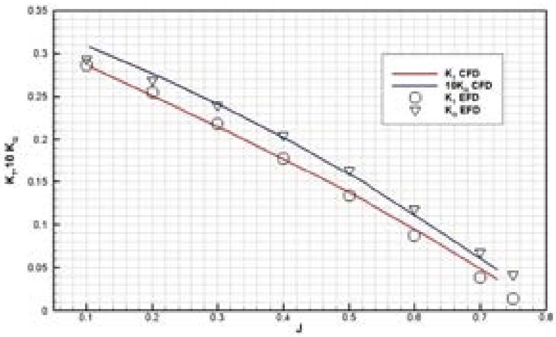

Fig. 7.
Open water propeller performance curves comparing CFD results with EFD

The study of propeller wake is influenced with different parameters; one of the most important factors is the vortices of the propeller which can result in a loss of energy, vibration or noise. The vortices generated by the propeller and their development in the wake region is depicted in Fig. 8, based on the iso-surface second invariant Q=50 colored by non-dimensional helicity, for three different cases corresponding to three different advance coefficients namely J=0.1, 0.4 and 0.7, respectively. Generally, the vortices show three types of spiral like structures; the first is released by the blade tips, the second by the propeller root and the third originates from the propeller hub. The intensity of the tip vortices seems to be higher than the intensity of the other ones. It can also be noticed that the hub vortices are suffering a local distortion in the downstream due to the significant change in the pressure and velocity in the far field and because of the viscous diffusion with the surrounding fluid downstream. The configuration of the vortical structures shows that its intensity and stability is affected by the propeller rotation, for higher advance coefficients the spiral structure seems to be more stable than that for lower ones.

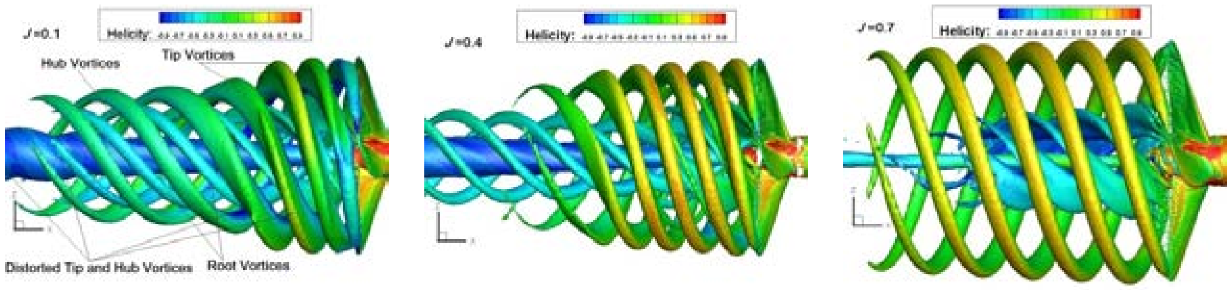

Fig. 8.
Vortical structure of the iso-surface Q=50 for J=0.1, 0.4 and 0.7 colored by non-dimensional helicity

3.3 Self-Propulsion

The simple body-force method is used to solve the self-propulsion in this study. The propeller is modeled as an infinite blade actuator disk instead of the actual propeller to simplify the problem and to increase the computational efficiency. The principle in the model is based on coupling the nominal wake obtained from RANSE solver with the open water data to solve the propeller behavior behind the ship. More details can be found in (Stern, 1994). The problem is solved for three different cases; bare hull ship, with simplified rudder model and ship with actual rudder, as previously described. The CFD results are computed for the self-propulsion parameters and compared with EFD results retrieved from (Win, 2014). Table 4 summarizes the comparison between CFD results and EFD results showing a reasonable agreement.

Table 4
Self-propulsion coefficients computed for ship with and without rudder compared to EFD results (Win, 2014)

Coefficient	Bare hull			With simplified rudder			With actual rudder		
	EFD	CFD	ε	EFD	CFD	ε	EFD	CFD	ε
Thrust coefficient, K_T	0.195	0.1983	-1.69%	0.198	0.208	5.05%	0.198	0.2022	2.12%
Torque coefficient, $10K_Q$	0.266	0.2307	-13.27%	0.228	0.2357	3.37%	0.228	0.2307	1.18%

For validation purpose, the effective wake including the interaction between hull-propeller-rudder is brought to attention in Fig. 9 for the streamwise velocity contours in *x*-direction at two selected sections in the wake region; at x/L_{pp}=1.0 and 1.025 from the forward perpendicular, respectively. The comparison shows a good agreement between CFD and EFD results.

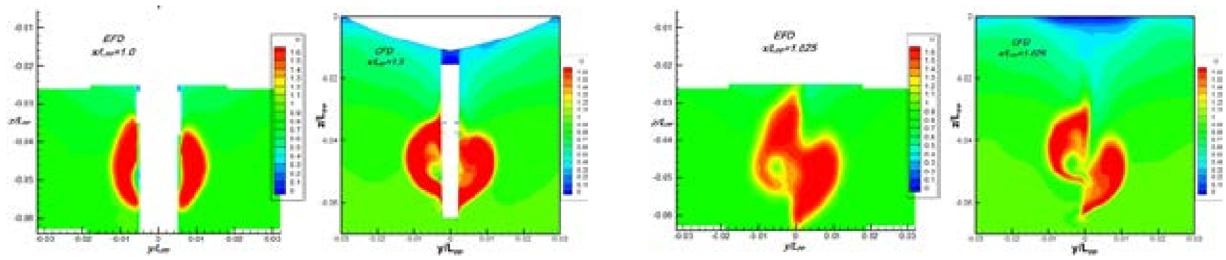

Fig. 9.
Streamwise velocity contours comparison between CFD and EFD

A closer look at the vortices in self-propulsion condition which can provide an explanation for the flow around the hull, propeller and rudder is plotted in Fig.10 for the second invariant iso-surface Q=100 colored by non-dimensional helicity. The vortices include three different vortical structures; the bilge vortices, the actuator disk tip vortices and the rudder leading edge vortices. The velocity and pressure distribution are also presented in Fig. 10 due to the correlation between velocity and pressure fluctuation that is considered as one of the reasons of generating the vortices.

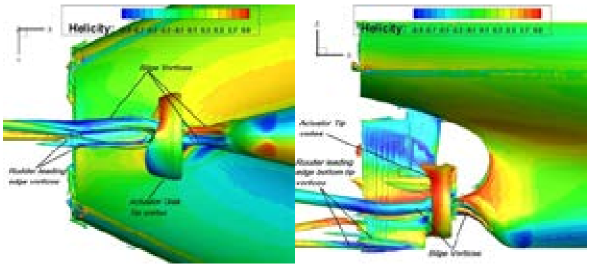

Fig. 10a.
Vortices structure bottom and side view

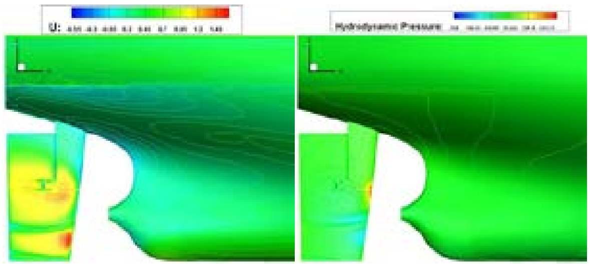

Fig. 10b
Velocity and pressure distribution at the stern

4. Conclusion Remarks

The objective of this paper was to investigate the versatility of the CFD tool to provide an alternate solution in the primary design stage of a ship compared to the experimental based methods. The objective was achieved by performing different simulations for different problems including ship resistance, free-surface, POW and self-propulsion. From the presented study, the following conclusions may be put forward:

- The resistance simulation showed that the EASM is having a higher level of accuracy with an error range between 2.1 and 4.01% compared to *k-ω SST* model which had an error range between 6.4 and 7.4%. Further enhancement of the computed results for both models can be achieved through extra verification and validation studies.
- Free-surface and local flow prediction showed to have a reasonable agreement with the EFD data, for both turbulence models.
- In POW simulation, average error for K_T is about 2.83% and for K_Q is about 6.87%, which can be considered as acceptable.
- In the self-propulsion simulation, the computed propulsion coefficients as well as the wake flow structure showed a noticeable agreement with the EFD results.

The overall agreement between CFD and EFD is satisfactory; yet, more rigorous validation studies are required.

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NUMERICAL SIMULATION OF THE HYDRODYNAMIC PERFORMANCES OF A SHIP MOVING IN ONCOMING WAVES

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Abstract: The Energy Efficiency Operational Indicator introduced by the International Maritime Organization as a method for monitoring the operational performance of a ship enables an assessment of the operational energy efficiency of a ship, which is expressed in terms of the CO_2 emitted per unit of transport work. Similarly, additional regulations related to the control of SO_x, NO_x, CO_2 emissions were introduced to monitor the fuel reduction through slow steaming, and improving or at least maintaining propulsive efficiency. Due to these regulations, CFD estimations become necessary therefore they gain more attention in the initial design stage. As a result, the CFD methods shifted from well validated steady resistance to more complex problems such as seakeeping and maneuvering. Since one of the main challenges is the accurate assessment of the added resistance of a ship in waves, the present work proposes a way of investigation the seakeeping performances for the KRISO Container Ship (KCS hereafter). The reason for choosing the KCS hull resides in the wide range of experimental and simulation data available for comparison and for verification and validation (V&V hereafter) of the method proposed in the present study. Five test cases of the ship model heaving and pitching in head seas are simulated at model scale. Special attention is given to the added resistance in waves since it may account for up to 15-30% of the total resistance in calm water. Validation is performed by comparing mean to fourth order harmonics of added resistance, heave and pitch motions with experimental data, while the verification is accomplished through a systematic grid refinement.

Keywords: Free-surface viscous flow, seakeeping, RANSE VOF.

1. Introduction

Understanding a ship behavior in real navigation conditions is important for estimating its hydrodynamic performances. Rough sea conditions leads to significant ship motions, which ultimately affect not only the ship resistance but also the propulsive efficiency. Since the fuel cost accounts for at least a half of the total operating costs, the problem becomes crucially important from economical point of view. Besides, the safety of the transported goods as well as the crew members' comfort on board are other important issues that motivate the need of a thorough insight into the subject. There are several ways to predict ship motions and added resistance in waves, including experiments, potential theories, and viscous flow solutions. The latter has gained popularity in the past decade due to a more physics-based modeling, capability of handling non-linear free-surface, especially for large amplitude waves and induced violent ship motions and breaking waves associated phenomena. Although at the beginning of the present century the theoretical approaches of the seakeeping were mostly based on the strip theory, mainly owing to its fast solution in spite of their drawbacks shown whenever were used for long incident waves or at high Froude numbers. The disagreements between strip theory and experiments for higher speed vessels, or geometric complicated hull forms, have therefore motivated research to develop and apply more advanced theories. A step forward has been made since the 3-D Rankine panel method began to be widely used in the numerical simulation with relative success at yet low computational costs. However, since important mon-linear phenomena that take usually place such as the wave breaking or the green-water occurrence cannot be predicted, another step had to be taken towards the use of the RANSE-based simulations. Several significant achievements were therefore reported in the past decade targeting not only to the resistance and powering computations of the full- and model-scale self-propelled hulls free to sink and trim, but also to the accurate prediction of the seakeeping performances at both full and model scale along with maneuvering calculations.

In the followings, a brief summary of the most important achievements will be provided. Lungu and Pacuraru performed a viscous free-surface flow simulation (2009) in which the solution of a RANS solver was coupled with a body force method in an attempt to investigate the flow features around a maneuvering containership equipped with a rotating propeller and rudder. Simonsen and Stern (2010) performed a comprehensive RANSE-based numerical simulations by using the CFDShip-Iowa code to obtain the heave and pitch motions and added resistance for the KCS model and the reported solutions proved to be accurate enough to motivate the effort paid. Enger et al. (2010) studied the dynamic trim, sinkage and resistance analyses of the model KCS by using the Star-CCM+ package. In their work, it was proven that the numerical solution agreed with the experimental data available in the public domain. In 2011 Carrica et al. reported two sets of computations for the KCS hull at model scale based on the use of the CFDShip-Iowa. The authors performed self-propulsion free to sink and trim simulations in calm water, followed by pitch and heave simulations in regular head waves, covering three conditions at two different Froude numbers of 0.26 and 0.33 respectively. Kim reported also in 2011 the results of the simulations performed on a 6500 TEU container carrier, being focusing on the global ship motions validated against the model test measurements. Later, Simonsen et al. (2013) investigated ship motions, flow field and resistance for an appended KCS model in calm water and regular head waves both experimentally and numerically. The authors focused mainly on large amplitude motions, and hence studied the near resonance and maximum excitation conditions. The results obtained using the CFD methods were compared to those from its experiments to show a satisfactory overall agreement. Similarly, Sadat-Hosseini et al. (2013) compared and verified the results from a CFD method and experimental for the KVLCC2 hulls in two different cases, i.e., with and without pitch

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motion. Tezdogan et al. (2015) compared the CFD viscous computation solution with the experimental data measured on the model KCS, then reported the results to the full-scale KCS in low-speed sailing, to investigate the differences. Although a great deal of promising results were reported, the prediction of added resistance is still difficult. At the 2010 Gothenburg Workshop (Larsson et al., 2013) and the 2015 Tokyo Workshop (Larsson et al., 2015), multiple researchers computed the added resistance of different ship hulls, and through cross-comparisons of the numerical solutions revealed that there is still enough room for further developments of the actual methods. Recently, the OpenFOAM open-source technique is rapidly gaining ground in various ship hydrodynamics applications. Among them some were already reporting encouraging progress. For instance, Park et al. (2013) developed SNUFOAM based on the use of OpenFOAM open source libraries to marine applications. Shen and Wan (2013) developed naoe-FOAM-SJTU and predicted added resistance at various wave stiffnesses. Shen et al. (2015) implemented dynamic overset grid technique into OpenFOAM to study the self-propulsion and maneuvering for the KCS model. Seo et al. (2016) reviewed numerical uncertainty for grid size, time step, and iteration number and identified the OpenFOAM uncertainty for a ship resistance simulation. An interesting study belongs to Vukcevic et al. (2016a, 2016b), who proposed a fluid dynamic hybrid model that combines a non-viscous computer code with a viscous one in an attempt to ensure both the efficiency and the accuracy of the solution.
The present research continues former numerical investigations on the KCS ship model reported by the author, which were aimed at computing ship resistance, the open water non-cavitating propeller (Lungu 2018a) and the cavitation on the K505 propeller (Lungu 2018b). The study is performed according to the requirements of the 2015 Tokyo Workshop (Larsson et al., 2015) for a ship moving in head waves at a Froude number of 0.261 in calm water and for a series of five oncoming waves of different wave lengths and heights.

2. Numerical Approach

The numerical solutions reported in the present paper are computed with the ISIS-CFD flow solver, part of the Numeca Fine^{TM}/Marine suite. Turbulent flow is simulated by solving the unsteady RANSE. The flow solver is based on finite volume method, which builds up the spatial discretization of the transport equations. The velocity field is obtained from the momentum conservation equations and the pressure field is extracted either from the mass conservation constraint, or from the continuity equation, transformed into a pressure equation. For turbulent flows the additional transport equations are discretized and then solved using the same strategy. The gradients are computed with an approach based on the Gauss theorem. A non-orthogonal correction technique is applied to ensure a formal second order accuracy. Inviscid fluxes are computed with a piecewise linear reconstruction associated with a stabilizing procedure which ensures a second order formal accuracy when flux limiter is not applied. Viscous fluxes are computed with central difference schemes. Based on the mesh quality, the model assures a second order discretization for the viscous term. Free-surface flow is simulated with a multi-phase volume of fluid approach. Incompressible and non-miscible flow phases are modeled through the use of conservation equations for each volume fraction of phase/fluid. An implicit scheme is applied for the discretization in time whereas a second order three-level time scheme is used for time-accurate unsteady computation. Velocity-pressure coupling is handled with a SIMPLE like approach. Although the free motion of the ship can be simulated with a 6 degrees of freedom (DOF hereafter) module, three degrees of freedom are kept fixed. An adaptive mesh refinement is employed for the seakeeping computations inside a hexahedral domain comprising the free-body and the free-surface. The EASM model is used for the turbulence closure and a viscous boundary layer consisting on 18 cells is introduced to keep the $y+$ below unity. All the computations are performed at the model scale and distributed over 120 processors. The length between perpendiculars (L_{pp} hereafter) of the model is 6.0702 m, while the maximum beam of waterline, and the draught are 0.8498 m and 0.285 m, respectively. The geometry of the hull and rudder are those officially provided by Larsson et al. (2015). Nine different grids are generated by the unstructured grid generator HEXPRESS^{TM} based on the provided geometry. Buffer cells as well as consistent inflation are used for achieving as high as possible quality cells inside the boundary layer regions for which the y^+ was kept below unity in most of the computations performed. Areas of a higher cell density are placed wherever the gradients of the computed physical parameters are expected to occur, i.e. around the ship hull and the free-surface of the water as Fig. 1 shows. Four grids denoted by $G1_{SK}$ to $G4_{SK}$ are generated at first for the grid convergence test. The $G1_{SK}$ grid is the coarsest one and consists of 3.46×10^6 cells, while the $G4_{SK}$ grid is the finest, which amounts 27.69×10^6 cells. In between the two, grid $G2_{SK}$ has 6.91×10^6 cells, whereas the $G3_{SK}$ grid has 13.86×10^6 cells. A wave damping zone has been inserted downstream and on the side of the domain, following the model described by Lungu and Mori (1993).

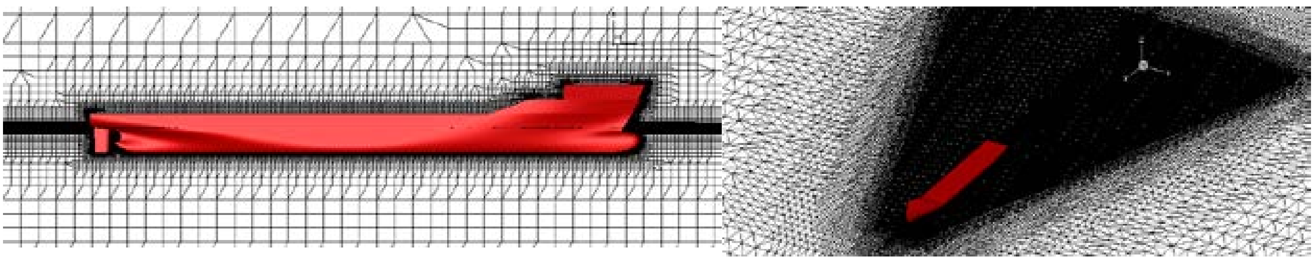


Fig. 1.
Computational Grid Around The Hull (Left) and on the Free Surface (Right)

2.1. Grid Convergence Test

At first, a series of four different unsteady computations in calm water at a speed of 2.017 m/s, to which the corresponding Froude number is 0.26, are performed on the $G1_{SK}$ to $G4_{SK}$ grids for verification and validation of the method purposes. The numerical solutions for the total resistance coefficient, sinkage and trim are tabulated in Table 1, where the computational case is denoted by C_0. The numerical solution computed in here is denoted by CFD whereas the experiment is denoted by EFD. As expected, Table 1 shows that the increase of the mesh resolution determines a reduction of the absolute computed error from 3.01 to 0.19 percent for the C_T, from 5.83 to 1.96% for the sinkage and from 8.02 to 2.13% for the trim angle. The higher levels of sinkage and trim errors compared to the corresponding one for the total resistance coefficient are attributable to the numerical technique, which did not employed any grid refinement neither close to the hull nor to the free surface, as it will be the case in the following simulations devoted to the seakeeping study. Although the level of the computed error may be considered as acceptable from an engineering point of view, it is worth mentioning that it is higher than the corresponding one for the solution computed in the previous work of the author, Lungu (2018b), in which a different size of the model was used. The difference may be attributable to the sensitivity the solver seemingly has on the scale of the model, as accepted by its authors, see Visonneau et al. (2006).

Table 1
Mean Values of the Total Resistance Coefficient (C_T), Sinkage (z), and Trim (θ) in Calm Water

C_0	Total resistance coefficient C_T				Sinkage z				Trim θ			
	Mean value ×10^3				Mean value ($/L_{PP}$)				Mean value [deg.]			
CFD	$G1_{SK}$	$G2_{SK}$	$G3_{SK}$	$G4_{SK}$	$G1_{SK}$	$G2_{SK}$	$G3_{SK}$	$G4_{SK}$	$G1_{SK}$	$G2_{SK}$	$G3_{SK}$	$G4_{SK}$
	3.7196	3.7385	3.7451	3.8422	-0.00195	-0.00196	-0.00201	-0.00203	-0.1514	-0.1576	-0.1584	-0.1611
EFD	3.835				-0.002070667				-0.1646			
ε %	3.01%	2.52%	2.34%	-0.19%	5.83%	5.34%	2.93%	1.96%	8.02%	4.25%	3.77%	2.13%

Fig. 2 bears out the free surface topology for the calm-water simulation performed on the $G4_{SK}$ mesh. It is worth noticing that both wave systems, i.e. diverging and transversal ones, are successfully captured. No wave reflections are detected on the downstream and lateral boundaries, a fact that may suggest not only the appropriateness of the boundary conditions formulation, but also the efficiency of the wave damper introduced there. As expected, two significant wave crests are detected in the immediate vicinity of the bow and right behind the hull transom.

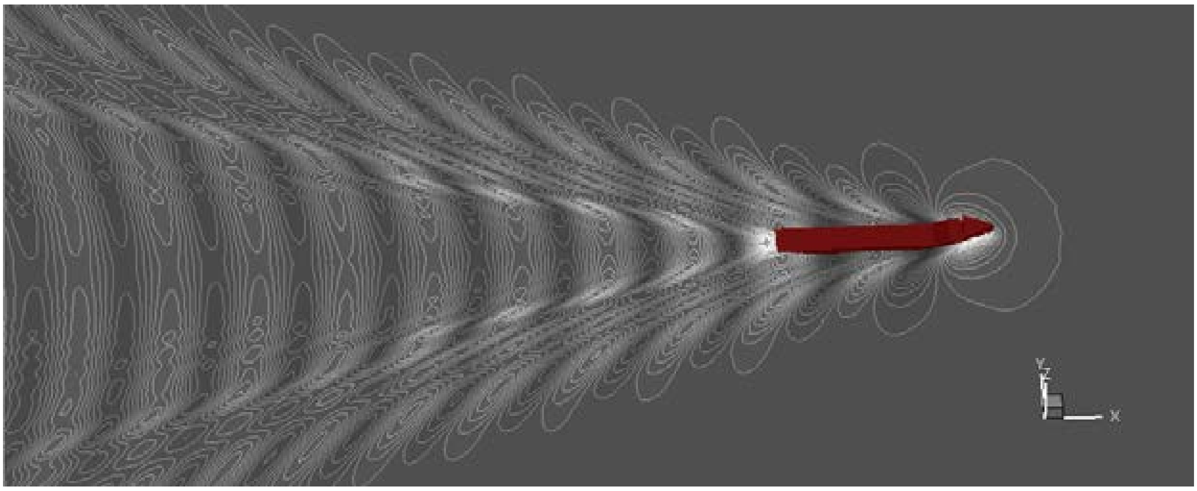


Fig. 2.
Computed Free-Surface Topology Around the Ship Hull

Based on the grid convergence test findings, in the followings all the seakeeping computations will be performed on the $G4_{SK}$ mesh only, slightly modified from the cells number point of view, from case to case, depending on the incident wave lengths and heights.

3. Seakeeping Results and Discussions

A series of five computations are performed to numerically simulate the model behavior in different oncoming wave 3DOF scenario. The heave and pitch motions are reported to the center of gravity of the hull and the wave crest at FP when t=0. The parameters of the five oncoming waves are: (a) - λ=3.949 m, Hs=0.062m; (b) - λ=5.164 m, Hs=0.078m; (c) - λ=6.979 m, Hs=0.123m; (d) - λ=8.321 m, Hs=0.149m and (e) - λ=11.840 m, Hs=0.196 m. Let these test conditions be denoted by $C_1 \ldots C_5$, for which the ratios between the wave length λ and the L_{pp} are 0.65, 0.85, 1.15, 1.37 and 1.95, respectively. The numerical analysis is further performed in terms of the harmonic amplitudes and harmonic phases of the total resistance coefficient (C_T), heave motion ($z/\zeta s$) and pitch angle ($\theta/k\zeta s$), which are reconstructed from the Fourier series. Because of the limited space reasons only the C_0 and C_5 solutions will be discussed in the following three subsections of the paper. The corresponding free-surface topologies computed for the aforementioned solutions are depicted in Fig. 3 and Fig. 4, respectively. The reason for the author's choice is that the two computational conditions are the most difficult to obtain since the wave heights are at extremities. That is, the smallest one requires a special attention from the meshing point of view, whereas the largest one is witnessing strong non-linear effects as possible green water embarking on the deck.

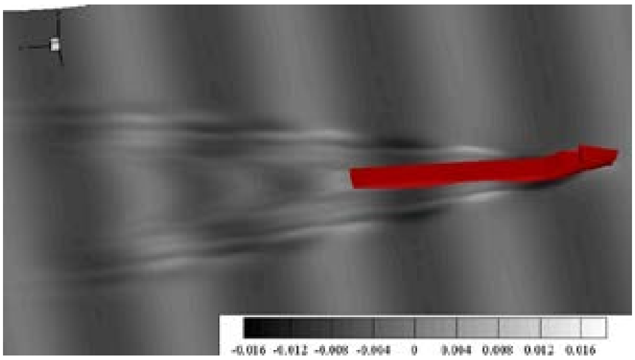


Fig. 3.
Computed free-surface the ship hull for the C1 computational scenario (oncoming wave of λ/Lpp=0.65)

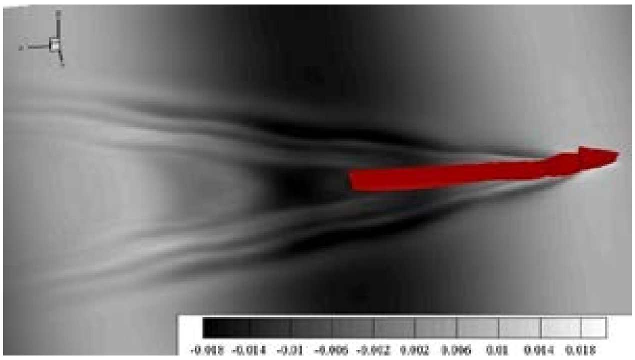


Fig. 4.
Computed free-surface the ship hull for the C1 computational scenario (oncoming wave of λ/Lpp=1.95)

3.1 Amplitudes and Phases of the Total Resistance Coefficient

Table 2 contains the comparisons between the Fourier decomposition of the computed solution denoted by CFD and the corresponding measured one by Larsson et al. (2015) for the two computational scenarios considered in here. Fig. 5 depicts the Fourier decomposition graphs for the total resistance coefficient for the two non-dimensional wave lengths considered in the present paper. The comparison performed in terms of the amplitude and phase reveals a level of errors ranging from 1.34% and 13.41% for amplitude and from 2.72% and 6.81% for phase. In both cases the largest departures correspond to the 3rd and 4th harmonics, seemingly due to the fact that the amplitudes 3rd and 4th harmonics are small compared to the amplitude of the 0th and 1st harmonics and consequently more difficult to capture, as Fig. 5 clearly shows. Nevertheless, it is worth noticing that the solutions reported in the present work are far less than those reported by Larsson et al. (2015), a fact that may suggest the accuracy of the computational method employed. The analysis of the 10 solution submitted to the Tokyo Workshop revealed an absolute average error for the 0th harmonic of 4.72% for the C_1 computational case and of 6.12% for the one denoted by C_5. For the first harmonic the comparison between the solutions submitted at the 2015 Tokyo Workshop and the experimental data revealed absolute average errors of 20.04% for λ/Lpp=0.65 and 11.97% for λ/Lpp=1.95. In terms of phase absolute errors, they varied from 4.45% to 5.20% for the first harmonics computed for λ/Lpp=0.65 and from 10.06% to 13.07% for λ/Lpp=1.95 for the 2nd harmonics.

Table 2
Harmonic Amplitudes and Harmonic Phases of the Total Resistance Coefficient (C_T)

C₁	C_T (λ=3.949 m, *Hs*=62 mm)								
	Amplitude×10^3					Phase [rad]			
	0th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
EFD	8.253	3.324	0.523	0.22	0.049	-1.0836	-0.6312	-2.7490	2.3787
CFD	8.1121	3.1911	0.5011	0.1915	0.0421	-1.0516	-0.6098	-2.6129	2.4701
ε %	1.71%	3.99%	4.18%	13.11%	13.41%	2.95%	3.39%	4.95%	-3.84%
C₅	C_T (λ=11.84 m, *Hs*=196 mm)								
	Amplitude×10^3					Phase [rad]			
	0th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
EFD	10.842	25.101	0.655	0.581	0.595	-0.3585	0.0890	1.5306	-0.8437
CFD	10.696	25.488	0.619	0.552	0.551	-0.3488	0.0842	1.6218	-0.9011
ε %	1.34%	-1.54%	5.50%	5.07%	7.33%	2.72%	5.42%	-5.96%	-6.81%

Comparing these figures with those tabulated in Table 2, one may conclude that the present model could simulate properly the flow since the absolute error is even four times smaller than that reported in 2015. In the opinion of the author this could be achieved only by making use of some numerical special treatment. Firstly, the unsteady approach is used with a time step corresponding to 1500 to 2000 time steps per wave period. Then, a 3D adaptive grid refinement is performed every 25 time steps inside the whole computational domain, so that the Courant number could be kept below

0.27 everywhere inside, regardless the cell position in respect to the hull or the free surface. Next, the number of the iterations used in computing the pressure is increased to 1000 while the convergence criterion is raised up to four orders. Obviously the computational cost of the simulation increased by almost an order of magnitude, but the level of accuracy attained may justify the effort spent for the purpose. The accuracy level can be proved by the good agreement shown in Fig. 6 proposes a comparison of the time history of the computed total resistance coefficient against the measured one for the two computational scenarios considered. T_e in the abscissa of the figure represents the wave encounter period, i.e. $1/f_e$, where $f_e = \sqrt{g/(2\pi\lambda)} + U/\lambda$ is the wave encounter frequency. In the equation above U stands for the ship speed. Both aforementioned comparisons reveal only slight departures in amplitudes but with no significant phase-shift.

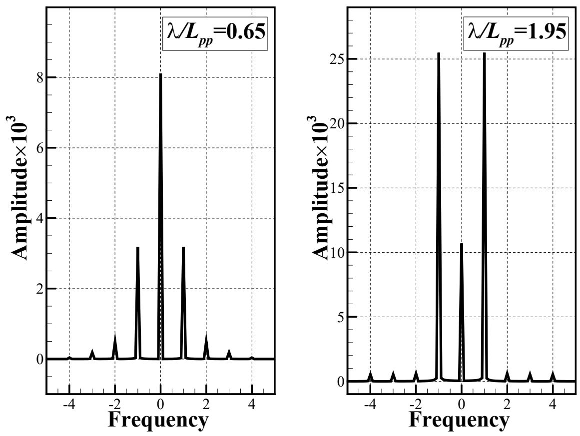


Fig. 5. *Fourier decomposition for the C_T amplitude: left: λ/Lpp=0.65; right: λ/Lpp=1.95*

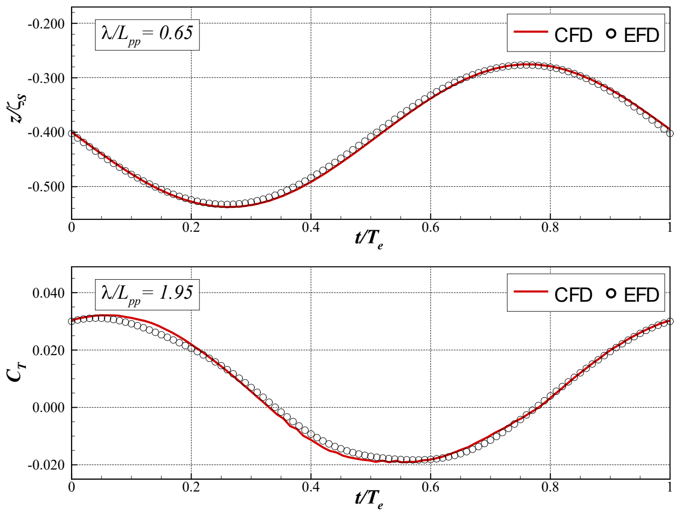


Fig. 6. *Time history of the computed drag coefficient variation compared with the experimental data, Larsson et al. (2015). Up: λ/Lpp=*0.65*, down: λ/Lpp=1.95*

3.2 Amplitudes and Phases of the Heave Motion

Next, the V&V exercise continues in terms of the heave motions. The computed harmonic amplitudes of the heave normalized with the wave amplitude $\zeta=H_S/2$, where H_S is the wave height, and the corresponding harmonic phases are tabulated in Table 3 and plotted in Fig. 7. The heave motion is expressed at the center of gravity when the wave crest is at the forepeak of the hull. The errors for the 0th, 1st and 2nd harmonics of the amplitude vary from 1.42% to 4.60% and from 3.34% to 23.45% for the 3rd and 4th harmonics. The computed errors of the phases vary from 2.51% to 4.74% for the first two harmonics and from 4.03% to 9.08% for the last two. On the contrary, the solutions reported by the participants at the 2015 Tokyo Workshop revealed an averaged level of errors between 10.53% and 66.21% for0th, 1st and 2nd harmonics of the heave amplitude, whereas the average error for the phase was 5.15% and 37.55%. Again, the comparison of the figures reveals a better agreement with the experimental data of the present solution. In spite of the fact that one may conclude that the computation method chosen in this study provide a satisfactory accuracy, the author's opinion is that there is still room for further improvements. From this point of view more studies are necessary to be performed.

Table 3
Harmonic Amplitudes and Harmonic Phases of the Heave Motion (z)

C_1	*z* (λ=3.949 m, *Hs*=62 mm)								
	Amplitude (/ζ)					Phase [rad]			
	0th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
EFD	-0.8092	0.1286	0.0005	0.0012	0.0004	1.5403	2.3131	2.5879	2.6863
CFD	-0.7876	0.1241	0.00049	0.00106	0.00033	1.5793	2.3992	2.6921	2.8811
ε %	2.66%	3.50%	4.60%	10.76%	20.92%	-2.53%	-3.72%	-4.03%	-7.25%
C_5	*z* (λ=11.84 m, *Hs*=196 mm)								
	Amplitude (/ζ)					Phase [rad]			
	0th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
EFD	-0.2005	0.9312	0.0206	0.0013	0.0002	-1.7205	1.3007	1.6636	0.5488
CFD	-0.1949	0.9444	0.0199	0.00131	0.00018	-1.6773	1.239	1.5125	0.5051
ε %	2.79%	-1.42%	3.25%	-3.34%	23.45%	2.51%	4.74%	9.08%	7.97%

Fig. 8 embodies a comparison of the time histories of the computed non-dimensional heave variations and the corresponding measured ones for the two computational scenarios considered. The same conclusions withdrawn when discussing Fig. 6 remain valid here, although a small phase shift seems to take place for the *λ/Lpp*=0.65 computational case.

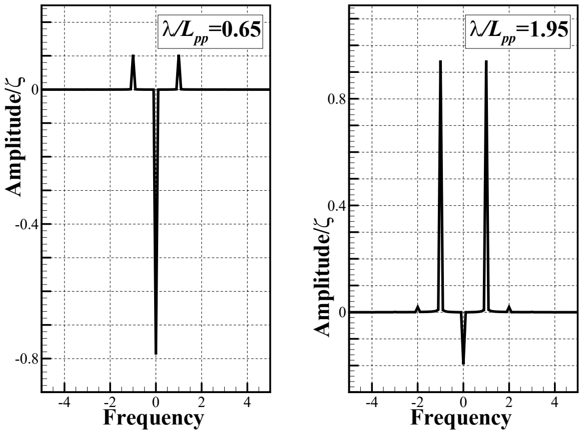


Fig. 7. *Fourier decomposition for the heave amplitude: left: λ/Lpp=0.65; right: λ/Lpp=1.95*

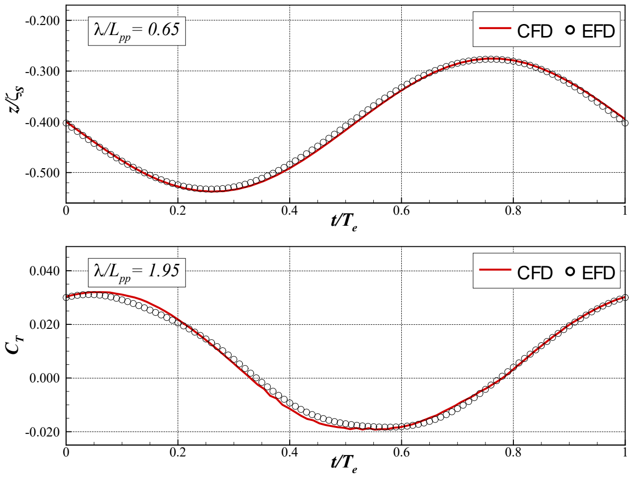


Fig. 8. *Time history of the computed heave/ζ amplitude variation compared with the experimental data, Larsson et al. (2015). Up: λ/Lpp*=0.65, *down: λ/Lpp=1.95*

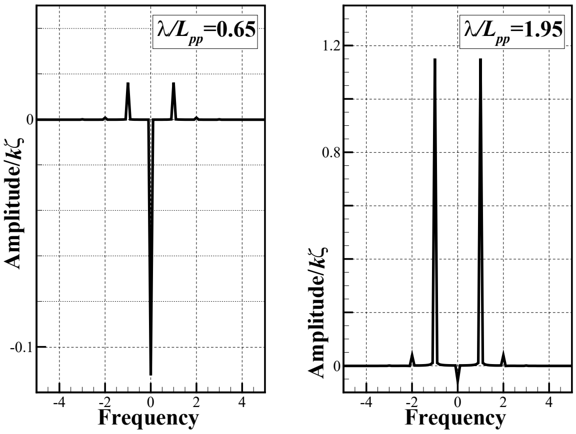
3.3 Amplitudes and Phases of the Pitch Motion

Similar to the previous two subsections, in the followings another V&V analysis is performed in terms of the θ angle of the pitch motion of the ship hull. The solutions for the same C_0 and C_5 computational cases are tabulated in Table 4, which shows the harmonic amplitudes and phases of the pitch angle. Again, the pitch motion is judged at the center of gravity when the wave crest is at the forepeak of the hull. The amplitude of the pitch angle is normalized in respect to the product of wave magnitude and wave number k, where $k = 2\pi/\lambda$. The tabulated CFD solution values are obtained through the Fourier decomposition as Fig. 9 shows and compared to the corresponding experimental data provided by Larsson et al. (2015). The absolute computational error varies from 2.74% to 32.89% for the amplitude and from 2.34% to 11.94% for the phase. Largest values are again corresponding to the 3rd and 4th harmonics for which the Fourier decomposition provided very small values, subjected to truncations and round-off errors. The report of Stern (2015) on the solutions submitted to the Tokyo Workshop concluded that the absolute average error for the 0th harmonic of the pitch amplitude varied from 9.96% for *λ/Lpp*=0.65 to 16.41% for the *λ/Lpp*=1.95 case, whereas for the 1st harmonic it varied from 38.68% for *λ/Lpp*=0.65 to 6.02% for the *λ/Lpp*=1.95 case. In terms of phase, the reported absolute error for the 1st harmonic varied from 4.31% for *λ/Lpp*=0.65 to 4.68% for the *λ/Lpp*=1.95 case. From all the above figures one may notice that the numerical method proposed in the present paper may lead to solutions whose accuracy is significantly better than those existent in the public domain.

Table 4
Harmonic Amplitudes and Harmonic Phases of the Pitch Angle (θ)

C_1	θ (λ=3.949 m, Hs=62 mm)								
	Amplitude (/$k\zeta$)					Phase [rad]			
	0th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
EFD	-0.1078	0.0163	0.0009	0.0002	0.0000	0.8492	2.3343	2.8913	-2.9384
CFD	-0.1123	0.0155	0.00083	0.00016	1E-07	0.8691	2.2154	2.6781	-3.1911
ε %	-4.20%	4.99%	7.68%	32.89%	29.70%	-2.34%	5.09%	7.37%	-8.60%
C_5	θ (λ=11.84 m, Hs=196 mm)								
	Amplitude (/$k\zeta$)					Phase [rad]			
	0th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
EFD	-0.0562	1.1185	0.0379	0.0017	0.0003	-0.5811	2.1387	0.8706	-0.3979
CFD	-0.0547	1.1522	0.0399	0.00156	0.00027	-0.5975	2.2212	0.8133	-0.4454
ε %	2.74%	-3.01%	-5.40%	6.40%	15.91%	-2.82%	-3.86%	6.58%	-11.94%

The time history of the computed pitch angle amplitude normalized by $k\zeta$ is depicted in Fig. 10 which bears out a comparison with the corresponding experimental data for the two wave lengths considered everywhere in this paper. Numerical data tabulated in Table 4 are confirmed by the graphs drawn in the figure, which emphasize reveal no significant errors in amplitude or in phase.



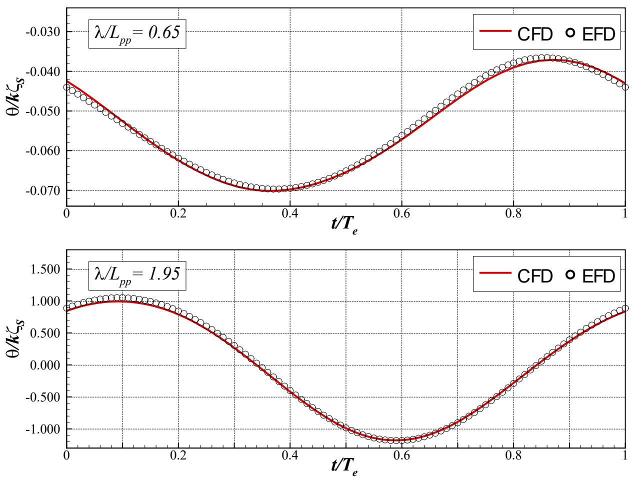
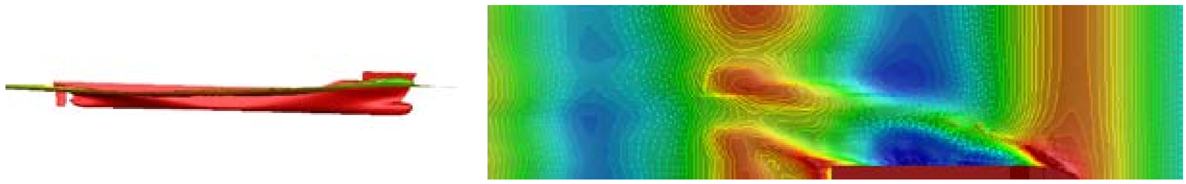


Fig. 9. *Fourier decomposition for the pitch amplitude: left: λ/Lpp=0.65; right: λ/Lpp=1.95*

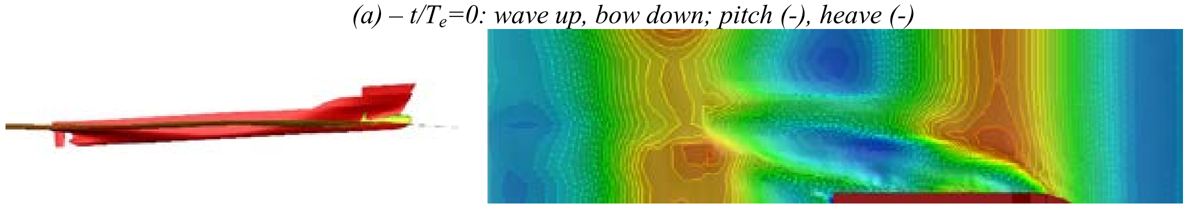
Fig. 10. *Time history of the computed pitch/kζ amplitude variation compared with the experimental data, Larsson et al. (2015). Up: λ/Lpp=*0.65, *down: λ/Lpp=1.95*

3.4 Ship Behavior in Head Waves

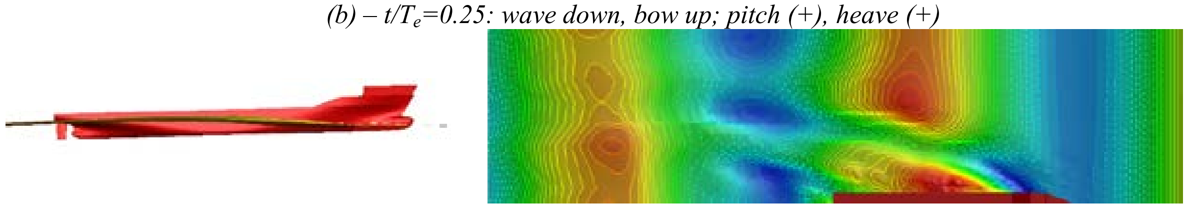
Obviously, the final goal of any numerical simulation concerned with the seakeeping problem is to correctly predict the ship behavior while navigating in waves. Since the previous discussions were only concerned to the V&V, in the followings an example of what such a simulation may be useful for the initial design of a ship hull is presented in Fig. 11, which shows the ship behavior in four different stages of a given navigation scenario. For the sake of diversity, the figure refers to a computational case not discussed so far, namely $\boldsymbol{C_4}$ for which *λ/Lpp=1.37.* The four instances are drawn at t/T_e=0, 0.25, 0.5 and 0.75 respectively. In this particular case t/T_e=0 corresponds to the situation in which the hull bow position corresponds to the top of the wave crest, whereas t/T_e=0.5 corresponds to its trough.



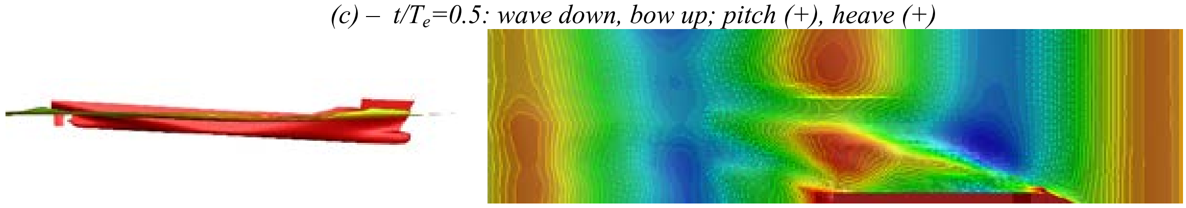
(a) – t/T_e=0: wave up, bow down; pitch (-), heave (-)



(b) – t/T_e=0.25: wave down, bow up; pitch (+), heave (+)



(c) – t/T_e=0.5: wave down, bow up; pitch (+), heave (+)



(d) – t/T_e=0.75: wave up, bow down; pitch (-), heave (-)

Fig. 11. *Ship Motions (left) and Wave Pattern (Right) Over One Full Encounter Period in the Computational Case C4, λ/Lpp=1.37*

The four instances of the ship behavior reveal that when both heave and pitch are negative, i.e. Fig 11 (a) and (d), the forecastle gets flooded and only the bulwark existence prevents the green water to wash the deck. On the contrary, when the heave and pitch are positive, i.e. Fig 11 (b) and (c), the ship bow goes out of the water and associated phenomena such as slamming are expected to happen.

4. Concluding Remarks

A simulation of the 3 DOF seakeeping behavior of the KCS model hull is presented. An extensive V&V check is performed on nine different computations to prove the robustness of the proposed numerical method by means of several comparisons with experimental data. Trial computations revealed that if the discretization is fine enough and the numerical model is suitably adjusted, the computational errors can be kept at a reasonable level. A special treatment for the open boundaries made possible the prevention of any wave reflection. The present study shall be extended to the 6 DOF case to completely edify the ship behavior in real sea.

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REDUCTION OF TOXIC EMISSION OF EXHAUST GASES AND FUEL CONSUMPTION OF FISHING BOATS AND VESSEL DIESEL ENGINES

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Abstract: The reduction of specific fuel consumption and exhausts toxic emission was possible by implementing preliminary fuel treatment that takes place directly in the fuel injector containing catalytic material. The reduction of the nitric oxides emission level in exhaust gases has been obtained by means of preliminary fuel chemical treatment which is based on the use of heterogeneous catalyst and turbulization canals on the atomizer needle. Turbulizing process as well as homogenization of flowing fuel is carried out at fuel flow in the passages situated on the non-operating needle part, while both crossing passages in the form of left-hand and right-hand thread and crossing grooves on the entire surface of the 2 needles may constitute the form of the said passages. Preliminary fuel treatment results in the average reduction of unit fuel consumption of those engines by 8%, while toxic emission of nitrogen oxides drops by 15%.

Keywords: diesel engines, preliminary fuel treatment.

1. Introduction

The main requirements for modern engines mostly refer to the reduction of toxic compounds emission and firstly this demand refers to nitrogen oxides. However, shipowners primarily pay attention to the issue of operation costs' reduction which are mostly affected by fuel cost. It concerns shipowners of both seagoing ships and smaller vessels. The latter include fishing cutters and fishing boats. It should be underlined that currently the reduction of toxicity of exhaust gases and fuel consumption is carried out by the means of injection systems with electronic control of fuel injection (Common Rail type accumulators) as well as catalytic reactors in exhaust systems. It should be highlighted that simultaneous fuel consumption reduction as well as the level of toxic compounds emission have not been achieved due to the difficulties in engine running optimization under the criteria – engine efficiency (reduction of fuel consumption) increases together with the raise of cycle maximum temperatures, and the high temperature facilitates forming of greater concentration in nitrogen oxides exhaust gases. However, in the fishing vessels that are already in operation, meeting the ecological and economical requirements is not feasible, not only due to the age of the said vessels (Tab. 1 – more than 60% of the Polish fishing vessels are older than 20 years and their age structure is diversified for the particular groups of fishing boats and fishing cutters length) but also due to the modernization problems of the existing engines in terms of installation and control of their operation (Клюс, 2007).

Table 1
Age Structure of Polish fishing Vessels

Years	**<5**	**5-15**	**15-20**	**20-30**	**>30**
Number	54	116	180	175	307

Since the structure of engines for the fishing fleet does not allow for the incorporation of modern common rail injectors and other items reducing the volume of toxic compounds in the exhaust gas, it appears to be advisable to seek for new methods to reduce same. Simultaneously, the operational cost should be reduced mainly by lower fuel consumption. The methods should meet a number of requirements such as simplicity and possibility to be applied in the old generation engines.
The Maritime University in Szczecin conducts research on preliminary fuel treatment on fishing fleet engines and the results that have been obtained so far provide positive results of the direction.

2. Preliminary Fuel Treatment

Let's consider the theoretical grounds for preliminary fuel treatment. As it is known, the first combustion period – self-ignition delay time – has the main impact on the course of thermodynamic effects in internal-combustion engine cylinder (Hejwood, 1988); its shortening leads to lowering of the temperature in the combustion chamber, and hence to mitigation of nitrogen oxides production conditions. From an analysis of various research findings, we can calculate self-ignition delay using this relation:

$$\tau = B \cdot 10^{-2} \sqrt{C} \sqrt{\frac{T_k}{p_k}} \cdot e^{\frac{E_a C^{0,34}}{R T_k}} \tag{1}$$

where:

B, C – constants, T_k – temperature in the combustion chamber when fuel injection starts, p_k – pressure in the combustion chamber when fuel injection starts, E_a - activation energy

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According to Heywood [2], the delay time can be determined from this relation:

$$\tau = (0{,}36 + 0{,}22 \cdot c_m) \cdot \exp[E_a (\frac{1}{\bar{R} T_2} - \frac{1}{17{,}19}) \cdot (\frac{21{,}2}{P_2 - 12{,}4})^{0{,}63}] \quad (2)$$

where:

c_m – mean piston speed,

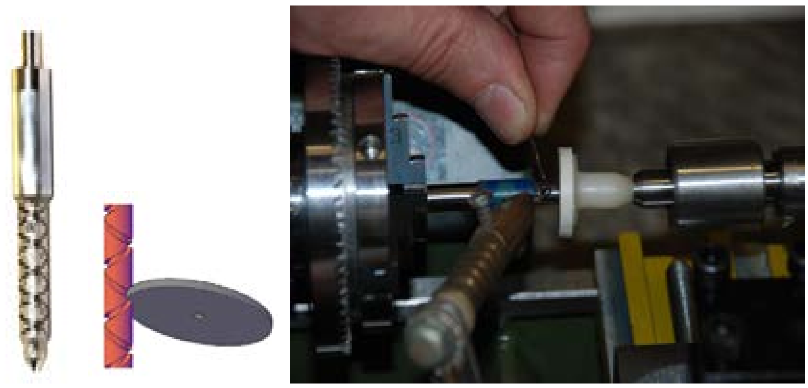
P_2 and T_2 – pressure and temperature in the combustion chamber.

Analyzing the relations defining self-ignition delay time we can see that it depends on such factors as pressure and temperature in the combustion chamber, rotation speed of the shaft and engine kinematics as well as activation energy. It should be noted that in attempts to improve economical and ecological performance of new and used engines there is no practical possibility to change parameters such as pressure or temperature, and basic design features. One possible direction to affect these self-ignition engine parameters is to decrease values of activation energy (Клюс, 2007).

To facilitate overcoming the activation energy, we can deliver more energy to the reaction environment (e.g. by heating) or use a substance that easily reacts with the substrate (low activation energy), and thus formed compound easily converts into a product (also low activation energy). A catalyst is a substance that facilitates a conversion from a reactant into a product and, notably, is not consumed in the reaction. It follows that the presence of a catalyst (e.g. metals of the platinum family) and its contact with fuel before injection into the combustion chamber is desired. Atomization process of petroleum fuels for self-ignition engines occurs in injectors' holes to which fuel is provided through passages injector body and tube channel. The tube channel may be used for preliminary fuel treatment, to be precise, catalytically active material may be applied on the tube channel elements.

The presence of a catalyst in the fuel system has another justification. Chemical properties of fuels used in self-ignition engines can be changed. In paraffin hydrocarbons, the most common group among diesel fuels, paraffin can be dehydrogenated in the presence of a catalysts. In the relevant reactions paraffin hydrocarbons change into olefins C_nH_{2n} and hydrogen molecules are released. Hydrogen, with its high diffusion coefficient, high flammability, high rate of combustion and a wide range of mixture combustibility, reduces self-ignition delay time in the conditions prevailing in the combustion chamber (Hejwood, 1988). The application of catalyst material of platinum group was done using by electro-spark alloying is characterized by a low temperature on the elements of the nozzle needle.

Turbulizing process as well as homogenization of flowing fuel is carried out at fuel flow in the passages situated on the non-operating needle part, while both crossing passages in the form of left-hand and right-hand thread.



a) b) c)

Fig. 1.

A photo (a) of a Multi Hole Fuel Injector with Preliminary Fuel Treatment with the Method of Making Turbulizing Passages (b) and Application of Catalyst by Electro-Spark Alloying (c) for Preliminary Fuel Treatment in Multi Hole Injector

3. Laboratory Test

The theoretical assumptions for the preliminary fuel treatment process were verified at a test station where the process of the disintegration of the fuel jet was subject to the analysis.

Particle size distribution in an atomized fuel jet was determined at the first stage of the tests for the proposed method of preliminary fuel treatment. For that purpose, a laser diffraction method was applied with the use of an instrument, made by Malvern, of Sraytec type and of a common rail injector test bench of Bosch EPS200A type (fig. 2). As a research facility, an injector for engine of 359 type equipped with three-hole atomizer was selected. The selection of this injector was justified by the fact that most of fishing vessels is equipped with engines with direct fuel injection and 359 engines constitute their representative part. Apart from the study, the atomized fuel jets were directed to one of the jets in the area of laser beam. Therefore, separating of two remaining jets from that area did not constitute a technical issue. Drawing 5 presents the photographs of the measurement process of particle distribution and the suggested system for fuel discharge from two fuel jets.

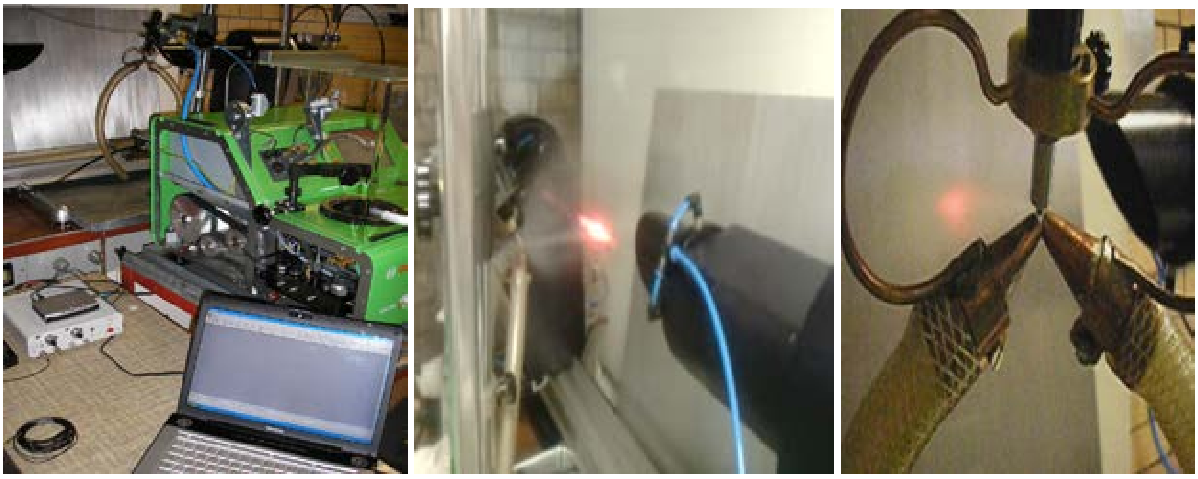
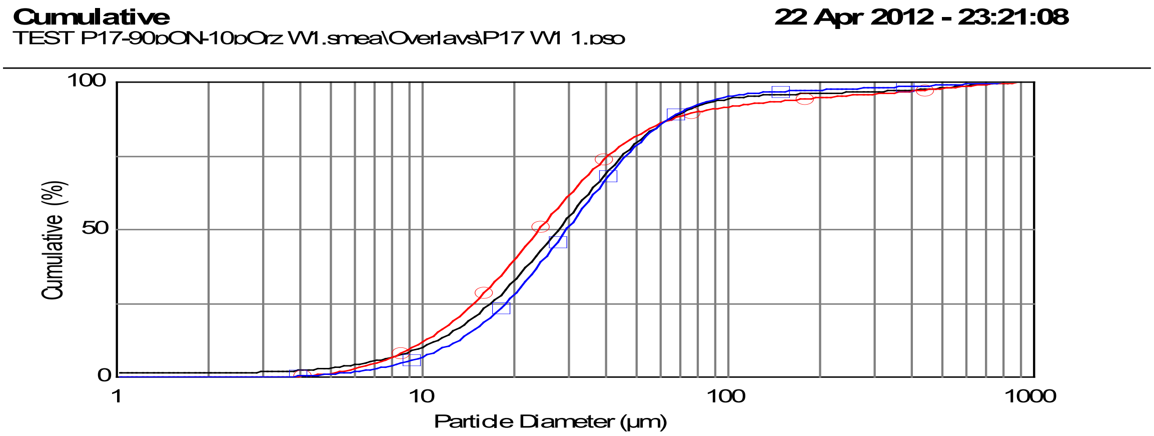


Fig. 2.
Test Stand for Particle Distribution in Atomizer Fuel Jet, Measurement of Particle Distribution in the Laser Beam Area And Separation of Two Remaining Jets From the Laser Beam Area

The laboratory tests results (fig. 3) proved an improvement of fuel atomization characteristics – at the application of primarily treatment the value of a mean Zauter diameter decreased, the number of particles of smaller diameter increased (Клюс, 2007).



	Date-Time	File	Sample	Dx(10)	Dx(50)	Dx(90)
[V]	3 Oct 2011-...	P17 W1	RYBY01	9.86	27.87	71.73
[V]	3 Oct 2011-...	P17 W2I	RYBY01	9.31	24.14	80.92
[V]	3 Oct 2011-...	P17 W3	RYBY01	11.79	29.66	70.64

[V]=Volume [N]=Number

Fig. 3.
Particle Size Distribution in Atomized Fuel Jet

4. Field Tests

The field tests were conducted on a four stroke self-ignition engine with direct fuel injection, 359 type (fig. 4). The set of instruments included an option to measure both the operational parameters and the ecological ones during the work according to a speed characteristics.

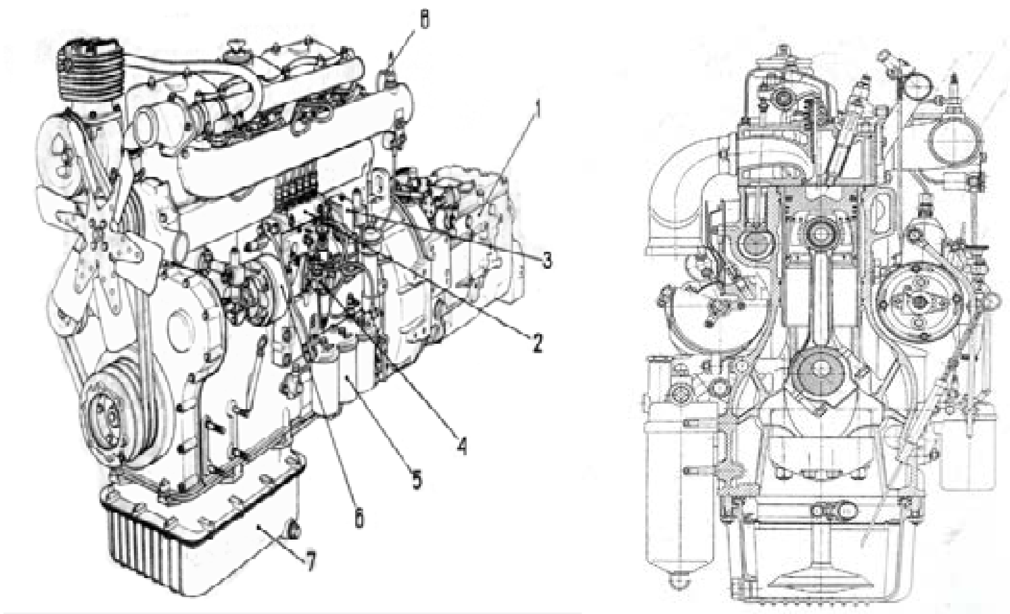


Fig. 4.
359 Type Engine

Fig. 5 - 9 present speed characteristics in a form of a power, unit fuel consumption carbon oxides, nitrogen oxides emission and smokes. Factory-made unit corresponds to the parameters of an engine at work with a factory set of injection equipment, PFT – equipped with a set of injectors with preliminary fuel treatment.

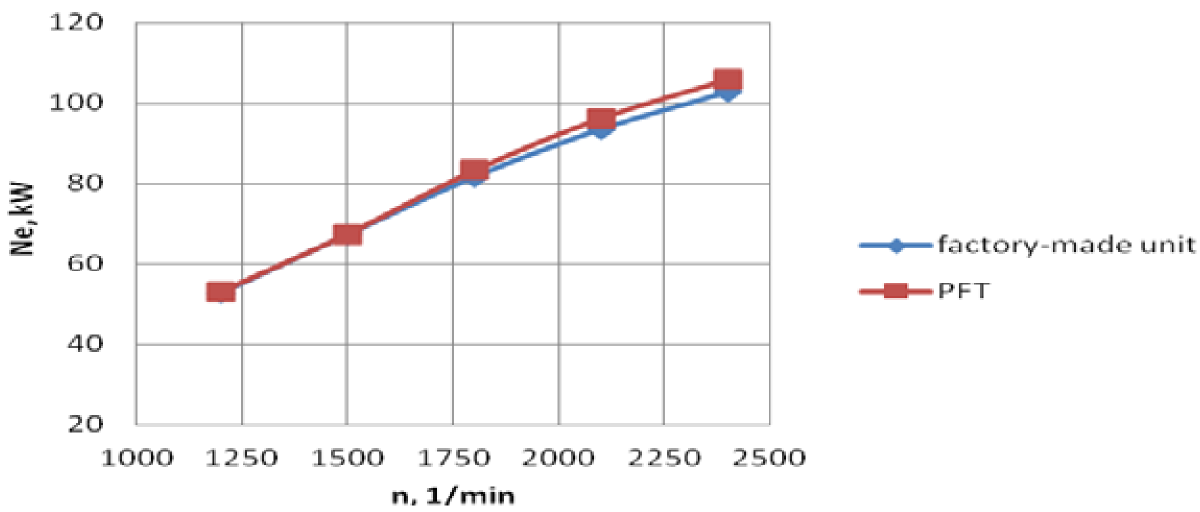


Fig. 5.
Speed Characteristics in a Form of a Power

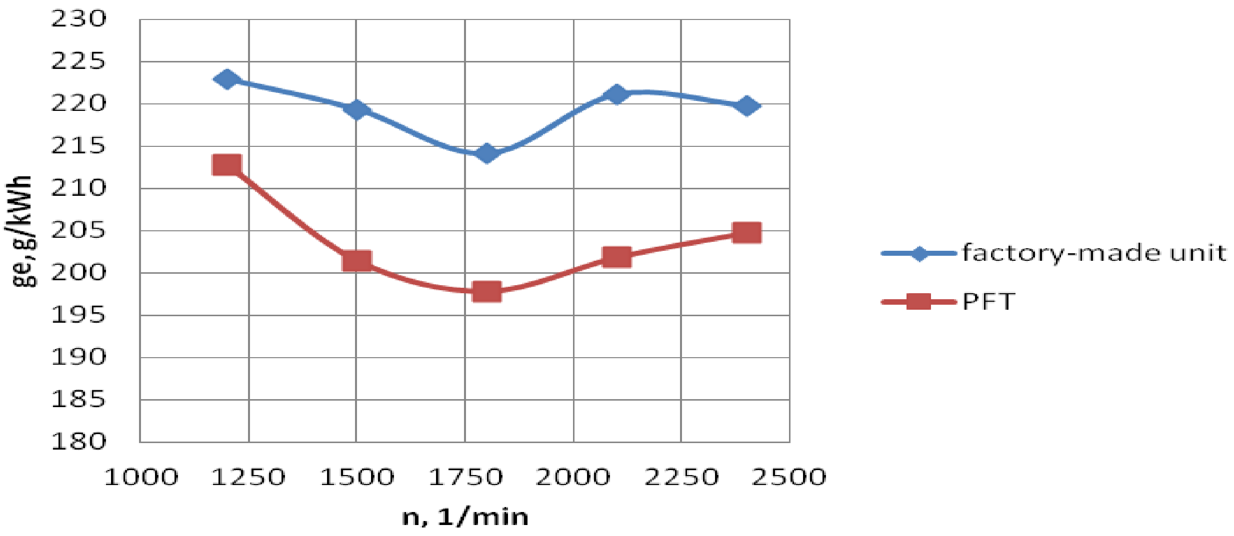


Fig. 6.
Unit Fuel Consumption Characteristics

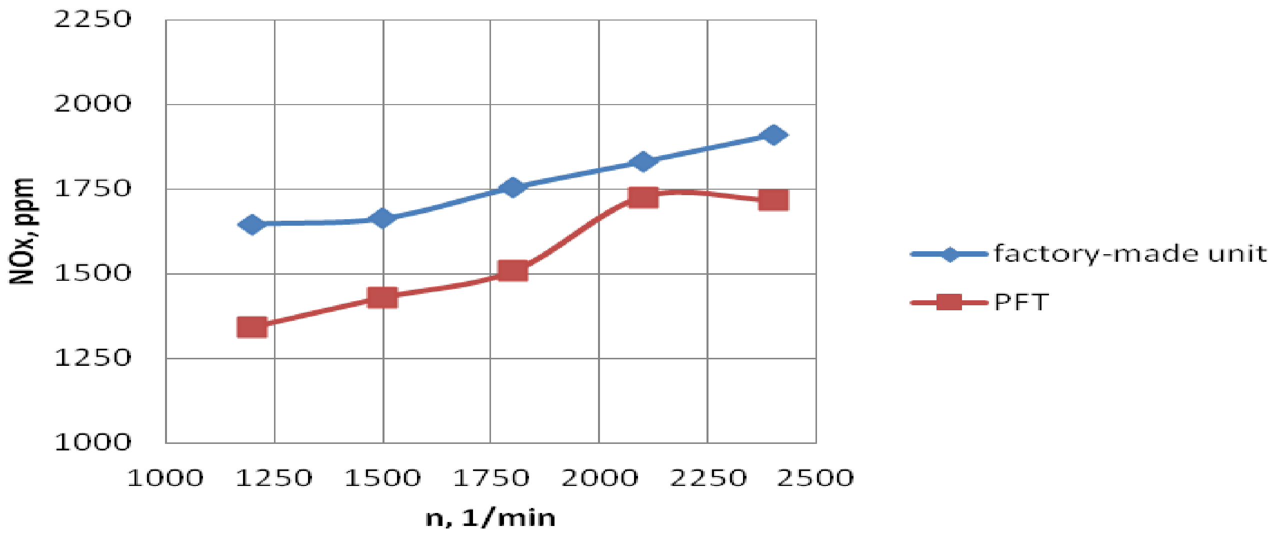


Fig. 7.
Emission Level of Nitrogen Oxides

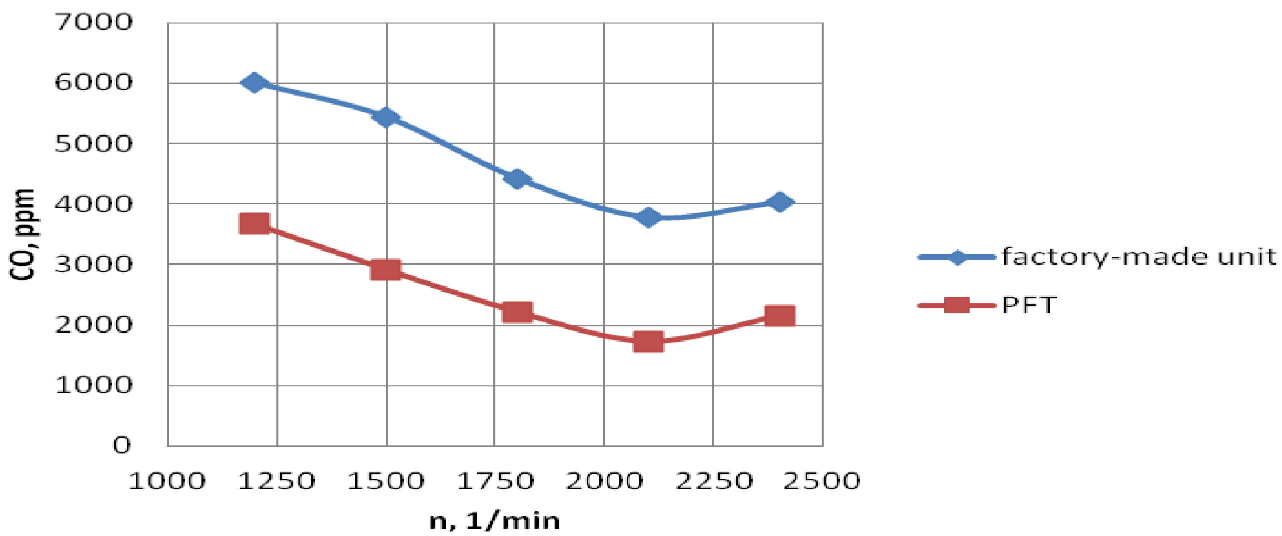


Fig. 8.
Emission Level of Carbon Oxides

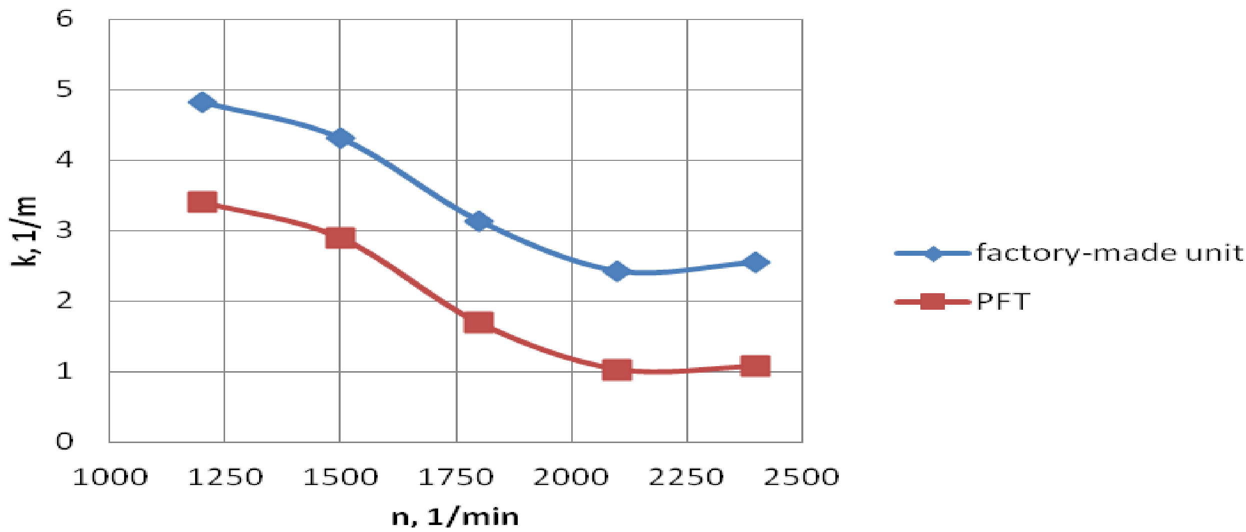


Fig. 9.
Emission Level of Smoke

5. Conclusion

The obtained results prove that there is a room for improvement of economic and ecological parameters of diesel engines when the preliminary fuel treatment process is applied. The treatment process consisting of contacting the catalyst with the fuel directly in the injector body. The technological process of applying the catalyst is simple and easy to perform and the application method proposed in the paper may be implemented at the shipowner premises without any technical problems. A very important aspect that should be highlighted is the low temperature not causing any thermal distortion of the precision elements of the injector. An increased efficiency of the catalyst may be obtained due to the turbulent nature of the fuel flow along the catalyst in the injector. It should be mentioned that making turbulizing passages is a technologically simple task and may be performed at the shipowner premises.

Acknowledgements

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THE ANALYSES OF THE POLISH MARINE CONTAINER TERMINAL MARKET BASED ON PORTER'S MODEL OF FIVE COMPETITIVE FORCES

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Abstract: Research has identified many criteria that contribute to evaluating an attractiveness of marine container terminal market in Poland, yet not much is known about how terminal top-managers look at these criteria and how they argue on the factors that contribute to their terminal choice strategy. This study uses Porter's model of five competitive forces to explore those criteria whose determine profitability of the investigated industry. We employ an in-depth methodology that incorporates both quantitative and qualitative methods for an analyzing of substitutes, buyers, suppliers, potential entrants and industry competitors. First, the industry competitors in the marine container terminal market are analyzed. Second, the buyers of the marine container terminal services are described, followed by the suppliers of the terminal infrastructure and superstructure and other services providers. Other competitive forces are the potential entrants and the substitutes they may change current or future situation in the investigated market. The results shall provide some substantial identification where the economic power is placed in the marine container terminal market and how the positions of the different players in the market can be enhanced.

Keywords: marine container terminal operators, container terminals, Porter's model of competitive forces, competition.

1. Introduction

Marine container terminal is the predominant node of transshipment container units. To enhance competitiveness, terminal operators deploy large, fast and partly or fully-automated vehicles to increase terminal yard's capacity and shorten transshipment duration. These capital-intensive investments may further rise barriers for the entry of new terminal operators. In terms of local supply, the marine container terminal market is an oligopolistic market, dominated by one or free terminal operators. The market is also very rate sensitive, as terminal operators need container cargos to fill their every-increasing terminal's capacity. In this sense, even mirror rate reductions might induce customers to shift their shipments to other marine container terminals.

Although attractiveness of sectors has been a subject for research in other industries, the way in which such attractiveness is in the marine container terminal market deserve further investigation. The aim of this study is twofold. First, two research questions were proposed to examine the impact of "the five forces" on attractiveness marine container terminal market. Second, an empirical study, based on attractiveness of MCTM of global marine container terminal operators located in Poland was conducted to validate the hypotheses. The remainder of this article is organized as follows. The next section describes the theoretical background. Research methodologies, including sampling and constructed measurements, are described in detail in subsequent section. The following section presents an empirical study on marine container terminal operators located in Poland. Anyway, conclusions and directions for future research are given in the final section.

2. Theoretical Background

Many research approaches have been proposed and used to evaluate an attractiveness of the market. One such model is the Porter's five forces model (Porter, 1979; pp. 137-145) was introduced as a strategy tool aiming to analyze the immediate competitive environment of individual industries. Having been developed as an industry analysis framework, the five forces model, considers the specific forces that determine competition. The impact of these five factors facilitates the competitiveness and economic potential of an industry.

The developing capabilities and sector's attractiveness are lower, the higher is the barging power of suppliers and customers, the higher is the entry possibilities of newcomers to the sector or just launching new substitution products on the market, and the higher struggle competition among current rivals in the market (Gierszewska and Romanowska, 2003; pp. 99). In the Porter's model, the relations among factors determine level of competition intensity in analysed sector and consequence of its profitability. The relations among "the five forces" are depicted in the Fig. 1

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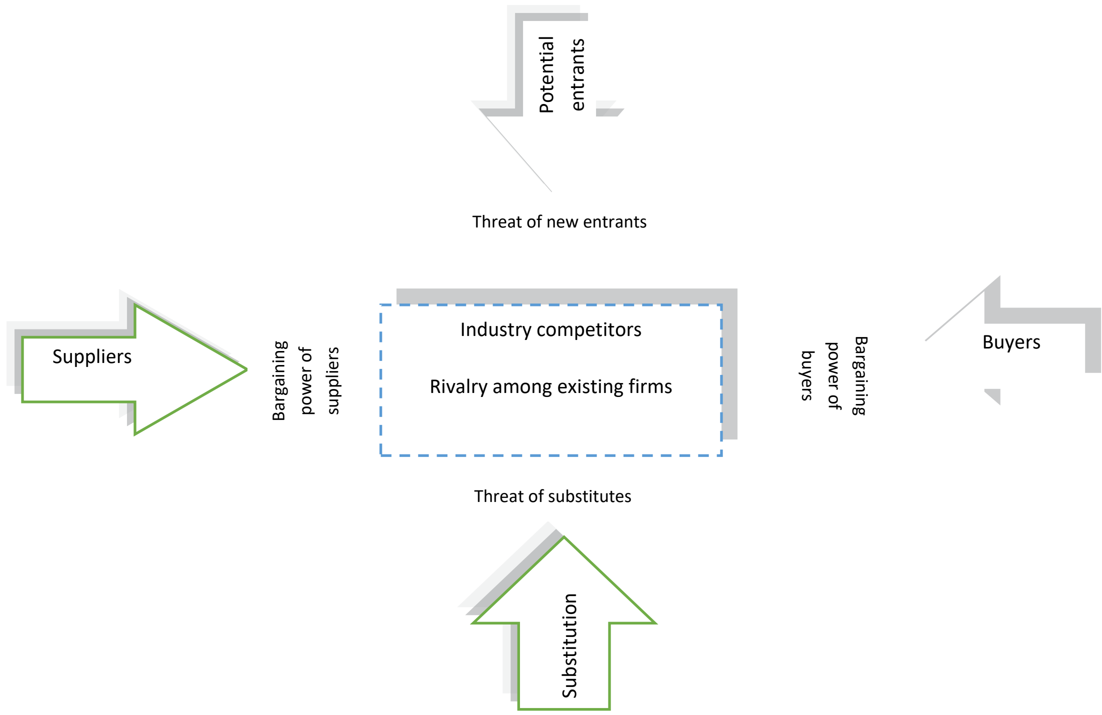

Fig. 1.
M.P. Porter's model of five forces
Source: (Porter, 1985; pp. 5)

The market attractiveness by M. E. Porter (Porter, 1980; pp. 25-40.) is considered to be closely related to the competitive situation in the market, i.e. economy competitiveness of companies and the country. M. E. Porter (Porter, 1980, 25-40), based on the five-forces model, argues that an attractive market is the one in which you can get the maximum profit or benefit, in other words, the more relevant market participants getting on for ideal competition, the less attractive it becomes.

We have in mind, that the model is still giving a critical judgment of some researchers (McGahan, 2000; pp. 1-16; Whittington, 2009; Van den Berghe and Verweire, 2000; Malhotra and Gupta, 2001; Burton, 1995; Ul-Haq, 2005; Brandenburger and Nalebuff, 1995; pp. 57-71; Yoffie and Kwak, 2006; pp. 88-98; Christensen, 2001; pp. 105-109; Grundy, 2006; pp. 213-229; Karagiannopoulos, Georgopoulos and Nikolopoulos, 2005; pp. 66-76; Siaw and Yu, 2004; pp. 514-523). According to (Obłój, 2007, 256-257) these criticism comes from main four limitation of using this model.

Firstly, the model derives from industry economy mainstream, that's why the model concentrates on closer environment of the company – branch. Unfortunately, it is a very limited perspective of analysis so it should be completed with: political, social and technological trends and events.

Secondly, the hard measured sounds which comes from the used model, though essential may be passed over in decision-making. Therefore, this model shall be completed with quality elements, which are not used in Porter's model.

Thirdly, this model analysis bargain powers of suppliers, customers; threats of potential newcomers, substitute's products, and finally rivalry of current competitors in the industry. The military language and the way of analyze comes from the economically concept of cut-throat competition. In some sectors, such competition concepts still exist but current situation in the global economy needs more sophisticated analysis. Once, the competitors entered into the strategic alliances and some others forms of cooperation and suppliers and customers has become strategic partners for some companies, the Porter's model turns into outdated and must be completed with cooperation dimension.

Fourthly, as indicated consulting and some results of researches not all analyzed forces are equally essential. For example, P. Ghewamat (Ghewamat, 1999; pp. 34-35) pays attention that barging powers of suppliers and substitution products maybe ignore in this model because they are not statistically significant in explaining strategical behavior of companies and profitability of branch. To the similar conclusions have come M. Sosnowski (Sosnowski and Obłój, 2004; pp. 65-67). According to his analysis, Polish managers mainly concentrates on its competitors and customers but they take the less notice of potential new entrants (entry barriers) and substitution threats.

The aim of this paper is to assessment on the potentiality of marine container terminal market. The fundamental question, which we would like to receive in this section is: Where is the economic power marine container terminals market? By economic power we mean: the potential to generate profits from invested capital in the long-run.

2. Methodology

2.1. Data Collection and Measures

The respondents for this empirical study were the all marine container terminal operators located in Poland. Questionnaires were personally presented to the respondents and discussed in detail if it has been needed. A total of 5 of 5 questionnaires were returned accounting for an effective rate of 100 per cent. The respondents have belonged to top-managers of their companies. The study was conducted in the marine container terminal operators in January – March 2018.

During the construction of the analysis's scheme, assuming that, the respondents of the research well-known M.E. Porter's concept "five competitive forces". In the proposed version of the approach, it is necessary to analyses bargaining power of suppliers, customers; the treats of substitutions, new entrants as well as industry competitors. In an attempt to reflect the wide range of competitive drivers. The competitive drivers were taken from various sources including writing papers and news reports and spoken opinions from scholars and seaports community.

Generally, industry's assessment by M. P. Porter's model the five forces is conducting by description form. It means that every identified factor is studied in relation to its impact at the given one competition force as well as performing a general assessment of every forces individually and finally assess of current or perspective situation in the investigated industry. Such description methodology is proposed by the M.E. Porter. The author has determined the factors which shall be take in the study of the industry and their influence at the given forces but he did not propose any assessment's method and draw the conclusions (Penc-Pietrzak, 2003; pp. 58; Giereszewska and Romanowska, 2003; pp. 316-320). The evaluation of every individual competitive forces is not very useful. In order to receive more detailed on assessment of competitiveness of the analyzed market the every individual factor was valued by attributing point using a five-point scale, anchored by 5 = 'high favorable' and 1 = 'high unfavorable'. Every factor was assessed by respondents (senior managers) and then it was calculated an arithmetic mean for every factor. This methodology was more developed by indication an attributed weights which scale ranges from 1 to 3 points. This attributed weights indicated by respondents show which factors are more or less important for the investigated industry. In the same manner as formerly, the attributed weights for every factor was calculated on arithmetical mean base. Then all attributed weights (in Table's columns) were summarized for every competitive force and received result was attributed value 100 per cent. Afterwards, it was calculated the share of every individual attributed weigh in the received result from the summarized of the arithmetical average contained in column. In the research all respondents belonged to top managers of the marine container terminal operators. This study sought answer for the following research questions:

- Q1: What are the most important competition drivers for MCTOs?
- Q2: Where is the economic power placed in the marine container terminal market?

3. Results and Analysis

This section presents the findings from all marine container terminal operators' responses. A logical question has been asked at the beginning of the research: where currently the economic power is placed in the marine container terminal market? Identification of main criteria and them weights in the Porter's model five forces for the marine container terminal operators were shown in the below tables. In this study, all competitive forces were separately evaluated.

Threat of new entrants; the threat of new entrants is the possibility that new marine container terminal operators may enter the industry. New entrants bring a desire to gain "proper" market share and often have significant resources. The most important criteria of new entrants treat are shown in Table 1. The most important threat of newcomers comes directly from two main drivers e.g. sector attractiveness and high of entry barriers. Currently, the container terminal market is characterized by relatively high return of equity and high market growth rate and those both criteria may encourage new terminal operators at the Polish market. Fortunately for the current market competitors there are high entry barriers which protect the "old" competitors. However, when newcomers entered into the investigated industry there is no large possibilities of repression from the all current marine container terminal operators.

Table 1
Threat of newcomers into the sector

	Evaluation criteria	Average weight the range from 1 to 3 points (1)	Rating threat of newcomers in the industry in the industry (the range from 1 – high unfavourable to 5 – high favourable points). (2)	The average weighted rating scale (1)x(2)=
1.	High of entry barriers	0,36	4,4	1,58
2.	Sector attractiveness	0,38	4,8	1,85
3.	Possibilities of repression from the current terminal operators	0,26	2,4	0,62
4.	Sum the weighted rating scale	1,00		**4,04**

Source: Own elaboration.

As mentioned before, the high entry barriers may protect old competition order in the marine container terminal market. Therefore, it is remarkably important to assess the degree of entry barriers for the industry. According to respondents, the current marine container terminal operators are pretty well protect against potential new entrants. They indicated the most important criteria of barriers entry as follows: capital required (0,57), access to distribution channels (0,57), localization (0,55), economy of scale (0,53), customers loyalty (0,37), broaden range of terminal' services provided by terminal operator (0,34), UE and State law regulations (0,31) (Table 2). As we can see from the table, according to top managers such factors as access to technology (0,20), brand identity (0,18) and switching costs (0,15) are much less important entry barriers. The capital required is very high when newcomers are going to do major investments to enter this industry. This industry is not an easy business to start because it is capital intensive. The top-managers indicate that very important entry barrier is access to distribution channels which mean in this paper access to hinterland. Currently, the marine container terminal operators want to be closer to market-orientated operations, shipper preferences and terminal performance would play a vital role in setting up the high entry barrier. Localization is crucial important for newcomers because the "first best localization" is occupied by current competing terminal operators. For example, the marine container terminals located in seaports Gdynia or Szczecin-Świnoujście have worst localization then Deepwater Terminal Gdansk located in Gdansk seaport. Therefore, to the DCT may call the largest container vessels as can enter into the Baltic Sea, so this terminal transforms into the hub terminal meanwhile others terminals become the feeder terminals. However, when seaport Authority develop its infrastructure then it appears new localization for potential newcomers. In this way, the localization barrier may also become unimportant. Gdansk Port Authority, for example, has been building outer seaport with large terminal's infrastructure which allow the newcomers to enter the business and to take into concession "the first best" location which allows to service the largest container vessels. The terminal operators form seaports Gdynia and Szczecin-Świnoujście also may take an opportunity from this investment. Therefore, the Gdynia Port Authority undertook similar investment to keep the current terminal operators in its area. It is known that a un (loading) process for a terminal's services exhibits economies of scale over the range of output when average cost declines over that range. So, the economy of scale compels the potential newcomers to enter into the terminal market on a large or small scale. In the first case, the current MCTOs may react very sharply on the new entrant though it is very unlikely (see investigated results on industry competitors). In the second case, the new entrant will bear a high costs and very likely will withdraw from the market. The customer loyalty, it is next important factor meaningfully restrictive entrance of newcomers into the market. The top-managers know that possesses the loyal customers make up additional asset of their competition predominance over new entrants because new terminal operators will have to spend a lot of money to take a new and existing customers. In spite of that knowledge, the terminal operators have a lot of problems with building a strong relationships with customers (see – bargaining power of customers). Broad range of service assortment provided by terminal operator decides on its strategic position strengthened. The extension of terminal service assortment is twofold. The first, marine container terminal operators broaden and improve its core and additional service assortment. The second, for example, marine container terminal operators located in Gdynia seaport, heavy cargo units have been added. In this way, the terminal operators wants to build strong loyalty with existing customers and to gain the new ones for new activity. The UE and state law regulations may install entry barriers. The UE or state government may impose on marine container terminal operators new solutions concerning on getting rid of bottleneck in terminals and their hinterland due to inadequate infrastructure or terminal's services. In this way, the terminal operators may need to bear extra costs on congestion, or just reduction emission in accordance with green initiatives (Klopott and Miklińska, 2017; pp. 523-536; Klopott and Miklińska, 2016; pp. 639-644). Access to terminal technology is not very important entry barrier because this technology is well-known by the market participants. Similarly, the switching costs are not regards as important for entry barrier by respondents because a change of supplier is not so high, especially, if it concerns the terminal equipment. Although it can be meet with opposite opinion (Wiegmans, Masurel and Nijkamp, 1999; pp. 120). Brand identity regards to perceive quality and value terminal's services by customers. Unfortunately, the top-managers indicate that this factor is the less important as an entry barrier because the customers follow the low price or just sea lane offered by container shipping company in the marine container terminal. Therefore, to get the success the new entrants have to provide terminal's services at a low price and/or high quality to establish their market value.

Table 2
Entry barriers

	Evaluation criteria	**Average weight the range from 1 to 3 points** **(1)**	**Rating entry barriers in the industry (the range from 1 – high unfavourable to 5 – high favourable points).** **(2)**	**The average weighted rating scale** **(1)x(2)=**
1.	Economy scale	0,12	4,6	0,53
2.	Capital required	0,12	4,6	0,57
3.	Brand strong of terminal operator	0,07	2,4	0,18
4.	Switching costs of	0,06	2,6	0,15

	Evaluation criteria	Average weight the range from 1 to 3 points (1)	Rating entry barriers in the industry (the range from 1 – high unfavourable to 5 – high favourable points). (2)	The average weighted rating scale (1)x(2)=
	supplier			
5.	Access to distribution channels	0,12	4,6	0,57
6.	Access to technology	0,08	2,4	0,20
7.	UE and State law regulations	0,09	3,4	0,31
8.	Customers loyalty	0,11	3,4	0,37
9.	Broad range of terminal' services provided by terminal operator	0,10	3,4	0,34
10.	Localisation	0,12	4,4	0,55
11.	Sum the weighted rating scale	1,00		**3,76**

Source: Own elaboration.

Bargaining power of suppliers indicates on how dominant suppliers can reduce marine terminal operators power in negotiation for a renting a seaport's infrastructure or purchasing terminal facilities (terminal's vehicles – cranes and so on) and their profitability. Increased supplier power is determined by a number of factors. According to respondents opinions, the bargaining power of suppliers in the investigated market comes from the following factors: quality of final terminal's service depends on quality of supplier's products (0,79); switching costs (0,60); concentration power (0,51); unrepeatability quality of services provided by suppliers (0,51); sharp struggle competition in the supplier's sector (0,44) (see table 3). When terminal's facilities used by marine terminal operator are significantly influencing on the end quality terminal's services then the supplier will have to negotiation better terms of delivery. The top-managers also indicate that they will also face a significant switching cost if they decide to change terminal's supplier. Furthermore, concentration of power in the sector includes a relatively small number of suppliers because they often offer an unrepeatable quality of terminal's infra- and superstructure as well as services.

Table 3
Bargaining power of suppliers

	Evaluation criteria	Average weight the range from 1 to 3 points (1)	Rating bargaining power of suppliers in the industry (the range from 1 – high unfavourable to 5 – high favourable points). (2)	The average weighted rating scale (1)x(2)=
1.	Concentration in the sector	0,13	3,8	0,51
2.	Quality of final terminal's service depends on quality of supplier's service	0,17	4,6	0,79
3.	unrepeatability quality of services provided by suppliers	0,16	3,2	0,51
4.	Facility and lower switching costs of suppliers	0,16	3,8	0,60
5.	Large share of supplier in creation of terminal's operator profit	0,11	2,6	0,29
6.	Possibilities entering of suppliers into the terminal's market	0,06	1	0,06

7.	Sharp struggle competition in the supplier's sector	0,15	3	0,44
8.	Possibilities integration forward	0,06	1,2	0,07
9.	Sum the weighted rating scale	1,00		**3,26**

Source: Own elaboration.

The sharp struggle competition of the terminal's suppliers is meaningfully differential. A huge power of supplier has a provider of marine container terminal's infrastructure – Port Authority because of one's local or regional monopolistic position, (see table 4). In turn, in the superstructure suppliers market, there is a strong struggle competition in spite of a limited number of suppliers existing within investigated market. Moreover, some respondents pay attention that lastly increased power of well-qualified blue-collar workers suppliers in the marine container terminals. Temporarily, this problem has been solved by employment of workers from the Ukraine.

Table 4
Choose suppliers

	Evaluation criteria	Average weight the range from 1 to 3 points (1)	Rating choose suppliers (the range from 1 – high unfavourable to 5 – high favourable points). (2)	The average weighted rating scale (1)x(2)=
1.	Seaport's infrastructure supplier	0,58	3,6	2,08
2.	Superstructure suppliers	0,42	3,2	1,35
3.	Sum the weighted rating scale	1,0		**3,43**

Source: Own elaboration.

Anyway, this poses challenges for marine container terminal operators as they will be highly dependent to renting, leasing or just buying from these various types of suppliers. In the analyzed market, there is a very low power of suppliers to integrate forward meaning so there are the lack of danger to cut out marine terminal operators and reach end customers directly.

Here we will pay attention to **bargaining power of customers** of marine container terminal market. The strength of this competitive force depends on several criteria that determine customers' power. The position of the customer becomes stronger if the marine container terminal operator bears high investment costs and if the level of marine container terminal's capacity utilization is low (Wiegmans, Masurel and Nijkamp, 1999; pp. 105-128.). The bargaining power of buyers is fairly high (see Table 5). According to respondents opinions, the bargaining power of customers in the analyzed market comes from the following factors: facility and lower switching costs of suppliers (0,63); customer's concentration (0,61); quality of final terminal services depends on quality of suppliers' products and services (0,57); sharp struggle competition in the customer's sector (0,56); large share of supplier in creation of terminal's operator profit (0,47); possibilities entering of suppliers in the terminal's market (0,32); possibilities integration forward (0,32); unrepeatability quality of services provided by customers (0,30) (see table 5). In the analyzed market, the most crucial factor of buyer are switching costs because customer may easy to switch one terminal operator to another as their terminal's product offerings are not highly differentiated. Obviously, the switching costs are different for two main groups of customers: liner shipping companies and forwarders. Usually, the shipping companies conclude a trade agreement with marine container terminal operator for short or medium term. It this situation, the switching costs are comparatively high. From the other side, the most forwarders have no any signed trade contracts with terminal's operator so the switching costs for them are very low. Therefore, the forwarders are the most disloyal customer group for the marine container terminal operators because their gain a low profit margin. When the marine container terminal operator rises the price for terminal's services then the forwarders moves its activity to other terminal operator, if provided it is just and feasible. The concentration of power also is very important factor, especially if concerns to liner shipping companies which entered into global terminal market (Notteboom and Rodrigue, 2012; pp. 271; Marek, 2016; pp. 11-37). The members of liner shipping alliances have a stronger negotiation power compare to MCTO. The forwarders are acting in the perfect competition in the container market so by the definition they have a weak negotiation power then the MCTO. That's why, the forwarders have to adopt to requirements and way of work imposed by terminal operator. The quality of terminal's services influence directly on quality of services provided by liner shipping companies and forwarders, it also means, that MCTO has a strong negotiation power. Sharp struggle competition in the customer's sector indicates on low level of concentration power. Large share of customers in creation of terminal's operator profit strengthens bargaining power of the customers albeit the customers will put pressure terminal's operator on price cutting. To our knowledge, the keeping customers should be a paramount concern of every marine container terminal operator. Therefore, they shall determine what customers need in terms of terminal's services and deliver upon those needs in efficient manner.

Table 5
Bargaining power of customers

	Evaluation criteria	**Average weight the range from 1 to 3 points (1)**	**Rating bargaining power of customers (the range from 1 – high unfavourable to 5 – high favourable points). (2)**	**The average weighted rating scale (1)x(2)=**
1.	Customers concentration	0,13	4,6	0,61
2.	Quality of final terminal's service depends on quality of supplier's service	0,14	4	0,57
3.	Unrepeatability quality of services provided by customers	0,10	3,2	0,30
4.	Facility and lower switching costs of suppliers	0,14	4,4	0,63
5.	Large share of supplier in creation of terminal's operator profit	0,12	3,8	0,47
6.	Possibilities entering of suppliers into the terminal's market	0,11	2,8	0,32
7.	Sharp struggle competition in the customers' sector	0,13	4,2	0,56
8.	Possibilities integration forward	0,11	2,8	0,32
9.	Sum the weighted rating scale	1,00		**3,79**

Source: Own elaboration.

The lower prices for terminal's services the customer's lower costs and higher profits. When terminal's services customers have the ability to provide the same services themselves instead of buying it from MCTO, their power is also significant. The possibilities entering of customers in the terminal's market and possibilities backward integration depends on the type of customers. For example, liner shipping companies have bought some marine container terminals to improve its core business activity. Finally, the unrepeatability quality of services provided by customers are the least important because the services are relatively easy to copy.

Threat of substitutes. The threat of substitutes, generally, in the analyzed market is not so important for top-managers. In this market, substitutes are differentiated from the core terminal's services that the main competitors within the market offer. The threat of substitutes is fairly low (see Table 6). According to respondent's opinions, the threat of substitutes in the analyzed market comes from the following factors: sector attractiveness (1,52); sector age (1,17); speed of technology change (0,88). The higher attractiveness of the sector the higher threats of new terminal's services or substitutes. For example, high demand for containers movement developed in-land container terminals network and new multimodal connection called Silk Route. It means that, forwarder may sent container by sea transport using marine container terminal or alternatively may sent container by multimodal rail transport using in-land container terminals. In this connection, the multimodal rail transport becomes a substitute for sea transport and in-land container terminal's services becomes a substitute for marine container terminal's services.

Table 6
Threat of substitution services

	Evaluation criteria	**Average weight the range from 1 to 3 points**	**Rating threat of substitutes terminal's services (the range from 1 – high unfavourable to 5 – high favourable**	**The average weighted rating scale**

		(1)	points). (2)	(1)x(2)=
1.	Sector attractiveness	0,38	4	1,52
2.	Sector age	0,34	3,4	1,17
3.	Speed of technology change	0,28	3,2	0,88
4.	Sum the weighted rating scale	1,00		**3,57**

Source: Own elaboration.

In this way, the existing customers may switch the new transport connection and create a negative impact on the analyzed industry's market share and its profitability. The wandering answer of respondents concern the final factor. According the top managers, there is not large treats of substitute by increase speed of technology change because the changes in terminal's technology are longer than 5 years.

We will now discuss the last competitive force from Porter's model - **rivalry among competitors**. This force describes how the other four powers interrelate and shape the structure of competition in the analyzed industry. There are certain factors by which competitive rivalry is determine in the market. The respondents determined the main competition factors in the industry as follows: number of competitors (1,61); share structure in the sector (1,54); customer's strategy (0,91) (see Table 7). The analyzed market currently compete only 5 marine container terminal operators. In Poland, there are three main seaports, i.e. Gdynia, Gdansk (located in Gdansk Bay, on the southern Baltic) and the port complex Szczecin-Świnoujście situated in the western part of Poland's coastal area. The Gdynia seaport has agreements three marine container terminals operators: Baltic Container Terminal Ltd. (belonging to ICTSI – International Container Terminal Services Inc. – Manila), Gdynia Container Terminal Inc. (belonging to Hutchinson Port Holding – Hong Kong) and OT Logistics Group Inc. (belonging to Polish Capital – with a diversified commodity portfolio – included container operations). The Port of Gdansk included the following container terminal: Deepwater Container Terminal Inc. (owned by The Macquarie Pension Funds). The port complex Szczecin-Świnoujście, meanwhile, embraces two container terminals, and that are OT Port Świonujście Inc. (owned by OT Logistic Group) and DB Port Szczecin Ltd.

Table 7
The competition struggle inside industry

	Evaluation criteria	**Average weight the range from 1 to 3 points** **(1)**	**Rating competition struggle inside industry (the range from 1 – high unfavourable to 5 – high favourable points).** **(2)**	**The average weighted rating scale** **(1)x(2)=**
1.	Numbers of competitors	0,37	4,4	1,61
2.	Share structure in the sector	0,37	4,2	1,54
3.	Customer's strategies	0,27	3,4	0,91
4.	Sum the weighted rating scale	1,00		**4,06**

Source: Own elaboration.

The share structure of the industry is diverse. The DCT has a predominant position on the Polish marine container terminal market because of its localization. The other two competing terminals located in seaport Gdynia (BCT and GCT) are approximately the same size so the rivalry among them is highly intense. The remaining three terminal operators are quietly small size. In spite of the industry growth rate is high, rivalry is still very intense because terminal operators see chances or just feel pressure to improve their position. Additionally, there is not significant differentiation between the terminal's services offerings of individual marine container terminal operators, the level of rivalry is also intense. Customer's strategy offered by individual terminal operators are diversified. The respondents pay attention that they compete against each other by: price (price war) and quality of terminal's services; speed of terminal's services; effectiveness of used resources, additional terminal's services offerings; linking customers with terminal operator by offering loyalty package; transport service connection offerings. Only one top-manager indicates that the operator implements low cost strategy. Other four respondents declare that implement differentiation strategy. By the differentiation strategy terminal operators decide to diversify the number of features of a terminal's services to provide more choices to the consumer. Terminal operators make this decision after conducting sufficient market research to determine the needs and desires of their customers. To make a profit, the cost of adding a new feature must be affordable and there must be a reasonable expectation that customers will pay a higher price for the core or additional terminal's services or both. In this way, the terminal operator has created a differentiation that provides a competitive advantage.

Anyway, the existence of high **exit barriers** in the industry, if a marine container terminal operator wishes to leave the industry will also trigger high rivalry. The respondents indicate that the most important exist barriers for the industry are: assets specialization (1,35) and high fixed costs of exit (0,86) (see Table 8). The high degree of specialization of assets means that the terminal operator may have a great problem with selling them for a good market price. The close competitors will try to purchase the assets by minimum price. The high fixed costs are close connected with signed trade contracts with infra- and superstructure providers. The large fine penalty of breaking off the trade contracts is important exit barrier of terminal operator from the industry.

Table 8
Exit barriers

	Evaluation criteria	**Average weight the range from 1 to 3 points (1)**	**Rating exit barriers in the industry (the range from 1 – high unfavourable to 5 – high favourable points). (2)**	**The average weighted rating scale (1)x(2)=**
1.	Assets specialisation	0,29	4,6	1,35
2.	High fixed costs of exit from the sector	0,22	4	0,86
3.	Psychological barriers	0,10	1,8	0,18
4.	Strategic barriers	0,16	2,2	0,35
5.	Political barriers	0,12	1,6	0,19
6.	Social barriers	0,12	1,6	0,19
7.	Sum the weighted rating scale	1	15,8	**3,11**

Source: Own elaboration.

The other factors of exit barriers such as: strategic, political and social barriers are not important for terminal operators in spite of pushing to corporate social responsibility concept. It must be notice that by strategic barrier means big significance of the local market for headquarters of terminal operator. The intensity of competitive rivalry in the industry is extremely high. All marine container terminal operators face intense competition and they are competing with each other over price, core and additional terminal's services and promotions intermittently. It should be noticed that entry barriers are much higher than exist barriers, so it means that, current terminal operators are well protecting against potential new entrants in to the marine container terminal market.

4. Conclusions

Not all of these forces are equally important when assessing the overall attractiveness of marine container terminal industry in Poland. In the terminal market entry barriers are relatively high and exit barriers relatively low. This implicates that profits in the marine container terminal market are high and not so risky. This situation directly comes from a high industry growth rate. Furthermore, the terminal operators make new investments into increase their terminal capacity. This deteriorates the market because all existing terminal operators make an efforts to fill their terminal capacity and this runs to competition intense. The current importance of the actual competitive forces of the groups of actors in the terminal market was visually depicted in Fig. 2.

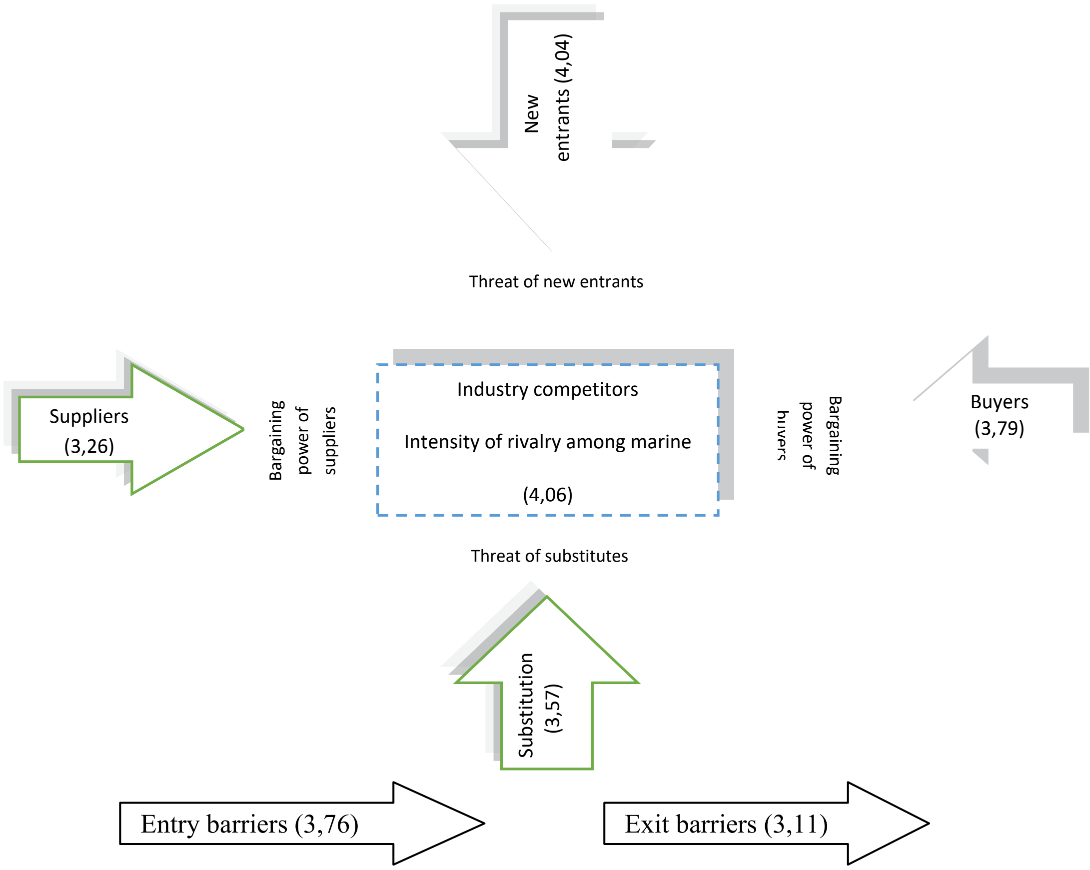

Fig. 2.
Investigated results of competitiveness marine container terminal market based on M. Porter's model of five forces
Source: own elaboration.

Figure 2 shows our syntheses that the competitive strength of the industry competitors is relatively weak, and therefore there is considerable room for improvement. The suppliers of marine container terminal infrastructure and the customers of the terminal services have especially strong economic power. The strength of their economic power obviously restricts the profitability of industry competitors. The threat of potential entrants and the threat of substitutes further decreases the economic power of industry competitors.
Future research should lead to consider the prospects for marine container terminal operators in the close future. Moreover, future efforts should aim at further identifying best practice in competitiveness assessment and should contribute to developing a more general framework for successful model implementation. Furthermore, future research should investigate the measurement of the marine container terminal service performance as a starting point for improving the core and additional terminal service assortment.

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IMPLEMENTATION OF THE GREEN PORT CONCEPT IN THE PORT OF KOPER

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Abstract: European transport market has changed significally in the last two decades. The establishment of production facilities in the countries of Central and Eastern Europe has made cargo flows from Adriatic ports growing, as their location enables shorter transit times to the hinterland countries. As the strategic goal of Adriatic ports is to become one of the most important gateway regions in Europe, traffic growth represents a great financial and development opportunity for them, but at the same time, it has a significant impact on environmental pollution and the quality of life in the surrounding area. To support European ports development in an environmental friendly way, several studies and environmental priorities has been published within the EU. The port of Koper as the leading container and car carrying port of the North Adriatic area is trying to follow those directions. Its goal is to increase traffic along with the concern for the environment, so their future investments will be part of the strategy to become a green port. The paper therefore presents EU priorities that the North Adriatic ports, especially Koper, will have to implement, insofar as they want to acquire the status of green port.

Keywords: green port concept, environmental friendly seaports, sustainable development, port of Koper.

1. Introduction

The importance of the ports for the European economy are well known, as they represent one of the most important nodes in the transportation of goods. In the last ten years, after the global crises and with the expansion of world trade, especially world container traffic grew substantially. This rapid economic growth pushed ports to follow the trends as are new size of ships (trade growth and economies of scale are main reason for the increasing sizes of ships), higher productivity of cranes, shorter time of stay in ports... In these new conditions, ports need to modernize port facilities and include new technologies if they do not want to loss cargo, maintain the throughput level and competitive position on the market. The new investment in the technology and modernization must be also in accordance with new standards regarding "green" perspective. Green port is a port in which the port authority and port users pro-actively and responsibly develop and operate, based on an economic green growth strategy (PIANC, 2014). In line with the concept of the green growth, sustainable port initiatives has been developed by combining sustainable economic growth with environmental measures for an improved cost-benefit strategy (Lam and Notteboom, 2012).

Green port strategy and green port development are new trends in the world as ports are bigger and bigger and port development can have a negative impact on the surrounding area. There are researches in the field of ecological issues in ports and port management policies in relation to green port development (Peris-Mora et al., 2005; Darbra et al., 2009, Nebot et al., 2017). The main conclusions shows that there is a need for innovative solutions for sustainable port development.

In EU project Portopia (European Port Industry Sustainability Report 2016) ten environmental priorities of the ports have been selected. These are air quality, energy consumption, relation with the local community, garbage / port waste, ship waste, port development (land related), water quality, dust and dredging operations. The selection model of the priorities was obtained from 91 EU ports that participated in the study. The same research was performed also in the year 2006 and the study exposes that situation changed dramatically. Twenty years ago the problem of air quality was not observed as one of the crucial port's problems. At that time, the biggest problem was the port development (especially at the waterside). The project highlights that over all this time the issues of port development (landside), dredging and dust were always present, but not in the same order of priorities.

Nowadays, the problem of the air quality is in the top of environment priorities of the ports, especially due to the ships. Lam and Noteboom (2014) expose that ships are a major source of air pollutants such as CO_2, SO_2, NO_x and PM_{10}. Anyhow, Merico et al. (2016) state that harbour logistic has a relevant role in determining the total impact of shipping on air quality of the nearby coastal areas. According to the IMO (IMO 2014) international shipping contributes approximately 2,4% of global GHG (green house gas) emissions and it will increase in the future. Gibbs (2014) present possible actions for reducing emissions with the reduction of the ship speed (Green flag programme), green ship promotion and on shore power supply. The field of shore power supply and energy management in seaports is becoming of special importance (Accairo et al., 2014; Zis, 2014, Copolla et al., 2016).

According to study made by OECD in 2011 Environmental impact of international shipping – the role of the ports (OECD, 2011), shipping has a great impact to the ports and to the ports vicinity. The study highlights following areas of greater impacts: the noise and gases from ship engines and noise from cranes used for loading and unloading, dust when handling with coal and grain, and road and rail traffic to and from the port. They identify main environmental impact of ports as problems of port activities, problems at the sea done by ships calling the port and the problems of emissions from transport networks serving the port hinterland. Similar impacts were indicated by Lam and Notteboom (2012). They range them in three main groups: air pollution, water pollution and the maintenance and upgrading of port infrastructure, causing a high impact on marine ecosystems due to dredging and civil works.

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There is a strong need of the common policy instruments for managing presented environmental impacts. The sustainability is the future, thus ports must work in accordance with this trend. This is valid also for NA ports. In the paper, we present how Port of Koper, as one of the NA ports, deals with this issues and how they define measures for the establishment of green port.

2. Ports in the North Adriatic

World seaborne trade volumes reached 10.3 billion tons in 2016, and reached an expansion of 2.6 % over the previous year. This is still below the average of 3 % recorded over the past four decades. Anyhow, the projections for the 2022 show that volume will grow with an estimated compound annual growth rate of 3.2 %. Volumes are set to expand across all segments; the fastest growth is expected in the segment of containerized trade and major dry bulk commodities (UNCTAD, 2017). As maritime transport produce around 1 billion tons of CO_2 annually and is responsible for about 2.5 per cent of global greenhouse gas emissions from fuel combustion, the expected growth could be an environmental problem.
Maritime transport on the Europe-Asia-Europe route has been increasing constantly over the last decade. The northern European ports have had the leading role in this trade making a large number of European hinterland countries' maritime supply dependent of them. The importance of North Adriatic (NA) is increasing in last decade, but ports of Koper, Rijeka, Trieste, Venice and Ravenna are still medium size or smaller ports in the EU port system. These ports became important player in the EU transport market due to their location. They offer the shortest route from Asia through the Suez Canal towards the countries of central and eastern Europe. The route is 2,000 Nm shorter compared to the northern European ports (NAPA, 2017). In addition, they are located on European TEN-T Adriatic Baltic and Mediterranean Corridor (Figure 1), and the land transport from this part of Europe to the countries of Central and Eastern Europe is shorter, as well.

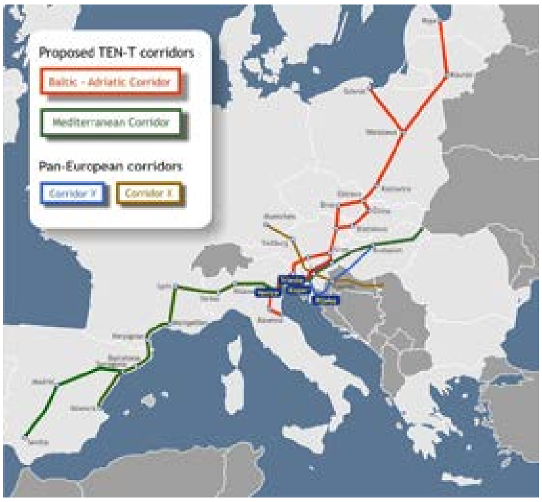

Fig. 1.
Location of NA ports
Source: http://www.portsofnapa.com

Northern Adriatic ports of Koper, Rijeka, Trieste, Venice and Ravenna are part of the European port system and they present a North Adriatic Port (NAP) system. These ports have the similar geographic characteristics and they work in a relatively closed system in which the market and customers are limited. For this reason the ports are forced to co-operate while at the same time compete with each other as they share a very similar gravitational area. Markets of NA ports includes northern Italy, the western Balkans, as well as countries of central and Eastern Europe. This is an area of great economic potential and the northern Adriatic ports control a moderate share of total overseas services for these countries presently.
The insensitivity of maritime traffic in NA ports is presented in Figure 2. The main transport corridor is to and from ports of Trieste, Koper, Venice, Ravenna and Rijeka that are at the same time the main ports in NA. In the figure are included also a touristic terminals, where the traffic in summer time is very intensive.

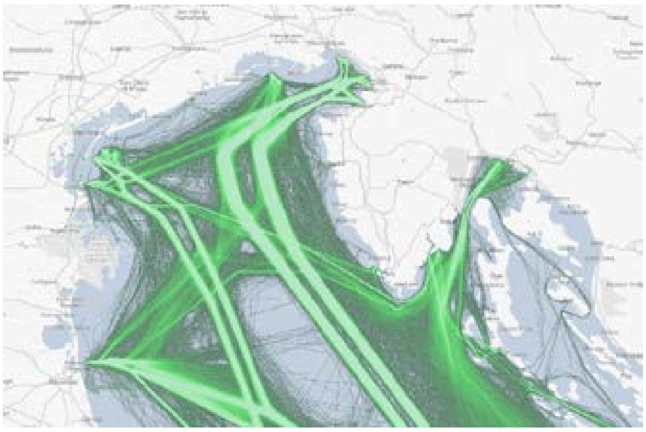

Fig. 2.
Maritime flows in North Adriatic
Source: https://www.marinetraffic.com/en/

The five NA ports are located in three different countries, with different transport policies and development plans. All the NA ports are international multipurpose ports and have their certain specializations, a factor that does not affect each other's business to a considerable extent.

Table 1
Characteristics of NA ports in 2017

	Koper	Rijeka	Venice	Trieste	Ravenna
Total throughput (mio t)	23,367	12,615	25,135	61,955	26,508
Total area [ha]	2.800	1.500	2.200	2.300	1.203
Length of quay [km]	3,3	8,65	30,0	12,0	5,9
No. of calls	1.995	na	3.459	2.339	2.939
Max sea depth [m]	13.5	14	11.4	18	10.5

Source: The data from the port authorities

The main cargo in the port of Koper are containers and cars, meanwhile dry bulk represent 33,9 % of all throughput. Liquid bulk is the main cargo in the port of Rijeka (63,4 %) and in the port of Venice (35 %). The biggest throughput is in the port of Trieste, where crude oil present 70,6 % of total throughput. In the port of Ravenna dry bulk presents 43 % and general cargo 39,8 % of total throughput.
Ports as a "nerve centre" are under the pressure of port performance, where very often economy issues are contradictory to the "green decisions". Consequently, ports must find a balance to follow both goals simultaneously.

3. Port of Koper as a Green Port

"Green Port" concept is a new concept of port development that is focused on the reduction of the emissions and on the implementation of greening approach in the further development. Therefore, there is a need of the implementation of policies relevant for reduction of the emissions of harmful substances in the atmosphere and in the sea, the appropriate landscape design with trees that absorb the noise and pollution, use of renewable energy for port operations and activities (solar, wind, energy from the sea), recycling… Port of Koper is located near to the old city centre of Koper and is part of the urban centre, therefore the port pays attention for the wellbeing of the people that live and work in this populated area. They aim is to ensure the preservation of the environment and to operate in symbiosis with the community. Slovenia's National Spatial Plan includes the plan for the expansion and spatial organization of the Port of Koper in accordance with legislative provision and strict environmental standards. Consequently, the port's development and future operational plans already include environmental guidelines.
The "green development" of the Port of Koper must take into consideration that the port is the most important generator of the development of transport and logistics in Slovenia. The port operate as a multifunctional port and is designed for the handling various types of goods. Activities are performed by twelve specialised terminals, i.e.: container and ro-ro terminal, car terminal, general cargo terminal, livestock terminal, fruit terminal, timber terminal, terminal for minerals, terminal for cereals and fodder, European energy terminal, alumina terminal, liquid cargoes terminal and passenger terminal (Port of Koper, 2018).
Port of Koper is connected to all major world ports by regular shipping lines and the number of ships' calls constantly increase. The distance from Koper to the main industrial centres in Central Europe is approximately 500 km shorter compared to the North European ports that represents good basis for further port's economical and infrastructural development. Road connections from port to the hinterland is excellent, but railway is the main type of transport for the transport of good to and from the port. Presently, over 650 wagons arrive to and leave the port on a daily basis and by

this 60 % of cargo is transported by rail. Consequently, the inland transport follows "green development" directions, with an aim to shift as much as possible cargo on trains.

3.1. Development of "Green port"

To become a "Green Port" is necessary to plan a growth of the port on proactive base. All the activities must be focused on greening approach - in the port and within supply chains. Port of Koper has accepted a detailed development strategy, where all activities of work and planning of the port include the field of environmental protection, energy conservation and environmental care. A detailed environmental policy is presented at their dedicated web site (http://www.zivetispristaniscem.si). Moreover, ESPO (The European Sea Ports Organization) awarded Port of Koper for creating a sustainable future for the port and its surroundings in 2014 (Port of Koper, 2018). Namely, ESPO performs regular surveys in all EU ports, to check if they obtain the environmental priorities. Their development strategy on environmental management is based on measures and solutions that should be introduced to meet legislative demands, with the use of best available technology, to insure as little as possible impacts on the environment.
To protect the environment and natural habitats, they follow some main guidelines that consist of the introduction of modern energy-efficient technology, monitoring and result reporting of emissions into the environment, prompt and efficient responses in emergency situations that can happen in the port, and with constant improvement of the environment management system. In this way, they ensure that the development of port operations is in balance with the environmental, social and economic demands.

3.2. "Green" Activities in Port of Koper

Port of Koper started with the green activities years ago. The port implemented international quality standards for the protection of the environment, health and safety and food safety management. Nowadays, they manage all operations in accordance with these standards. The constantly monitoring of the air, water and noise is necessary to improve the ecology of the port zone. By introduction of vegetation (more than 2,000 trees, including 200 olive trees, have been planted in the last ten years) and the creation of new habitats in port surroundings, the port of Koper is one of the cleanest and greener ports in EU.
Furthermore, the port started with the Waste Management Centre years ago, and they were the first port in the NA to include these green activities in the daily operations. In the Centre, by using appropriate recycling methods, they sort and collect majority of waste generated at the port for further processing. All biodegradable waste is managed in a way to be converted into compost. They provide these processing services also for other enterprises and concerns in the region.
One of the activity that can increase environmental problem in port is dredging. Today ships require a depth of at least 14 m and many ports must use dragging to accommodate such big vessels. This situation is also in the Port of Koper where natural depth on container terminal is 12m (Basin 1), meanwhile at the Basin 3 the depth is 17,2 m. In order to follow increasing carriers' of employing bigger and bigger vessels, they have to remove every year around 80.000 m3 of sediments in all. Part of this dredging material is used as row material for civil engineering application in the port area. With appropriate treatment this material can be used also as a building composite, but in this moment a production is still too expensive.
The biggest environmental problem presents a European Energy Terminal, where they handle coal and iron ore. The terminal area is exposed to a strong northern wind named bora that often blew over 100 km/h. In the beginning they used water spray system to prevent dusting in the wider area. In the last years they developed a paper mill sludge; the cellulose pellets that are a waste by-product of the pulp and paper industry. The dust-suppression system involves mixing the pelletized paper mill sludge with water and then spraying the resultant solution on the stockpiles of coal and ore. When the mixture dries, short cellulose fibres cover coal and ore with a crust that prevents dusting.
The green investments are done also on the Container terminal. Throughput of containers has grown very fast in the last years and the existing container terminal is at the limit of the capacity. With such an intense growth of TEUs transhipped in Koper, it is necessary to start with the construction on a new container terminal and reconstruction and extension of the current container terminal (Twrdy et al., 2013). The extension of Pier I for 100 metres and new warehousing surfaces for containers are in line with the estimated growth of traffic, as well as with the exploitation of present and future terminal capacities. New projects and potential investments at the container terminal are important steps for the development of the Port of Koper, enhancing its performance and increasing its market share. According to this Port of Koper purchased 2 Super Post Panamax cranes, 22 electrical RTG cranes and 2 RMG electrical cranes. All new investments in transport infrastructure equipment on container terminal are environmentally friendly and present a new step for the development of the port. Moreover, the new equipment, when moving, creates electricity and returns it back to the network. Newer devices thus return up to 15% of the electricity consumed for handling purposes.

3.3. New Activities for "Green port"

The biggest environmental problem in the port are ships. The CO_2 emissions that derived the ship on the berth present 74% of all emissions occurring during the sailing time of ship. The emissions from ships at the berth are 10 x greater than those from ports own operations (Gibbs, 2016). The solution is so called "cold ironing", that present on shore

connection between ship and terminal for providing electrical power to a ship while its main engines are turned off. In this way, ships have a power from the landside for refrigeration, cooling, heating, lightening and emergency equipment. For the ports, cold ironing requires significant modification of the existing electricity grid, which is a very expensive and relatively long lasting process.
In the case of Port of Koper, cold ironing system implementation were analysed during the Elemed project. According to the performed analysis, it was proposed construction in phases to enable better financial feasibility of the project and the gradual adaptation to the requirements. Proposed solution for the Port of Koper provides a flexible and open cold ironing concept, able to operate in a standalone mode or integrated in a future smart grid.
Other activities that are planned in Port of Koper are use of solar energy, where the roofs of warehouses shall be equipped with photovoltaic cells. The creation of biofuels from processing waste engendered by port operations is another action that is planned in the near future. With the use of 'grass-carpets' on the roofs of semi-open storage the port will look greener also from the top. These carpets have positive ecologic effects on the buildings themselves and on the wider environment. By reducing building overheating, they indirectly provide lower energy consumption for cooling processes during the summer period.
Establishment of Technology park with an exposition of typical machinery used in operations, will provide an overview, displaying the history of Koper, the development of the seaport and the new expansion projects, including the new sports and recreational facilities. A viewing platform will offer an impressive panorama of the port and its broader surroundings.
The long-term plans can be oriented towards smart port development, with the use of smart infrastructure and superstructure in every-day operations. By this, a smart lightening, smart waste collection and processing, smart water management and faster interventions in potential environmental disasters can be introduced. The interface port-city should benefit from such development. Namely, new foreseen smart technologies will speed-up ports' smart development, with special focus also on environmental issues and long-term sustainability.

4. Conclusion

Ports are complex environmental systems and all activities must be planed and monitored with the EU standards or recommendation. As example - there are presently no international requirements that would mandate or facilitate the use of cold ironing, but just international standards according to which cold ironing must be implemented in near future. For lowering air sulphur ports sector is acting as a driver on international political initiatives (recommendations) - for the ports and for the shipping companies. With these actions, they try to convince shipping companies to reduce carbon emissions.
Port of Koper intends to increase their cargo operations from the current 23,4 million tons to 30-40 million tons in five to ten years, almost doubling the cargo capacity, and potential number of vessels calling the port. Further development of Port of Koper will depend on the rate of investment in increasing capacity. Implementation of cold ironing enables the possibility of synergistic implementation of other necessary investments in Port of Koper. Proposed solution for the Port of Koper provides a flexible and open cold ironing concept, able to operate in a standalone mode or integrated in a future smart grid. Further investments in new machinery will decrease energy consumption and at the same time allow the return of a certain degree of electricity back to the electricity network. Furthermore, the upcoming smart technologies for the ports, and once introduced by the Port of Koper, will give a new basis for future port-city sustainable development.
To obtain sustainable development is necessary to obtain the balance between environmental issue and economic benefits. The enlargement of port area in Port of Koper is in accordance with Slovenia's National Spatial Plan, with legislative provision and environmental standards. The green port concept that anticipate less carbon emission, cold ironing and new equipment complies with these standards and present a positive effect on welfare and ecological protection of wider area.
In this context, cooperation with other North Adriatic ports and exchange of experiences is more than desirable and it has to be stimulated through future projects. Just with the common "green" strategy for port environment is expected to create a winning combination between economy and ecology.

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MARKET CONCENTRATION OF STRATEGIC ALLIANCES MEMBERS IN THE MARITIME CONTAINER SHIPPING MARKET ON TRADE LANES PASSING ACROSS THE ATLANTIC AND THE PACIFIC – SELECTED ISSUES

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Abstract: Strategic alliances have significant impact on Maritime Container Shipping Markets. The vertical and horizontal integration as well as mergers and acquisitions have changed the market dynamics. The MCSM is a strongly integrated market on the supply side. The aim of this paper is to determine, based on empirical data, whether this market is still competitive for its participants, whose are not party of main alliances, and operates services passing across Atlantic and Pacific. For this purpose the Herfindahl-Hirshman Index for members of alliances, namely 2M, THE Alliance and Ocean Alliance, was calculated. The results of computation indicate that the market is moderately concentrated for services passing through Atlantic and still competitive for services passing across Pacific.

Keywords: Herfindahl-Hirshman Index, maritime container shipping market, market concentration, strategic alliances.

1. Introduction

Maritime Container Shipping Markets (MCSM) are main part of the global supply chains, with respect to time and distance. Therefore maritime container shipping is one of the fastest developing transportation branch. The reasons of growing significance of container shipping are mainly possibility to transport almost every type of commodity and cost reduction due to simplify transshipment operations.
Introducing containers to the transportation process implied the need to change the existing transportation model in the way to enable integration of every branch (Notteboom, 2012; David et al., 2016; Charłampowicz, 2017). Every node of the transport process had to be modified to correctly operate containers. The maritime transport market had to adapt to the new conditions. It was made through readjustment of vessels for shipping containers and as a consequence also through readjustment of ports for their handling. This type of actions significantly reduces the transportation cost (Lee & Song, 2017). The reduction of transport costs catalyzed further actions of global trade liberalization. Containerization is considered to be one of the main factors for globalization in the 20th century (Bernhoffen et al., 2017). The dynamic growth of the new transportation branch strengthened the position of shipping companies. In 21th century enterprises, in order to further increase their market share, started to establish strategic alliances that led to reduced costs, risk sharing and increased efficiency of the service provided (Rau & Spinler, 2017; Charłampowicz, 2017).
The aim of this paper is to determine, based on empirical data, whether the market it still competitive for its participants on the supply side, whose are not members of main alliances, and operates services passing across the Atlantic and the Pacific. The paper is divided as follows:

- Section 2 provides brief characteristics of the MCSM;
- Section 3 describes the methodology and data;
- Section 4 presents results of calculations;
- Section 5 outlines research limitations;
- Section 6 discusses the results of calculations and presents final conclusions.

2. Maritime Container Shipping Market

2.1. Brief characteristics of the supply side of the MCSM

According to World Trade Statistical Review 2017, transport, as an exported commercial service, has 17,7 per cent of share in the commercial services (other services are: good-related services, travel and other commercial services). Transport as an imported commercial services has 21,8 per cent of share (WTO, 2017). In both categories there were around 5 per cent decline year-to-year. In the period of time 2006-2016, transport (calculated as an average of exports and imports), as a category in the commercial services of the world trade has noted growth of around 37 per cent, which is the slowest dynamics of increment among other categories (WTO, 2017). International seaborne trade has noted growth of around 2,6 per cent year-to-year (Review of Maritime Transport, 2017). In the period of time 2006-2016 the international seaborne trade has noted growth of approximately 33,6 per cent, with an average increase of 2,9 per cent yearly. Within maritime transportation, container shipping has around 16,7 per cent of share (Review of Maritime Transport, 2017). In 2016 global containerized trade expanded 3,2 per cent year-to-year, with volumes attaining an estimated 140 million TEU's (Review of Maritime Transport, 2017). In the period of time 2006-2016 the global containerized trade has noted growth of approximately 55,5 per cent, with an average pace of growth of about 4,8 per cent yearly.

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Table 1 presents the change of quantity and capacity of container vessels in last decade comparing last quarter of 2007 and 2017. Despite of decrease in the number of deployed vessels by around 4,3 per cent, there was significant increase in overall deployed capacity from 123,2 mTEU to 183,8 mTEU, which is almost 50 per cent growth. MDS projects (MDS Transmodal Container Shipping Bulletin November 2017, 2017), based on the ships on order and not taking into account those that will be scrapped, that by 2020 global fleet capacity could grow by 13 per cent with capacity, in ships of 15000 TEU or more expected to increase by about 64 per cent.

Table 1
Change in the total deployed capacity and total number of vessels

	2007 Q4	2017 Q4	Dynamics of growth
Total deployed capacity (mTEU)	123,2	183,8	49,2%
Total no of vessels	5097	4879	-4,3%

Source: own calculation based on MDS Transmodal Container Shipping Bulletin November 2017

Placing higher orders for container ships in recent years has caused an oversupply. Although, in 2016, TEU capacity per delivered ship was 12 per cent lower than in 2015, the new vessels are larger than existing fleet (Review of Maritime Transport, 2017). This situation continues to exert pressure on ports to accommodate to larger vessels. Due to cascading effect this trend also applies on smaller ports, forcing the authorities to constantly adaptation of infrastructure and suprastructure of container terminals. The main reason of introducing mega container ships was the need of achieving the economies of scale.

2.2. Strategic Alliances on the MCSM

The MCSM has to face very volatile and rapidly changing market realities (Notteboom, 2002). The way to prevent these unpredictable situations for the supply side of the market was market concentration. This concentration of the market on the supply side is expressed in twofold: subjective capital integration, and organizational and functional form expressed through alliances established on the main routes of container transportation (Grzelakowski, 2013). The reasons for these strategic agreements are: risk sharing, economies of scale, knowledge and technology exchange, vertical integration and strengthening of market position (Rau & Spinler, 2017). Referring to the service characteristics, where the main factors are port calls, average number of deployed vessels and average duration, there are minor differences among alliances (Panayides & Wiedmer, 2011). Research conducted by (Rau & Spinler, 2017) confirms that the main drivers of change in the alliances are: competitive intensity, alliance complexity cost and freight rate volatility, while shorter lead times increase market concentration. Participation in the alliance has no influence on management, including sales and marketing, pricing or maintenance of vessel (Stopford, 2009, p. 534), and besides alliances compete with each other (Lee & Song, 2017). (Hirata, 2017) found out that due to strategic alliances static equilibrium does not exist. Empirical study of (Hirata, 2017) revealed that liner companies makes only normal profit regardless of increasing concentration level.

The immanent feature of the transportation industry is its vulnerability to integration (Matczak, 2015). The MCSMs have witnessed unique transformations unheard of in other transportation sectors. Through mergers & acquisitions (M&A), as well as formation of alliances, the three major alliances controlled 80% of the market. Some M&As require the alliance to be reorganized (Lee & Song, 2017).

Participation in strategic alliances has numerous advantages, which affects the MCSM. First of all, presence in the alliance reduces costs and risks for alliance members, that are generally top operators. Strategic alliances affects on smaller enterprises, which cannot draw benefits from economies of scale or risk-sharing. The market power of the strategic alliances members rises battening on the smaller operators. Table 2 presents the members of the 3 main strategic alliances with their market share written in brackets.

Table 2
Members of the current main operating strategic alliances with their global market share (in brackets).

Name of alliance	Ocean Alliance	THE Alliance	2M
Members of the alliance	CMA CGM (11,7%)	ONE (7,0%)	APM-Maersk (18,0%)
	COSCO (9,2%)	Hapag-Lloyd (7,2%)	MSC (14,7%)
	Evergreen Line (5,0%)	Yang-Ming (2,9%)	
	OOCL (3,1%)		

Source: MDS Transmodal; Review of Maritime Transport; Alphaliner TOP100

3. Methodology and Data

3.1. Market Concentration

Market concentration refers to the extent of which a small number of enterprises accounts for a large proportion of provision of goods or/and services on the researched market (OECD). According to the theory of industrial organization economics the higher market concentration, the higher possibility for entities engaging in monopolistic practices, which results with poor economic performance and misallocation of the resources. The ownership concentration, which is related to the supply side of the market, measures the extent to which shares of corporate assets (or market) are widely or narrowly held by business entities (OECD).

3.2. Herfindahl-Hirshman Index

Herfindahl-Hirshman Index (HHI) is based on the total number and market share of enterprises in the industry. This indicator is typically used by the regulators to provide an assessment of market concentration (OECD; Qazi et al., 2017). It is computed as a sum of the squares of percentage market shares of entities in the studied business. Mathematical formula for HHI is as follows:

$$HHI = \sum_{i=1}^{n} s_i^2 \tag{1}$$

where n stands for total number of examined carriers and s_i represents the percentage market share of the i^{th} carrier. The maximum value of HHI, according to equation 1, is 10000, which stands for pure monopoly (OECD). HHI below 1000 represents unconcentrated competitive market, value between 1000 and 1800 indicates moderately concentrated market and value above 1800 shows highly concentrated market (Qazi et al., 2017).

4. Results

Table 3 presents results of calculation of HHI for alliance members on services passing across the Atlantic. Table 4 shows results of computation of HHI for alliance members on services passing across the Pacific. Calculation has been made on data collected from MDS Transmodal Container Shipping Bulletin (MDS, 2016; MDS 2017).

Table 3
Results of calculation of HHI for members of strategic alliances – services passing across the Atlantic.

Name of alliance	Operator	Q4 2016 Operators' HHI	Q3 2017 Operators' HHI
2M	APM-Maersk	441	400
2M	Mediterranean Shg Co	676	676
THE Alliance	Ocean Network Express	4	49
THE Alliance	Yang Ming Marine Transport Corp.	1	4
THE Alliance	Hapag-Lloyd	196	100
Ocean Alliance	CMA CGM	144	144
Ocean Alliance	OOCL	1	4

Source: *own calculations based on MDS Transmodal 2017, AXS Alphaliner.*

On the services passing across the Atlantic HHI for 2M alliance members dropped for about 3,7 per cent. THE Alliance noted decrease of HHI in 23,9 per cent. HHI for Ocean Alliance, on the other hand, increased by 2,1 per cent. Overall HHI for the members of the three main strategic alliances, on the services passing across the Atlantic, dropped for almost 5,9 per cent from 1463 in Q4 2016 to 1377 in Q3 2017.

Table 4
Results of calculation of HHI for members of strategic alliances – services passing across the Pacific.

Name of alliance	Operator	Q4 2016 Operators' HHI	Q3 2017 Operators' HHI
2M	APM-Maersk	225	289
2M	Mediterranean Shg Co	49	25
THE Alliance	Ocean Network Express	225	225
THE Alliance	Hapag-Lloyd	25	25
Ocean Alliance	Evergreen	100	81
Ocean Alliance	CMA CGM	169	169
Ocean Alliance	OOCL	16	25
Ocean Alliance	COSCO Shipping Co Ltd	144	121

Source: *own calculations based on MDS Transmodal 2017, AXS Alphaliner.*

Regarding to services passing across the Pacific, the HHI for 2M alliance increased by around 14,6 per cent. The HHI for THE Alliance remained the same. The Ocean Alliance HHI dropped by around 7,7 per cent. Overall HHI for members of the three main strategic alliances, on the services passing across the Pacific, increased by 0,7 per cent from 953 in Q4 2016 to 960 in Q3 2017.

5. Research Limitations

The ability to utilize and have a full access to *Science Direct* journals made it possible to review the subject in interesting areas. None the less, the fact of relying on only one database greatly limited the possibility of conducting a more extensive literature research.
Another significant research limitation was connected with the lack of possibility of possession more empirical data from the market. The possibility to conduct research based on publicly available reports like UNCTAD Review of Maritime Transport and briefs reports such as MDS Transmodal Container Shipping Bulletin greatly limited the possibility of conductive more extensive research.

6. Conclusions and Discussions

MCSM has to face volatile and rapidly changing market conditions propelled by the increasing customer requirements, technology advances, political disruptions and intensifying competition. The most important factor, for market participants on the supply side, has become cost reduction. The way to achieve marginal cost reduction was deploying ever-larger vessels and consolidation. Through M&A and establishing strategic alliances the market position of alliance members has been strengthened.
The aim of this paper was to determine the market concentration of the MCSM on the services passing across the Atlantic and the Pacific using Herfindahl-Hirshman Index. The results of the calculations indicate that market is moderately competitive for its participants on the supply side. Calculated level of HHI for members of three main strategic alliances, on services passing across the Atlantic, indicated that this market is moderately concentrated (HHI=1377). However concentration level dropped for 5,8 per cent year-to-year, the 2M alliance captures dominant market share of this trade lane (46 per cent of market share). Members of main alliances (2M, THE Alliance, Ocean Alliance) captures 84 per cent of the market share, which leaves small business opportunities for competition for operators, whose are not members of the strategic alliances. Despite the dropping concentration level for operators from main alliances, the market share of all others operators has also dropped from 18 per cent in Q4 2016 to 16 % in Q3 2017.
Calculation of HHI level on services passing across the Pacific indicates that market is still competitive for its participants. Current level of HHI for all alliance members is 835, although this index has risen by 3,2 per cent year-to-year, which represents fragmentized, unconcentrated, competitive market. Comparing to the services passing across the Atlantic, this market is more divided, dominant market share (>50% of market share) is divided by 4 top operators from 2M and THE Alliance (APM-Maersk, ONE, COSCO and CMA-CGM combined have 51 per cent of market share). Members of three main alliances captures 75 per cent of the market share, which also leaves small business opportunities for smaller entities, although the concentration level of the market indicates that the market on the services passing across the Pacific is still competitive for its participants on the supply side.
The main conclusions of this paper are:

- MCSM heading towards to more concentrated market, where few operators will dictate the conditions for other participants;
- Market is moderately concentrated for services passing through the Atlantic, which means it is more difficult for operators, whose are not members of the main strategic alliances, to compete with the top operators;
- Market is still competitive for its participants on the supply side on the services across the Pacific;

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SHIP PROPULSIVE PERFORMANCE ASSESSMENT AND GHG EMISSIONS REQUIREMENTS

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Abstract: Maritime transport represents a considerable source of Greenhouse Gases (GHG) emissions, with negative impact on environment and climate change. As a technical measure to quantify and reduce CO_2 emissions from ships, the International Maritime Organisation (IMO) has introduced Energy Efficiency Design Index (EEDI). After a brief overview of the issues related to shipping GHG emissions, the paper presents an assessment of propulsion performances for different type of merchant ships, taking into considerations EEDI requirements. Alternative combinations between diesel engines and optimal efficiency propellers have been analysed. For every ship type, size and speed, different diesel engines have been selected and propellers have been redesigned to absorb delivered power and to give maximum efficiency at the required speed. For every study case, an attained EEDI has been computed and compared with required IMO EEDI. The impact of two parameters from EEDI formula: power and speed has been assessed to find solutions for EEDI reduction.

Keywords: shipping emissions, ship propulsion system, EEDI.

1. Introduction

Actual trends in shipbuilding and shipping market, fluctuations in fuel costs and environmental impact of Greenhouse Gas (GHG) emissions from ships, demand propulsion systems designed to deliver the maximum efficiency with minimum fuel consumption.

As a technical measure to quantify and to reduce CO_2 emissions from ships, the International Maritime Organisation (IMO) has introduced Energy Efficiency Design Index (EEDI) measured in mass of CO_2 emitted per unit of transport work. In the continuous efforts to improve ship propulsive performances, to reduce fuel consumption and associated CO_2 emissions with their negative environmental impact, the indirect relationship between ship propulsion system design and EEDI criteria represents a real challenge for a naval architect. EEDI becomes an important tool in the design stage by improving ship hull, engine and propeller design and promoting less pollutant equipments.

After a brief overview of the issues related to shipping GHG emissions, the study includes an assessment of propulsion performances for two types of merchant ships, bulk carriers and container ships, taking into considerations IMO EEDI requirements. These two ships classes account 42% of the total shipping CO_2 emissions (Olmer et al, 2017) and represent around 54% of the cargo carrying fleet (Carlton et al, 2013). Alternative combinations between diesel engines and optimal efficiency propellers have been analysed. For every ship type, size and speed, different diesel engines have been selected and propellers have been redesigned to absorb delivered power and to give maximum efficiency at the required speed. For every study case, an attained EEDI have been computed and compared with required IMO EEDI (value calculated as function of ship type). The impact of two parameters from EEDI formula: power and speed has been assessed to find solutions for EEDI reduction.

2. Greenhouse Gas Emissions From Ships

Greenhouse Gases (GHG) trap and hold heat in the atmosphere and contribute to climate change. The main greenhouse gases are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases. To compare their contribution to global warming, data are expressed in carbon dioxide (CO_2) equivalents. The negative environmental impact for each gas depends on its concentration, how long it remains in the atmosphere and how strongly it absorbs energy (Global Warming Potential - GWP).

An important source of GHG emissions from human activities is fossil fuel combustion for peoples and goods transportation. In 2015 the European Union (EU) transport sector has been responsible for around 25.8% of total EU 28's GHG (EEA), in 2016 the United States transportation sector contributed with 28,5% of 2016 USA's GHG (EPA). Shipping GHG emissions account around 3% of global emissions and it is expected to grow in the next years. In EU, maritime transport GHG emissions represent 12.8% from total EU's transport GHG emissions (Figure 1), but compared with other transport technologies, it is generally considered the most carbon efficient and environmental friendly.

CO_2 is an important greenhouse gas emitted by ships. As result of fuel combustion, CO_2 shipping emissions depend on the quality and quantity of the fuel burned. In 2007, shipping emitted approximately 1100 million tonnes of CO_2 and was responsible for 3.5% from global CO_2 emissions (IMO 2014). In 2015, total shipping CO_2 emissions accounted around 932 million tonnes of CO_2 what was around 2.6 % from global CO_2 emissions (Olmer et al, 2017) (Figure 2). Regarding the percent share of CO_2 emissions by ship class, three types of merchant ships: bulk carriers, container ships and oil tanker, account around 55% of the total shipping CO_2 emissions (Figure 3) and represent around 84% of the cargo carrying fleet (Olmer *et al.,* 2017).

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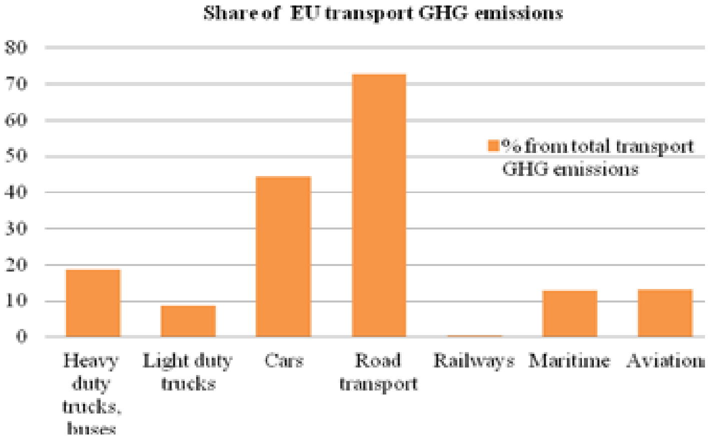

Fig. 1.
Share of EU transport GHG emissions
Source: Data source: EEA-European Environment Agency

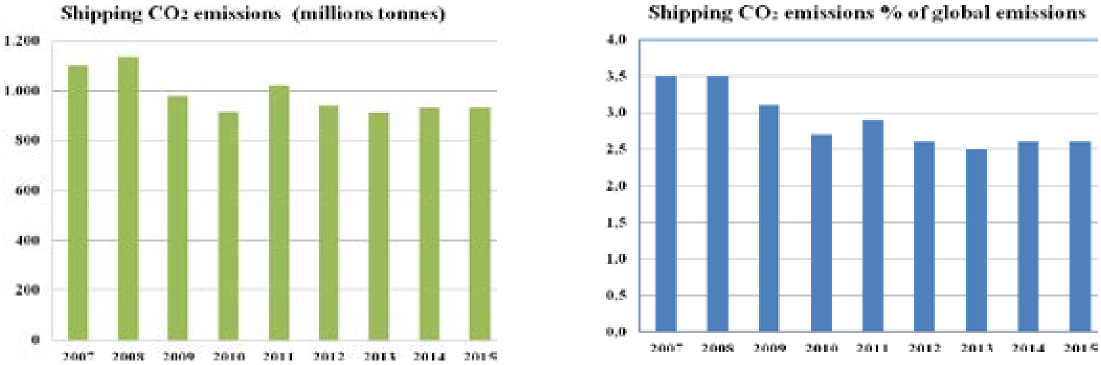

Fig. 2.
Total shipping CO_2 emissions 2007-2015
Source: Data sources: IMO from 2007÷2012 (IMO 2014); ICCT from 2013÷2015 (Olmer et al, 2017).

Fig. 3.
Average percent share of CO_2 emissions by ship class
Source: Data source ICCT (Olmer et al, 2017)

In 2050 the maritime CO_2 emissions are expected to be higher than in 2012, without further action on efficiency and emissions, based on different scenarios, increases between 50% and 250% may occur (IMO, 2014).
To reduce CO_2 emissions from ships, the IMO International Maritime Organisation has adopted in 2011 technical and operational energy efficiency measures for ships. As a technical measure, IMO has introduced Energy Efficiency Design Index (EEDI), mandatory for new ships from 2013. The Ship Energy Efficiency Management Plan (SEEMP) with Energy Efficiency Operational Indicator (EEOI) has been implemented as operational measure, in order to assist shipping company in managing ship energy efficiency.

3. Energy Efficiency Design Index

Energy Efficiency Design Index (EEDI) is a mandatory technical measure to reduce emissions from new ships. EEDI becomes an important tool in the design stage by promoting less pollutant equipments and improving ship hull, engine and propeller design. Expressed as impact to environment from shipping versus benefit to society, EEDI formulation is based on the ratio between total CO_2 emissions and transport work.

$$EEDI = \frac{impact\ \ to\ environment}{benefit\ \ to\ society} = \frac{CO2\ emissions}{transport\ \ work} \tag{1}$$

The CO_2 emissions depend on the installed power, respectively quantity and quality of fuel combusted in propulsion and auxiliary engines. The transport work is expressed as the ship capacity multiplied by ship speed. An attained EEDI (measured in g CO_2/tone-mile) must to be computed based on IMO formulation and guidelines and the value has to be below the limit required IMO EEDI.

$$EEDI_{attained} = \frac{Power \cdot CO_2\ conversion\ factor \cdot Specific\ fuel\ consumption}{Capacity\ \cdot Speed} \leq EEDI_{required} \tag{2}$$

The above formula represents the simplified form of Energy Efficiency Design Index. The relationship is more complex, including different coefficients and corrections factors to adjust the EEDI value for particulars situations. The EEDI formula is not applicable to all ships types and all propulsion systems. EEDI requirements have been developed and extended for ships of 400 GT and above, vessels responsible for approximately 85% of CO_2 emissions from international shipping (e.g., bulk carriers, container ships, tankers, general cargo ships, refrigerated cargo carriers, RoRo cargo ships, LNG carriers). Formula may not be applicable for ships with diesel-electric propulsion, turbine propulsion, hybrid propulsion system (except LNG carriers and passenger ships).
The required EEDI is the maximum allowable value of the attained EEDI and it is defined by a Reference line value, function of ship type and capacity, using following formula:

$$EEDI_{required} = (1 - x/100) \cdot Reference\ line\ value = (1 - x/100) \cdot a \cdot b^{-c} \tag{3}$$

where b is ship capacity, a,c values depend on ship type and x is a reduction rate according to year of built for new ships.
A brief analysis of the main parameters from attained EEDI equation is necessary in order to compute the index and to search technical measures and solutions to reduce it:

- *Power* for EEDI calculation is taking into account the power required for propulsion and auxiliary machines (measured in kW). Installed power is estimated in ship design stage and several solutions may be found to reduce it.
- *CO_2 conversion factor* is a non-dimensional conversion factor between consumed fuel and CO_2 emissions and depends on type of fuel used.
- *Specific fuel consumption* (measured in g/kWh) defined as amount of fuel use per unit of engine power is a characteristic of the engine.
- *Capacity* is defined as follows: deadweight for conventional vessel types, 70% deadweight for containerships, and gross tonnage for passenger and RoRo ships.
- *Speed* is the ship speed measured in knots and represents an important parameter in ship design.

The indirect relationship between ship propulsion system design and EEDI criteria represents a real challenge for a naval architect. Before main propulsion system selection, required propulsive power must be estimated function of ship resistance. Ship resistance is particularly influenced by ship speed, dimensional and form characteristics of the hull and its displacement. Improvements in ship hull dimensions, forms and hydrodynamics may lead to minimize propulsive power and EEDI reduction. Taking into consideration the cubic law between ship speed and power for a conventional propeller, a solution to reduce fuel consumption and CO2 emissions is to adopt lower ship speed. Another solution is to increase speed without increasing the installed power by improving propeller design and propulsion efficiency.
Propeller is one of the main components of a conventional ship propulsion system, with an important role in the interaction between engine and ship hull. Propeller has to be designed to absorb minimum power and to give maximum efficiency at the required ship speed. An optimal combination between engine power/speed and propeller diameter, a good flow in propeller plane shall improve the energy efficiency. In the continuing efforts to increase ship propulsion performances and to reduce fuel consumption and GHG emissions, various energy saving devices have been used into practice on shipbuilding market. Some energy saving devices have been developed to improve the flow around the propulsion and propulsive efficiency (e.g. full or semi-ducts, fins). Some unconventional propulsion and energy saving devices attempt to improve propulsive efficiency by producing thrust and reducing the rotational energy losses (e.g. contra-rotating propellers, rudder bulbs, etc.).
Other technical methods to reduce EEDI are: increase of ship capacity (deadweight), use fuel/energy sources with lower carbon content, use of renewable energy (wind power, solar power). Related to ship capacity, it is know that by

increasing ship dimensions and deadweight, installed power increases proportional with dwt at the power two-third, and taking into account EEDI formula (2), the increase of denominator exceeds that of numerator.

4. Propulsive Performance Assessment and EEDI Calculation

For the present study related to ship propulsive performance assessment taking into considerations EEDI requirements, two types of merchant ships have been selected: bulk carriers and container ships, with significant CO_2 emissions (Olmer et al, 2017) and over 50% of shipping. Bulk carriers are generally single screw vessels with high block coefficient, operating for long time at low and moderate service speed (around 14.5 knots or lower for bulk carriers with capacity below 30000 tdw). Fixed screw propellers directly coupled with slow speed diesel engines are used for propulsion. Propellers open water efficiency for bulk carriers are relatively low. Container ships design speed is around 15-27 knots, propellers open water efficiency have higher values and slow speed or medium speed engines are suitable.
The study was carried out for two different size bulk carriers (75000 tdw, 27000 tdw) and two container ships (4000 TEU and 500 TEU). Alternative combinations between diesel engines and optimal efficiency propellers have been analysed. Different diesel engines have been selected and propellers have been redesigned to absorb delivered power and to give maximum efficiency. Taking into account that propeller performances are related to ship speed, the work has been focused on propeller design and the impact of power and speed on EEDI formula. The aim was to find the best solution to increase propulsive performances and to reduce Energy Efficiency Design Index. For every study case, an attained EEDI has been computed and compared with required IMO EEDI (values calculated as function of ship type using parameters from Tables 1, 2).
For power estimation and propeller design, ship's resistance is necessary as initial data and the results related to effective power, given as ship resistance multiplied with ship speed, are plotted in Figures 4 and 5. It should be noted that the impact of hull forms improvement and ship resistance reduction on EEDI are not the subject of the present work.
For every ship type and size, for different slow diesel engines, the propellers have been designed to absorb delivered power and to give maximum efficiency at the required combination power-speed. A sea margin (SM) of 15% and an engine margin (EM) between 0 - 10% have been assumed in the propeller design. The main characteristics of the designed propeller are presented in Tables 3, 4.
Generally, higher propeller efficiency is associated with a larger propeller diameter and lower rpm. It is recommended to install the largest propeller diameter that can be accommodated to hull lines. In Tables 3,4, the values of designed propeller diameter have been marked with different colours: yellow for the maximum propeller diameter, green for the diameter corresponding to the minimum value of the attained EEDI, red for the diameter corresponding to the maximum value of the attained EEDI. For every study case (ship type and size, power engine, propeller design conditions) the engine power versus EEDI and the speed of the ship (obtained with designed propeller) versus EEDI have been plotted in Figures 6, 9 and Figures 7, 10. In these diagrams the required EEDI correspond to Phase 1 (2015-2019).

Table 1
Coefficients for required EEDI calculation

Ship type	a	b	c
Bulk carriers	961.79	DWT	0.477
Container ships	174.22	DWT	0.201

Table 2
Interpolation interval for EEDI reduction

Ship type	Phase 0 2013-2014	Phase 1 2015- 2019	Phase 2 2020-2024	Phase 3 2025-
Bulk carriers >20000 tdw	0%	10%	20%	30%
Container ships > 15000 tdw	0%	10%	20%	30%

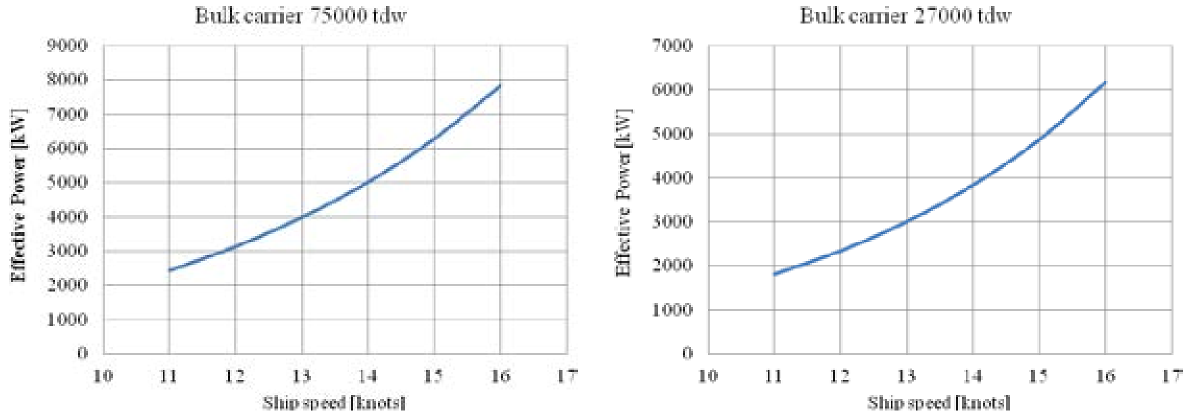

Fig. 4.
Bulk carriers effective power (effective power=ship resistance × ship speed)

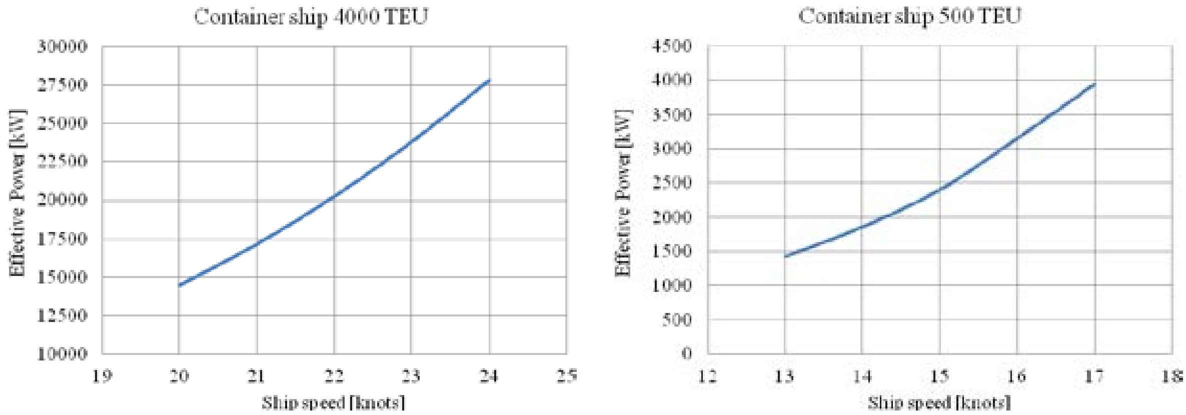

Fig. 5.
Container ships effective power (effective power=ship resistance × ship speed)

Table 3
Propeller characteristics for 75000 tdw bulk carrier and 27000 tdw bulk carrier

	Propeller design condition		Bulk carrier 75000tdw					Bulk carrier 27000tdw				
			Main engine	Propeller characteristics				Main engine	Propeller characteristics			
	SM %	EM %	MCR [kW]	D [m]	RPM	P/D	efficiency	MCR [kW]	D [m]	RPM	P/D	efficiency
case1	15	0	8900	6.16	117.00	0.672	0.529	6900	5.50	129.00	0.685	0.536
case2	15	10	8900	6.14	113.00	0.670	0.529	6900	5.48	124.55	0.685	0.537
case3	15	0	10680	6.37	117.00	0.680	0.540	6810	5.13	146.00	0.660	0.516
case4	15	10	10680	6.34	113.00	0.680	0.539	6810	5.10	141.00	0.663	0.515
case5	15	0	8600	6.67	100.00	0.700	0.554	6090	4.64	167.00	0.640	0.484
case6	15	10	8600	6.65	96.55	0.699	0.553	6090	4.64	161.24	0.633	0.487
case7	15	0	10320	6.90	100.00	0.713	0.563	5675	4.95	146.00	0.654	0.500
case8	15	10	10320	6.88	96.55	0.710	0.563	5675	4.94	141.00	0.651	0.500
case9	15	0	9730	6.45	111.00	0.686	0.544	5500	5.37	125.00	0.678	0.530
case10	15	10	9730	6.42	107.17	0.687	0.542	5500	5.34	121.00	0.678	0.531
case11	15	0	10175	6.70	105.00	0.700	0.555	6200	5.90	110.00	0.707	0.558
case12	15	10	10175	6.67	101.38	0.700	0.554	6200	5.87	106.20	0.709	0.557

Table 4
Propeller characteristics for 4000 TEU container ship and 500 TEU container ship

	Propeller design condition		Container ship 4000 TEU					Container ship 500 TEU				
			Main engine	Propeller characteristics				Main engine	Propeller characteristics			
	SM %	EM %	MCR [kW]	D [m]	RPM	P/D	efficiency	MCR [kW]	D [m]	RPM	P/D	efficiency
case1	15	0	45200	8.79	102.00	0.88	0.65	5675	4.85	146.00	0.740	0.580
case2	15	10	45200	8.74	98.50	0.880	0.650	5675	4.81	141.00	0.750	0.587
case3	15	0	40680	8.61	102.00	0.87	0.650	5220	4.37	167.00	0.730	0.560

	Propeller design condition		Container ship 4000 TEU					Container ship 500 TEU				
			Main engine	Propeller characteristics				Main engine	Propeller characteristics			
	SM %	EM %	MCR [kW]	D [m]	RPM	P/D	efficiency	MCR [kW]	D [m]	RPM	P/D	efficiency
case4	15	10	40680	8.58	98.50	0.880	0.650	5220	4.37	161.24	0.730	0.564
case5	15	0	41220	9.82	80.00	0.957	0.670	4350	4.24	167.00	0.720	0.560
case6	15	10	41220	9.76	77.24	0.960	0.680	4350	4.23	161.24	0.720	0.560
case7	15	0	34320	8.34	102.00	0.865	0.645	5500	5.20	126.00	0.78	0.600
case8	15	10	34220	8.30	98.50	0.870	0.642	5500	5.17	121.65	0.790	0.606
case9	15	0	31640	8.21	102.00	0.86	0.642	4480	3.91	196.00	0.69	0.534
case10	15	10	31640	8.17	98.50	0.87	0.644	4480	3.89	189.23	0.69	0.537

EEDI requirements for bulk carriers and container ships have been plotted in Figure 8 and Figure 11, together with maximum and minimum values of attained EEDI for every ship type and size. For studied cases, all variations have been achieved by changing the main engine characteristics (power/speed, specific fuel consumption) and ship speed (obtained with optimal propeller designed to consume delivered power with maximum efficiency). The attained EEDI was not below required EEDI in all situations.

Most favourable results have been obtained for 75000 tdw bulk carrier, due to ship capacity and relatively low speed. In 6 cases the attained EEDI was below required EEDI phase 1. With the most efficient propeller (Case 7) a speed above 14.5 knots has been obtained with an attained EEDI below EEDI base line value. Cases 7 and 8 indicate the solution to reduce EEDI by increasing speed without increasing the installed power by improving propeller efficiency.

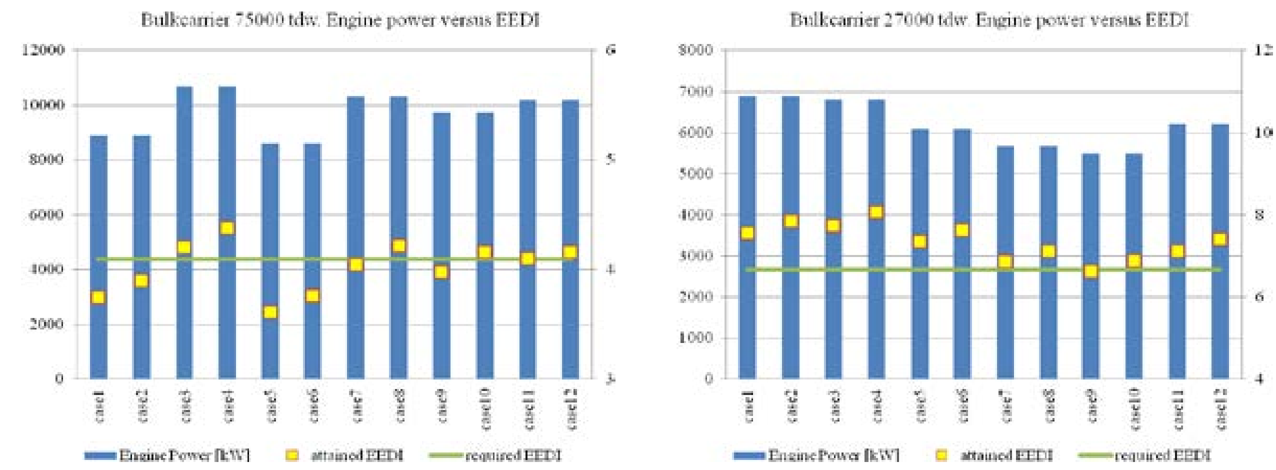

Fig. 6.
Engine power versus EEDI for bulk carriers

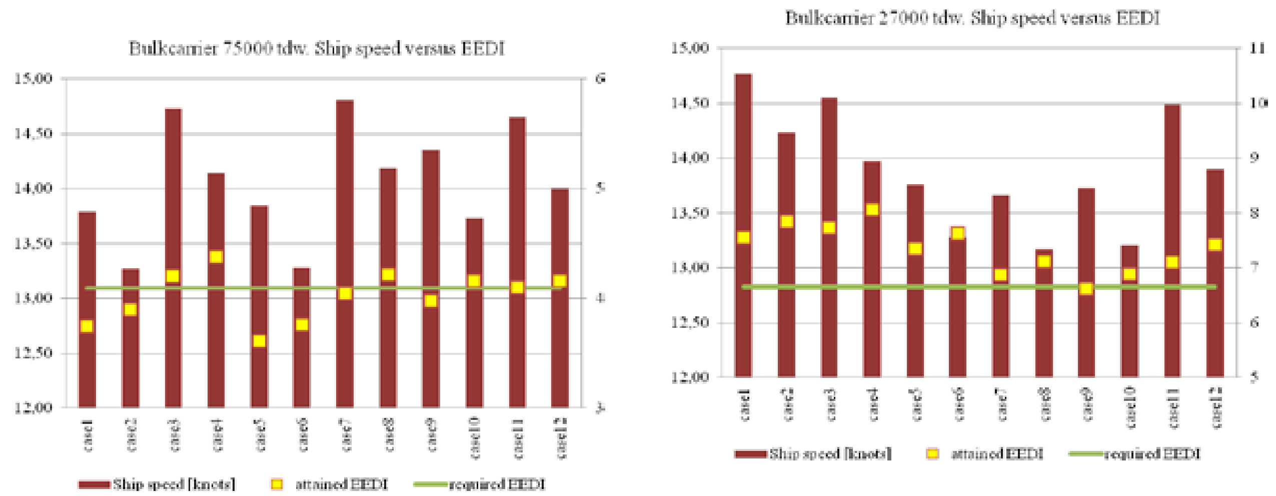

Fig. 7.
Ship speed versus EEDI for bulk carriers

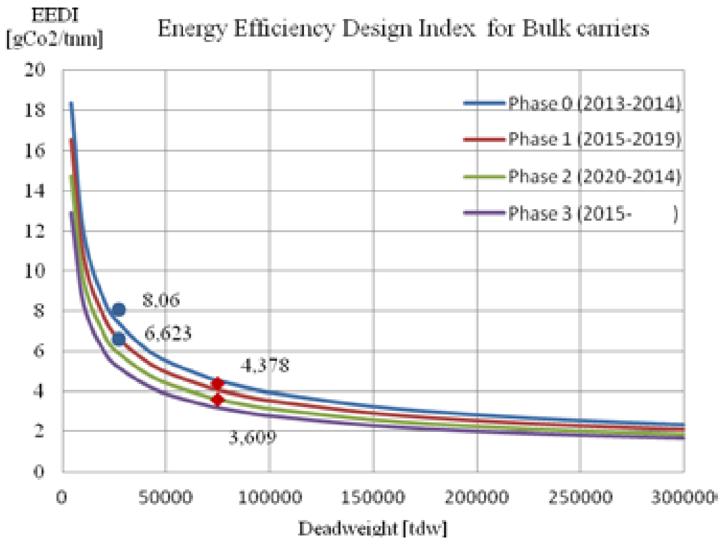

Fig. 8.
Energy Efficiency Design Index for bulk carriers

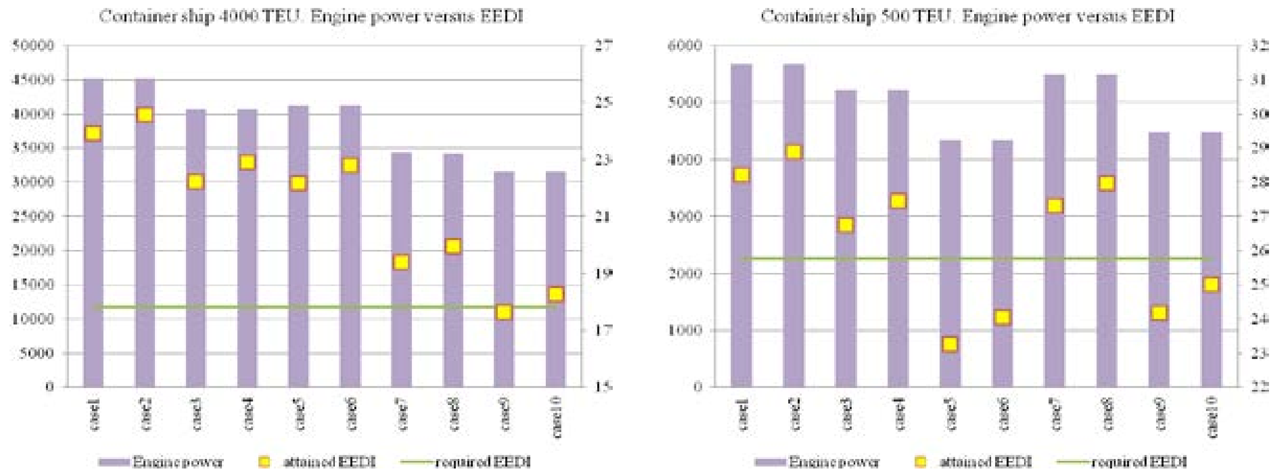

Fig. 9.
Engine power versus EEDI for container ships

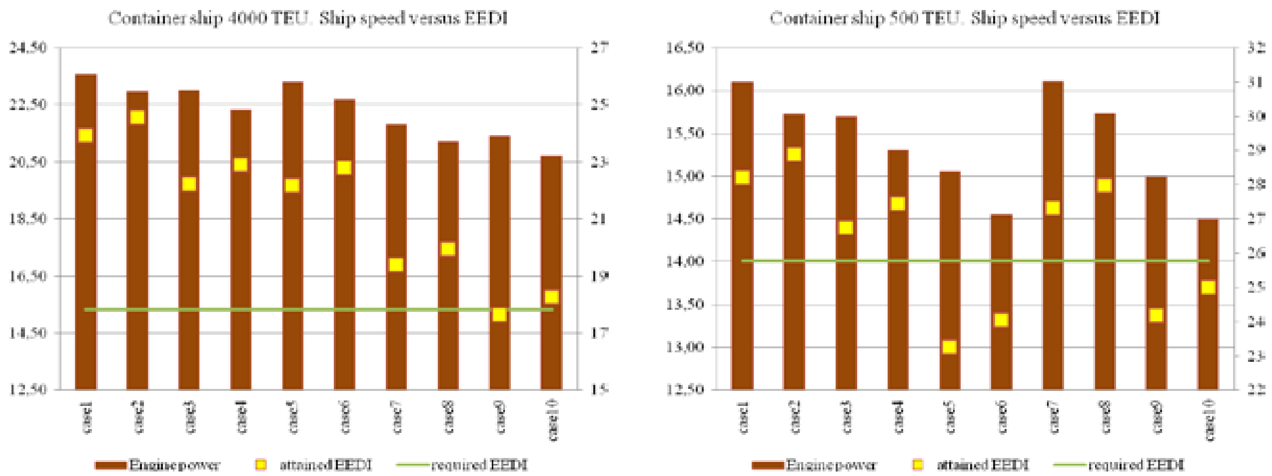

Fig. 10.
Ship speed versus EEDI for container ships

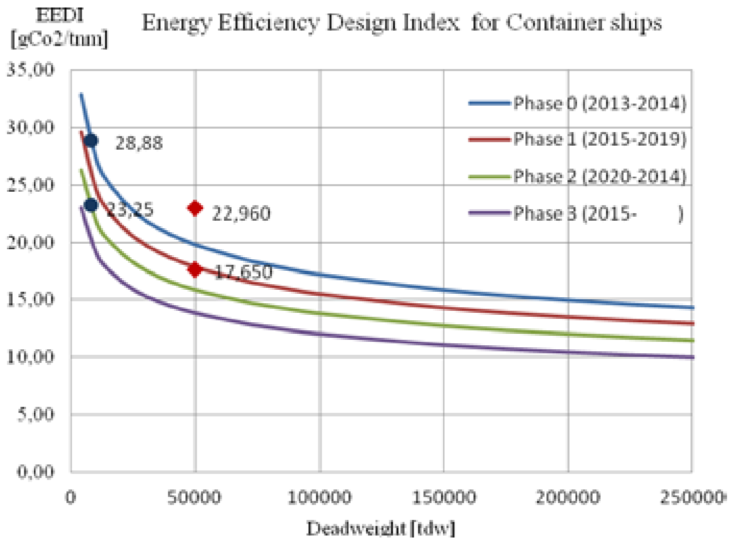

Fig. 11.
Energy Efficiency Design Index for containerships

Not the same things can be concluded about the 27000 tdw bulk carrier study. The only EEDI favourable case has been obtained by reducing engine power and ship speed (case 9). It should be noted that for this ship, the values of hull propeller interaction coefficients were higher. Hull forms improvements and most efficient combinations main engine/propeller may lead to EEDI reduction. The search for new two stroke engines with low revolution rate rpm and minimum fuel consumption may improve the results. For 4000 TEU container ship, only in case 9 the attained EEDI was below required EEDI phase 1, for the lower engine power and a relatively low speed. 4 favourable cases from EEDI requirements point of view have been found for 500TEU container ship, but for the ship's speed below 15 knots. For these 3 vessels, the choice of maximum diameter propeller did not lead to an attained EEDI below required EEDI phase 1. All the studied cases were presented, even if some results were unfavourable in terms of propulsion performance and/or EEDI requirements. Improvements in ship hull forms and hydrodynamics, search for other combination main engine/propeller may improve the results.

5. Conclusion

Actual trends in shipbuilding, fuel costs and environmental impact of Greenhouse Gas (GHG) emissions from ships, demand propulsion systems designed to deliver maximum efficiency with minimum fuel consumption. EEDI becomes an important tool in the design stage, being reduced by improving ship hull shape and less structural mass, engine and propeller design and promoting less pollutant equipments. In the continuous efforts to increase ship propulsive performances, to reduce fuel consumption and associated CO_2 emissions with their negative environmental impact, the indirect relationship between ship propulsion system design and EEDI criteria represents a real challenge for a naval architect. Fundamental to the ship propulsion system design is the selection of the main components (prime mover, transmission and propulsion) adjusting each to the constraints imposed by all other (Harrington, 1992) and integrating them into a functional system to achieve the required propulsive performances with low emissions and acceptable costs.

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VEHICLE DYNAMICS ANALYSIS – WET ROAD SURFACE

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Abstract: This paper deals with vehicles' Škoda Superb III motion analysis during evasive manoeuvres and driving in the curve road tests with emphasis on usable coefficient of adhesion between tyre and road surface in lateral direction. All the individual road tests had been carried out both with and without using Škoda stability system ESC. Experimentally determined values of coefficient of adhesion and lateral acceleration have been utilized for the calculation of modern vehicle limit speed on wet surface in curve and for determination of the time of the lane change manoeuvres, which can be used for traffic accident forensic reconstruction. Many road tests have been carried out on dry road surfaces; this paper shows the difference of dry and wet road conditions as well. The tests show improved constant value which can be used for calculation of minimal time of lateral displacement in conventional formula.

Keywords: adhesion, lateral acceleration, driving, wet road surface, stability system, manoeuvre.

1. Introduction

At present, great emphasis is placed on vehicle safety. For this reason, modern vehicles are mandatory equipped with a range of assistance systems that help to maintain vehicle stability even under limited adhesion conditions. One of these systems is the electronic stability system (ESC), used in Škoda vehicles, which makes it possible to achieve higher lateral acceleration driving critical manoeuvres. This article deals with the experimental finding of the achievable lateral acceleration of the Škoda Superb III vehicles on wet surface and shows the differences between driving with the support of the assistance systems and without them as well.

There are many studies aimed at assessment of benefits of electronic stability systems in vehicles with respect to accident occurrence and their ability of accident avoidance. In traffic accident reconstruction in Canada (Chouinard, 2011) was found that presence of electronic stability systems has positive influence on accident occurrence. This was marked as the ESC efficiency and expressed as percentage decrease of accidents that could be influenced by presence of electronic stability system (loss of stability, avoidance manoeuvre etc.). Efficiency of ESC was determined to be higher during accidents with injury of the vehicle passengers. Other studies came to the similar conclusions as well (Page, 2006; Farmer, 2006; Lie, 2006; or Kreiss, 2005).

From the dynamic measurements of the vehicle's braking and braking performance in the curve (Panáček, 2016) it is clear that modern vehicles achieve similar acceleration (or deceleration) values both in the longitudinal and lateral directions regardless of driving speed and can use lateral adhesion even during intensive braking. At the same time, it has been shown that vehicles equipped with a stability system have the possibility to use higher adhesion coefficient than vehicles without these systems and achieve higher driving limits (Semela, 2015). For maximum efficiency, however, these systems require information about the actual value of the adhesion coefficient (Lee, 2004; Rajamani, 2010).

2. Experimental Section

As part of Škoda Auto company cooperation with Institute of Forensic Engineering, Brno University of Technology (IFE, BUT) several vehicles were provided for testing followed by crash tests. Two of those vehicles were used for dynamic tests as well. The main objective of these tests was to verify driving limits of modern vehicles on wet road surface and estimate the impact of assistance systems on achievable vehicle lateral acceleration.

2.1. Tested Vehicles

All the performed driving tests were carried out with modern vehicles Škoda Superb III 1.4 TSI with a manual transmission and Škoda Superb III Combi 1.4 TSI with an automatic transmission. Parameters of tyres (tread depth and tyre pressure) used on both vehicles are listed in tables below.

Table 1
Škoda Superb III tyres

Continental WinterContact 215/55 R17 94H				
Tyre	Front left	Front right	Rear left	Rear right
Tyre tread depth	8.0 mm	8.1 mm	8.5 mm	8.5 mm
Tyre pressure	2.1 bar	2.1 bar	2.1 bar	2.0 bar

Source: IFE, BUT

Table 2
Škoda Superb III Combi tyres

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Continental ContiWinterContact 235/45 R18 98V				
Tyre	Front left	Front right	Rear left	Rear right
Tyre tread depth	7.9 mm	7.9 mm	7.2 mm	7.3 mm
Tyre pressure	1.9 bar	1.8 bar	1.9 bar	1.9 bar

Source: IFE, BUT

2.2. Measuring equipment

For the purpose of determining the vehicle dynamic parameters a Racelogic VBOX Sport (GPS based measuring equipment) was used. During this testing a vehicle speed, acceleration and position were measured with the update frequency of this equipment of 20 Hz. Any driving input during the vehicle testing was observed using cameras VIRB Garmin Ultra 30 placed inside the vehicles. The position of steering wheel was also monitored by potentiometer.

Fig. 1.
Placement of measuring equipment
Source: IFE, BUT

2.3. Testing Course/Polygon

All the dynamic tests with Škoda vehicles were carried out on a special testing area used for truck testing – the Tatra Company in Kopřivnice (CZ). All the dynamic tests were carried out at the section of the testing area used for circular tests – the surface was made of asphalt, air temperature during the tests was between 7 and 15°C and there was permanent light rain during the testing.
Two series of testing were carried out with both vehicles. The first one was steady-state circular test – driver's aim during this test was to achieve limit speed of the vehicle while driving with and without the assistance systems, trying to maintain radius of the driving course 10 and then subsequently 20 m.
The second test was severe lane-change manoeuvre based on ISO 3888-2, where the driver's goal was to achieve maximum speed through the course while maintaining vehicle driving stability. All the tests have been for the reason of repeatability made by only one 30-years old experienced driver (this also allowed the driver to familiarize himself with both the driven vehicle and the test course thus allowing him to achieve limit speeds).

3. Results

During the dynamic tests carried out at the Tatra Company testing area in Kopřivnice 18 steady-state circular tests were performed by both Škoda Superb III and Škoda Superb III Combi vehicles. Each of the vehicles was tested on circular course with inner circle diameter of 10 and 20 m. All the tests were made with the ESC system enabled and disabled (this was achieved by pulling the control fuse of the assistance system out).
From the measured values of lateral acceleration were selected only those gained after reaching the limit speed of the drive. From these selected values a mean value of the lateral acceleration was calculated on 95% confidence interval (see figure below).

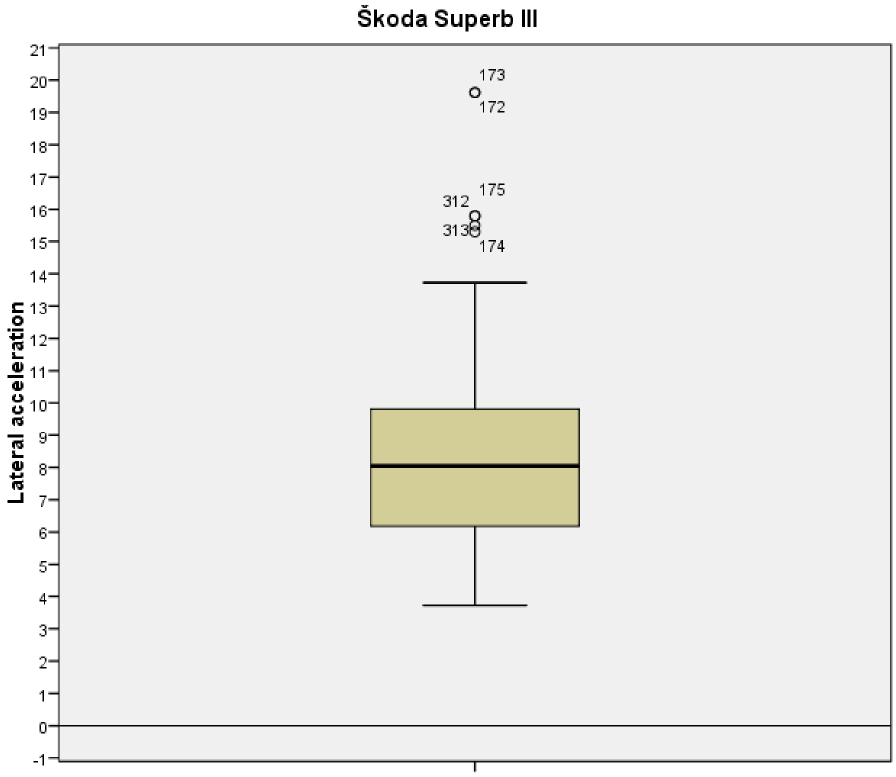

Fig. 2.
Mean lateral acceleration of Škoda Superb
Source: IFE, BUT

The results of both vehicles testing can be seen in the tables below. In the tables there can be seen whether the stability system (ESC) was activated or deactivated, inner radius of the driving course and average radius achieved by the driver during the test, average limit speed of the vehicle during the test and mean value of the lateral acceleration. There is also value of the coefficient of lateral adhesion calculated using following formula:

$$\mu_y = \frac{v^2}{g.r} \tag{1}$$

Where:

v – vehicle speed
g – gravitational acceleration
r – achieved radius of the test

Table 3
Škoda Superb III steady-state circular test results

Test no.	ESC	Radius [m]	Achieved radius [m]	Vehicle speed [km/h]	Mean lateral acceleration [m/s^2]	Coefficient of lateral adhesion [-]
1	OFF	20	21.0	50	8.1	0.94
2	OFF	20	22.0	50	8.7	0.89
3	ON	20	22.0	50	8.1	0.89
4	ON	20	22.0	52	9.1	0.97
5	ON	10	12.5	38	9.2	0.9
6	ON	10	12.5	39	8.5	0.96
7	OFF	10	12.0	38	8.2	0.95
8	OFF	10	12.0	37	8.6	0.90

Source: IFE, BUT

Table 4

Škoda Superb III Combi steady-state circular test results

Test no.	ESC	Radius [m]	Achieved radius [m]	Vehicle speed [km/h]	Mean lateral acceleration [m/s^2]	Coefficient of lateral adhesion [-]
1	ON	10	11.5	35	7.4	0.84
2	ON	10	12.5	38	7.7	0.91
3	ON	10	12.0	37	7.9	0.90
4	OFF	10	12.0	37	8.6	0.90
5	OFF	10	12.0	38	9.1	0.95
6	OFF	10	12.5	38	8.5	0.91
7	OFF	10	12.5	39	8.4	0.96
8	OFF	20	23.0	51	8.4	0.89
9	ON	20	22.0	51	9.1	0.93
10	ON	20	22.0	50	8.8	0.89

Source: IFE, BUT

Škoda Superb III Combi was first of the tested vehicles. Unfortunately, precaution of the driver could be seen by prefatory tests, which is also visible from the lower values results of lateral acceleration. In the progress of time of tests on the same testing track, the experience and confidence of the driver increased and precaution decreased.

The second part of dynamic tests was severe lane-change manoeuvre. 12 tests with Škoda Superb III vehicle and 19 tests with Škoda Superb III Combi vehicle were carried out in total. From these tests 8 successful drives were picked for each of the vehicles as a representative sample showing limit values by normal vehicle. The goal of these tests was to determine the minimum time required to make the lane-change manoeuvre.

The length of the lane change manoeuvres has been estimated from the video records. The beginning of steering was set as the start time of the manoeuvre, as the end of the manoeuvre was considered by finalization of lane change manoeuvre on testing track (when the vehicle got completely to the same direction as before the manoeuvre). The results are introduced in tables below.

Table 5

Škoda Superb III lane-change manoeuvre length

Test no.	ESC	Intended speed [km/h]	Achieved speed [km/h]	Lateral distance [m]	Manoeuvre length [s]
1	ON	50	47	2.7	1.68
2	ON	60	53	2.7	1.52
3	ON	67	65	3.1	1.44
4	ON	70	66	2.7	1.20
5	OFF	50	47	2.7	1.56
6	OFF	60	57	2.7	1.32
7	OFF	70	65	2.7	1.40
8	OFF	75	69	3.2	1.44

Source: IFE, BUT

Table 5

Škoda Superb III Combi lane-change manoeuvre length

Test no.	ESC	Intended speed [km/h]	Achieved speed [km/h]	Lateral distance [m]	Manoeuvre length [s]
1	ON	50		3.0	1.36
2	ON	55		3.0	1.64
3	ON	60		3.0	1.40
4	ON	67		2.7	1.56
5	OFF	55		2.7	1.68
6	OFF	60		2.7	1.28
7	OFF	70		2.7	1.32
8	OFF	75		2.7	1.24

Source: IFE, BUT

It is possible to assume a sharp change of lateral acceleration with two maximums before vehicle stabilization (left and right) in case of lateral displacement with the help of two curves lane change manoeuvre. However, the course of the lateral acceleration of vehicle is comparable to sinusoid undulation. We could deduce theoretical formula for calculation of minimal necessary manoeuvre time, however we need to consider transitional curves as well in the beginning and end of the manoeuvre that prolong the minimal necessary manoeuvre time in sum.
For the purposes of traffic accident reconstruction in the Czech Republic are commonly used Weiss formula (Burg 2009) and so called Kovařík formula which only differs by using constant of 3.13 (opposed the Weiss formula that uses constant of 2.67).

$$t \geq 2{,}67.\sqrt{\frac{y}{a_y}} \tag{2}$$

Where:

t – minimal time of lane-change manoeuvre
y – lateral distance of the manoeuvre
a_y – maximal lateral acceleration.

With the later development of vehicles and based on carried out tests, the constant was changed to 2.6 (Bradáč 2005, Semela 2015).
As the alternative following formula can be used (Fundowicz, 2015) that calculates the distance travelled by vehicle in terms of lateral displacement manoeuvre. The formula reflects the gradual change (increase and decrease) of lateral displacement in terms of manoeuvre based on forces balance in lateral direction and it allows calculating the minimal distance travelled by vehicle during lane change manoeuvre.

$$S_{MIN} = v.\sqrt{\frac{Y}{1{,}56.\mu_y}} \tag{3}$$

Where:

v – vehicle speed
Y – lateral distance of the manoeuvre
μ_y – coefficient of adhesion in lateral direction.

Based on above mentioned, the durations of lateral displacement manoeuvres gained from video records and acceleration course were used for the calculation of empirical formula constant which is often used by calculation of minimal necessary time of lateral displacement. The average value of maximal lateral acceleration of vehicles on wet surface was about 8.5 m/s^2. The average lateral distance evaluated by GPS device was 2.8 meters.
The calculation of searched constant was made on basis of following formula:

$$k = t.\sqrt{\frac{a_y max}{y}} \tag{4}$$

Where:

t – minimal time of lane-change manoeuvre
y – lateral distance of the manoeuvre
$a_y$max – maximal lateral acceleration.

The constant was found to be 2.51, so we can assume that despite the wet surface, modern vehicle can achieve better values of lateral acceleration and that formula for calculation of minimal necessary time of lateral displacement can be always used, but with improved (lower) constants.

3. Discussion and Conclusion

By comparison of values of lateral acceleration reached during steady-state circular tests there could be observed differences between activated and deactivated assistance stability systems (ESC). Maximal values always depend on driver's experience and willingness to get vehicle to its limit while remaining in designated area of test track. The higher lateral acceleration values can be seen by vehicles with activated assistance systems (best seen at Škoda Superb III results).

During the steady-state circular tests it was possible to reach limit values necessary for the loss of the vehicle stability. This situation was evident for example during circular test at 10 m testing course radius with limit value of lateral acceleration reaching 10 m/s^2, vehicle was significantly tilted and the slip of left front impellent wheel could be seen.
The determination of minimal necessary time of lateral displacement by modern vehicles is depending on reachable value of lateral acceleration of the vehicle. The tests showed that in relating of tyre and assistance system development, the constant used for calculation needs to be corrected to lower values. For instance, the value of constant found by Panáček and Semela (Panáček 2016) was 2.6 by Volvo V40 AWD at dry surface and the last test shows the possibility to use the constant value of 2.5. Modern vehicles significantly move the limits of driving dynamics that can be best seen on achievable values of lateral acceleration during dynamic tests that reached 8.5 m/s^2 on average while driving on wet road surface, as this value is close to value of lateral acceleration measured during testing on dry road surface (Panáček, 2016), which was reaching 8.5 – 9.5 m/s^2.

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MODERN TECHNOLOGIES IN RESCUING OCCUPANTS FROM SPECIAL VEHICLES USED IN THE LOGISTIC PROCESSES

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Abstract: The process of rescuing vehicle occupants through a blocked door is an integral part of logistic support in the field of all vehicles operation using in all the world. Rescuing human lives is a priority, and the logistic activities affecting the vehicle life cycle are dealt with afterwards. In this paper, a kit of special agents and technical means is designed for the purpose of penetrating into special vehicles used in the dangerous places and all the world in order to rescue their occupants through blocked doors or through armour protection (body). Practical verification tests of the new technology were devised and conducted. Based on these tests, the kit design was then finalised. For the penetration into a crashed or damaged special vehicle from outside, entrance openings were used. These were doors and lids. The technology was verified by six tests conducted on an armour door demonstrator. The first set of tests was based on a "cold process" technology, i.e. unbolting and the use of a combi tool. In the next set of tests, this technology included the use of a power cutter and a combi tool. In the last step was used the plasma for cutting the blocked door or through the armour. For this measurement was used the metalografical analysis of plasma cutters. The above-mentioned technical solutions have a positive impact on the management of state assets and form an inseparable part of the traffic's logistics.

Keywords: farmer, hinge, cordless cut off tool, combi tool, petrol power cutter.

1. Introduction

"Cold process" technology is based on unbolting and the use of a combi tool. The technology lies in unbolting door, or possibly lid hinges (where possible), and making an entrance opening between the door and the pillar on the hinged side, or between the lid and the roof, so that a combi tool could be inserted to prize the door or lid open. The combi tool also allows cutting a door restrictor. A similar problem was dealt with by the (Dostál et al., 2011; Dostál et al., 2014). The "cold process" technology comprising the use of a power cutter and a combi tool. This technology can be employed in cases when door or lid hinges cannot be unbolted and have to be cut with a power cutter. Using a claw bar, an entrance opening is made between the door and a pillar, or possibly between the lid and the roof, where a combi tool can be inserted to prize the door or lid open.

The world has material for special rescue operations at their disposal. This material is available at military rescue units – rescue companies of engineer battalions and military fire-fighting units. The material is similar to that commonly used by the units of Fire Rescue Service when rescuing occupants from crashed vehicles. Nevertheless, this material is insufficient for rescuing occupants from armoured vehicles, and its use is rather limited. A similar problem was dealt with by the (Binar et al., 2011, Sukáč et al., 2015).

Based on available information, it could not be proved the special vehicles on the world have portable rescue kits at their disposal that could be included into standard equipment of selected vehicles and used to open these vehicles.

Fire Rescue Squad, Rescue Platoon, Rescue Company are in possession of a HOLMATRO hydraulic rescue device, a power cutter, and lighting equipment, making the squad currently capable of efficiently operating and rescuing occupants from both crashed passenger cars and lorries by daylight and night. Nevertheless, this equipment is not sufficient for special vehicles. The similar advance did choose by the (Binar et al., 2015, Kazda et al.,2015).

Also, the Rescue Company makes use of salvage vehicles VT-72 (recovery tank) and AV-15 (recovery vehicle).The VT-72 tank may be used in an impassable terrain (shifting, tilting, overturning of crashed vehicles using a winch).

2. Materials and Methods

For the purpose of practical verification of the newly designed technology and the kit of special agents and technical means for the penetration into crashed or damaged armoured vehicles from outside, an armour door demonstrator was devised and manufactured. When devising the demonstrator, the team of researches took account of the requirement for the dimensions and materials to be the same as in the special vehicles (Binar et al., 2014; Joska et al., 2010).

The demonstrator consisted of a door frame and a door. The door, dimensioned 1,020 mm x 1,370 mm and 6.5 mm thick, was manufactured from armour plate of Secure 500 quality (refer to the annex for the attest).The door was fitted with hinges from 30 x 10 mm to 70 x 15 mm cross-section on the outside and with latches of 30 x 15 mm cross-section representing anti-burst latches (top and bottom) on the inner side and a door lock latch of 30 x 10 mm

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cross-section (in the middle). Also, on the inner side, the door was fitted with a restrictor made of a pole 20 mm in diameter. The hinges, the latches and the door restrictor were manufactured from materials of quality class 11 and 12 (refer to Fig. 1). The hinges were on the left side of the door and the anti-burst latches with the lock on the right side (ČSN 2004, ČSN 2005).

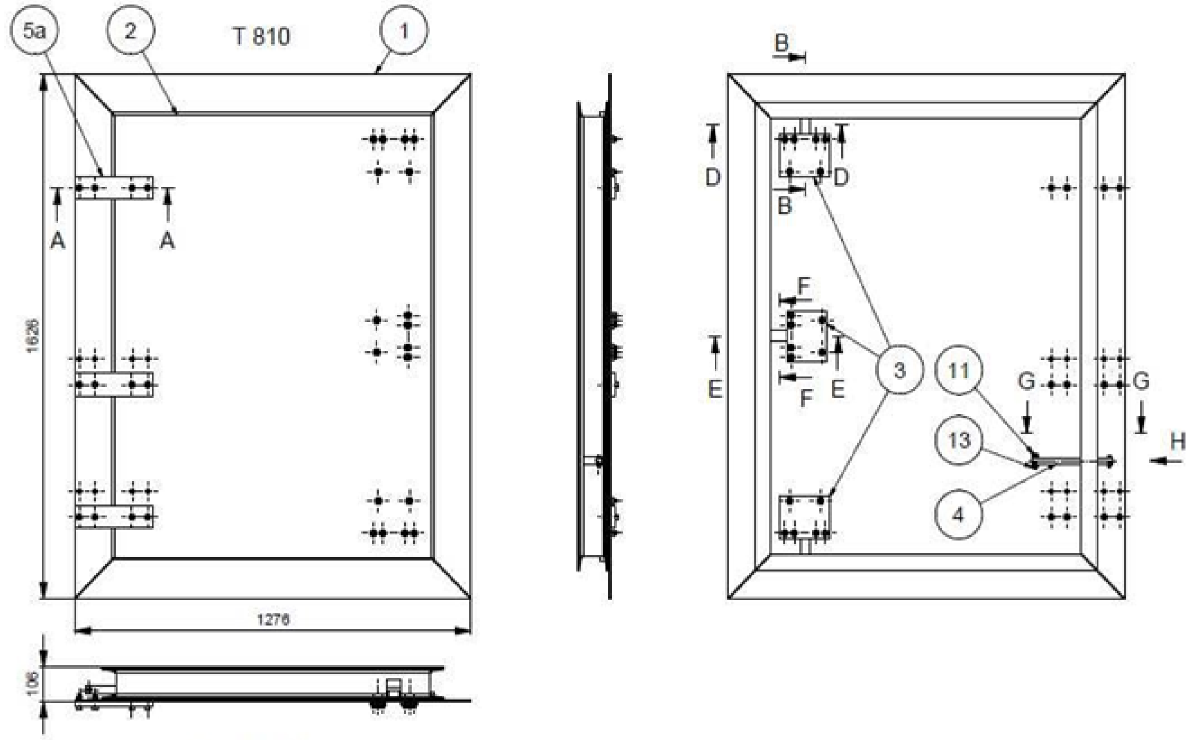

Fig. 1.
Scheme of a door frame and a door of an armour demonstrator

2.1. Tests of Penetrating Through an Armour Door Demonstrator

The following penetration tests were conducted on an armour door demonstrator using a "cold process" technology, comprising the use of a power cutter and a combi tool. For the testing, a newly designed kit of special agents and technical means was used.

2.2. Test no. 1 – Cutting Door Demonstrator Hinges Off Using a Cordless Cut Off Tool

During the test, 4 pcs of hinges of 30 x 10 mm cross-section were cut off. DEWALT DC415KL cordless cut-off tool with a NORTON Vulcan A cutting wheel 125x1, 6x22 A46S-BF41, Metal/Inox was employed.

2.3. Test no. 2 – Cutting Door Demonstrator Hinges Off Using a Petrol Power Cutter

During the test, 3 pcs of hinges of 70 x 15 mm cross-section were cut off.
A HUSQVARNA K960-K970/350 petrol power cutter with a diamond cut-off wheel 350 mm in diameter was employed.

2.4. Test no. 3- Cutting Door Demonstrator Hinges Off Using a Plasma Machine Cutter

For cutting during the test we used PLASMA 36 Invertor. During the test, 4 pcs of hinges of 30 x 10 mm cross-section were cut off.The Neophot 32 and the Olympus C-5050 digital camera were used for observation, photographic documentation and metalografical analysis.

2.5. Test no. 4 – Opening a Door Demonstrator By Prizing Off Anti-Burst Latches and the Lock

After door hinges were cut off, an attempt to open the door was made by prizing off anti-burst latches of 30 x 15 mm cross-section and a lock latch of 30 x 10 mm cross-section. A Holmatro CT 4150C combi tool with an SR 10 PC petrol pump was employed. On the hinged side, an opening between the door and the frame was prized open and wedged so that spreading points of the Holmatro combi tool could have been inserted. Then, the spreading points of the Holmatro combi tool were inserted between the door and the door frame on the hinged side, and an opening approx. 15 cm wide was made. The opening was then wedged, and the combi tool was moved to the opening as close to the anti-burst latches as possible. The door was opened by further spreading.

2.6. Test no. 5 – Opening a Door Demonstrator By Prizing Anti-Burst Latches and the Lock

Another test of the door demonstrator opening by prizing off two anti-burst latches of 30 x 15 mm cross-section and a lock latch of 30 x 10 mm cross-section was conducted by a hand-operated Holmatro combi tool.
A Holmatro HCT 5111 hand-operated rescue combi tool was used. On the hinged side, an opening between the door and the frame was prized open and wedged so that spreading points of the Holmatro combi tool could have been inserted. Then, the spreading points of the Holmatro combi tool were inserted between the door and the door frame on the hinged side, and an opening approx. 15 cm wide was made. The opening was then wedged and the combi tool was moved to the opening as close to the anti-burst latches as possible. The door was opened by further spreading.

2.7. Test no. 6 – Opening a Door Demonstrator By Prizing Off Anti-Burst Latches and the Lock

Another test of the door demonstrator opening by prizing off two anti-burst latches of 30 x 15 mm cross-section and a lock latch of 30 x 10 mm cross-section was conducted using Weber-Hydraulic equipment.
A Weber-Hydraulik door-opening kit was used. The kit contained a spreading device with a hand-operated pump. Hinges were first dismounted from the door demonstrator. On the hinged side, an opening was prized open between the door and the door frame and wedged so that a point of the spreading equipment could have been inserted. Then, the spreading points of the spreading equipment were inserted between the door and the door frame on the hinged side, and an opening approx. 10 cm wide was made. The opening was then wedged and the spreading equipment was moved to the opening as close to the anti-burst latches as possible. During spreading, the spreadi ng equipment was damaged by falling on the ground, and the process of opening by means of this equipment could not be finished.

3. Results and Discussion

For practical verification of the newly designed technology and thek it of special agents and technical means for the penetration into a crashed or damaged armoured vehicle from outside, 5 tests for the penetration through an armour door demonstrator were conducted. The door demonstrator copied the doors of key armoured vehicles used in the ACR (Pandur II CZ, Dingo, Iveco LMV and TATRA 810) in terms of its dimensions and materials used.
The “cold process” technology, comprising the use of a power cutter and a combi tool, was employed. When cutting hinges, a cordless cut off tool and a petrol power cutter were used. For the purpose of the door opening by prizing off anti-burst latches and a door lock, combi tool with a petrol unit, a cordless combi tool and a hand-operated combi tool were used. The times required for individual operations are stated in the table below:

Table 1
The results of armour door demonstrator penetration test

Test no.	Equipment	Source of energy	Operation	Time required [s]
1	DEWALT DC415KLcordless cut-off tool	battery	cutting hinges off	**180**
2	HUSQVARNA K960 K970/350 power cutter	petrol engine		**450** **145**
3	PLASMA 36 Invertor	petrol central		**180**
4	Holmatro CT 4150C combi tool	petrol pump SR 10 PC	door prizing	**140**
5	Holmatro CT 5111 combi tool	hand-operated		**240**
6	Weber-Hydraulik SPS 270 E Weber-Hydraulık door opening kit / hydraulic tool	hand-operated / battery		**300/30**

Note:1) 4 pcs of hinges of 30 x 10 mm cross-section were cut.
2) 3 pcs of hinges of 70 x 15 mm cross-section were cut.
3) The time of cutting using a HUSQVARNA RESCUE FR-3 wheel
4) A test of cutting the door restrictor was conducted in the length of 50 seconds

For a better image on the figure 2 you can see the metalografical analysis of plasma machine cutter. In the case of a flat plasma cut the armour on the upper surface is more affected. Here the heat-affected depth can be estimated at about 2,5 and 3,0 mm. The timeframe of them operation is the same as the time frame of the first measurement. This solution is most safer for breathing and comfortable for a crew in crashed vehicles compare when we used petrol power cutter.

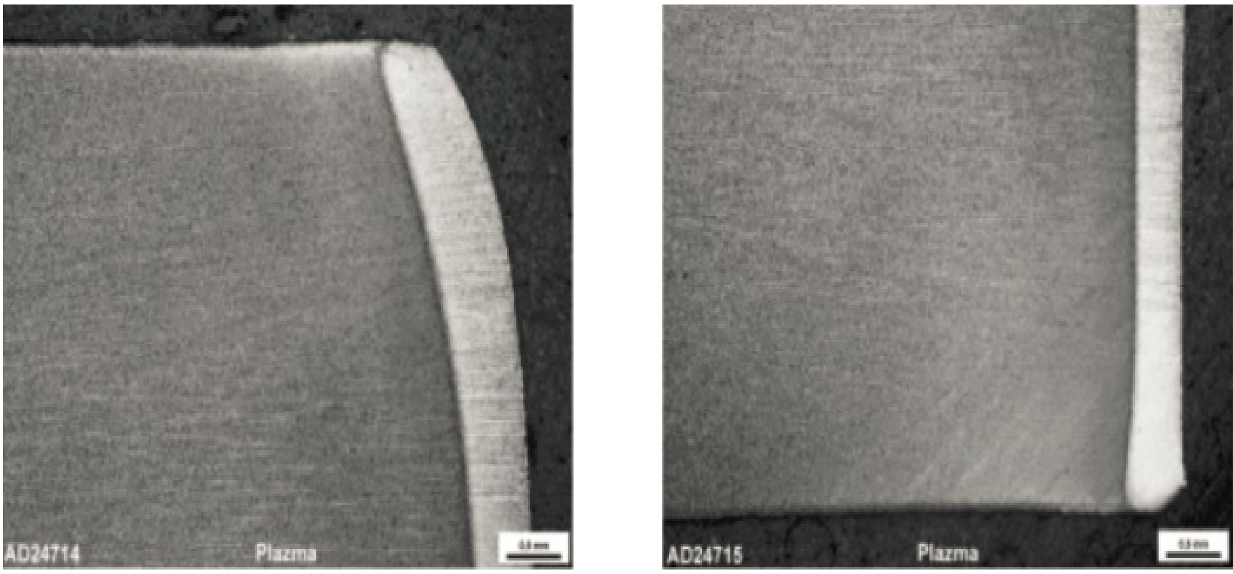

Fig.

Fig. 2.
Metalografical analysis of plasma cutters

The test results proved that the newly designed technology, tools and agents allow efficient penetration through an armour door demonstrator. The shortest time of penetration, i.e. below 5 minutes, is reached by the combination of HUSQVARNA K960-K970/350 petrol power cutter with a HUSQVARNA RESCUE FR-3 wheel and a Holmatro CT 4150C combi tool and an SR 10 PC petrol pump.

4. Conclusion

Six penetration tests were conducted on an armour door demonstrator using a “cold process” technology, comprising the use of cutters and a combi tools. In test no. 1, hinges on the door demonstrator were cut off using a cordless cut-off tool. In test no. 2, door hinges were cut off using a petrol power cutter. In test no. 3, cutting door demonstrator hinges off using a plasma machine cutter. In test no. 4, the door demonstrator was opened by prizing off anti-burst latches and a lock. In test no. 5, the door was opened by prizing off anti-burst latches and a lock. In test no. 6, the door demonstrator was opened by prizing off anti-burst latches and a lock.

The tests results proved that the newly designed technology, tools and agents allow efficient penetration through an armour door demonstrator. It follows from the results in Table 1 that the combination of HUSQVARNA K960-K970/350 petrol power cutter with a HUSQVARNA RESCUE FR-3 wheel and a Holmatro CT 4150C combi tool and an SR 10 PC petrol pump ensures the shortest time of penetration through the armour door demonstrator, i.e. below 5 minutes.

Acknowledgement

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VEHICLE DAMAGE DURING PARKING MANOEUVRES

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Abstract: The article is focused on problems of damage vehicles during low speed turning manoeuvres of vehicles, so called parking manoeuvres. Based on the analysis of real typical events investigated by insurance company, five crash tests related to the most common courses originated while parking were performed. Performed tests only deal with parking into and out of the row of perpendicularly standing vehicles because this is the most widespread way of parking. Two new vehicles from Skoda manufacturer and three other older ones have been used for tests. The course of the crash test itself was documented and the attention was aimed at individual damages of vehicles during manoeuvres. Searching of interaction of individual elements on vehicles for possibility of regressive demonstration of mutual correspondence has been especially discussed. The attention was also paid to characteristic damages caused by vehicle impact configuration. Further on the examples of gained data at qualifying real insured events dealt with by insurance companies are stated. The purpose of the experiments was to qualify the technical acceptance of origin of the given vehicle damage depending on the description of the insured event. For the analysis itself the comparative method with performed car crash tests has been used.

Keywords: Vehicle damage, parking manoeuvre, insurance company, accident.

1. Introduction

Solving traffic accidents, when there are no injuries or deaths of people can seem to be insignificant. However, insurance company is the matter for which the insured events coming into being in collision at low speeds are more and more important. The reason are the increasing payments of insurance benefits. Proper solution of a damage event that came into being at a low speed is often difficult. Such damages are, from the point of view of financial means of insurance companies as demanding as much more serious traffic accidents. Crash tests, either carried out by the experts in the field of traffic accidents or by insurance companies´ employees are frequently the only possibility how to ascertain sufficient amount of quality documents and, subsequently, how to uncover a prospective intention to commit an insurance fraud. Committing insurance frauds in the field of insurance of motor vehicles is a serious problem in many European states. Solving insurance fraud became a major problem in the beginning of the 90s of the 20th century when it became impossible to overlook the ever-increasing number of the said cases. Uncovering such frauds became one of the main priorities of insurance companies that started developing algorithms for uncovering insurance frauds. Viaene (2002) dealt with the subject matter of insurance fraud on the general level. Viaene et al. (2004) dealt with the classification of the individual methods for uncovering frauds with vehicle insurance. Viaene (2009) dealt with the strategy for detecting fraudulent claims in vehicle insurance cases, where they focused on the procedure of general operational control of fraudulent claims in favour of those, which involve the phase of the preliminary inquiry, verification and the subsequent negotiation, which eventually lead to a court trial. If any discrepancy is found or absence of one or more key elements (the same statements of the participants, the corresponding damage of the vehicles, etc.). Then there is the suspicion, which can be classified as abusing the insurance benefits.
In the forensic practice, the above-mentioned topic was dealt with by experts like Burg (2009), Hugemann (2007) and Weber (1995). These sources show the general principles according to which we can manage insurance frauds: the least possible risk, realisation in the foreseeable time, reaching the maximum profit, minimal technical and organisational complications. Further, they describe the individual tools and methods, which are used for solving the cases suspicious of an insurance fraud, such as morphology (science of shapes), collision position, detailed assignment of characteristic traces and damage, and eventually the comparison of the intensity of damage. Moreover, the individual types of insurance frauds are being classified according to the type of their being carried out: intentionally, invoked, fictitious, provoked and used traffic accidents. Of course, if it is necessary to apply used methods when reconstructing traffic accidents such as described by e. g. Brach (2011), Rivers (2010), they can be used as well.
The matter of crashes of vehicles at low speeds is currently dealt with by the organisation RCAR (Research Council for Automobile Repairs), which works in the field of crash testing. The aim of these so called bumper tests is to use such systems in the automobiles that would decrease the costs of the repairs, if there was a front-end impact at speed of up to 15 km/h.
The motivation of carrying out the above stated tests was the absence of the known characteristics of damage in the improper manoeuvres within perpendicular parking. For the possibility of a more detailed assessment of the individual suspicious cases of damaged automobiles, the authors carried out their own series of crash tests at low speeds that are characteristic for the selected parking manoeuvres.

2. Performed Crash Tests

We used 2 modern and 3 older automobiles for the crash tests, which were already discarded. They were:
- Skoda Superb 2.0 TDI (2015) black color,
- Skoda Fabia 1.4 TDI (2015) black color,

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- Opel Astra 1.4 16V (1998) silver color,
- Opel Vectra 1.8 16V (1996) red color,
- Daewoo Nexia 1.5 MPi (1996) green color.

The documentation was carried out by UAV (DJI Phanthom 3), a video camera (Panasonic HC-V720) and a camera (Nikon D7100).
The very interesting part for the experts can be the comparison of the damage, which comes into being in a crash at a low speed on a new and an older car. The culprit who commits an insurance fraud can use more cars of various age and value.

2.1. Damage of the Corner of a Parked Car and a Side of a Parking Car

The first crash test was carried out using a Skoda Suberb and an Opel Astra cars. The mutual crash of both the cars simulated the parking manoeuvre in which the driver of the Skoda car tried to park the car on the right of the Opel car. The speed of the parking car during the crash test equalled the above stated manoeuvre, i.e. approximately10 km/h. The Opel Astra car was parked at the right edge of its parking lot and none of its wheels was outside the designated lot. Such a parking space is typical especially for the car parks that are crammed, typically at shopping centres and in cities.
In the second test we used a Daewoo Nexia and an Opel Vectra cars. The parked Opel was damaged by the Daewoo, whose driver had not estimated properly the distance of the right side of his car from the parked car in the parking manouvre. The speed of the Daweoo car was also about 10 km/h, the Daewoo was at approximately the same angle of about 40 to 45°, when there was the contact of the cars, similarly to the first case, Fig. 1. The Daewoo car, partially went over the longitudinal border of the parking lot, which was the reason for the contact of rear bumpers of the cars.
The main difference between the two stated crashes was in the intensity of the crash and the damage of the cars, caused, especially, by the more significant depth of the deformation of the Skoda Superb car and Opel Astra. This higher crash intensity also caused a longitudinal shift of the parked Opel Astra car by 30 cm, the car had been secured by gearing the 1st gear. The Opel Vectra car clearly shifted its position in the second crash.

Fig. 1.
The course of the crash tests, left Skoda Superb x Opel Astra, right Daewoo Nexia x Opel Vectra

2.1.1. The Analysis of the Damage of the Cars Skoda Superb and Opel Astra

The parking manoeuvre, which was carried out by the driver of the Skoda Superb car at a small speed caused a damage on both the cars, however, a more significant damage was caused on the Skoda car, which caused the mutual collision. The first contact with the Opel car was visible on the left edge of the front door of the Skoda car, where the body of the car, namely the black varnish, was damaged. On the back door, there was, besides the abrasion, also a visible deflection of the car body, which came into being as a result of the contact of the door with the right part of the bumper of the Opel car. Furthermore, there was an abrasion of the varnish of the body of the car above the left rear wheel. The Opel car was damaged especially on the right edge of the rear bumper and the edge of the fender of the right rear wheel, Fig. 2.
Due to the damage of the body of both the cars and the height correspondence of the damage it was possible to prove the mutual crash. Even after the body of the car having been washed with warm water the door and the fender, it clearly

had visible grooves from the other car. In the combination with the caused deformation of the back door these are the marks that clearly prove the mutual collision of the cars.

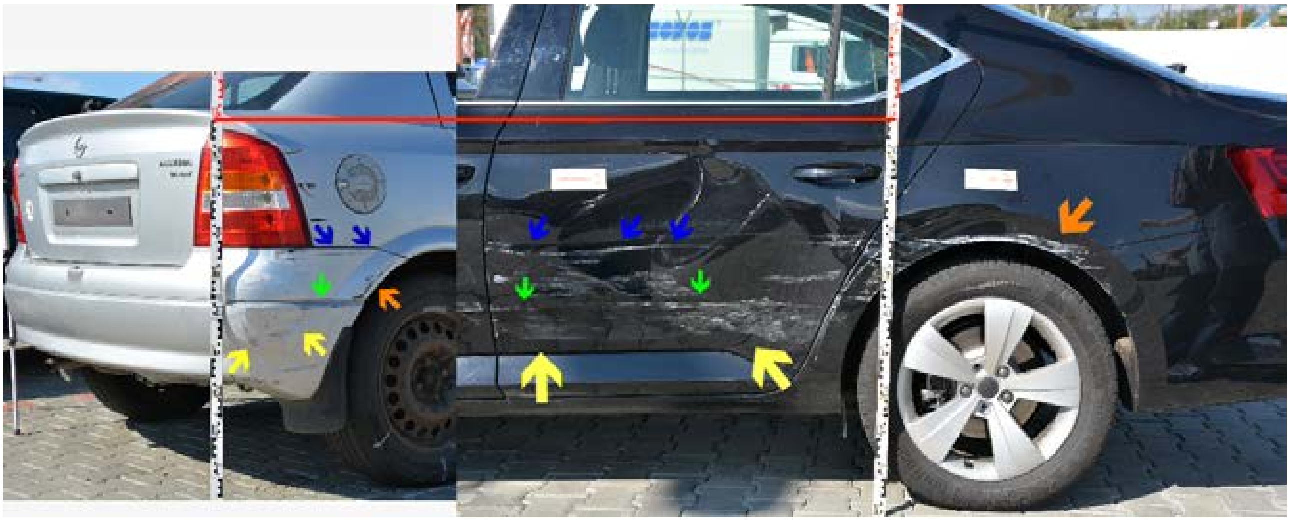

Fig. 2.
Correspondence of damage vehicles Opel Astra and Skoda Superb

2.1.2. The Analysis of the Damage of the Cars Daewoo Nexia and Opel Vectra

The Daewoo Nexia car, which caused the collision was damaged slightly more that the parked Opel Vectra car. The biggest damage of the Daewoo car was the semicircle abrasion of the varnish in the approximate height of 60 to 70 cm. This damage was probably caused by the cover of the rear light of the Opel car. On the green varnish of the Daewoo car we could also see the deflections and abrasions of its black varnish, which were, due to theis position, caused by the unvarnished part of the bumper of the Opel car. The varnished part of the bumper on the same level clearly showed green traces after the mutual contact.
Backward proving of the mutual collision is made more difficult by the fact that both the cars were older and they already had had some damage that was not linked with the test clash. The Daewoo was caused a dominant damage mainly in the area between the back edge of the door and the rear wheel of the car. This place corresponded with the varnish damage on the rear bumper of the Opel car. After washing the body of the red car with warm water most of the marks got completely lost, which can, in a real case, make the assessement more difficult.

Fig. 3.
Correspondence of damage vehicles Opel Vectra and Daewoo Nexia

2.2. Damage of the Side of the Parked Car and the Front Corner of the Parking Car

The third crash test was carried out by the Skoda Fabia and Opel Vectra cars, which had been parked in the other direction, i.e. the front part of the car was in the direction from the car park, and a slowly coming Skoda car was trying to park parallel with the mentioned car. As a result of a bad parking manoeuvre there was a slight contact of the car bodies in the angle of about 15º. The parked Opel Vectra had been secured by a handbrake. In the crash there was no shift in either transverse or longitudinal direction. However, the traces of the mutual contact of the cars were visible on

the front door of the Opel car and they followed to the handle of the back door. The varnish abrasion on the Opel car was whole without any more significant traces of interruption. The parking manoeuver was, therefore, done by the driver at a constant speed without stopping.
The crash test of the Skoda Fabia and Opel Astra cars simulated a parking manoeuvre when the Skoda driver was trying to park between two other parked cars, however, he crashed into one of them. The test showed a typical damage caused at a slow speed of a car bumping into a parked car under the angle of approximately 35°. The Skoda car first caused the damage on the right door of the Opel Astra car by its left front headlight and there was also the shift of the rear part of the parked car in the transverse direction. After that the Skoda Fabia driver started turning the steering wheel from the parallel position into the right position by which the car was supposed to be moved into the selected parking lot. Before finishing the whole parking manoeuvre the left front headlight of the Skoda car as well as the upper part of the bumper and the body of the car above the bumper damaged the Opel Astra car almost on the whole length of its body. In the final position both the cars were not parallel with the lines delimitating the parking lots for the cars. The Opel Astra car had been secured by handbrake for the whole time of the test.

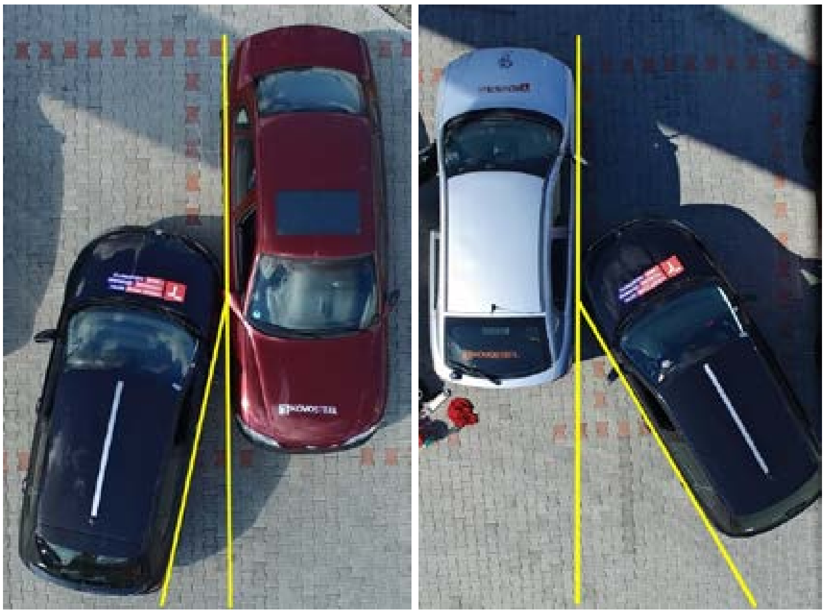

Fig. 4.
The course of the crash tests, left Skoda Fabia x Opel Vectra, right Skoda Fabia x Opel Astra

2.2.1. The Analysis of the Damage of the Cars Skoda Fabia and Opel Vectra

Mild abrasions of the varnish of the body of the Skody Fabia car caused by the crash test were only a surface damage. The first more significant groove was caused in the area of the edge of the bumper above the right fog headlight. Slight, consistent abrasion was also directly above the right part of the front bumper, approximately at the height of *55* to *60 cm*. While the Opel car showed noticeable abrasion on the upper part of the back door, the Skoda car did not show any damage at the same height. Due to the fact that in this case there was no colour coating, which would disappear after having been washed but a damage of the varnish as such, it could have been assumed that the abrasion on the Opel car had been caused by another part of the car that the varnished body of the Fabia car (possibly by the right front headlight of the Skoda Fabia car). The slight consistent abrasion on the Skoda car on the edge between the bumper and the right front fender corresponded with the protective bar on the door of the Opel car.
This crash test had the mutual contact of both the cars, however, it had not marked any of the automobiles with clearly visible marks, which would be the guide to proving the mutual collision. From this point of view, it had been almost impossible to prove backward the mutual collision of both the cars or determine the culprit of the crash. The traces upon the Škoda Fabia car had not disappeared after washing, however, they had not carried out any dentification signs.

Fig. 5.
Correspondence of damage vehicles Opel Vectra and Skoda Fabia

2.2.2. The Analysis of the Damage of the Cars Skoda Fabia and Opel Astra

Left front headlight of the Skoda Fabia car and the part of the body above the front bumper on the same side caused the damage of the body of the Opel car at the approximately same height of about 60 cm along the whole length of the silver car. As a result of a very low speed of the car that had done the braking manoeuvre in the wrong way the Opel car had been caused the typical wavy damage. The Skoda Fabia car was caused, as a result of the crash, depression on the left front headlight, depression, as abrasion on the left part of the bumper and the area right above it. The attachment of the headlight had not been damaged.
The bodies of both the cars showed damage that corresponded with each other regarding the height. Due to the range of the damage on the Skoda Fabia car, there was no doubt that the car had been a participant of a damage event. Backward proving of the mutual collision had again been very difficult. Significant deformation of the corner of the body of the Skoda car and a slight damage of the back door of the Opel car had not enabled the unequivocal primary crash configuration.

Fig. 6.
Correspondence of damage vehicles Opel Astra and Skoda Fabia

2.3. Damage of the Side of the Parked Car by the Corner of the Car going Backwards from a Parking Lot

The last test focused on going backwards from a parking lot when there were two cars parked on both sides. On the right from the Skoda Superb car going backwards from the lot there was an Opel Vectra car parked and it had been secured by a handbrake. The Skoda car driver first moved in the backward direction and then he started turning the wheels to the left. The bumper test simulated the parking manoeuvre when the drivers watch mainly the rear part of their car, however as a result of insufficient control of the front part there is a contact with the parallely parked car. In the second part of the parking manoeuvre the driver turned the steering wheel fully to the left and started going forwards to reach unblocking his car and to be able to go backwards again, Fig. 7. However, by this manoeuvre he damaged both the cars even more.

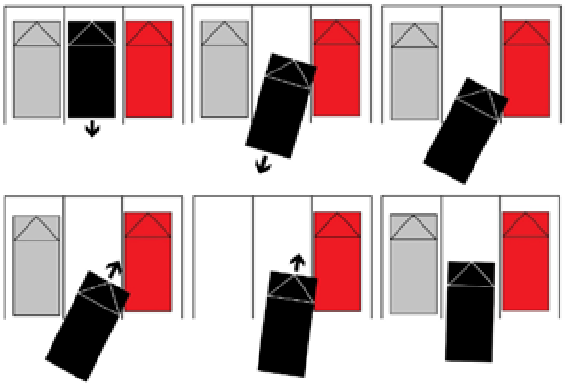

Fig. 7.
The course of the crash tests, up going backwards, down going forward

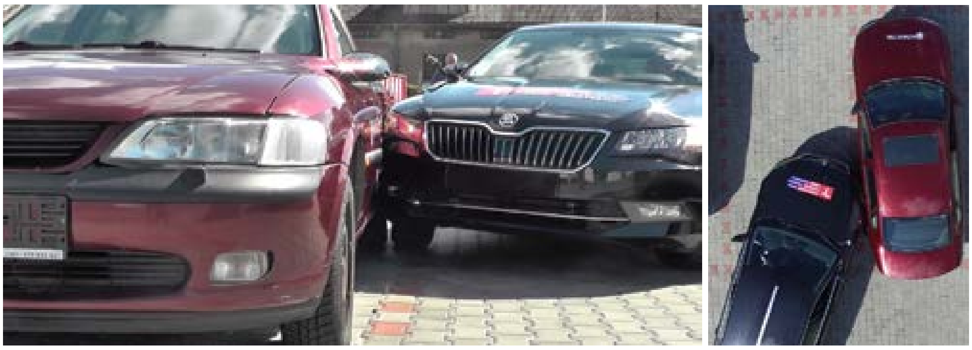

Fig. 8.
The moment of the stopping backwards going Skoda Superb

2.3.1. The Analysis of the Damage of the Cars Skoda Superb and Opel Vectra

The range of the damage on the Opel car was, after the first part of the parking manoeuvre (going backwards) larger than that on the Skoda car, also as a result of its being old and having visible corrosion on the body of the car. The corrosion was the reason for the full destruction of the edge of the rear fender. When going forward, the attachment of the headlight of the Skoda car was damaged. When exactly was the attachment torn away was clear only after finishing the whole bumper test and watching the video recordings.
Due to the fact that both the bodies of the cars were damaged, i.e Skoda Superb as well as Opel Vectra, it would be possible to prove the mutual collision even backwards. All the damage of the cars corresponded regarding the height.
Skoda Superb kept the groves even after having been washed, including those that still had the red varnish. To remove the marks on the black car of the culprit it would be needed to carry out an expert repair including cementing, edging, and overcoating of the damaged area.

Fig. 9.
Correspondence of damage vehicles Skoda Superb and Opel Vectra

3. Assessing the Crash Tests

3.1. Damage of the Corner of a Parked Car and a Side of a Parking Car

When comparing the crash tests of the cars Superb x Opel Astra with the test of Daewoo Nexia x Opel Vectra it was clear that the approach angle of the cars doing the parking manoeuvre was in both the cases almost the same. However, the analysis of the damage of the cars showed that while in the first bumper test there was a significant deflection of the body of the Skoda car in the area of the back door and a damage of the edge of the fender of the left rear wheel, the Daewoo car remained without a more significant damage. The range of the damage of the Skoda car can be attributed to the higher intensity of the crash and there was also a closer contact with the parked car and the shift . The Daewoo car touched the Opel Vectra car only slightly and the mutual abrasion of the car was only minimal.

3.2. Damage of the Side of the Parked Car and the Front Corner of the Parking Car

The angle of the approach of the cars within the above stated crash tests was different. While the Skoda Fabia car driver bumped the parked Opel Vectra car in the maximal angle of 15°, in the case of the crash of the Astra car the approach angle was more than double, i.e. approximately 35°. The analysis of the damage of the cars clearly showed that in the model crash of the Skoda Fabia car into the Opel Astra car there was a more significant range of damage on both the cars. If one car bumps into another one under the angle of about 35°, there is going to be a greater "penetration" into the corner of the body of the car than under the angle of 15°. The crash first slowed the Skoda car down significantly before finishing the manoeuvre and interrupting the contact between the car bodies. It can be assumed that in the case of the crash of the cars under a larger angle than 45° the parking manoeuver cannot be finished due to the mutual wedging of the cars.

3.3. Damage of the Side of the Parked Car by the Corner of the Car going Backwards from a Parking Lot

The test where the crash was done by a Skoda Superb car going backwards into the Opel Vectra car, brought an interesting finding useful for assessing real damage events. The first contact of both the cars was between the front corner of the Skoda car with the area of the front and the back left door of Opel car. The driver of the car kept on going backwards and only on the level of the rear fender of the parked Opel car he wedged the cars. At that moment the Skoda car driver had the possibility to align the steering wheel and try to continue going backwards or to try to free the mutually wedged cars by going forwards. If the driver decided to keep on going backwards, there would probably be even further damage of the bodies of the cars (varnish grooves, deflections) of the already damaged parts. The Skoda Superb car, however, went forwards by which it caused tearing off the right headlight from its attachment. In such cases the costs of the repair will be higher than if there was no tearing off of the attachment.

4. Solving Real Damage Events Using the Carried Out Crash Tests

Crash tests are often the only way to properly assess real damage events. The crash tests can provide an overview of the characteristic damage for the given manoeuvre. Subsequently, if the experts have a sufficiently wide database, they can use a simple comparison method to assess individual damage in case of real damage to vehicles. In particular, the fact whether the nature and location of the vehicle damage described corresponds to the course of its occurrence. In the following two examples, we will demonstrate the use of the information obtained from the crash tests described above.

4.1. Fiat Bravo x Audi A5

According to an announced damage a Fiat car allegedly damaged a parked Audi car when leaving a parking lot (going backwards). Subsequently, there was supposed to be another bump when the driver of the Fiat car finished going backwards and started going forwards. She stated the following information to the insurance company: *"When leaving the parking lot I damaged another parked car, I got into a skid"*. The owner of the damaged car stated*: "She was leaving the parking lot, she skidded on ice and bumped twice into my car – into the front part as well as the rear part."*
The bump into the front part of the parked car was assessed by the insurance company as real and the damaged party was paid a sum commensurate to the damage on his car. However, the second part of the parking manoeuvre was assessed as unreal. The damage of the back part of the Audi car had probably been caused by a different accident of an older date. This is so-called "used traffic accident".
For the described manoeuvre when a driver is going backwards from a parking space and simultaneously damages the front part of another parked car it is characteristic that the damage is in the area of the edge between the bumper and the fender. What is also typical is the damage of the front bumper.

Fig. 10.
Left: there is a drawing of the occurrence of damage, middle: there is the characteristic damage from the crash test, right: there is the real damage

The characteristic damage resulted from comparing picture material from the crash test of the Skoda Superb and Opel Vectra cars with the photographs of a real damage event. In the crash test there was a deeper damage of varied character as a result of the bad technical state of the other car. The areas of the edge between the front bumper and fender showed a similar character of damage, only of a smaller range, Fig. 10.

4.2. Skoda Roomster x Unknown Vehicle

The abrasion of the body of the Skoda Roomster car, and thus the occurrence of a damage event, was caused by an unknown culprit. It was an announcement of damage that the owner of the car should have covered from the accident insurance. The damaged party announced the following information to the insurance company: *"At the car park in front of the house an unknown car caused damage (deep abrasion) on the side of the co-driver."* The insurance company assessed the damage event as a real one, however, the culprit stayed unknown.
When two cars come into a slight contact on the sides, there is usually abrasion of the varnish on the body of the car on the edge of the front and the back door. The cause of this can be the fact that the sheet of metal is curved on the edge of the door. Making the sheet metal double improves the strength of the place and in the case of a contact with another car there is not such a springy reaction of the material. The result is a characteristic damage of the varnish of the body of the car on the edge of the front and the back door, Fig. 11.

Fig. 11.
Left: there is the characteristic damage from the crash test, right: there is the real damage

5. Conclusion

The damage of cars that came into being as a result of a crash at a low speed is, currently, paid more attention. These often come into being also because of manipulated damage events. Sometimes the border between a real accident and an insurance fraud is very difficult to recognize and the assessment of some cases is not easy.
Five crash tests that dealt with parking into and out of the row of perpendicularly standing vehicles s were carried out. The photographs of each test documented the damage, which was caused as a result of the crash. The assessment of the model cases of the carried our parking manoeuvre showed several facts. It is the speed and the angle of the crash that has the significant influence on the damage of both the cars. In the case that the angle is smaller than 15° there is only slight abrasion of the cars and the damage is not of a large scale. In the case of the approach angle being more than 15° there is deeper abrasion of the body of the cars as well as slight deformations along the whole length of the side of the parked car. If the cars crash under an angle that is bigger than 45°, there are significant deformations at a particular spot. The drivers, who crash into a parked car in an incorrectly carried out manoeuvre can, in their effort not to cause any more damage, make the situation even worse.

Acknowledgements

To conclude, authors of this article would like to express their thanks to all colleagues and collaborating experts, who helped with the arrangement of performed crash tests. They would also like to thank the Skoda Auto Corp., Kovosteel Recycling Ltd. for provision of vehicles and space and Czech Insurance Corp. for vehicles damages from real accident.

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VEHICLE PROCUREMENT CRITERIA EVALUATION

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Abstract: The vehicle procurement is one of the several factors which influences the vehicle fleet energy efficiency. The appropriate choice of vehicle reduces transport and maintenance costs. During vehicle procurement process managers consider many different interdependent criteria that have a different impact on the vehicle fleet energy efficiency. In this sense, vehicle fleet managers are faced with a problem how to determine the relevance of criteria in order to increase fleet's energy efficiency and decrease the transport and maintenance costs. In this paper, the authors have conducted a survey among vehicle fleet managers in transport and logistics companies evaluate which criteria are more important to them and which are less important. Also, the survey was conducted among students of Faculty of Transport and Traffic Engineering in order to compare their results with the experts results. Authors gave 30 criteria that were evaluated. As result of conducted survey the most important 3 criteria from experts point of view are adaptability of the vehicle to the transport requirements, fuel / energy consumption and preventive maintenance costs.

Keywords: vehicle procurement, energy efficiency, criteria, vehicle fleet.

1. Introduction

Transport and logistics companies with their own vehicle fleet for freight transport are observed in this paper. The main goal of these companies is to maximize profit by providing transport and logistics services. This goal can be achived through reducing transport (TC) and maintenance costs (MC), on the one hand, and on the other, by increasing energy efficiency (EE) of vehicle fleet. Vehicle fleet management is important tool for reducing CO_2 emissions and fuel costs, i.e. transport costs, as well as to improve transport sustainabillity (Ansaripoor et al., 2014). Vujanović et al. (2010) in their paper emphasize that companies are trying to increase their own vehicle fleets energy efficiency. In this respect, one of the several ways to increase energy efficiency is the implementation of integrated fleet maintenance management (Vujanović et al., 2017). According to the Federal Railroad Administration (2009) increased energy efficiency can be achived through various improvement measures, such as engine improvements and emission regulations, non-engine technological improvements on vehicle and changes in fleet composition, operational measures. Regarding to this, by using the Exhaust gas recirculation system, in the first decade of 21st century, fuel consumption decreased by additional 6% (Federal Railroad Administration, 2009). Besides that, an increase in energy efficiency can be achived by using aerodynamic devices on the vehicle (Saricks et al., 2003), by reducing vehicle weight (Maintenance Council, 1998), by using wide-based tires instead of using double tires (Federal Railroad Administration, 2009), as well as with operational measures which involve the application of modern information technologies (McKinnon, 1999).

The vehicles during their operational lifetime cause increasing of transport, maintenance and spare parts costs (curve 1), from one hand and from the other the level of availability and technical reliability decreases (curve 2). At the moment when the cost curve exceeds the „acceptable costs“ line (line 3), or the curve of the required availability / technical reliability is below the required level (line 4), the vehicle fleet renewal is considered by vehicle fleet managers (Figure 1). P_k is quality indicator. (Bunčić & Momčilović, 2014)

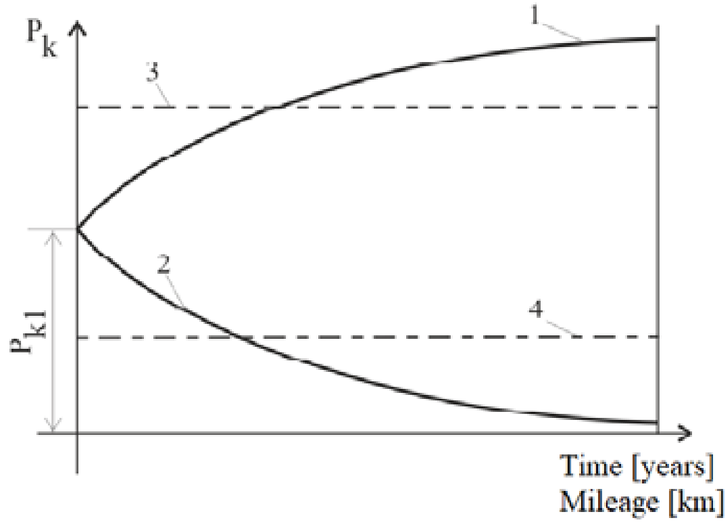

Fig. 1.
Curves of vehicle costs and technical reliability during vehicle operational lifetime
Source: (Bunčić & Momčilović, 2014)

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According to Stokić et al. (2018), the number of vehicles in EU is growing and there is a growing need for efficient vehicle procurement process management. The vehicle procurement represents one of the basic activities of vehicle fleet operation management and key precondition for efficient transport system operation, i.e. cost-effective usage, availability, maintenance, as well as vehicle environmental sustainability (Manojlović, 2012). Besides that, the insufficiently good choice of vehicles during the procurement process can also increase the transport and maintenance costs and to decrease vehicle fleet energy efficiency, which all together contribute to achiving less profit than it is possible (Stokić et al., 2018). In order to make the right decision during vehicle procurement process, the vehicle fleet managers need to consider several different criteria. Regarding to this, the criteria that should be considered during decision making process are defined in this paper. This contributes to the energy efficiency increasing, overall transport and maintenance costs reduction for a given volume of transport work, which enable observed companies to achive defined goal.

The paper is structured as follows. The chapter 2 shows literature review regarding the criteria that are considered during vehicle procurement process. The criteria classification is presented in chapter 3, while the chapter 4 is dedicated to the conducted research and analysis of the obtained results. The conclusion and future research are given in chapter 5.

2. Literature Review

In this chapter is given a literature review of the papers of the other authors who dealt with the vehicle procurement problem, as well as the criteria that need to be considered in order to successfully solve this problem.

In his work, Fourie (2010) considers the transformation of a vehicle fleet in the most cost-effective way. In that sense, Fourie (2010) states that it is necessary to consider a vehicle that meets the transport requirements in the best possible way, as well as is it better to buy a used vehicle (older or newer) or to purchase a brand new vehicle. Based on this, it is necessary to consider all costs, both variable (cost of driver labor, depreciation, vehicle operational costs, fuel economy, insurance, corrective maintenance cost, fuel consumption, oil, tires and preventive maintenance costs) and fixed, related to the vehicle operation. In addition, the brand and vehicle type have great importance regarding to transport and maintenance costs. Also, it is important if there is a certain discount that a sales agent can offer, as well as financial benefits from financial institutions (credit or leasing). Among the most important criteria is the useful load capacity of the vehicle. (Fourie, 2010). Ansaripoor et al. (2014) used stochastic programming and conditional value risk in their work to calculate the uncertainty in the vehicle procurement decision making process. The main goal of their paper was to reduce costs and risk simultaneously. They observed criteria such as average fuel prices (current and future projection), average electricity price needed for powering batteries for electric vehicles, operating costs for different fossil fuel technologies (diesel, gasoline and electric), fuel and electricity consumption per 100 kilometers, as well as pollution costs caused by CO_2 emission. Total fixed vehicle costs, monthly vehicle leasing costs and monthly leasing costs for batteries (for electric vehicles) were also observed. Lin et al. (2009) in their paper have tried to apply DEMATEL method in order to deal with the importance and causal relationships among the evaluation factors of alternative fuel vehicles (six different alternative fuels were observed). For the purpose of their research Lin et al. (2009) observed 21 different criteria that were divided into 5 groups, such as safety (leak safety, fuel ignition safety, refuel safety, in vehicle fuel storage safety and storage safety); pollution (air, noise, leak, discard); performance (cruising range, refuel rate, horse power, torque, fuel efficiency); accessibility (fuel accessibility, accessibility in usage, maintenance accessibility); costs (repair cost, maintenance cost, fuel cost and new car cost). As the first three criteria, the authors quote "new car cost", "cruising range" and "fuel efficiency". Also, "air pollution" is a criterion that has an impact on the all other criteria, while the criterion that is influenced by the all other criteria is "cruising range" Lin et al. (2009). Vujanović et al. (2010) state that the vehicle fleet energy efficiency can be increased by using more efficient engines with new technologies applied, as well as by proper selection of the vehicle type for a specific transport task (better utilization of the cargo space). Besides technologies applied to the engine, energy efficiency can be increased by implementation of new technologies that are applied specifically on the vehicle in order to improve vehicle aerodynamics, reduce rolling resistance, reduce vehicle mass, improve vehicle transmission. Also, new technologies that can be applied on the vehicle are electronic speed limiter and use of better motor oils. Although they do not specify specific criteria, Nicolas et al. (2014) in their paper state that during vehicle procurement process attention should be on sustainable mobility (social, ecological and economic). Regarding to this, the vehicle environmental aspect should be taken into account. The vehicle procurement process must be observed through the vehicle safety, vehicle age, emissions and cost efficiency criteria (OECD/ITF, 2011). Also the criteria such as vehicles compatibility, reliability, fuel efficiency, vehicle environmental level, warranty, procurement costs determined by state contracts, vehicle operation lifetime, relationship with vehicle manufacturer (does the manufacturer provide good customer support), development and availability of sales network and the value of the used vehicles should be considered as well (McDaniel et al., 2009). Degirmenci et al. (2017) in their paper were researching whether the ecology is ahead of electric vehicle price and vehicle range confidence, from the aspect of buyers. They observed the ecological performances of vehicle, vehicle price and range confidence, based on which they carried out research among users.

All mentioned criteria can be devided in several groups. Detailed division of criteria is expleined in next chapter.

3. Criteria Classification

Within this chapter a clasification of the criteria which are observed during vehicle procurement process was carried out. All criteria have impact on either transport costs or maintenance costs, while some of them are closely related to the vehicle energy efficiency. Also, the observed criteria can have multiple impacts, regarding to that, some of them can simultaneously affect transport costs and maintenance costs and energy efficiency. One example of criterion that has a threefold impact is the vehicle age. Older vehicle causes higher fuel consumption and therefore higher transport costs and greater impact on energy efficiency than newer one. In addition, older vehicle require more frequent interventions for both preventive and corrective maintenance.

All criteria can be classified into four basic groups. The first group includes constructional criteria that define the vehicle construction characteristics that must be met in order to successfully complete the transport tasks. This group includes vehicle dimensions, turning radius, vehicle power, capacity, adaptability to loading and unloading operations, type of drive, etc. The second group of criteria implies the initial costs of vehicle procurement (the price of a new / used vehicle). This group of criteria has great importance in order to carry out the vehicle classification (to separate vehicles which price is above and below planned budget for vehicle procurement). The third and perhaps the most important group of criteria for a good choice of vehicles is a group of vehicle operation criteria. This group includes the age of the vehicle, mileage, the warranty period, the vehicle maintenance cost (in the warranty period), coverage of service centers, vehicle repair costs (when the vehicle is not in the warranty period), fuel economy, fuel price, spare parts availability, the possession of modern on-board systems that increase the safety and energy efficiency (for example Forward Collision Warning System and eco-driving systems that provide active support to the driver while driving etc.). Last, but not the least significant group, there is a group of post-operation criteria that include the vehicle residual value when replacing (reselling), the recyclability of vehicle parts and the recyclability of whole vehicle.

Although the criteria are different and divided into different groups, they are mutually dependent, i.e. the criteria from one group can affect one or more criteria from another group. For example, the vehicle price is influenced by the equipment that vehicle consists in, engine power, useful vehicle load, etc.

As it is mentioned above, all criteria can be divided into four different groups and every criterion have a particular impact or on transport costs or maintenance costs or energy efficiency, but some of them may have multiple impacts. The authors selected 30 criteria on the basis of literature review, their own experience and through interview with experts. These criteria are given in Table 1., as well as their affiliation to these groups and their impact on transport costs / maintenance costs / energy efficiency.

Table 1

Observed criteria and their affiliation to groups and impact on transport costs / maintenance costs / energy efficiency

Criteria	Name	Group*	Impact**
C1	Vehicle price	II	TC
C2	Fuel / energy consumption	III	TC, EE
C3	Price of fuel used by the vehicle	III	TC
C4	Price of spare parts (for corrective maintenance)	III	MC
C5	Preventive maintenance costs (services)	III	MC
C6	Maintenance costs during the warranty period	III	MC
C7	Discounts that can be made when buying a vehicle	II	TC
C8	Financial benefits when buying a vehicle (credit / leasing)	II	TC
C9	Remaining value of the vehicle when replacing (reselling)	IV	TC
C10	Construction characteristics of the vehicle	I	TC, MC
C11	Compliance with transport requirements	I	TC, EE
C12	Compatibility with existing vehicle fleet	I	TC, MC
C13	Useful vehicle capacity	I	TC, EE
C14	Engine power / torque	I	TC, EE
C15	Tank / battery capacity	I	TC, EE
C16	Existence of on-board security systems	I	MC
C17	Possession of cruise control	I	TC, EE
C18	Vehicle condition – mileage, age	III	TC, MC, EE
C19	Type of drive (conventional, alternative, hybrid, electric)	I	TC, MC, EE
C20	Air pollution caused by vehicle	III	EE
C21	Noise caused by the vehicle during operation	III	EE
C22	Possibility to rebuild a vehicle to use an alternative drive	I	TC, MC, EE
C23	Possibility to recycle parts and the vehicle after use	IV	TC, EE
C24	Good previous experience with the vehicle manufacturer	II	TC, MC
C25	Duration of manufacturer's warranty	III	MC
C26	Terms of warranty of the manufacturer	III	MC
C27	Relationship with vehicle manufacturer	III	TC, MC, EE
C28	Vehicle exterior appearance	I	TC, EE
C29	Vehicle comfort	I	TC, MC, EE

Criteria	Name	Group*	Impact**
C30	Vehicle interior appearance	I	TC, MC, EE

** I – Constructional criteria; II – Initial vehicle procurement costs; III – Vehicle operation criteria; IV – Post operation criteria*
*** TC – Transport costs; MC – Maintenance costs; EE – Energy efficiency*

Also, the impact of criteria on transport costs / maintenance costs / energy efficiency is illustrated on figure 2.

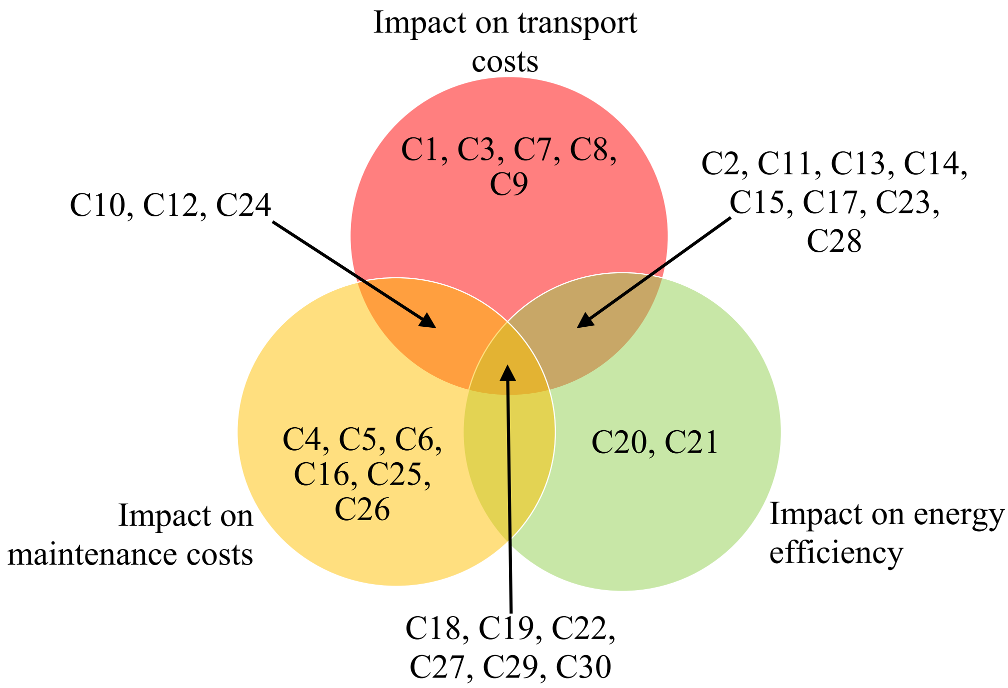


Fig. 2.
Criteria impact on transport costs / maintenance costs / energy efficiency

It is necessary to briefly explain that the criteria such as „vehicle comfort“ and „vehicle interior appearance“ has impact on driver and driver has impact on fuel consumption and if fuel consumption is increased, the energy efficiency is decreased due to emissions. Also, if the vehicle is not comfortable it can cause a driver fatigue and thus traffic accident. Traffic accidents are closely connected to vehicle maintenance costs, as well to insurance costs. Besides before mentioned criteria, we should briefly explain „vehicle exterior appearance“ criterion. This criterion has impact on transport costs and energy efficiency. For example if vehicle has spoilers, the aerodynamics of the vehicle is improved and therefore fuel consumption and emissions are reduced and energy efficiency is enhanced.

Satisfaction with the provided service quality / vehicle quality / spare parts quality are considered under „Good previous experience with the vehicle manufacturer“ criterion, also under criterion named „Relationship with vehicle manufacturer“ good customer support and coverage of service centers are considered.

Since the criteria do not have the same importance, it is necessary for managers to rank the criteria by relevance, in order to make the best decision during the vehicle procurement process. One of the possible ways to evaluate the criteria and to choose most appropriate vehicle is to apply one of the methods of multi-criteria decision making. The first step before applying one of the multi-criteria decision making methods involves evaluating the criteria by the experts, which is the result of this paper. In this regard, the authors of this paper carried out a survey among experts from transport and logistics companies, that included the evaluation of the observed criteria. The description of the conducted survey and the obtained results are presented in the next chapter.

4. Criteria Evaluation

This chapter provides a description of the conducted research in order to collect data about vehicle procurement criteria evaluation, as well as the obtained results.

4.1. Research Description

In June 2018 an anonymous online survey entitled „Vehicle procurement criteria“ was conducted. The survey included 23 experts in this field (professor and assistant from the Faculty of Transport and Traffic Engineering, University of Belgrade, who work in this area, as well as employees from several transport and logistics companies from the Republic of Serbia). Also, 22 students from the mentioned faculty (department for road and urban transport) were included in the survey. All students that participated in survey are final year of basic academic studies and have attended all courses envisaged by this level of study. Although, it is important to mention that students can not be observed on the same way as experts from transport and logistics companies, but the aim of their participation was to find out the differences in attitudes about the relevance of the observed criteria in relation to the experts.

4.2. Demographic Information

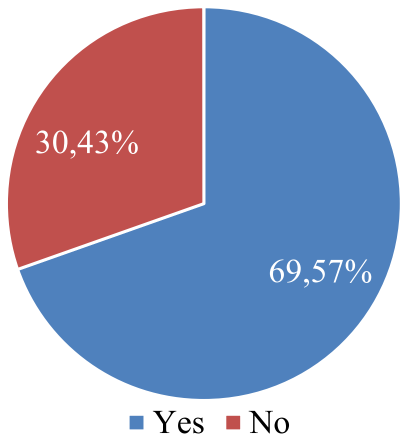
On the basis of experts demografic information, we can see that 91,3% of the male population participated in the survey and only 2 females (8,7%). This is not suprising due to the business activity of the observed companies (transport and logistics) where in the most cases are men employed. Regarding the age structure, the respondents aged between 35 and 44 years (52.2%) and respondents between the ages of 25 and 34 (30.4%) have the dominant participation. Regarding the level of education, it can be seen that the vast majority of respondents have a university degree (63.5%), 21.7% have completed a college, while only one respondent has completed high school and one has PhD.
Of the 22 surveyed students, 63.6% were male respondents, while 36.4% were female respondents. According to the level of studies, it is expected that most respondents are between 18 and 24 years old, and in that sense 19 students belong to that group, and only 3 respondents belong to the group of age from 25 to 34 years. The demographic information of respondents are shown in the Table 2.

Table 2
Respondents demographic information

Demographic information		Experts		Students	
		Frequency	Percentage	Frequency	Percentage
Gender	Male	21	91,3%	14	63,6%
	Female	2	8,7%	8	36,4%
Age	18-24	0	0,0%	19	86,4%
	25-34	7	30,4%	3	13,6%
	35-44	12	52,2%		
	45-54	2	8,7%		
	55-64	2	8,7%		
	65 and above	0	0,0%		
Education level	High School	1	4,4%		
	College	5	21,7%		
	Bachelor of Science	7	30,4%		
	Master of Science	9	39,1%		
	Doctor of Science	1	4,4%		
	Student	0	0,0%	22	100,0%

4.3. Results

In order to determine the validity of the assessment, i.e. experts competence, one of the questions was whether the experts have to deal with vehicle procurement on their job. Out of the 23 interviewed experts, 70% of them stated that they have that obligation, but it should be emphasized that 2 respondents from the Faculty of Transport and Traffic Engineering in Belgrade have declared that they do not have vehicle procurement in their job description, but since they deal with discussed topic, they can be considered as experts and that would increase the mentioned percentage to almost 80%. The vast majority (almost 90% of respondents) stated that when they purchasing a vehicle, they decide to purchase a new vehicle rather than a used one. This is in accordance with the recommendations of some authors. The answers to the above questions are illustrated on Figure 3.



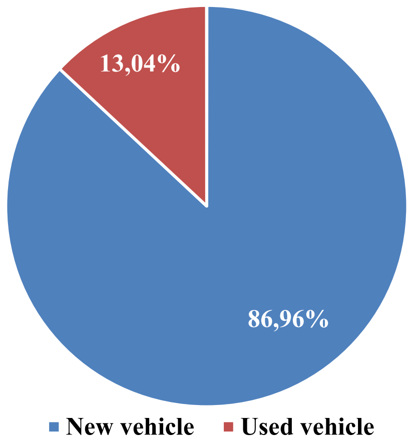


Fig. 3.
Answers to the questions „Is vehicle procurement in your job description?" (left) & „Would you rather buy new or used vehicle?" (right)

The main part of the survey was related to the evaluation of the criteria that are observed during vehicle procurement process. The authors proposed 30 criteria on the basis of literature review, interviews with experts and their own experience. All these criteria are presented in Table 1. (Chapter 3). Besides given criteria, respondents were also given the opportunity to add criteria that they consider as relevant and it is not mentioned. For an easier criteria review, all the criteria will be listed below: 1) vehicle price 2) fuel / energy consumption 3) price of fuel used by the vehicle 4) price of spare parts (for corrective maintenance) 5) preventive maintenance costs (services) 6) maintenance costs during the warranty period 7) discounts that can be made when buying a vehicle 8) financial benefits when buying a vehicle (credit / leasing) 9) remaining value of the vehicle when replacing (reselling) 10) construction characteristics of the vehicle 11) compliance with transport requirements (type and quantity of cargo / type and volume of load compartment) 12) compatibility with existing vehicle fleet 13) useful vehicle capacity 14) engine power / torque 15) tank / battery capacity 16) existence of on-board security systems 17) possession of cruise control 18) vehicle condition – mileage, age 19) type of drive (conventional, alternative, hybrid, electric) 20) air pollution caused by vehicle 21) noise caused by the vehicle during operation 22) possibility to rebuild a vehicle to use an alternative drive 23) possibility to recycle parts and the vehicle after use 24) good previous experience with the vehicle manufacturer 25) duration of manufacturer's warranty 26) terms of warranty of the manufacturer 27) relationship with vehicle manufacturer 28) vehicle exterior appearance 29) vehicle comfort 30) vehicle interior appearance.
The average grades given by experts and students for each of the above mentioned criterion are graphically shown on Figure 4.
As can be seen from the Figure 4, experts gave higher grades to most criteria, i.e. they consider them more important than students do. In this sense the overall average grade for all observed criteria which was given by the experts was 7.01, while the students gave an overall average grade of 6.57. It is important to emphasize that there are no significant differences in the estimates of the criteria between these two populations. The criterion that has the highest difference in the average grade obtained by experts or students is the criterion entitled "Vehicle maintenance costs during the warranty period", where experts evaluated this criterion for 2.02 grades more than students did. Visible differences (difference from 1 to 2 grades) can be seen for the criteria such as the price of fuel used by the vehicle, the price of spare parts (for corrective maintenance), the preventive maintenance cost (services), the construction characteristics of the vehicle, the possession of cruise control.
It is very interesting to note that besides the subjects related to energy efficiency and reduction of environmental pollution caused by road transport, students had less ecological awareness than experts, and therefore criteria such as air pollution caused by vehicle and noise caused by the vehicle during operation, are considerably lower graded. On the other hand, students gave greater importance to criteria such as vehicle exterior appearance, vehicle comfort, vehicle interior appearance. Based on this, a certain level of inexperience among students may be seen and due to that it is justified because these two groups of respondents (experts and students) are separated.
The first five most important criteria from the point of view of the experts are: 1) compliance with transport requirements (type and quantity of cargo / type and volume of load compartment), 2) fuel / energy consumption, 3) preventive maintenance costs (services), 4) spare parts price (for corrective maintenance), 5) vehicle condition – mileage and age. On the other side, the first five most important criteria from the point of view of the students are: 1) fuel / energy consumption, 2) vehicle condition – mileage, age, 3) vehicle price, 4) compliance with transport requirements (type and quantity of cargo / type and volume of load compartment) and 5) vehicle comfort.

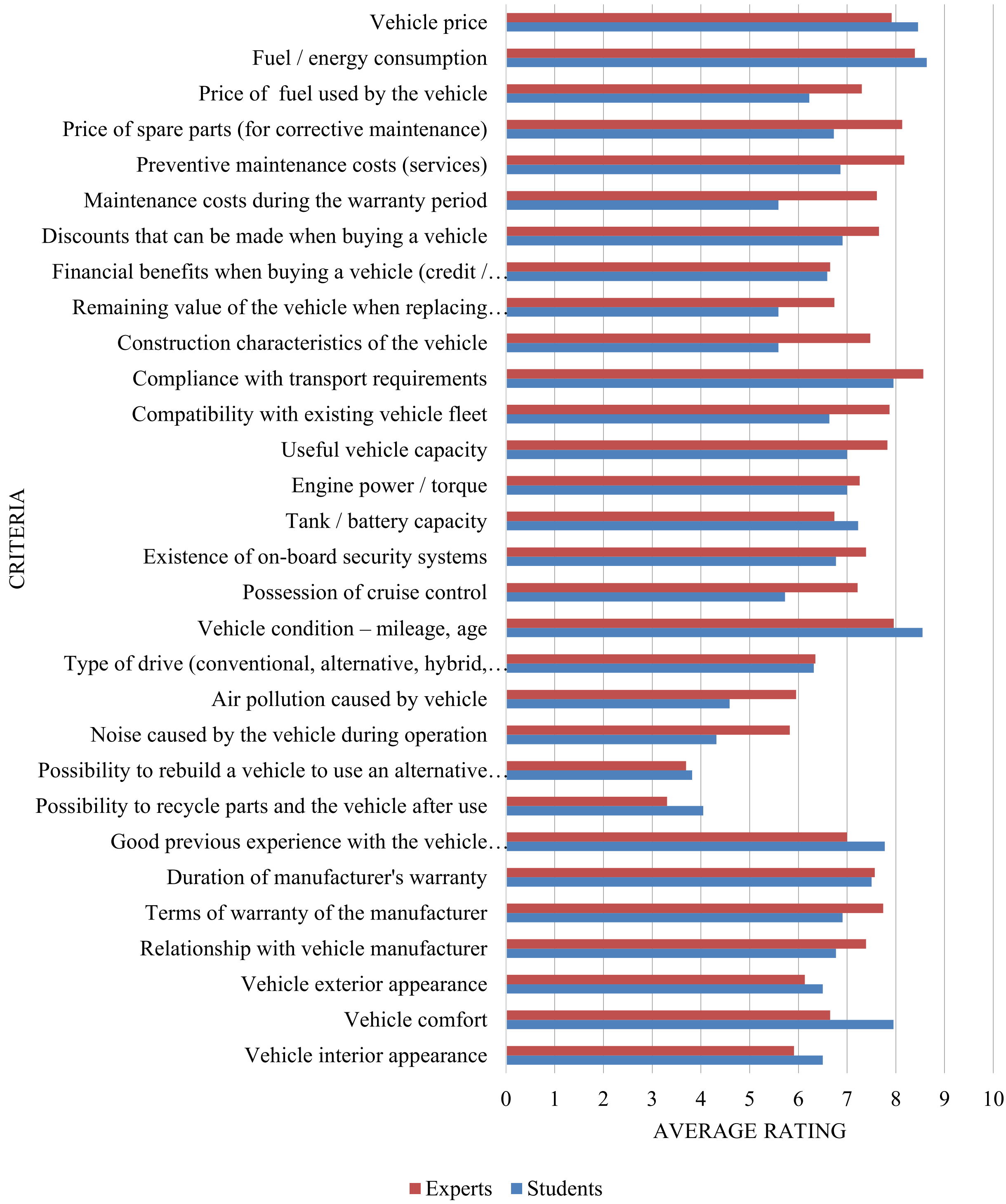


Fig. 4.
Average grades given by experts and students for each criterion

The second part of the questionnaire was dedicated to vehicles with an alternative type of drive (alternative fuel vehicles). Respondents were asked whether they thought about purchasing alternative-fuel vehicles, of which 60% of the experts answered negatively, while 40% said they thought about purchasing these vehicles. This is graphically illustrated on Figure 5.

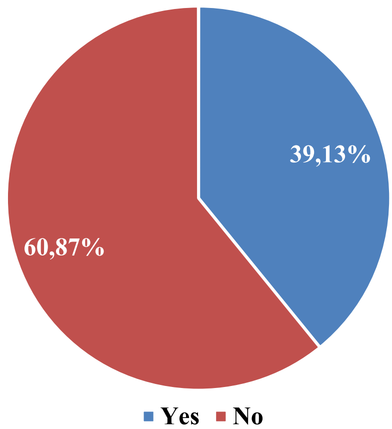
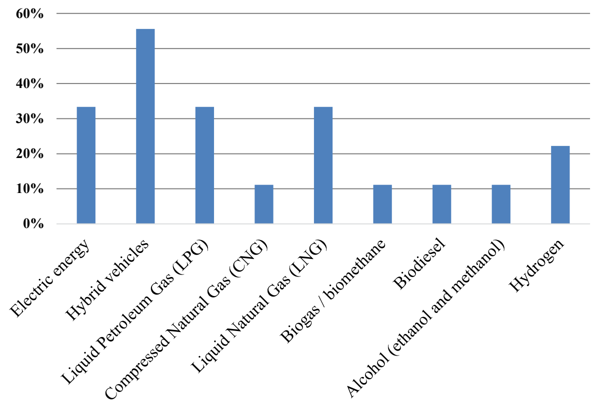


Fig. 5.
Respondents' answers to the question „Did you think about alternative-fuel vehicles procurement?“

If the respondents answered positively to the previous question, they were asked an additional question which alternative propulsion they were thinking about. On this question, the respondents could give more answers, and therefore the percentage sum of the answers shown in Figure 6 (left) is greater than 100%. In this regard, the majority of respondents said that they thought about hybrid vehicles (> 50%), while the vehicles with propulsion on the liquefied petroleum gas and liquefied natural gas, as well as electric vehicles were observed in a slightly smaller percentage (about 30%). The compressed natural gas, biogas, biodiesel and alcohol (ethanol and methanol) are propulsions that cause the least interest among respondents (about 10%). (Figure 6 - left)
On the other hand respondents that didn’t think about alternative-fuel vehicles procurement were asked a question what is the main reason why they didn’t consider this type of vehicles. As they stated, the main reasons are insufficiently developed infrastructure of the alternative fuel stations, as well as high price of alternative-fuel vehicles. (Figure 6 - right)



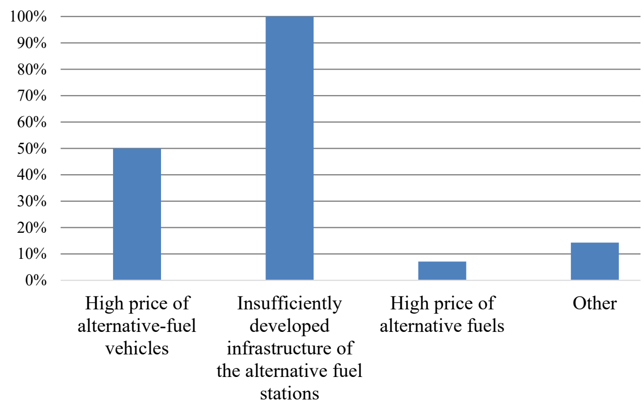


Fig. 6.
Answers to the questions which alternative propulsion you were thinking about (left) and what is the main reason because you didn’t consider alternative-fuel vehicles (right)

5. Conclusion

This paper examines the criteria on which companies owning their own fleet can successfully carry out the vehicle procurement process and fleet renewal fleet. By choosing an appropriate vehicle, the company reduces its transport and maintenance costs on the one hand, and increases fleet’s energy efficiency on the other hand and thereby increase its profit and competitiveness on the market. The authors conducted an anonymous online survey entitled „Vehicle procurement criteria“, which included 23 experts in this field and 22 students from the Faculty of Transport and Traffic Engineering, University of Belgrade – department for road and urban transport. The 70% of analized experts in their job have already participated in the vehicle procurement process. The experts and students evaluated 30 different criteria which were defined by authors on the basis of literature review, interviews with experts and their own experience. Experts’ and students’ grades are presented separately in order to see differences in the evaluation of observed criteria.
Overall average grade for all observed criteria which was given by the experts was 7.01, while the students gave an overall average grade of 6.57. "Vehicle maintenance costs during the warranty period", was criterion with highest difference in the average grade obtained by experts and students (experts evaluated this criterion for 2.02 grades more than students did). Also, it is very important to say the students were less ecologically aware. In that sense students

evaluated air pollution and noise caused by vehicle with lower grades than experts. Differences from 1 to 2 grades can be seen for the criteria such as the price of fuel used by the vehicle, the price of spare parts (for corrective maintenance), the preventive maintenance cost (services), the construction characteristics of the vehicle, the possession of cruise control etc. In fact, no significant differences (more than 2 grades) in the evaluation of the criteria were observed, and there are many criteria that are similarly evaluated.

The first five most important criteria from the point of view of the experts ar the point of experts' view are: 1) compliance with transport requirements (type and quantity of cargo / type and volume of load compartment), 2) fuel / energy consumption, 3) preventive maintenance costs (services), 4) spare parts price (for corrective maintenance), 5) vehicle condition – mileage and age. On the other side, the first five most important criteria from the point of students' view are: 1) fuel / energy consumption, 2) vehicle condition – mileage, age, 3) vehicle price, 4) compliance with transport requirements (type and quantity of cargo / type and volume of load compartment) and 5) vehicle comfort.

Also, the authors discussed the experts attitude on alternative-fuel vehicle procurement. As the result of that came that more than 60% of the experts didn't consider procurement of alternative-fuel vehicles, and as two main reasons for that respondents state insufficiently developed infrastructure of the alternative fuel stations, as well as high price of alternative-fuel vehicles.

The subject of further research will be a determination of the criteria relative weights, their interdependence and application of some MCDM methods, as well as concrete example of the successfully applied multi-criteria decision making method in vehicle procurement process in one or more transport and logistics companies in the Republic of Serbia.

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IMPROVEMENT OF AERODYNAMIC PROPERTIES OF THE SPORTS CAR MODEL "FORMULA STUDENT" USING AN UNDERSIZED MODEL PROTOTYPE

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Abstract: Lately, the significance of aerodynamics in the modern vehicle manufacturing sector has grown increasingly. With the increasing popularity of sports cars, the shape of their body, elements and wings, which determine air resistance and compressive forces, play an important role. The Article analyzes aerodynamic properties of a "Formula Student" car and their impact on the body shape. The designed "Formula Student" sports car body prototype allowed designing the exact car model using sculptural plasticine, which was tested in the aerodynamic tube. Results of experimental tests in wind tunnel: air resistance force dependence on air flow speed and downforce dependence on air flow speed also were presented.

Keywords: Aerodynamics, vehicle, Formula Student, prototype, calculations.

1. Introduction

"Formula Student" competitions are known and organized all over the world, which bring together teams of students from different countries who design, test and race with "Formula Student" cars made by themselves. As students compete, safety during the race is the key aspect. "Formula Student" cars are made following strict technical requirements defined in instructions, which indicate the critical points of the frame construction, engine limitations, requirements for the body and many other parameters. However, as in other automobile sports, it has always been attempted to maximize the dynamics of the car and reach the best possible lap time. To achieve this, there have been used two-way modifications: improving the engine or an automobile's aerodynamic elements. As the construction uses sports motorcycle engines which generates 70 – 80 kW or even more power, even having installed the mandatory calibrated restrictor in the intake manifold, they remain competitive. Therefore, in order to improve race car lap time, much attention should be paid to the car's aerodynamic qualities.

A suitable aerodynamic package can increase the car's downforce. (Mariani *et al.,* 2015) performed a numerical CFD/3D "Formula Student" automobile modelling with and without the front spoiler. He found out that driving at 85 km/h speed, the downforce of the automobile without the front spoiler is 1226.8 N/1376.0 N for the front/rear axis correspondingly. Having fixed the spoiler, the downforce of front wheels increased to 1499.2 N, though the downforce of rear wheels reduced to 1274 N. Overall downforce of the car increased by 170.4 N (Mariani *et al.,* 2015). With the increased downforce, the car can pass the racetrack corners faster, but in order to achieve the maximum speed and lose as little power as possible, it is necessary to reduce the air resistance. In order to achieve this, both standard and sports car producers try to reduce the air resistance coefficient. (Hetawal *et al.,* 2014) performed a numerical "Formula Student" automobile modelling using ANSYS programme. Three different automobile configurations were chosen for modelling and it was examined how the counterflow stream increases pressure to the car body and aerodynamic details (Fig. 1).

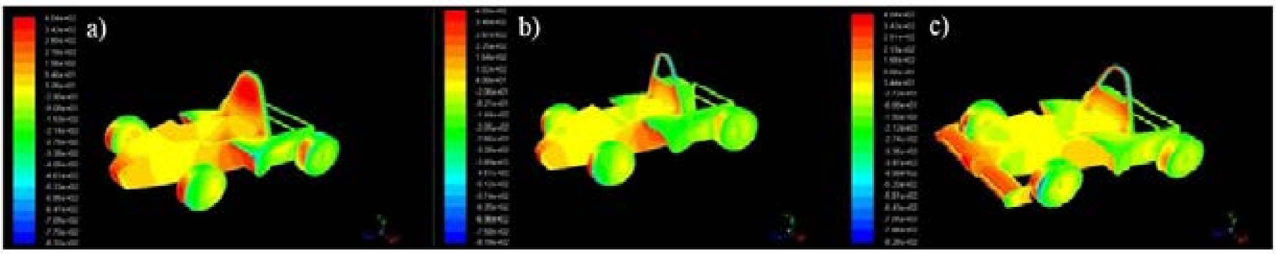

Fig. 1.
"Formula Student" automobile models affected by the counterflow stream pressure to the car body and aerodynamic details: a) with a closed firewall; b) with a partly-opened firewall; c) with a front spoiler
Source: (Hetawal et al., 2014)

It was found out that the model's with a closed firewall air resistance coefficient is 0.85. Having modified the firewall, the air resistance coefficient has dropped to 0.75, and to 0.7 with the additionally installed front spoiler (Hetawal *et al.,* 2014). When designing "Formula Student" cars, other aerodynamic elements have been added, such as underbody tunnels or the rear spoiler. This increases the downforce of the car and reducing the air resistance coefficient. (Dharmawan *et al.,* 2018) performed a numerical "Formula Student" car modelling using the AUTODESK FLOW DESIGN programme with the front and rear spoilers being mounted. The gained results were compared with the modelling data without using aerodynamic elements. It was found out that having mounted the front and rear spoilers,

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the lower air pressure is generated to the car‘s front, also the direct streamline flow is formed, which covers up the car and redirects the opposite air flow. Due to these changes, the air resistance coefficient has reduced about 23% from 0.728 to 0.560 (Dharmawan *et al.,* 2018).
Although the air resistance force is often determined using various computer simulation programmes, it is necessary to validate the gained data with the real test results. The most commonly used is one of three types of wind tunnels (Tavoularis, 2005), which can be used to test the objects of a real size or scale models with appropriate proportions.

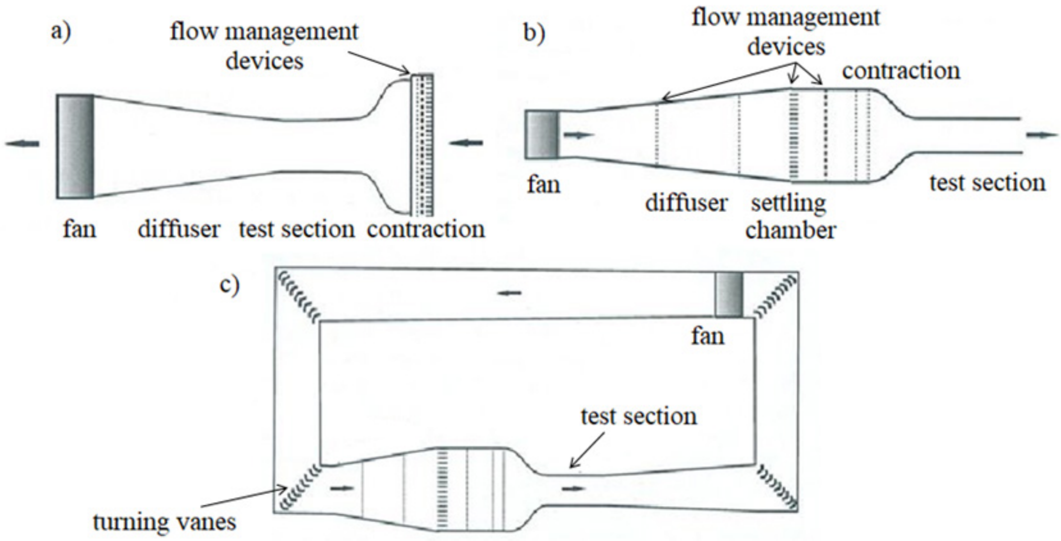

Fig. 2.
Types of wind tunnels: a) Suction wind tunnel; b) Blowdown wind tunnel; c) Closed-circuit wind tunnel
Source: (Tavoularis, 2005)

(Hammond and Flay, 2008) performed tests of the twice reduced "Formula Student" model in the suction type wind tunnel. Rolling road facility was also used for the tests, ensuring the real conditions of experiment. The tests were performed regulating the front and rear spoilers' angle of attack and changing the air flow rate from 10 to 15 m/s. It has been determined that changing only the angle of attack, the car's air resistance coefficient varies from 0.9 to 1.1 and the weight distribution between the front and rear axles has changed from 43% from the front and 57% for the rear to 33% and 67% correspondingly (Hammond and Flay, 2008).

2. "Formula Student" Model New Body Designing

During the designing stage of "Formula Student" there have been done frame construction, reduced by a scale of 1:10, on which the body shape is modelled using sculptural plasticine.

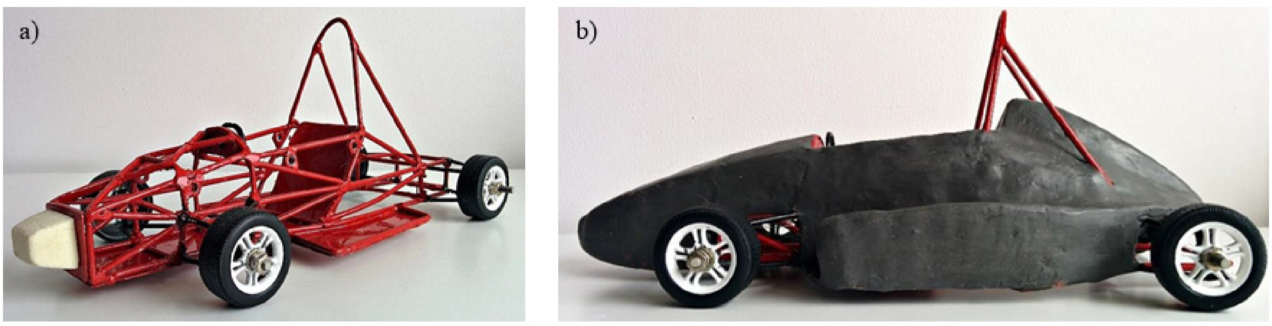

Fig. 3.
"Formula Student" model: a) – framework construction; b) – modelled body

At the start of the modelling stage, the following principles were implemented:
- The model body should be as close as possible to "the form of a drop", looking from the side because "the drop" form is the most streamlined form known in nature (Katz, 1995).
- Vacuum zone filling. The largest vacuum occurs at the rear of the car. In the case of the "Formula Student" model, vacuum occurs at the rear of the car and behind the driver's seat. The following solutions are chosen to reduce these aerodynamic phenomena:

- When modelling the cars body engine cover is created, which would fulfil the vacuum zone behind the driver's seat.
- The rear spoiler.
- For the emerging vacuum at the rear of the model, a solution is chosen – sidepods are modelled, which would lead the air flow to the back of the model thus reducing the occurrence of air deflection phenomena.

Generation of downforce. For the body, one of the most important priorities is to generate more downforce without increasing air resistance. The sidepods are one of the most important body elements, which aim at reducing the vacuum zones at the rear of the car and generate the additional downforce. Air intake cavities are also designed to provide additional function of air flow for an engine and exhaust system cooling. The sidepods are designed of a special form, with a rising angle, viewed from an air intake cavity to the rear side. It is this form which will generate the downforce.

The front body part. When modelling the front part, attempts are made to make the form as closely as possible to the frame construction, but also considering the angle of attack, which will create the downforce at the front body part.

3. Digital Designing of "Formula Student" Model New Body

In the programme "SolidWorks" there have been modelled separate elements on the framework construction. Digital designing consists of the following stages:
- The front body part on the framework construction (Fig. 4., a).
- Front body, sidepods and engine cover on the framework construction (Fig. 4., b).

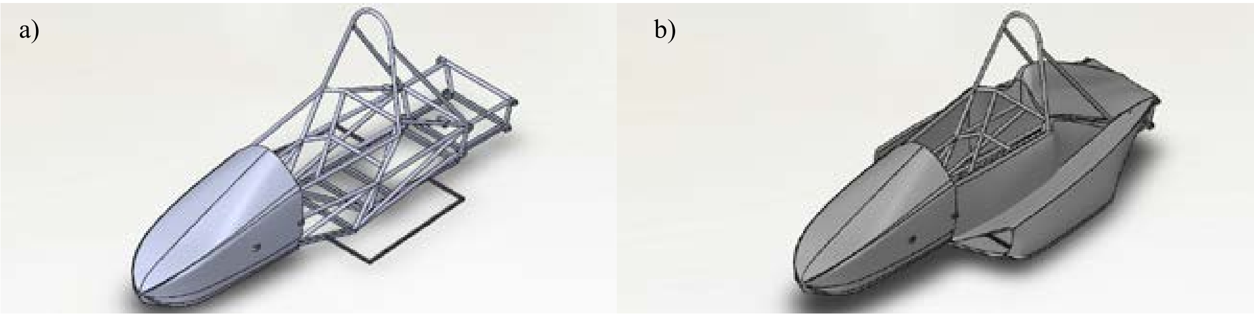

Fig. 4.
Stages of the body parts modelling

When modelling the front body part (Fig.5., a), the following aspects were taken into consideration:
1. *Form*. Attempts were made to make it as streamlined as possible and as closely as possible to the frame construction.
2. *Angles.* Considering the official requirements of the "Formula Student", sharp corners at the front of the body or other protruding parts are prohibited. All forward sides of the body that can injure a person must be rounded in at least 38 mm. radius (Committee, 2016). Because the designed body is 10 times smaller than the real one, the front radius cannot be smaller than 3.8 mm. The radius of the designed body in the horizontal axis is 5 mm, in the vertical axis it is 8 mm.
3. *Profile corner of the form (attack corner).* The corner between the lower and upper surface parts was kept 20º. At a larger angle, a higher downforce is created in the front part of the body, but the air resistance is increased accordingly. As a result, the chosen angle is a kept balance between the resistance and downforce.
4. *Thickness.* The thickness of a detail's side is designed to be 2 mm, because this thickness part can be considered a rigid surface. It was tried to keep the detail surface area as small as possible because otherwise the resistance force would increase. When choosing the thickness it was also considered that the manufactured part will be processed till finishing stage.
5. *Dimensions.* After designing the front body part, the following dimensions were obtained: length 104 mm, width 55 mm and height 62 mm.

When designing the engine cover, the main aspect was form. The aim was to eliminate the vacuum zone, appearing at the car's rear part and behind the driver's seat. The detail is attempted to be designed as much similar to the form of a drop as possible, improving its streamline form. The rear body part also reduces turbulence at the rear.
The dimensions of the rear body part are the following: length 89 mm, width 54 mm and height 51 mm.
When designing the sidepods (Fig. 5., b), the following aspects were considered:
1. *Form*. To keep it as close as possible to the framework construction, but also as streamlined as possible.
2. *Sidepods angle*. 12 degrees corner is kept. The following functions are performed:
   - Generated downforce;
   - Air flow direction;
   - Cooling.

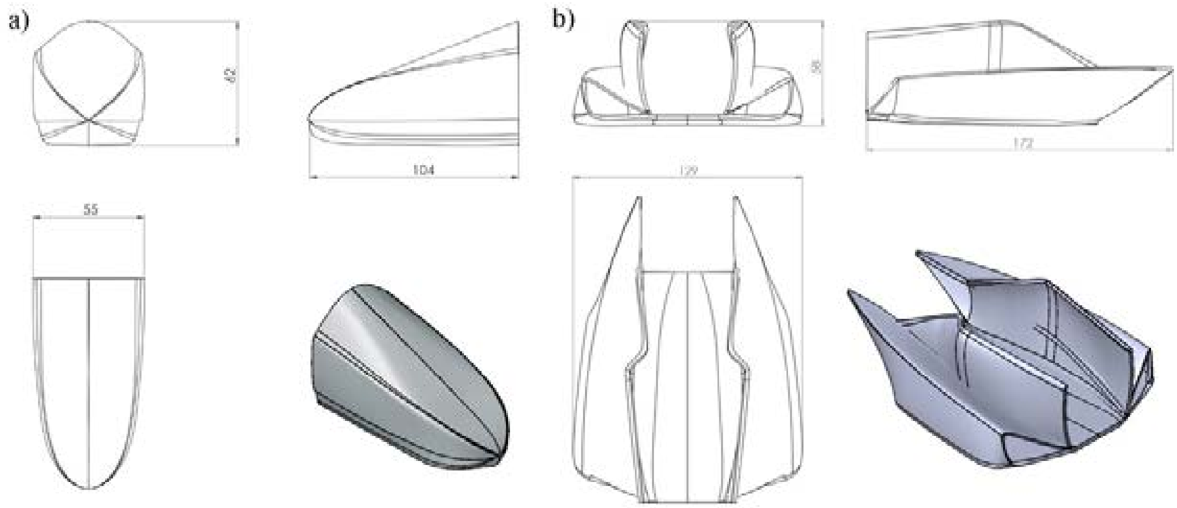

Fig. 5.
Aerodynamic parts designing: a) – front body part; b) – sidepods

The new body was made and mounted on “Formula Student“ model. Using experimental tests in the wind tunnel, there were determined air resistant and downforce in sports car “Formula Student” model: without the body (Fig. 6., a), with the old body No.1 (Fig. 6., b) and with the newly designed body No.2. (Fig. 6., c). The measuring equipment provides the data in grams (g), which are converted into force (N). In every case, the air resistance coefficient has been calculated and the comparative analysis of data has been performed.

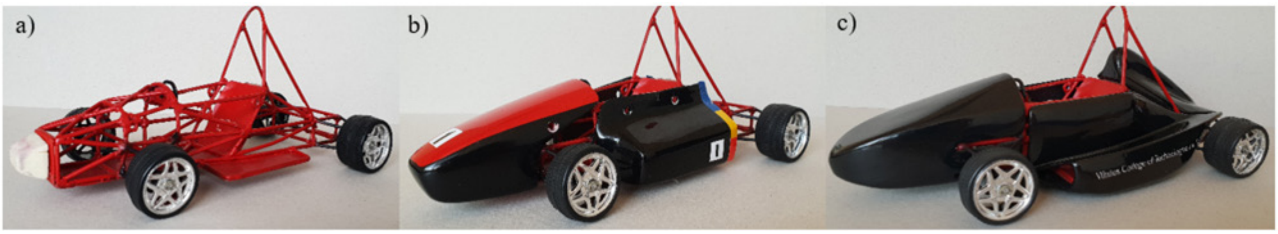

Fig. 6.
“Formula Student“ model prepared for measurement in wind tunnel: a) – without the body; b) – with old body; c) – with new designed body

4. “Formula Student“ Model Air Resistance Coefficient Establishment Methodology

“Formula Student“ model aerodynamic force research has been performed in the suction type wind tunnel (Fig. 7) with different variations of the model: without the body, with the body No.1 and with the newly designed body No.2. During the experiment the following aspects affecting the researched sports model were measured: air resistance force (D, N), downforce (D_{df}, N), air flow speed (U, m/s), and air temperature (T_{air}, °C).

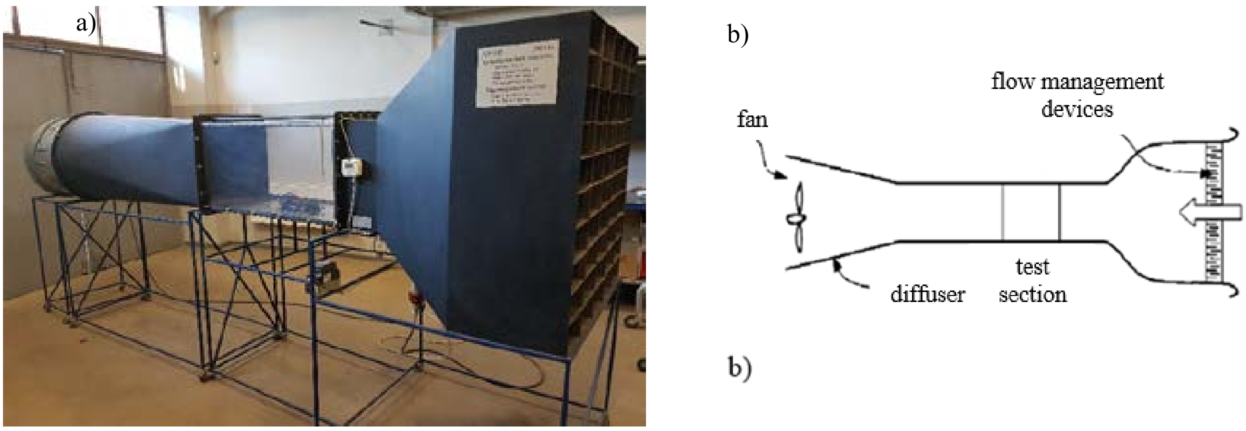

Fig. 7.
Suction type wind tunnel: a) –wind tunnel for research; b) – schematic view of wind tunnel

In the wind tunnel, the air flow has been created by the installed electric fan, operated by the frequency converter from 10 to 60 Hz. The air flow speed and temperature have been measured by the installed anemometer (measuring values 0 – 30 m/s, accuracy 3%) in the test chamber.
The drag coefficient (C_D), which quantifies the aerodynamic sleekness of the vehicle configuration (Katz, 2016):

$$C_D = \frac{D}{0.5\rho U^2 S};$$

where: D – air resistance force, N;
ρ – air density, kg/m^3;
U – air flow speed, m/s;
S – frontal area of vehicle, m^2.

The frontal area of vehicle model without body parts $S = 0.005$ m^2; with mounted old body (No.1) $S = 0.006$ m^2; with new body (No.2) $S = 0.0058$ m^2.

5. Results and Discussion

The graphs (Fig. 8) show the air resistance and downforce values measured during the tests. The biggest air resistance force in all values of speed appear in the model without the body. With the body No.1, the air resistance force has reduced by ~9,5%, with the newly designed body No.2 it has reduced by ~40%.
Such a dramatic change in forces was determined by the shape and size of body parts (Fig. 4., b). Increasing the angle of attack of the front part, the downforce becomes bigger, though the air resistance also increases correspondingly. When selecting the angle of attack of 20º, the balance between air resistance force and downforce is kept.

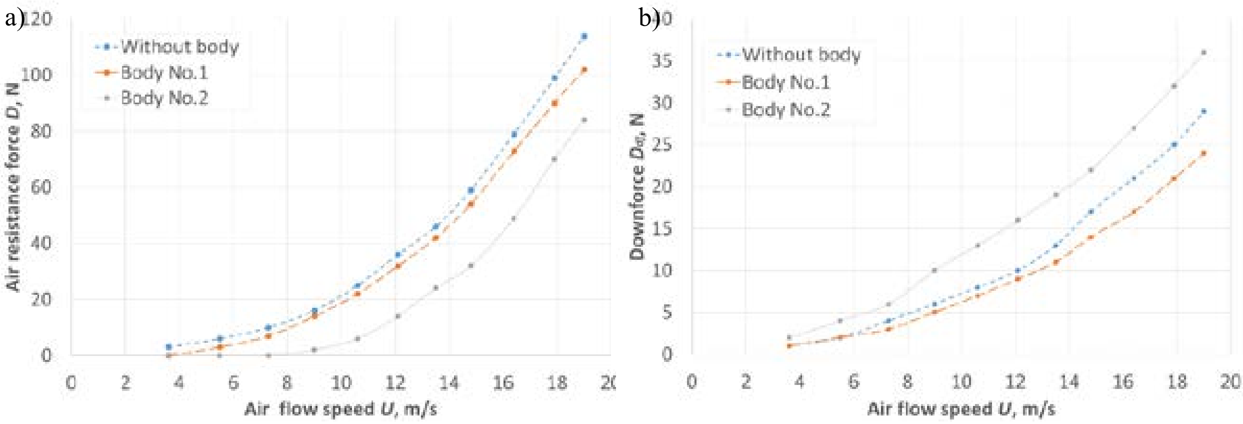

Fig. 8.
Results of experimental tests in wind tunnel: a) – air resistance force dependence on air flow speed; b) – downforce dependence on air flow speed

Having compared the downforce with the body No.1 and without the body, it has been established that the force reduces by ~16%, with the newly designed body No.2, the compression force increases by 31%. This was largely due to the shape of the front and sidepods angles of attack and the surface area. The mounting of the engine cover reduces the vaccum zone emerging in the rear part of the “Formula Student“ and also reduces the air turbulence. Having calculated the air resistance coefficient, it has been determined that for the model without a body: $C_D = 0.874$; with the body No.1 $C_D = 0.683$; with the body No.2 $C_D = 0.434$.

6. Conclusions

The experimental study of the aerodynamic forces of the “Formula Student“ model revealed that the largest air resistance force in the examined speed range was obtained studying the model without the body where the calculated drag coefficient was $C_D \approx 0.87$. Having applied the old body No.1, the air resistance force reduced by ~9,5%, drag coefficient reduced by ~21%. Having improved the front, sidepods and mounting the engine cover, air resistance force reduced by ~40%, drag coefficient reduced by ~50%, which is $C_D \approx 0.43$.
Comparison of the forces affecting the model without the body and the old body reveals that the downforce has reduced by ~16%. Upgrading of the front, sidepods and mounting the engine cover, increased the downforce by 31%. Mounting of the engine cover reduces the vacuum zone appearing at the rear of the “Formula Student“, also reduces the air turbulence.

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ASSESSMENT OF PROPERTIES AFFECTING THE LIFE CYCLE OF THE SPARE PART OF THE MEANS OF TRANSPORT

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Abstract: The article describes the results of environmental impact research on the degradation of rubber spare parts and their chemical-mechanical properties when used in transport vehicles with regard to financial costs in the field of logistics. Samples were exposed and measured at different temperatures, simulating outdoor temperatures that affect the material and thus affect its life. It provides the results of thermogravimetric analysis, material characteristics of plastic deformation and shore hardness measurement of polymer material used in the spare part of the transport vehicle (Billingham, 2007; Binar et al., 2018). The samples used conform to ISO 76-19-1 (ISO, 2010) and ČSN 62 1522 (ČSN, 1993). Based on the research, recommendations are made on optimal conditions for the storage and use of materials (Cheng, 2013).

Keywords: thermogravimetric analysis, plastic deformation, Shore hardness, polymeric material, transport vehicle, thermo-oxidative ageing.

1. Introduction

Polymeric materials are used in spare parts of the means of transport. Exposure to environmental conditions (e.g. Temperature, Oxygen, UV radiation) occurs in decomposition processes, resulting in accelerated aging of the material (Billingham 2007). In the field of vehicle operation, an increased incidence of damage to polymeric materials on rubber bellows has been identified, which protects the connections at constant speeds from external impurities. As a result of the damage, the active parts of the constant speed connections are irreversibly worn by external impurities resulting in their destruction and subsequent repair. As a result, the vehicle becomes inoperable and unable to perform the required tasks. Given that road transport is an integral part of global transport, this is a serious problem.
The aim of this paper is to explain how the chemical-mechanical properties of polymeric materials from which the polymer is made are influenced by ambient temperatures and thermo-oxidative aging.
Another objective was to carry out basic research to find and confirm the composition and basic mechanical properties of the disc on both sides, both inside and outside.

2. Materials and Methods

For the purpose of assessing the properties of polymeric material used in rubber waves to protect the constant speed couplings in vehicles, new and old bellows were used to allow a more accurate assessment of the influence of ambient temperature and thermo-oxidative aging on the cycle life of the polymeric material below.
The filler / reinforcement contents and temperature stability of the test material were tested using thermogravimetric analysis using Q500, TA Instruments.
Temperature stability and filler content, including carbon black, were determined in all samples from the decomposition curve. The temperature program differed due to different types of polymeric materials and filler content. The defect samples were heated under an inert atmosphere of nitrogen (60 ml/min), from room temperature to 550 °C at 10 °C/min, then cooled to 300 °C at 10 °C/min and then the atmosphere was switched to air followed by heating to 750 °C at a rate of 10 °C/min. The other samples (10.9 to 18.8 mg) were heated under an inert atmosphere of nitrogen (60 ml/min) from room temperature to 750 °C at 10 °C/min, then the atmosphere was transferred to air and held for 5 minutes.
Shore hardness was determined by measuring the physical and mechanical parameters of materials in accordance with ISO 7619-1 (ISO 2010, Kazda 2015). Samples were measured by Shore A for 15 seconds (ShA15). The measured location was determined 12 mm from the edge of the measured body. The final value is the arithmetic mean of the 5 measurements that have been given at positions of at least 5 mm. Measurements were made on samples after simulation of "winter" thermo-oxidative degradation at -15 °C/-20 °C and "in summer" at + 30 °C/+ 35 °C (Taweepreda et al. 2013).

3. Results and Discussion

3.1. Mechanical Properties

The chemical-mechanical properties of the polymer material were based on tensile testing using a 10 kN Shimadzu AGS-G test machine or 250 kN Dartec test machine at a specific test speed. Specific condition measurements (machine type, test speed) were maintained throughout the accelerated aging of the sample. The bodies for this evaluation were

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cut out of the bladders of the truck used between and outside to avoid the homokinetic joint from environment impurities.
Characteristic parameters of bellow tensile properties were selected as follows: tensile strength (TS), which equals the tensile strength at break (TS_b) for the rubbers in the experiment, elongation at break (E_b), which characterizes the elongation of a specimen at break, and tensile stress at 200% elongation, which is referred to as 200% modulus in this experiment (Ehrenstein, 2004).

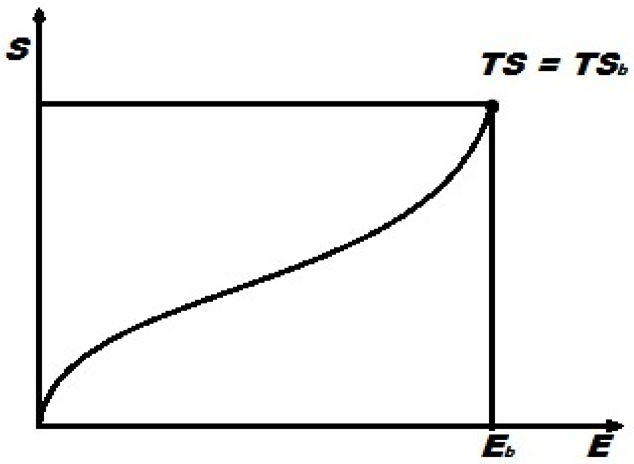

Fig.1.
The shape of the tensile curve characteristic of the rubber tested: S- tensile stree, E- percentage elongation, E_b - elongation at break, TS- tensile strength, TS_b - tensile strength at break

The polymer bellow specimens were exposed to accelerated thermo-oxidative ageing at temperatures -15°C/-20°C simulating a "winter" and temperatures +30°C/+35°C simulating a "summer"; the temperatures were set according to standard ČSN 62 1522 (ČSN 1993).

4. Results and Discussion

4.1. Thermogravimetric Analysis (TGA)

Different types of polymeric materials tested were shown by different distribution curves as shown in Figure 1. The curves are almost identical for the type-new-new type-internal-new rubber bellows material that was decomposed in two decomposition steps at temperatures of about 390 and 620°C (Ti, the fastest material loss temperature) and the greatest material loss (92%) occurred at 390°C. Weight loss approx. 0.2% below 150°C is attributed to volatile events, most likely humidity. All materials were completely decomposed under an inert atmosphere of nitrogen. Within the scope of this TGA article, the same composition of all observed bladder samples was confirmed (Cheng et al., 2016).

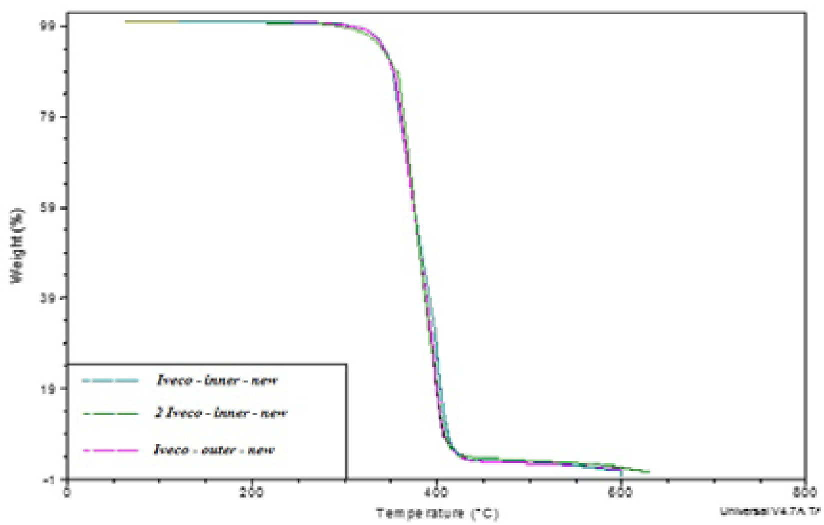

Fig. 2.
Decomposition curves of polymeric materials

4.2. Shore A Hardness Measurement

Shore A hardness was measured in rubber waves every 15 s. Only a limited number of samples were made due to the conical and wavy bellows shape; therefore their hardness was measured only after the tensile test, when the samples were stretched and deformed. Hardness values are therefore approximate.
In the following Tables 1 and 2, the hardness test results for rubber bellows are given after exposure to winter and summer simulating temperatures.

Table 1
Shore A hardness measured every 15 s in samples made from the original outer bellows after accelerated thermo-oxidation aging at -15 ° C / -20 ° C simulating "winters" and temperatures + 30 ° C / + 35 ° C simulating "summer"

Bellow-outer	**Shore A hardness – 15s**			
	Length of exposure in simul. years	**0 years**	**1 year**	**2 years**
-15°C/-20°C "winter"	Ø ShA	87.2	86.9	90.7
	Std.dev.	2.4	3.7	1.5
+30°C/+35°C"summer"	ØShA	87.2	93.8	94.4
	Std. dev.	2.4	0.9	1.4

Table 2
Shore A hardness measured every 15 s in samples made from the original internal bellows, after accelerated thermo-oxidative aging at -15 ° C / -20 ° C simulating "cold" temperatures + 30 ° C / + 35 ° C simulating "summer"

bellow – inner	**Shore A hardness – 15 s**			
	Length of exposure in simul. years	**0 years**	**1 year**	**2 years**
-15°C/-20°C "winter"	Ø ShA	74.8	78.6	82.4
	Std.dev.	4.9	3.5	3.7
+30°C/+35°C "summer"	Ø ShA	74.8	93.0	92.3
	Std.dev.	4.9	1.3	1.3

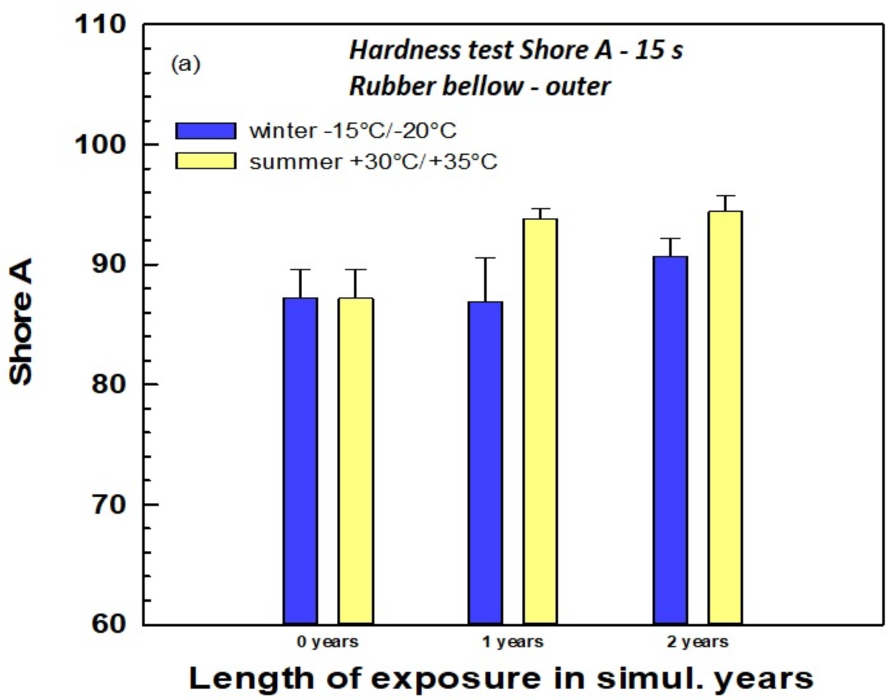

Fig. 3.

Hardness test of Rubberbellow (a) outer

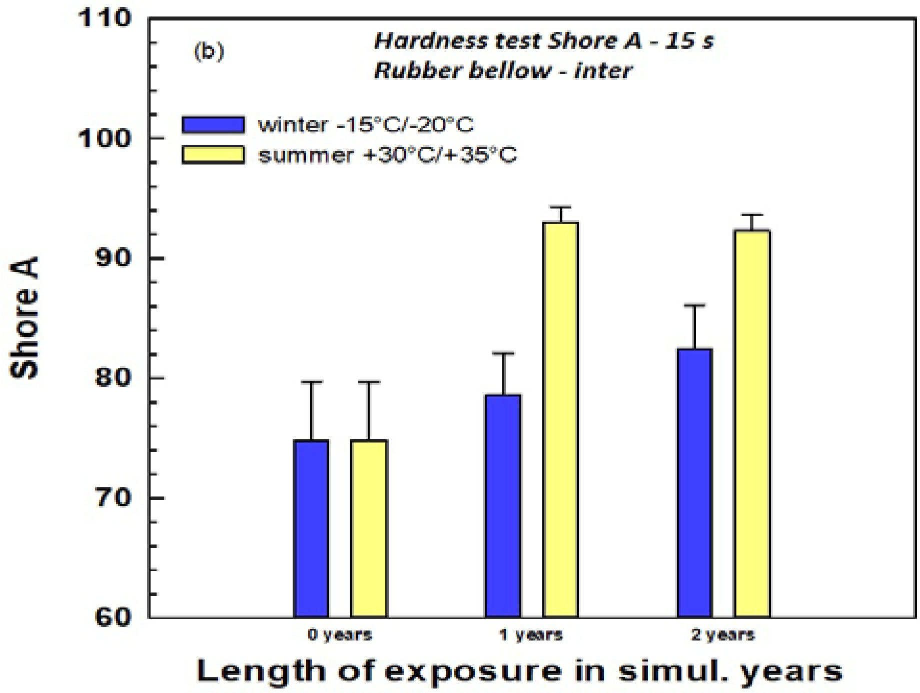

Fig. 4.
Hardness test ofRubberbellow (b) inter

3.4. Evaluation of Mechanical Properties

The plastic deformation of the polymeric material of Iveco rubber bellows was tensile tested. The tensile strength R_m [MPa] and modulus of elasticity E [MPa] characteristics measured are stated in Tables III. and IV.

Table 3
Tensile test results – Rubber bellow – outer

Rubber bellow- outer						
Length of exposure in simul. years	0		1		2	
Mechanical properties	R_m[MPa]	E [MPa]	R_m [MPa]	E [MPa]	R_m [MPa]	E [MPa]
-15°C/-20°C“winter”	19.82	1.0	20.58	1.1	17.42	1.2
+30°C/+35°C“summer”	19.94	1.0	21.25	2.4	19.10	2.3

Table 4
Tensile test results – Rubber bellow - inter

Rubber bellow- inter						
Length of exposure in simul. years	0		1		2	
Mechanical properties	R_m [MPa]	E [MPa]	R_m [MPa]	E [MPa]	R_m [MPa]	E [MPa]
-15°C/-20°C “winter”	20.51	1.3	21.98	1.0	22.01	1.2
+30°C/+35°C summer”	20.85	1.3	23.01	2.7	18.29	2.5

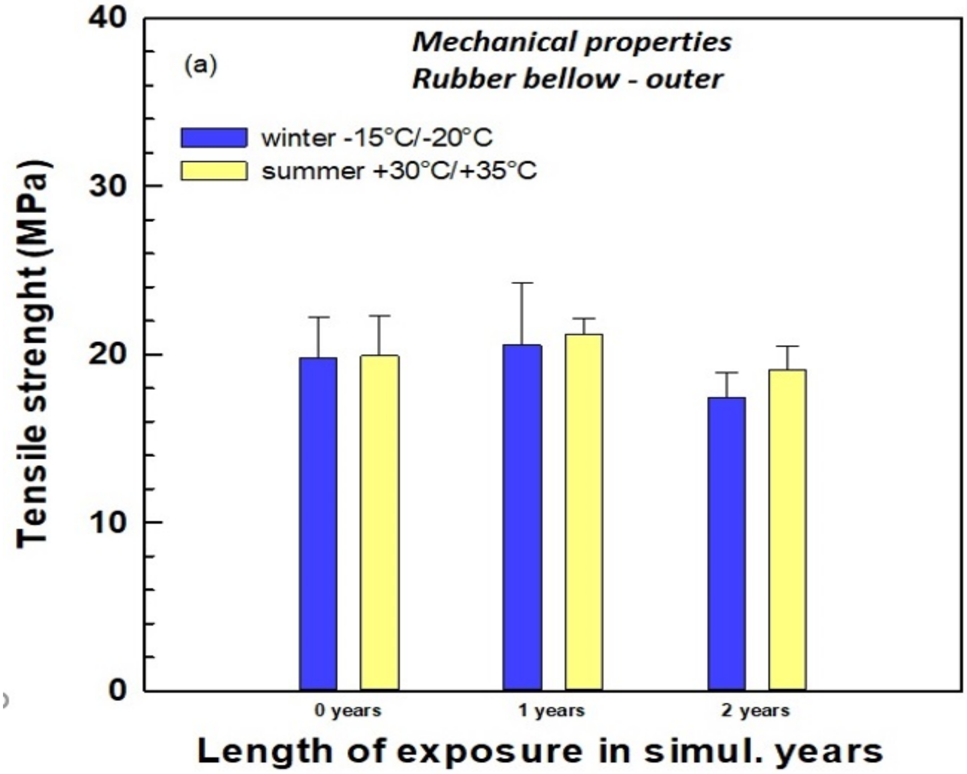

Fig. 5.
Tensile test ofRubberbellow (a) outer

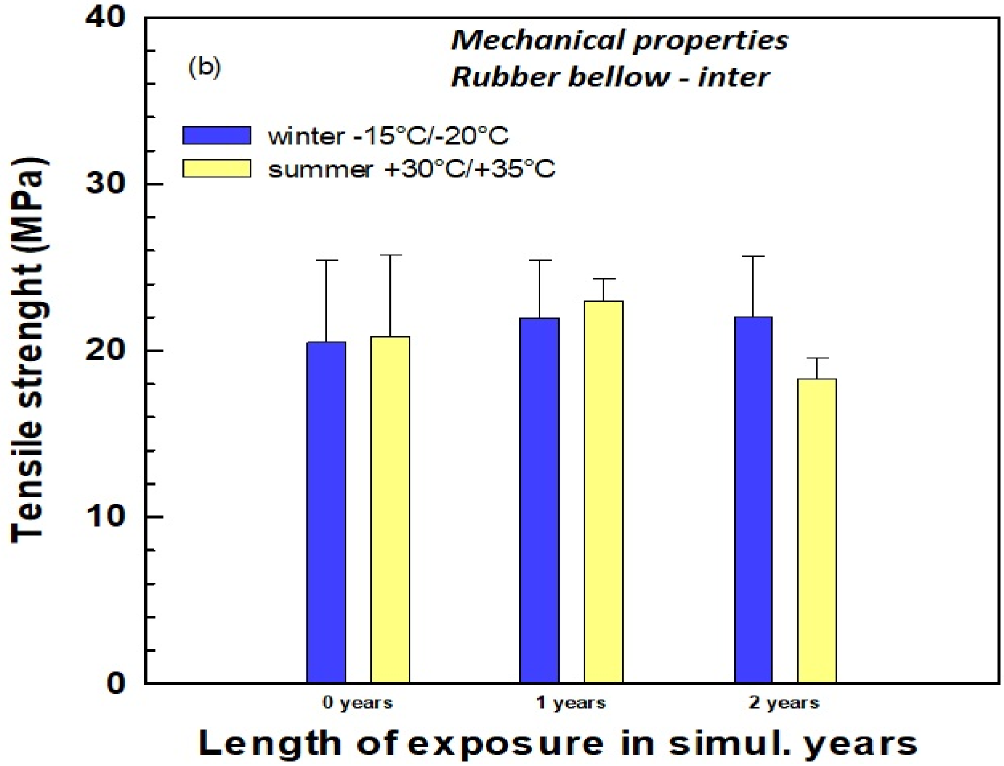

Fig. 6.
Tensile test ofRubberbellow (b) inter

Based on the results obtained, it can be stated that the results of measuring the mechanical properties are in accordance with the hardness measurement. In case of part a) - external, it can be stated that at the winter temperature, the hardness values are slightly increased and the tensile strength decreases slightly. The level depends on the length of exposure.
At summer temperature, hardness expands significantly after the first year of use and exposure and continues to grow. Tensile strength decreases and it can be assumed that the elongation at higher temperature will be significantly higher compared to winter conditions (Samsuri, 2010).

In the case of part b) - inter, the behaviour of the samples is the same, both parts are from the same polymer as confirmed. The only difference can be observed in the Shore A hardness assessment, where the "winter" simulation and the subsequent measurement of the samples yielded lower values than in the case of external parts exposed under the same conditions.es then in case of the outer parts exposed at same conditions (Naruse et al., 2012).

5. Conclusion

In winter temperatures, the soft bellows of the lorry are slightly hardened and their tensile strength increases slightly. At summer temperatures, the hardness increases even after the first year of exposure, as does their "bracing" speed, while tensile strength decreases, resulting in early tearing. Chemical analysis has shown that the rubber mat is made of polyester.

Based on the result, it can be stated that their exposure to high and low temperatures for several years brings about the release of their functional characteristics, which lead to continued use of the vehicle to its damage and stops performing its function.

The solution could be, for example, when changing the mixture used in the production of bellows. The second and third variant solutions are the modification of the external part of the chassis - either its parameters or the production technology, or its conditions, in order to prolong the life of the outer bellows, as the damage was mainly caused by them (Vahdati et al., 2005).

Acknowledgments

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INVESTIGATION OF AUTONOMOUS VEHICLES FIT INTO TRADITIONAL TYPE APPROVAL PROCESS

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Abstract: To register your car a special document have to be submitted in Europe: Certificate of conformity for new cars. The certificate of conformity is issued by the manufacturer and shows that vehicles technical characteristics meet safety and environmental standards. It can be either a European (EC) or a national certificate. Paper presents the typical type approval processes for traditional cars and summarizes the main questions that should be addressed during the development of type approval process fit for autonomous vehicles.

Keywords: type approval process, autonomous vehicles.

1. Introduction

In order to sell a vehicle in a specific market, the manufacturer must approve or confirm officially that it meets or exceeds all applicable regulatory standards and specifications. There are three existing methods (Martins, 2010) to officially indicate that a vehicle meets regulatory standards and specifications as presented in table 1.

Table 1
Official methods to indicate that a vehicle meets the regulation

Method name	Certificator / Approval	Examples
Type Approval / Homologation	Government	EU, China, India
Self-Certification	Manufacturer	US and Canada
Combined Self-Certification and Type Approval	combined	Brazil

Source: own

Vehicle Type Approval or Homologation is the confirmation that production samples of a design will satisfy the legal requirements of the market. There are two main methods of type approval in Europe. One is based on the EC Directives and the second is part of United Nations Economic Commission for Europe regulations (UNECE). Both are regulating approval of whole vehicles, vehicle systems and single components. Type approval process contains procedures, events, and timing, which must be followed in order to accomplish homologation in global markets. Because it is approved by a third party and since different markets may have different approval authorities, there could be situations where, even though the regulatory requirements are exactly the same, specific homologation testing and homologation processes are necessary.

In the framework of self-certification process the manufacturer internally should validate that a vehicle meets the applicable regulatory standards of a specific market. Self-certification process contains documentation of requirements, test methods, responsibilities, and evidence required to demonstrate compliance. The vehicle can be registered and sold based on the manufacturer’s self-certification declaration. Government agency has the right to test vehicles to verify compliance to the requirements.

2. Type Approval Process

The vehicle consists huge number of components and systems, each of which must conform to corresponding requirements. Vehicle manufacturers and suppliers of relevant parts to automobile manufacturers must ensure that their products meet those requirements. Type approval makes a distinction between ‘components’ for vehicles - such as lighting components, glazing, rear view mirrors, etc - and ‘systems’ for vehicles, which determine compliance of many components together, such as for braking, steering, crash performance and emissions (VCA). Levels of type approval process are presented in figure 1.

2.1. Component Type Approvals

Component type approvals are designed to approve a component that may be fitted to any vehicle. Manufacturer have to make available about a dozen or more pre-production cars that are equal to final product. These prototypes are used for testing compliance with EU safety regulations, noise and emissions limits as well as production requirements (of individual parts and components, such as seats or steering wheel airbags). If all important requirements are met, the national authority delivers an EU vehicle type approval to the manufacturer authorising the sale of the vehicle type in the EU.

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2.2. System Type Approvals

System type approvals based on component approval are focusing on approval of a set of components or a performance feature of a vehicle that can only be tested and certified in an installed condition (e.g., ie: installation of lights, braking performance or crash tests with dummies)

2.3. Whole Vehicle Type Approval (WVTA)

Once all components and systems have been approved, a manufacturer can request approval of the Whole Vehicle Type. Upon submission of the relevant manufacturer's information document, including reference to the separate type approvals of all systems and components, a European WVTA Certificate will be issued by a type approval authority. The manufacturer shall produce a Certificate of Conformity (CoC) for each vehicle manufactured in conformity with an approved type. A 'type' can best be described as a 'range' of vehicle models that share fundamental characteristics.
The type approval system also allows for a multi-stage approval procedure that applies when the vehicle is built up in more than one step (e.g. by a chassis manufacturer and a body builder). The European WVTA certificate of a vehicle type issued by the approval authority of one member state has to be accepted by all other European member states and allows for the registration of a new vehicle all over the EU.

2.4. Conformity of Production

Conformity of Production (CoP) is a vital part of the approval process. The manufacturer must bring evidence of its capacity to maintain compliance with the approved type for each and every new vehicle manufactured during serial production. This ensures that quality standards are upheld when the vehicle is actually being produced in large numbers. A type approval authority or an authorised technical service conducts the necessary tests and authors a test report. It can use the manufacturer´s test facilities if it is satisfied that the equipment and processes applied meet the necessary quality standards. Finally, the approval authority issues a European WVTA approval certificate. The manufacturer is then responsible for ensuring ongoing Conformity of Production (CoP). By issuing and signing the Certificate of Conformity (CoC) the manufacturer takes full responsibility that all separate regulatory acts are met.

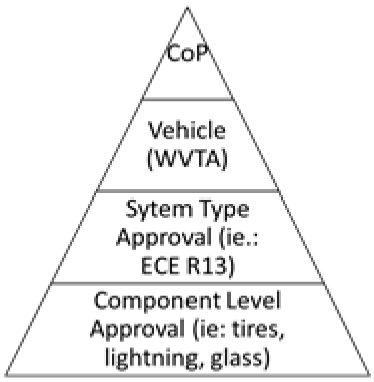

Fig. 1.
Levels of Type Approval

3. Self-Certification Process

First step of self-certification process is definition of complete set of valid prescriptions. In US the Federal Motor Vehicle Safety Standards, or FMVSS, are legal requirements, which are mandated by the government. These define performance and design standards on vehicles to improve safety protection, and they are a sample of self-certification requests.
Items, as motor vehicle equipment and motor vehicles manufactured, to be sold in the United States markets are regulated by US Vehicle Safety Act and they should be certified to comply with all applicable FMVSS. National Highway Traffic Safety Administration's or NHTSA's regulations on motor vehicle certification to be found at 49 CFR Part 567. Principles on the certification of motor vehicle equipment are described as subject to the FMVSS and are published in 49 CFR Part 571, Subpart B.
Main characteristic of US regulations that they are rigorous and robust. There is a robust legal framework and data-driven process which is used by US regulators to develop technical regulations for road vehicles. Main aim of the methods is to validate if the vehicles certified to the relevant technical requirements. There are 65 motor vehicle and motor vehicle equipment safety standards in the U.S., most of them (29) focus on pre-crash (active or crash avoidance) safety, another big branch (27) is about cover crash (passive or crash worthiness) safety and there are some standards about cover post-crash safety (5) and additional 'special' safety standards (4) (Curry, 2016).

Regulations in Canada are described in Canadian Motor Vehicle Safety Standards, or CMVSS, and they are very similar to FMVSS.
Tailpipe and evaporative emissions certifications require government approval in the United States as well. Regulations are set by Environmental Protection Agency (EPA). On the top of the regulatory requirements, vehicles must be also in-line with Voluntary Agreements and guarantee the minimum levels of performance for Public Domain safety ratings (NCAPs).
In Voluntary Agreements Original Equipment Manufacturers secure that the products met a specific requirement and are considered as to be equivalent of government regulations. One of the main aims of New Car Assessment Program (NCAP) is to develop vehicles to "improve occupant safety by developing and implementing meaningful and timely comparative safety information that encourages manufacturers to voluntarily improve the safety of their vehicles" (Hershman, 2001). Corporate Requirements are internal design requirements of producers, which are introduced to either to improve real world safety or to guarantee minimum levels of performance for Public Domain safety ratings.
Finally, production changes should be managed by the OEM with a robust control process, in order to guarantee ongoing regulatory compliance for life of the vehicle. The Compliance Demonstration Data should contain following parts to minimize the risks of some of the most difficult issues to defend in litigation (Martins, 2010):

1. Ensure compliance with FMVSS or Voluntary Agreements;
2. Shows compliance of design changes during a product's life-cycle;
3. Demonstrating a high level of safety; and
4. Proves supportive documentation for design decisions.

4. Comparison of Type Approval and Self Certification

In the comparison of the type Approval and Self Certification the main characteristic can be summarized as the following as in Fig 2.
In case of Type Approval the equipment manufacturer responsibility is to submit product samples for testing, prove compliance through witnessed testing and demonstrate ability to consistently build compliant vehicles, systems, and components. In the same process the role of the governmental approval authority is to review test plans, conduct or witness tests, grants approvals and monitor conformity of production.
In Self Certification process the producers' duty is to ensure compliance with regulatory requirements, document evidence to demonstrate compliance and ensure that products continue to meet regulatory requirements for the lifecycle of the vehicle. Governmental responsibility is to audit production vehicles on purpose and has the right to open an investigation and take the respective legal actions.

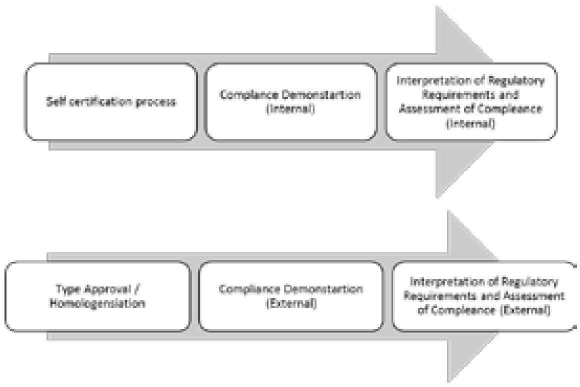

Fig. 2.
Comparison of Homologation and Self Certification

5. Specialities of Autonomous Vehicles

There are still a high number of obstacles for autonomous vehicles, from technical feasibility and legal background to general acceptance by the people. From automotive industry point of view, the main question is how to guarantee safety.
As described previously traditional vehicles have their own validation process either homologation or self-certification. In case of autonomous vehicles, software is an element, which must fulfil high-quality criteria and should be certified itself. Traditional designed test would not be able to measure software elements, and neural networks of autonomous vehicles in an acceptable timeframe (Tettamanti et al., 2016).
It has long been known that it is infeasible to test systems thoroughly enough to ensure ultra-dependable system operation (Pauer and Torok, 2018). As an example, take a theoretical fleet of one million vehicles tested one hour per day, that means 10^6 operational hours per day. If the safety target of this fleet is to have about one catastrophic computing failure in every 1,000 days, then the safety goal is a mean time between catastrophic failures of 10^9 hours, which is comparable to aircraft permissible failure rates (Koopman et al., 2016). The likelihood used in the calculation

means that catastrophic computing failures will happen more times during the life of the fleet of vehicles. To measure and standardise inspections the procedures should be developed and extended.
As first step of inspection process, development automotive vehicles should be classified. There are more classification in use; one of the most used is the SAE classification that is presented in Fig 3. (Hirz et al., 2018).

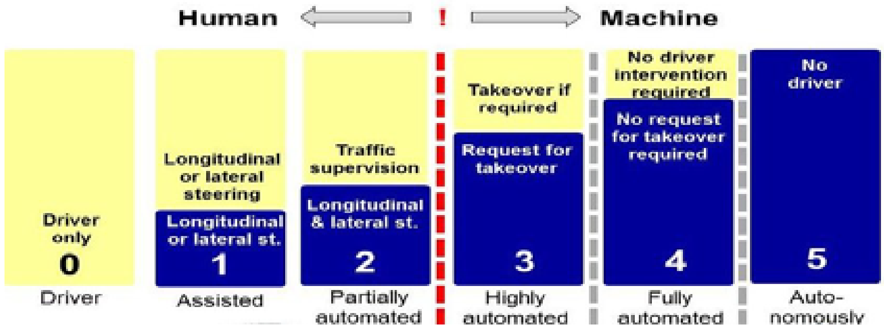

Fig. 3.
Autonomous vehicles SAE classification

Fig 3 shows that with increasing automation more and more complex systems are involved into the environment detection and decision process. Role of artificial intelligence and neural networks are increasing if vehicles are more and more self-driving. It is easy to follow as well, that software role is higher and higher with increasing SAE levels (Godoy et al., 2015; Li et al., 2015). It means that this tendency should be followed as well into the regulation and homologation process. Growing role of software's naturally increase the effect of program refreshments on vehicle behaviour in traffic and based on that the measurement, validation and quality assurance of each software updates. As result of these turn to version verification solutions of informatics should be a next step in development of automotive vehicles and make them suitable for the market.

6. Conclusions

Increased role of artificial intelligence and neural networks should be followed by a focused development in vehicle homologation process to handle specialties and make them compatible with current vehicle validation methods. Increasing role of software and their updates should be covered in the new specifications. In new homologation process development as very appropriate tool (Szalay, 2016) Zalaegerszeg Proving Ground is planned to utilised.

Acknowledgements

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INFLUENCE OF AERODYNAMIC FORCES ON THE STOPPING DISTANCE OF INTERCITY BUSES - invited paper

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Abstract: In this paper an analysis of the impact of drag force and lift force on the bus stopping distance was conducted. The model of the bus in the braking process is shown. Based on the model of the bus, a differential equation of motion was made with a complex solution of stopping distance which takes into account the aerodynamic forces. The stopping distance is analyzed depending on the speed at which the braking starts, changes in the adhesion conditions, the utilization of bus capacity, body shape, air temperature/density. It has been established that aerodynamic forces can influence the decreasing of the stopping distance up to 13% depending on the operating conditions. At lower bus speeds up to 50 km/h, the impact of aerodynamic forces is irrelevant.

Keywords: bus, stopping distance, drag force, drag coefficient, adhesion, braking.

1. Introduction

Aerodynamic forces (drag force and lift force), in addition to rolling resistance, are considered as a constant resistance in vehicle movement process. The intensity of aerodynamic forces depends on a number of factors: speed of vehicle, body shape, density and air temperature (Garrett et al., 2001). Drag force is a consequence of two phenomena that occur when the vehicle moves through the air: turbulence of air around vehicle body and friction of the air particle on the surface of the vehicle body (viscous friction) (Dedović et al., 2017; Gillespie, 1992). Disturbance of air flow is caused by different pressure on the front and rear zone of the vehicle. When the vehicle is moving, the pressure difference occurs due to the compression of the air particles in the front zone of the vehicle and the dilution of the air particles in the rear zone of the vehicle. The component of the drag force due to turbulence is the dominant component in the total drag force with a share of over 80% (Heisler, 2002; Wong 2001). It depends on the shape of the body, i.e. the aerodynamics of the body shape of the vehicle. Friction of the air particle on the surface of the vehicle is a component that depends on how the vehicle surface is smooth but also the size of the contact surface itself. Its share in drag force is about 10-15% (Heisler, 2002; Wong 2001). This component has a significant share when it comes to vehicles of larger lengths, buses, trucks or road trains. The primary impact of drag force on the vehicle is reflected in the reduction in vehicle speed and less on the change in dynamic axle loads. Due to the increase of the air pressure from the bottom of the vehicle and the decrease of the air pressure on the top of vehicle body, the lift force is also has an impact on the movement of the vehicle. The lift force is generally much less intense than drag force, and its impact on vehicle movement is manifested most often through the reduction of axle loads. By applying aerodynamic aids or due to the specific shape of the vehicle body, the lift force can be oriented in the opposite direction, i.e. "down" (Heisler, 2002; Reimpell et al., 2001). In this case, the dynamic axle loads are increased. Changing of the dynamic axle loads affect the adhesion between the wheel and the road surface and therefore on the performance of the vehicle in different operating conditions (drive or braking mode). When braking a vehicle, the action of the executive parts of braking system causes a decrease in vehicle speed. Also, the drag force contributes to decrease the vehicle speed. On the other hand, the lift force can lead to a reduction in axle loads, which negatively affects the length of the stopping distance. i.e. the stopping distance is increasing (Heisler, 2002). Bearing all the above mentioned in mind, the aim of the research in this paper is to quantify and signify the impact of aerodynamic forces on the stopping distance of intercity buses, primarily due to the large frontal area and the low value of the ratio of useful payload and the unladen mass of this category of vehicles.
In this regard, in the first part of the paper, the intercity bus model in the braking mode is defined. According to the model, an equation for a stopping distance is made, which takes into account the impact of aerodynamic forces. In the second part of the paper, the analysis of the stopping distance was performed for a typical example of intercity bus in different operating conditions. At the end of the paper, conclusions and directions for further research were made.

2. The Model

Fig. 1 shows the model of the intercity bus according to which the equations for the stopping distance are made.

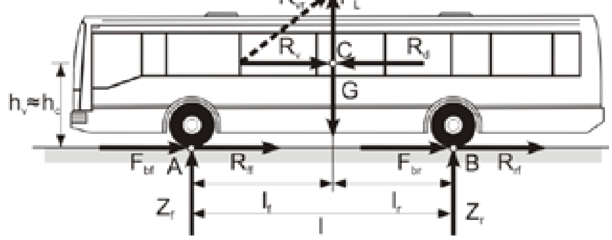

Fig. 1.
Model of Intercity Bus in Braking Process

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While braking, the following forces influence on the movement of the bus:

- F_{bf} - braking force on the front wheels
- F_{br} - braking force on the rear wheels

The maximum value of the total braking force, in relation to the available adhesion, is (Eq. (1):

$$F_{bf} + F_{br} = (Z_f + Z_r)\cdot\varphi = (G_A - F_L)\cdot\varphi \tag{1}$$

where:

- Z_f and Z_r - dynamic axle loads on front and rear axle
- G_A - weight of the bus (G_A=G_S+G_K; where: G_S - weight of the empty bus; G_C - total weight of passengers with luggage)
- F_L - lift force ($F_L = \frac{c_L \cdot \rho}{2}\cdot A\cdot V^2$; where: c_L - lift coefficient 0.2-0.3; ρ - air density; A - frontal area of the bus; V - bus speed
- φ - adhesion coefficient

In addition to the total braking force, the following resistance forces influence on the bus movement:

- R_f - total rolling resistance ($R_f = R_{ff} + R_{fr} = (G_A - F_L)\cdot f$; where: f - coefficient of rolling resistance; R_{ff} - rolling resistance on front wheels; R_{fr} - rolling resistance on rear wheels)
- R_d - drag force ($R_v = \frac{c_x \cdot \rho}{2}\cdot A\cdot V^2$; where: c_x - drag coefficient; $A = 0.9\cdot B\cdot H$; A - frontal area of the bus; B - bus width; H - bus height)
- R_i - resistance of inertia ($R_i = \frac{G_A}{g}\cdot a_d\cdot\delta$; where: a_d - deceleration; δ - rotating mass factor; g=9.81m/s^2)

Other labels in the Fig. 1 are:

- C - centre of gravity
- h_c - centre of gravity height
- h_v - point of application of drag force (height of metacentre, $h_v \approx h_c$)
- l_f and l_r - distance of centre of gravity from the front or rear axle
- R_{vr} - resultant aerodynamic force

Based on static equilibrium of forces in the braking process, a differential equation of motion is given by Eq. (2):

$$\sum X = 0 \;\Rightarrow\; R_i = R_{ff} + R_{fr} + R_d + F_{bf} + F_{br} \tag{2}$$

Based on Eq. (2), a general differential equation is obtained in the form, Eq (3):

$$\delta\cdot\frac{G_A - K_L\cdot A\cdot V^2}{g}\cdot\frac{dV}{dt} = \left(G_A - K_L\cdot A\cdot V^2\right)\cdot f + K\cdot A\cdot V^2 + \left(G_A - K_L\cdot A\cdot V^2\right)\cdot\varphi \tag{3}$$

General differential equation based on the stopping distance which includes aerodynamic forces can be given by Eq. (4):

$$dS_{Rd} = \frac{\delta\cdot\left(G_A - K_L\cdot A\cdot V^2\right)}{g}\cdot\frac{VdV}{\left(G_A - K_L\cdot A\cdot V^2\right)\cdot(\varphi + f) + K\cdot A\cdot V^2} \tag{4}$$

The solution of the differential equation represents the stopping distance, taking into account the influence of aerodynamic forces on the movement on the vehicle, Eq. (5):

$$S_{Rd} = \frac{\delta\cdot G_A}{2\cdot g\cdot b}\cdot\ln\frac{a + b\cdot V_1^2}{a + b\cdot V_2^2} - \frac{\delta\cdot K_L\cdot A}{g}\left[\frac{1}{2\cdot b}\left(V_1^2 - V_2^2\right) - \frac{a}{2\cdot b^2}\cdot\ln\frac{a + b\cdot V_1^2}{a + b\cdot V_2^2}\right]\ [m] \tag{5}$$

where:

- $a = G_A\cdot(\varphi + f)$
- $b = K\cdot A - K_L\cdot A\cdot\varphi - K_L\cdot A\cdot f$

- K and K_L - reduced drag and lift coefficients ($K = \frac{c_x \cdot \rho}{2}$, $K_L = \frac{c_L \cdot \rho}{2}$)
- V_2 - speed less than initial speed V_1 (in this research V_2=0 m/s)
- $\rho = 1.225 \cdot \frac{P}{101.325} \cdot \frac{288.16}{273.16 + T}$ $[kg/m^3]$ (Gillespie, 1992), where: P - atmospheric pressure [kPa]; T - air temperature [°C]

If the aerodynamic forces (R_d=0 and F_L=0) are excluded from the analysis, the stopping distance is given by Eq. (6):

$$S = \frac{\delta}{2 \cdot g} \cdot \frac{V_1^2 - V_2^2}{(\varphi + f)} \tag{6}$$

Equations Eq. (5) and Eq. (6) define the stopping distance of the vehicle at the initial speed V_1 with the maximum utilization of the available adhesion on all wheels.

3. Results and Analysis

Analysis of the impact of aerodynamic forces on the stopping distance is performed for the intercity bus with the following basic characteristics: G_S=11400 kg; G_K=3640 kg, B=2.5 m; H=3.24 m (Ivković, 2017; Nijemčević et al., 2001).

The following cases, based on changing of operating conditions are considered:

Case 1. Dependence of the stopping distance on the bus speed for empty bus (G_A=G_S), with a body shape whose drag coefficient is very large (c_x=0.9), poor adhesion conditions (φ=0.15, f=0.010), low air temperature (T=5°C)

Case 2. Dependence of the stopping distance on the bus speed for empty bus (G_A=G_S), with a body shape whose drag coefficient is very small (c_x=0.3), good adhesion conditions (φ=0.95, f=0.020), high air temperature (T=30°C)

Case 3. Dependence of the stopping distance on the bus speed for full-loaded bus (G_A=G_S+G_K), with a body shape whose drag coefficient is very large (c_x=0.9), poor adhesion conditions (φ=0.15, f=0.010), low air temperature (T=5°C)

Case 4. Dependence of the stopping distance on the bus speed for full-loaded bus (G_A=G_S+G_K), with a body shape whose drag coefficient is very small (c_x=0.3), good adhesion conditions (φ=0.95, f=0.020), high air temperature (T=30°C)

Case 5. The influence of the separate operating condition on the stopping distance for a low bus speed (50 km/h) and the constant other typical operating conditions

Case 6. The influence of the separate operating condition on the stopping distance for a middle bus speed (90 km/h) and the constant other typical operating conditions

Case 7. The influence of the separate operating condition on the stopping distance for a maximal bus speed (130 km/h) and the constant other typical operating conditions

Case 8. Furthermost/maximal impact of aerodynamic forces (at low and maximum bus speed, Case 8a, Case 8b, respectively): empty bus (G_A=G_S), with a body shape whose drag coefficient is very large (c_x=0.9); poor adhesion conditions (φ=0.15, f=0.010), low air temperature (T=5°C)

Case 9. Furthermost/minimall impact of aerodynamic forces (at low and maximum bus speed, Case 9a, Case 9b, respectively): empty bus (G_A=G_S), with a body shape whose drag coefficient is very small (c_x=0.3); good adhesion conditions (φ=0.95, f=0.020), high air temperature (T=30°C)

Case 10. Furthermost/maximal impact of aerodynamic forces (at low and maximum bus speed, Case 10a, Case 10b, respectively): full-loaded bus (G_A=G_S+G_K), with a body shape whose drag coefficient is very large (c_x=0.9); poor adhesion conditions (φ=0.15, f=0.010), low air temperature (T=5°C)

Case 11. Furthermost/minimall impact of aerodynamic forces (at low and maximum bus speed, Case 11a, Case 11b, respectively): full-loaded bus (G_A=G_S+G_K), with a body shape whose drag coefficient is very small (c_x=0.3); good adhesion conditions (φ=0.95, f=0.020), high air temperature (T=30°C)

The calculation of the stopping distance was performed in cases of empty and full-loaded buses. In the case of empty bus, when the adhesion conditions are unfavorable (Fig. 2, (φ+f) ≈0,15), the impact of aerodynamic forces on the stopping distance S_{Rd} at speeds of less than 30 km/h is very low (ΔS=S_{Rd}-S<20cm; <0.8%).

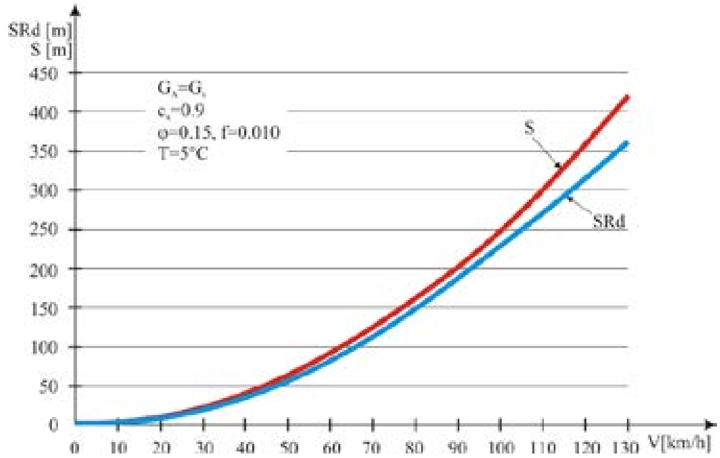

Fig. 2.
Dependence of the Stopping Distance on the Bus Speed for Empty Bus, with a Body Shape whose Drag Coefficient is very large, Poor Adhesion Conditions, Low Air Temperature

With the increase in speed (V=50 km/h), the stopping distance S_{Rd} stopping is 60.1m. This value is 1.34m (2.1%) lower than the stopping distance S. At a speed of 60 km/h, a double difference in the S_{Rd}-S stopping distance can be seen in relation to the speed of 50 km/h. It can be concluded that the speed of 60-65 km is the breaking point after which the stopping distance S_{Rd} significantly differs from the stopping distance S (expressed in meters). At the bus speeds of 75 km/h, 80 km/h, 95 km/h and 110 km/h the difference of stopping distance ΔS takes values: 6.6 m (ΔS%=4.7%), 8.4 m (ΔS%=5.4%), 16.3 m (ΔS%=7.3%), 28.4 m (ΔS%=9.5%) respectively. At the maximum speed of 130 km/h, ΔS takes values of as much as 52.9 m (ΔS%=12.7%). These results are caused by the following operating conditions: low adhesion coefficient φ, high drag coefficient c_x, low air temperature T, smallest possible weight of the bus, i.e. long bus $G_A=G_S$. The mentioned variables take such values that in a common correlation they influence the difference ΔS to be highest.
In the opposite case (Case 2, Fig. 3), in terms of the value of three operating conditions (high adhesion coefficient φ, low drag coefficient c_x, high air temperature T), but for an empty bus, the difference between the stopping distances S_{Rd} and S is insignificant for the entire range from V_{min} to V_{max}. At the maximum bus speed of 130 km/h, the difference ΔS is only 52 cm (0.76%).

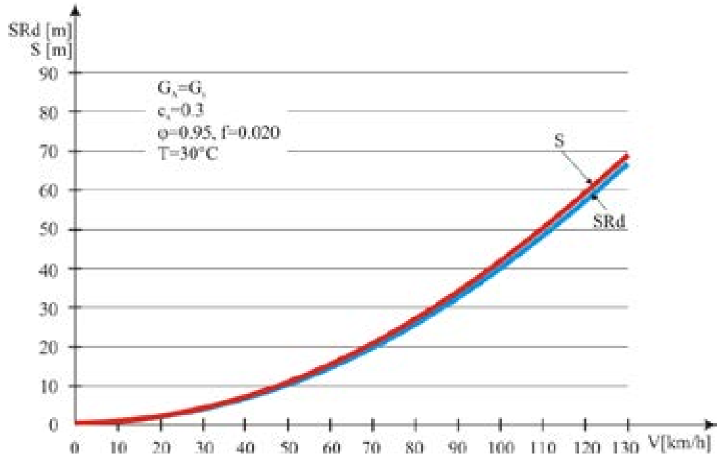

Fig. 3.
Dependence of the Stopping Distance on the Bus Speed for Empty Bus, with a Body Shape whose Drag Coefficient is very small, Good Adhesion Conditions, High Air Temperature

Figs. 4 and 5 show the dependence of the stopping distances S_{Rd} and S on the bus speed for full-loaded bus (the mass of the bus increased by 3640 kg) at the various operating conditions. For favorable operating conditions (from the aspect of achieving the shortest stopping distance S_{Rd}, Fig. 4), the more noticeable difference between the stopping distances, ΔS>3%, is achieved at a speed of 75 km/h.

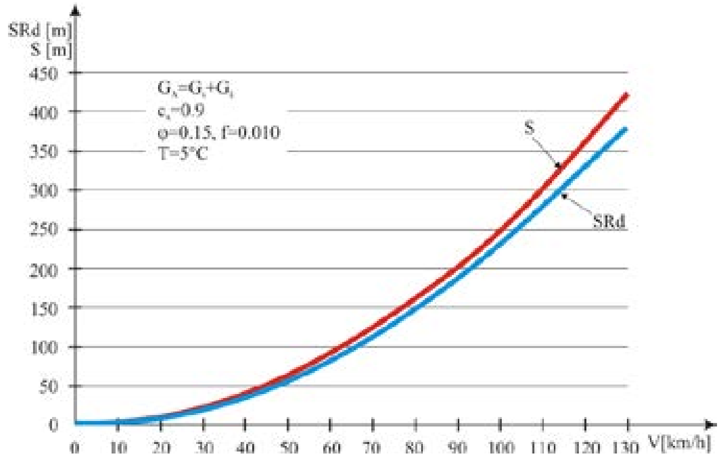

Fig. 4.
Dependence of the Stopping Distance on the Bus Speed for Full-Loaded Bus, with a Body Shape whose Drag Coefficient is very large, Poor Adhesion Conditions, Low Air Temperature

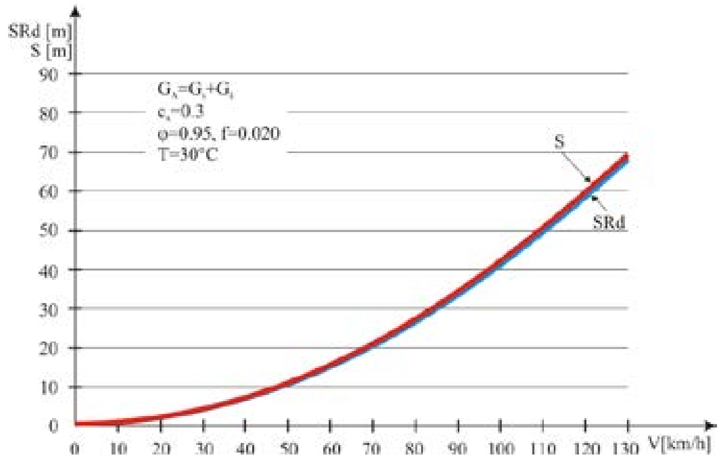

Fig. 5.
Dependence of the Stopping Distance on the Bus Speed for Full-Loaded Bus, with a Body Shape whose Drag Coefficient is very small, Good Adhesion Conditions, High Air Temperature

The change of ΔS increases with a change in bus speed with a lower intensity than shown in Figure 1. At the maximum bus speed, ΔS is 2.7% less than in the Case 1 shown in Fig. 2. For unfavorable operating conditions, the curves S_{Rd}=f(v) and S=f(v) are almost completely overlapping. The maximum value for ΔS (at a speed of 130 km / h) is less than 0.184% (12.5 cm) than in the Case 2 shown in Fig. 3. These results indicate that the change in capacity utilization of intercity buses does not significantly affect the SRd stopping distance.
The Figs. 6, 7 and 8 show the separate effect of operating conditions on the value of the S_{Rd} stopping distance. In the first step, typical values for all four parameters were adopted (Table 1).

Table 1
Typical Values of Operating Conditions

adhesion coefficient φ [-]	**drag coefficient c_x [-]**	**utilisation of bus capacity n [no. of passengers [kg, N]**	**Air temperature T [ºC]**
0.85	0.4	32 passengers (≈17854 N)	20

In the second step, one parameter was varied from minimal to maximum, while other parameters retained typical values. The analysis was carried out in three cases of speed: low speed - 50 km/h (Fig. 6), midle speed - 90 km/h (Fig. 7) and maximum bus speed - 130 km/h (Fig. 8).
In all three cases, the coefficient of adhesion has a dominant influence on the S_{Rd} stopping distance. At a bus speed of 50 km/h (Fig. 6) and a minimum adhesion coefficient (φ=0.15), with a typical value of other operating conditions, the stopping distance is about 58 m. The lower changes in the stopping distance occur when the coefficient of adhesion increases from the value φ=0.34 to the maximum value φ=1.0. This change in this range is about 18m. When changing the coefficient of adhesion from minimum to maximum, the change in the stopping distance is about 48 m. For the lowest value of the coefficient of adhesion, the difference of the stopping distances S and S_{Rd} is very small and it is ΔS=0.45 m. As noted in Fig. 5, the changes in other operating conditions (draf coefficient, utilization of bus capacity

and air temperature) are completely negligible from the standpoint of the influence on the value of the stopping distance at a bus speed of 50 km/h.

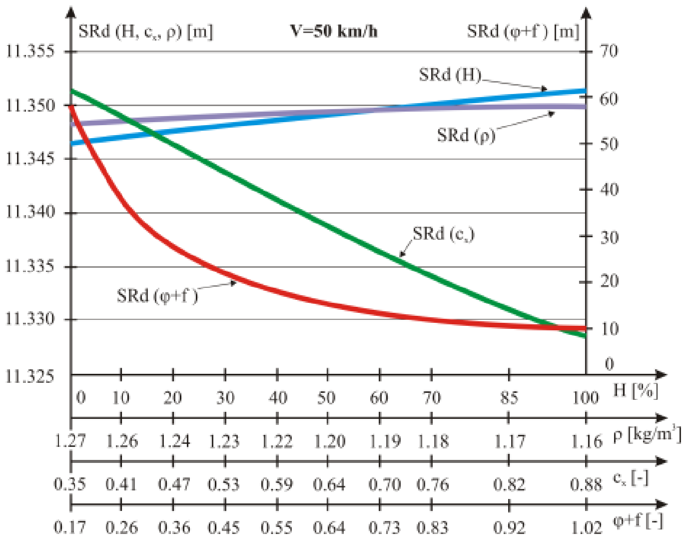

Fig. 6.
Influence of the Separate Operating Condition on the Stopping Distance for a Low Bus Speed (50 km/h) and the Constant Other Typical Operating Conditions

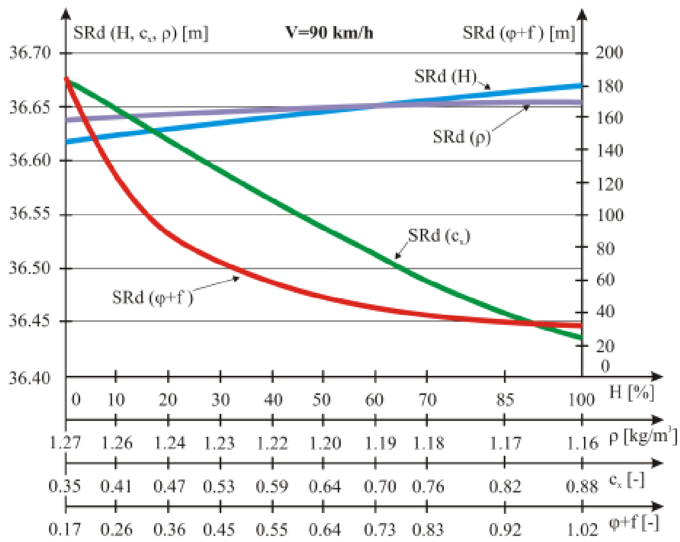

Fig. 7.
Influence of the Separate Operating Condition on the Stopping Distance for a Midlle Bus Speed (90 km/h) and the Constant Other Typical Operating Conditions

At a speed of 90 km/h (Fig. 7), the change in the coefficient of adhesion from minimum to maximum causes a change in the stopping distance S_{Rd} of 154 m. At the lowest adhesion coefficient, the difference in the stopping distances S_{Rd} and S is around ΔS=4.6m, which is about 10 times higher than in the case of a bus speed of 50 km/h. The maximum value of the drag coefficient (c_x=0.88) causes the difference between the stopping distances S_{Rv} and S about 0.4m (1%). The other two parameters, the utilization of bus capacity and the air temperature have an insignificant individually effect on ΔS (below 1%).
Fig. 8 (bus speed=130 km/h) show that the changing of the coefficient of adhesion from minimum to maximum causes a difference in the stopping distance S_{Rd} of 310m. If it is excluded from the analysis the drag force, the change in the stopping distance ΔS, at the minimum adhesion coefficient (φ=0.15) is 19.5 m (decrease by 5%). Changing of the air drag coefficient from minimum to maximum value causes the difference in the S_{Rd} distance by 1m. For c_x=0.4, the difference between the stopping distance ΔS is about 1.7m (decrease by 2.2%). The air temperature and the utilization of bus capacity slightly higher affect the values of S_{Rd} and ΔS than a speed of 90 km/h, but the changes are around 1%.

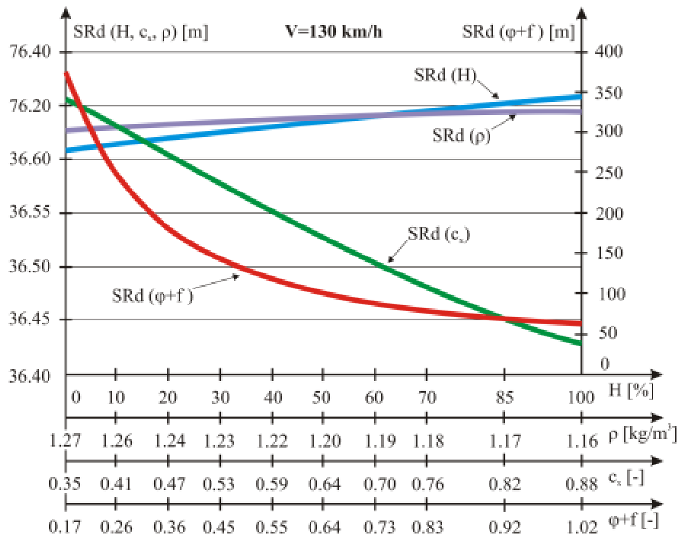

Fig. 8.
Influence of the Separate Operating Condition on the Stopping Distance for a Maximum Bus Speed (130 km/h) and the Constant Other Typical Operating Conditions

Table 2 and Fig. 9 show the furthermost minimal/maximal effects of aerodynamic forces on stopping distance of intercity bus. The data is given for the full-loaded and empty vehicle and for the low and maximum bus speed. When the bus is empty, the maximum shortening of the sstopping distance S_{Rd} is about 13%, in the case of primary unfavorable conditions of adhesion when the braking starts at a speed of 130 km/h.

Table 2
Minimal/Maximal Effects of Aerodynamic Forces on Stopping Distance of Intercity Bus

Case	Minimal/maximal effects	S_{Rd} [m]	S [m]	ΔS [m]	ΔS [%]
8a	max. impact, empty bus, V=50 km/h	60.109	61.449	1.340	2.181
8b	max. impact, empty bus, V=130 km/h	362.485	415.396	52.911	12.737
9a	min. impact, empty bus, V=50 km/h	10.124	10.136	0.011	0.113
9b	min. impact, empty bus, V=130 km/h	67.997	68.519	0.522	0.763
10a	max. impact, full-loaded bus, V=50 km/h	60.426	61.449	1.023	1.665
10b	max. impact, full-loaded bus, V=130 km/h	373.697	415.396	41.700	10.039
11a	min. impact, full-loaded bus, V=50 km/h	10.127	10.136	0.009	0.086
11b	min. impact, full-loaded bus, V=130 km/h	68.123	68.519	0.396	0.578

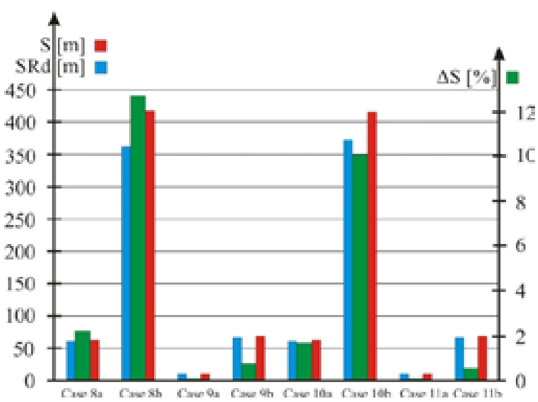

Fig. 9.
Minimal/Maximal Effects of Aerodynamic Forces on Stopping Distance of Intercity Bus

For the predominantly high adhesion coefficient and low speed of the change in the stopping distance is ΔS≈0.1%, ie. the influence of the aerodynamic forces is almost completely negligible. In case of full utilization of bus capacity, the ΔS values differ by a maximum of 2% at a speed of 130 km/h.

Conclusions

Based on the previous one, the following conclusions can be made:

- The most influential factor from the standpoint of impact of aerodynamic forces on the stopping distance is adhesion coefficient
- Under low adhesion conditions when the bus is empty, significant differences in the stopping distance occur at speeds higher than 60 km/h, the value of $\Delta S > 3\%$. With full utilization of bus capacity, identical differences occur at a speed of about 75 km/h. If the adhesion coefficient is high, in both cases (full and empty bus) the value of ΔS is very small ($\Delta S_{max} < 0.8\%$) for the entire range of speeds from 50 to 130 km/h, irrespective of the value of other variable operating conditions.
- By analyzing the bus while braking, in typical operating conditions, it can be concluded that after the adhesion coefficient, the most influential factor on the stopping distance S_{Rv} is the drag coefficient c_x. At high speeds, the highest value of drag coefficient causes a maximum change in the stopping distance of about 2%. The utilization of bus capacitiy and air temperature are two factors that quantitatively very similarly influence the change of the stopping distance, but these effects are very small (maximum value $\Delta S \approx 1\%$).
- In the furthermost/minimal case, the common influence of the most unfavorable values of the parameters from the standpoint of achieving of minimum value ΔS ($\varphi=\varphi_{min}$, $H=H_{max}$, $c_x=c_{xmin}$ and $T=T_{max}$, $V=50$ km/h) is reflected by decreasing of the stopping distance due to the impact of aerodynamic forces, in the amount of only 0.1%.
- In the opposite furthermost/maximal case case ($\varphi=\varphi_{max}$, $H=H_{min}$, $c_x=c_{xmax}$ and $T=T_{min}$, $V=130$ km/h), the common influence of the most favorable values of the parameters from the achievement of the maximum value of ΔS is reflected by the decreasing of the stopping distance due to the impact of aerodynamic force, in the amount of about 13% ($\Delta S \approx 53$m).
- The results in this research indicate that in the analysis of the stopping distance of intercity buses, in conditions of high adhesion and low speeds, the impact of aerodynamic forces can be irrelevant. Otherwise, at speeds higher than 60 km/h with low adhesion values, it is necessary to take into account the common influence of all four factors due to the evident differences between the stopping distances S_{Rv} and S.

REMARKS: The analyzes and conclusions presented in this paper take into account the specificity of intercity bus as a motor vehicle in relation to other categories of vehicles, which are primarily: a large frontal area and a relatively low value of the ratio of useful payload and the unladen mass. The impact of aerodynamic forces on the stopping distance may be more significant than the above if, during braking, the influence of the wind is calculated in the opposite direction from the direction of movement of the bus, which will be the goal of the next subsequent research in the future. Since the objective in this study relates strictly to the vehicle, the results do not include the impact of the driver's reaction time on the stopping distance in braking process, i.e. the stopping distance is elaborated from the moment of the occurrence of deceleration.

Acknowledgment

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DRAFT OF HANDLING EQUIPMENT FOR MATERIAL ELEMENTS TRANSPORTATION

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Abstract: The article deals with material handling in transport sector. The output is the proposal of handling equipment facilitating and streamlining handling and transportation of physical elements (loader cranes and container carriers, or their components). Using the proposed handling equipment enables to streamline the corporate logistic processes and solving problems currently arising in the company, especially in loading operations. Handling will be carried out directly in the manufacturing company and at the customer (transportation of spare parts within the after-sales service).The first part of the article focuses on characterizing the individual logistic problems arising during the manipulation with the material in the company. The first logistic problem is the manipulation with the components on the premises of the company (when unloading from the vehicles, when transporting the individual parts during the assembly of the equipment). The second logistic problem is the transportation of the components and spare parts directly to the customer within after-sales service. The third logistic problem consists in unloading the components transported from suppliers. The second part of the article deals with the proposal of a handling device consisting of the proposal of a suitable trailer, calculation of the stability of the handling device, proposal of individual components of the handling device and proposal of hydraulic lifting device including the hydraulic unit.

Keywords: transportation, freight transport, handling equipment, material handling.

1. Introduction

Manipulation in its basic division can be divided as manual, combined and mechanized handling. Manual handling consists in physical transportation of a physical object over a defined handling track by lifting, pushing, pulling, moving, rolling and putting down.
Handling device is defined as a tool or element which enables performing of handling operations using manual or mechanized handling by means of handling device. Handling device is not a detachable part of handling equipment. It is e.g. a tool for gripping the object, supporting the object, tool with a specific connection to the handling operation etc. Handling devices include also handling aids (Celjak, 2013), (Michalski, 2016).
The presented article is an output of a research project focused on prosing handling device for a concrete company engaged in selling hydraulic power devices of a wide power spectrum. Additionally, the company is engaged in selling accessories for loader cranes, manufacturing dropside trucks bodies and mounting of hook carriers which serve as a transport unit of large-volume containers (Cortes et al., 2017), (Koh et al., 2017). The internal structure of the company´s value-creating logistic chain conceals a number of logistic problems that are mentioned in the following part of this article.

2. Characteristics of Individual Logistic Problems

Handling with assembly components or spare parts conceals a number of logistic problems that have to be optimized in order to avoid unnecessary handling operations.

2.1. Logistic Problem 1.

Upon arrival of the articulated vehicle with a semi-trailer that primarily serves for the transport between the manufacturing company in Lengau and headquarters in České Budějovice, the company does not have any handling device that would be used for unloading the products from the load-carrying platform and store it in the pre-defined space. By this time, these operations were performed using a forklift truck. Its manipulation is not restrictive. The main problem is that the company has only one handling device of this type, which means this is often used for other handling operations and is not at disposal. Another disadvantage is its kinematics which does not allow placing the object behind an obstacle or over a slight horizon. This problem arises in the company hall, where the stored items are often moved or relocated. If the item or component were situated behind the parts that were not needed at that time, it was necessary to relocate those parts so that a handling space was created and the given products or components could be transported.
Since the designed device is transportable, it is possible to place it at any defined location so that the maximum radius of action is ensured. The designed handling device, however, will not be able to handle hydraulic jib cranes weighing 20 tonne-meters (hereinafter referred to as TM) and more. This is due to the fact that the stability of the whole system would not be ensured and the requirement of a total weight not exceeding 3,500 kg would not be met.

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Thus, the handling device will be placed so that it is able to unload the products from the load-carrying platform of the semi-trailer of the lorry and store them in a defined place. Furthermore, it will be possible to get this kinematic unit with the object being relocated through the already stored objects intended for the assembly process.

2.2. Logistic Problem 2.

The company also faces a problem of getting spare parts for the customer within the warranty period. The warranty period is usually between 1 – 3 years, depending on the type of the spare parts. The three-year warranty period is usually for so-called load-bearing components. One-year warranty period usually covers hydraulic and electrical spare parts. Since the market is very competitive, the company has decided to offer the customer the free transport of the spare part to the pre-selected place within the Czech Republic (within the warranty period). Of course, this service is offered only in case the guarantee is recognized as valid by the guarantee technicians.

By this time, this service has been provided by hired transport companies that have the necessary vehicles at disposal. However, there were often problems with unavailability of the trucks or that the service required trucks of higher weight, and therefore the rent was very expensive.

Since the proposed handling device was detachable from the trailer, the company management decided to use the trailer for the above mentioned purpose. Moreover, the advantage of the whole set would be the ability to load the contested object. A small disadvantage would be the fact that this handling device would not be available at the unloading point. This handling operation would thus have to be ensured by the customer.

2.3. Logistic Problem 3.

Since the company is not engaged only in selling hydraulic equipment, but also in manufacturing sub-frames and dropside trucks, it is necessary to ensure the transfer of materials necessary for their production. These are mainly various types of profiles and sheets, bars and chipboard parts. Handling with these materials has been ensured using a company van, which unfortunately did not have enough space for loading. Another constraint was unloading, when a forklift truck had to be used, which is frequently used and thus often unavailable.

The proposed handling device could be used also for the aforementioned operations. In such a case, the hydraulic device would be placed at a suitable place so that it could handle the unloading of the material from the load-carrying platform of the trailer and relocate the material to a place intended for raw material entering the assembly.

3. Design of Handling Device

The company determined the basic technical requirements and parameters for the device, which could be described as follows:

- category O2 (trailer of the maximum permissible weight exceeding 750 kg but not higher than 3,500 kg) (Curry and Deng, 2017),
- vertical loading on the hinge pin not higher that 100 kg (data from the trailer technical sheet),
- hydraulic range at least 9,000 mm,
- capability of manipulation with object of 500 kg weight at a range of 9,000 mm,
- capability of manipulation with object of 700 kg weight at a range of 7,000 mm,
- capability of manipulation with object of 900 kg weight at a range of 5,000 mm,
- required approval of legislation on road traffic,
- ensured stability of the whole set at given loading capacity (without the tow vehicle),
- the total height must not exceed 3,200 mm,
- securing of electrohydraulic unit to 25A (Yamazaki et al., 2017), (Gomez-Montoya et al., 2016),
- Capability of manipulation with the object in the 360° range.

3.1. Design of Category O2 Trailer

Starting condition for choosing the chassis was mainly the total weight not exceeding 3,500 kg. The trailer must have its own braking system, must be a two-axle one, must have the lowest load-carrying platform possible and must be legally included into the 02 category.

The company was offered a trailer from the company VEZEKO s.r.o. No concrete type was chosen. The reason is the specific anchorage of the hydraulic arm in the trailer. The coupling of the individual components (hydraulic device and trailer) will be ensured by means of joints, so that the disassembly and reassembly are as easy and fast as possible. The starting type is CARGO D35.2 with a load-carrying platform of 2600 x 1620 mm and the total weight not exceeding 3,500 kg. The frame consists of robust, hot dip galvanized frame with three transverse reinforcements. The trailer has a very modern design, with high strength and resistance to stress. The platform is fitted with the KNOTT or AL-KO axles. The floor is made of waterproof plywood with 6 pairs of anchoring meshes for cargo retention on the load-carrying platform in the situation when the handling unit is not used. The chassis is supplied with detachable aluminum side panels. However, these are unnecessary in our case; therefore the trailer was ordered only as a platform, that is, without aluminum sides (Mhalla et al., 2016).

Fig. 1.
Trailer of Category O2
Source: www.vezeko.cz

3.2. Calculation of Handling Device Stability

One of the most important parts of the design is the calculation of adequate stability when working with hydraulic power device. The stability will be ensured by four support points with dimensions of 6000 x 6000 using telescopic slides. This type has been chosen because of the total transport height of the device. If there were fixed supports, the height in the transport position would exceed the required condition of maximum 3200 mm. Furthermore, it is necessary that the vertical load on the hinge pin does not exceed 100 kg, which is the maximum value for tow trailers of N1 category, from the extract of the registration documents. Another condition is the fact that the overall weight of the set including the two-axle trailer must not exceed 3500 kg, which is the maximum allowed weight for the O2 category. For the calculation of stability, company program PACWIN was used. Firstly, the weight and dimensions of the chassis are fed into the program. In this case, it refers to the dimensions and the unladen mass of the trailer. Next, all the relevant weights will be entered. After completing all the necessary parameters, the program calculates the resulting stability / instability (lability).
The mass of the testing load for the stability test (Sulirova et al., 2017), (Esfandeh et al., 2016):

$$TL = K_s * P + 0.1 * G_p$$
$$K_s = 1.15 + \frac{\mu}{100}$$

where:
TL – mass of testing load,
Ks – stability factor,
P – loading capacity,
Gp – weight of the job system related to the load suspension point point,
μ - load limiter tolerance.

G_p and μ values must be documented by the manufacturer (ČSN EN 12999, 2003).
The EN 12999 standard deals with the minimum stability factor, where the whole SET can be considered safe and stable. The value of the stability factor is 1.4, or the sum of the stability moments must be at least by 40 % higher than the sum of the heeling moments (Fedorko et al., 2018), (Cokorilo, 2016).
For the stability calculation, the following peripherals will be considered:
- The mass of the hydraulic device distributed between the static and dynamic parts,
- The mass of the supporting cross mechanism,
- The mass of the drive unit,
- The mass of the tank,
- The mass of the pressure medium (oil),
- The mass of the hydraulic systems and additional hydraulic components.

The calculation considers additional load for increasing the total weight and thus for improving the stability. For detailed calculation, see (Setka, 2017).

Table 1
Mass of individual components and mutual position x, y, z.

Peripherals	**weight (kg)**	**Location in axis x**	**Location in axis y**	**Location in axis z**
trailer	580	2457	0	374
structure	290	2750	0	603
tank	40	800	0	900
oil	32	800	0	900
Unit	18	800	0	1200
ballast	1100	2850	0	1250
front support legs	260	0	0	365
rear support legs	260	6300	0	365
hydraulic device (mounting parts)	0	2882	0	643
hydraulic device (static parts)	419	2806	217	1010
hydraulic device (dynamic parts)	482	3045	-200	1601
resulting axle load	3481	2790	-2	930
possible load	19	2910	0	613
loss of load-bearing capacity due to the axle overload	0	0	0	0
maximum load	3500	1790	-2	928
recommended gravity center of the possible load on the load-carrying platform (mm)	1160 - 4745			

Source: computing program PACWIN – NET; Palfinger software

Table 2

Mass distribution and relevance

Peripherals	**Load on hinge pin (kg)**	**Rear double axle (kg)**	**Relevance**
trailer	80	500	Stability + load
structure	10	280	Stability + load
tank	29	11	Stability + load
oil	23	9	Load
Unit	13	5	Stability + load
ballast	0	1100	Stability + load
front support legs	260	0	Stability + load
rear support legs	-315	575	Stability + load
hydraulic device (mounting parts)	6	23	Stability + load
hydraulic device (static parts)	6	413	Stability + load
hydraulic device (dynamic parts)	-33	515	Stability + load
resulting axle load	74 (3%)	3407	
possible load	0	19	
loss of load-bearing capacity due to the axle overload	0	0	
maximum load	73 (2%)	3427	-

Source: computing program PACWIN – NET; Palfinger software

Table 3

Mass distribution and relevance

	Heeling moment			
	A	B	C	D
Moment of stability (mt) - MS	9.16	11.01	9.51	8.62
Heeling moment (mt) - MT	4.32	3.72	3.77	4.13
Position of tow vehicle center of gravity to tilting axis D-TR	3000	3536	3000	2764
Distance between load and tilting axis D-LC	6525		5825	6293
Weight of hydraulic device parts within the tilting axis W-CI	648	683	683	648
Position of center of gravity of static parts of hydraulic lifting device D-CWI within the tilting axis	2333	2931	2735	2430
Weight of the hydraulic device dynamic parts outside the tilting axis W-CO	253	218	218	253
Position of center of gravity of the hydraulic lifting device D – CWO dynamic parts outside the tilting axis	2875	2521	2589	2643
Resulting stability factor	2.12	2.96	2.52	2.08

Source: computing program PACWIN – NET; Palfinger software

From the resulting values, especially the resulting stability factors it follows that such designed set with a total weight of 3481 kg is stable in all quadrants. The highest value of the stability factor (2.96) is in the B quadrant, the lowest value (2.08) is in the D quadrant. The sun of the stability moments is by 208 % higher than the sum of the heeling moments. During the implementation it will thus be necessary to load the whole set by necessary "ballast" so that the whole set has the required stability according to the EN 12999.

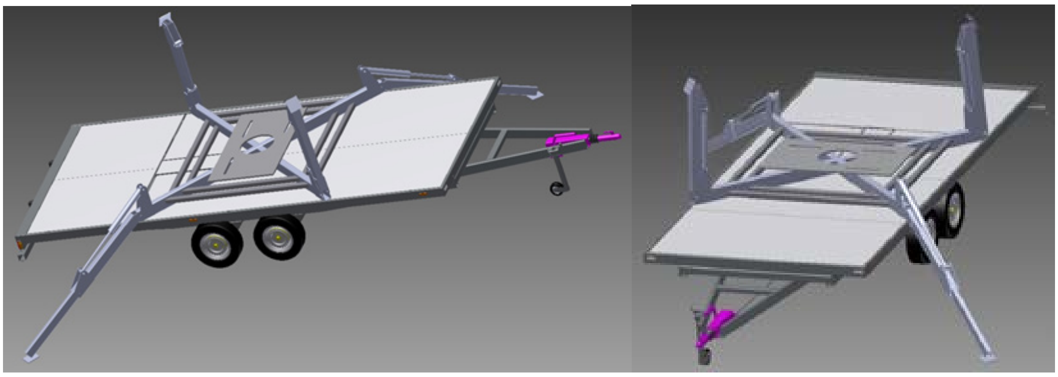

Fig. 2.
Load-bearing support frame of the trailer
Source: authors

3.3. Hydraulic Lifting Device PK_6501_HP

Hydraulic lifting crane PK 6501 HP was chosen as a lifting device for the handling device. HP stands for "High Performance". It is a lower power lifting device. The first two digits refer to the lifting capacity in tonne-meters, which is in this case 6.5 TM. This value is purely theoretical and it is based only on the calculation, not on the testing in practice. The main reason is the kinematics of the device. 01 means that the hydraulic device has one lever mechanism. In this case it refers to the lever mechanism between the main and tilt jib (Kampf et al., 2017). The main parts of the hydraulic device include the pedestal, support legs or support mechanism, tower, main jib, tilt or second jib with telescopic arm system.

Fig. 3.
Hydraulic lifting device PK_6501_HP
Source: authors

3.4. Hydraulic Unit

The hydraulic unit will serve as a source of pressure and volume flow of hydraulic oil in the system. It will consist of an electric motor that will be powered by the voltage of 380V. The electric motor will have forced cooling (blades) mounted on its rotor, which will cool the heating coil during the operation. This is a very important aspect since the motor will work even when the hydraulic device is not working but the system will still be active (the oil will circulate in the hydraulic circuit). The hydraulic aggregate will be equipped with a STOP button, whose activation will interrupt the power supply and the engine rotor will stop spinning and therefore the system will not be supplied with the oil pressure. This is absolutely necessary in terms of security. On the shaft of the electric motor, eccentric gear pump will be attached, which will consist of one gearwheel with external gearing and one gearwheel with internal gearing (Krol et al., 2017), (Moczko et al., 2018).

4. Results

4.1. Design Assessment From Logistics Point of View

The first logistic problem becomes to a certain extent an overall ailment of the whole object. Furthermore, there are no "conventional" handling devices for unloading from trucks to storehouses. Since the hydraulic radius of the proposed handling device is 5200 mm, it can be positioned so that it serves the load-bearing platform without problems and place the object to a given site in the store. The site can be at the distance not larger than 5200 mm from the pivotal axis, if its nominal weight is not higher than 1120 kg (11.0 KN). If the weight of the suspended object is closer to 1680 kg (16.5 KN), the radius of action will be reduced from 2 x 5200 mm to 2 x 3500 mm.
The main advantage of the proposed hydraulic lifting device will be the capability to store and handle the objects which are not closest to the distribution point (thus eliminating the ineffective handling operations for additional relocation of the stored items in the storehouse). Using this handling device, it will be possible to place the items to pre-determined, fully used space (Blaho et al., 2017).
Since the company has only one forklift truck at disposal, this will also reduce the downtimes when the forklift truck had to be used in the storehouse and was not available at other places in the company.
Furthermore, after dismantling the trailer, it will be possible to take an item from the store and transport it either to service or assembly workshop. A disadvantage is the fat, that it will be necessary to use also a trailer, since the truck is not self-propelled (Varun et al., 2017), (Kamaryt and Kleinova, 2016).
The second logistic problem has been completely solved by using the handling device. The weight of the trailer itself is 550 kg, so the load capacity is 2950 kg. This could be handled by hydraulic arm without any problems. It is only necessary to ensure that the given object is placed in the horizontal direction so that the suspension device is not overloaded. The trailer will be equipped with mechanical fittings, which will serve as fixing points for bindings and

securing transport elements. The objects of higher weight can be also relocated using the handling device, but cannot be loaded onto the trailer, because this way one of the axles would be overloaded and the vehicle would not be suitable road traffic.
The third logistic problem arises when purchasing and transporting the material to the assembly workplace. This workplace has so-called temporary intermediate storehouse, where the semi-finished products are stored until they are used for further technological operations in a short time horizon. For these operations, the trailer will be used, which will transport the material, and using the handling device, it will store it in the intermediate storehouse (Ivkovic et al., 2018).

4.2. Assessment of Proposal From Economic Point of View

The first logistic problem can be assessed in terms of time savings. The estimated time savings could be around 25 % per hour. This value is not that significant; however, it should be taken into account that the transport of spare parts is an every-day issue. Thus, any time and hence financial savings will be noticeable.
The second logistic problem can be expressed exactly. The rent of the N2 category trailer, the most frequently used trailer even for transporting less bulky objects, is CZK 25 / km. The usability of payload is very low, therefore the rent if often not economical, yet necessary due to the need to comply with the conditions of sale. The cost of operating the trailer can be estimated at CZK 8 / km. However, the cost of operating the tow vehicle, which is approximately CZK 9 / km, must be included. After aggregating these two items, the savings is about 32 % per one km. In addition, the lengthy process of ordering the carrier by the sales department or looking for another carrier is reduced if the carrier´s vehicles are fully utilized (Shepelev et al., 2016).
The third logistic problem consists in transporting the material from the purchasing point to the manufacturing hall of the company. The advantage of using a trailer is the possibility to transport bulky items which could not be transported in loading space of the van ensuring these operations. Furthermore, using this set (van + trailer) it is possible to transport larger quantity of material per the same time unit. The financial savings thus consists in time savings. The exact numbers will be known after testing in practice (Kostrzewski, 2012).

Conclusion

In the introduction, three logistic problems were defined that were supposed to be solved by using the given handling device. The statements and individual assessments are only theoretical, since the handling device was not finished at the time of writing this article and was still under development.
However, based on the development it can be said that using the handling device can solve the first logistic problem from the technical point of view; it only cannot be stated to which extent the solution will be favorable in terms of finance and logistics.
The proposed device is also capable of solving the second logistic problem; however, there is a matter of storing material at the place of the customer´s request. This problem can be solved by a different construction and weight solution, which, however, would be at the expense of the performance of the hydraulic device (the hydraulic arm would reach the lower lifting moment so that it does not exceed the weight limit) and there would be a problem with the overall stability, or lability of the set. The components of the imported device must be agreed with the customer over the phone and it is necessary that the customer carries out the unloading at their own expense, which, however, does not have a significant financial impact on the process of the spare parts transport.
It is assumed that the handling unit will be able to fully solve the third logistic problem. However, the economic point of view can only be evaluated after longer period of time when the crane is assembled and is operational.
The authors see a certain disadvantage of the construction in the form of fitting the load-bearing construction to the hydraulic device and trailer. Since the principle of handling consists in supporting the weight of the system by support legs so that the trailer would be able to move, the authors see a possible in pin connection, which could get stuck and due to the influence of the mechanical and dynamic strain fails to perform its function. Therefore, it will not be possible to detach easily the self-supporting body from the trailer.

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COST MANAGEMENT IN LOGISTICS OF WAREHOUSING: THE USE OF ACTIVITY-BASED COSTING IN THE LOGISTICS SERVICE PROVIDER

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Abstract: The activity-based costing method is considered as a universal management tool that applies to flow mapping and cost behavior. The basic idea of activity-based costing is to find the true causal link between cost and performance and to display these facts in the calculation system so that the outputs are as close as possible to the reality. This method defines the structure of business processes and activities. Activity-based costing primarily focuses on improving the assignment of overhead costs, which are often allocated on a direct cost basis or direct worked hours. This method was imported to address the problems encountered by logistics service providers. The aim of this article is to use activity-based costing as a management method in a logistics service provider with regard to the cost management. The article is based on research of the world literature especially Web of Science database and Scopus database, in-depth interviews with managers that is the method of the qualitative research and an analysis of internal data of the logistics service provider. The basic advantages of qualitative research are the detailed description and insight into the study of the issue, in addition it responds well to local situations and conditions and can search for local causal connections. The article shows the possibility of using activity-based costing to better calculate the logistics costs of warehousing in a selected logistics service provider.

Keywords: activity-based costing, logistics costs, logistics service provider, cost calculation, warehousing.

1. Introduction

The logistics services which are provided must be a source of value not only for the final customer but for all interested stakeholders. A prerequisite for evaluating the effectiveness of all activities is cost monitoring across the entire supply system, including logistics service providers.

Definition of company processes whose costs will be included in total logistics costs, including their allocation to cost objects (orders, services, departments, processes, etc.). It is a basic step in monitoring and evaluating logistics costs to support decision-making tasks (Kučera, Hyršlová and Sommerauerová, 2017).

As stated by Richards and Grinsted (2013 and 2016) warehousing, as an integral part of the logistics system, dynamic and interactive activity is geared to the level needed to meet demand. When delivering logistics services, it is important to make efficient use of both time and warehouse or local space. According to Accorsi, Manzini and Bortolini (2012) and Accorsi, Manzini and Maranesi (2014), emphasis should be placed on planning all warehouse activities, including receipt, warehousing, assembly, kitting, picking and ordering from customers. Warehouses make it possible to unify, distribute bulk goods, transfer and collate cross-docks and provide value-added services.

The concept of logistics costs is defined by many authors. According to Straka and Malindžák (2005), logistics costs are expressed as the sum of all costs associated with the implementation of logistics processes. These costs are associated with the realization of material flows, mostly costs related to transportation, warehousing, financial reinsurance, insurance and information flows. According to Bazaly et al. (2006), logistics costs can be understood as the sum of all the costs associated with organizing, controlling and implementing the logistics process itself, within all the articles in the supply chain. Pražská and Jindra (2002) divide logistics costs into the same groups as Schulte (1994); these authors agree on the definition of logistics costs: supply costs, warehousing costs, transport costs and handling costs. Kučera (2017) argues that logistics managers are usually interested in providing high quality services to their customers at minimum cost.

2. Literature Review and Methodology

Activity-based costing provides a new approach to tracking and assigning costs. Unlike traditional calculation methods, it does not use the cost allocation of a costing unit (such as a product) through cost centres, but through activities that are necessary for the creation of performance. The reasons for this shift in cost allocation can be found in changes (high diversification of product portfolios, service differentiation, short product life cycles, growing customer demands for product diversity and quality, growth of suppliers and customers) that accompany business activity (Bokor and Markovits-Somogyi, 2015; Hansen and Mowen, 2007). Traditional calculations cease to provide relevant driving information in these unstable conditions. They provide an answer to the question as to what costs have been incurred and how they have been allocated to in-house centres, or how each product or product group is involved in the costs, but does not answer the question as to why these costs have arisen (Wang, 2017). The activity-based costing calculation returns to the cause-effect relationship. It abandons the traditional assumption that the causal cost is mainly volume (for example: time consumption, material value) (Gros and Grosová, 2012; Stevenson and Cabell, 2002).

The basic purpose of the activity-based costing calculation is therefore to accurately express the relationship of costs to the cause of their occurrence, especially when the increase in costs is not due to an increase in the volume of the final

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outputs. From a methodological point of view, it is basically a full cost calculation (absorption method) that can be combined with a non-absorbent method (Mocanu, 2008). Narsaiah and Chary (2017) claim that activity-based costing has become a tool in the hands of logistics service provider to surmount the problems with regard to cost management.
In terms of origin, the activity-based costing is linked to the 1980s with the names of Kaplan, Cooper and Johnson. At this time in the USA, the first articles are published (dealing with the originators of the emergence of overheads and the deficiencies of traditional costing procedures in the scheduling of these overheads). At the same time, the first concepts of the activity-based costing method were presented as methods for assigning overhead costs as well as for measuring and evaluating costs and process performance (Cooper and Kaplan, 1987; Cooper and Kaplan, 1992; Kaplan and Cooper,1998).
Bokor and Markovits-Somogyi (2015) present that, given the general characteristics and the current adaptation of the activity-based costing method, the costs of certain logistics services consist of four parts (see Figure 1):

- direct costs derived from the accounting system,
- variable indirect costs from primary activities, the allocation is based on performance,
- fixed indirect costs arising from primary activities, the allocation is based on time consuming,
- indirect costs from secondary activities, the allocation is time-based.

Time consuming is the total duration of logistics services (transport, warehousing and sometimes other activities).

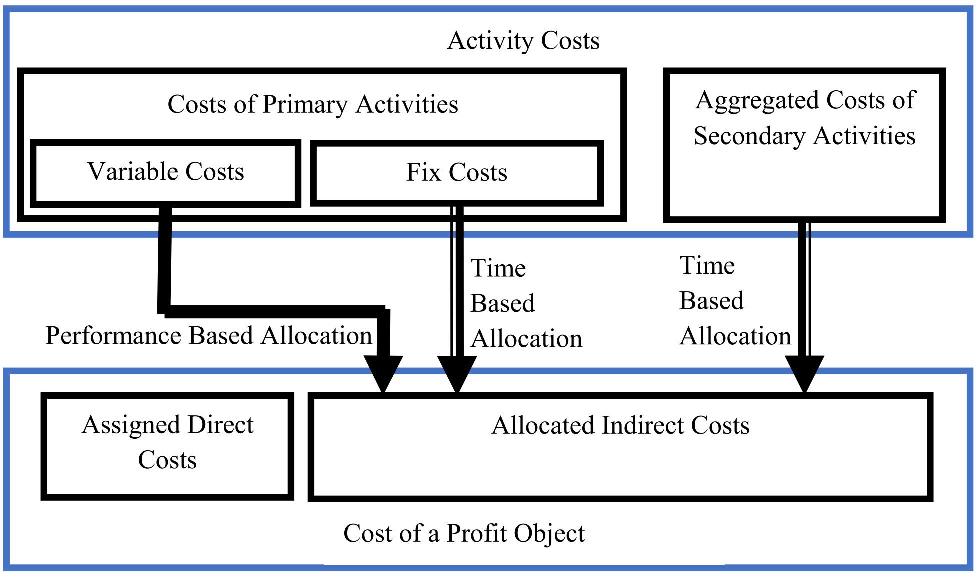

Fig. 1.
Activity-Based Costing Model
Source: Bokor and Markovits-Somogyi (2015)

Primary activities are indexed as i = 1 ... n, while profit objects, i.e. logistics services, are indexed as j = 1 ... m. The formula (1), which consists of four components, is used to calculate costs.

$$C_j = C_j^d + \sum_{i=1}^{n} C_{v_i} \frac{P_{ji}}{P_i} + \frac{T_j}{\sum_{j=1}^{m} T_j} \sum_{i=1}^{n} C_{f_i} + \frac{T_j}{\sum_{j=1}^{m} T_j} C^{sa} \text{ [CZK]} \quad (1)$$

Where:

C_j Cost of profit object j [CZK]
C_j^d Direct cost of profit object j [CZK]
C_{v_i} Variable cost of primary activity i [CZK]
P_i Performance of primary activity i [differently expressed power units]
P_{ji} Performance consumption of profit object j at primary activity i [differently expressed power units]
T_j Time consumption of profit object j [hours]
C_{f_i} Fix cost of primary activity i [CZK]
C^{sa} Aggregated costs of secondary activities [CZK]

The four components can be merged into three components:

- assigned direct cost,
- allocated variable indirect cost, allocation is based on relative performance consumptions,
- allocated fix indirect cost, allocation is based on the relative time consumption:

$$C_j = C_j^d + \sum_{i=1}^{n} C_{v_i} \frac{P_{ji}}{P_i} + \frac{T_j}{\sum_{j=1}^{m} T_j} \left(\sum_{i=1}^{n} C_{f_i} + C^{sa} \right) \text{[CZK]} \quad (2)$$

The cost efficiency, i.e. the average cost of a primary activity (as service generator) can be calculated as follows:

$$c_i = \frac{C_i}{P_i} = \frac{C_{v_i} + C_{f_i}}{P_i} \text{[CZK/differently expressed power units]} \quad (3)$$

Where:

C_i Cost of primary activity i [CZK]

Hansen and Mowen (2007), Mocanu (2008) Langfield-Smith et al. (2015) and Watanapa, Pholwatchana and Wiyaratn (2016) emphasize that the activity-based costing method helps businesses to improve cost management through two views, namely cost and management view (process view).

Table 1

Main Warehouse Activities and Cost Drivers

Activities	**Cost Drivers**
Order receipt	Order volume and order source (electronic data interchange, fax, phone, internet, or post)
Unload incoming goods	Quantity and packaging (pallets or cartons)
Palletize	Quantity of cartons
Check incoming goods	Quantity and quality of supplier (including returns)
Put away incoming goods	Quantity and number of returns
Picking	Number of visits to pick location and percentage of back orders

Source: Gríful-Miquela (2001)

Gríful-Miquela (2001) stated in his article that the cost structure of logistics service providers to third parties was analysed with particular regard to warehousing. Activity-based costing has been shown to be a useful tool for assessing the operating costs of logistics service providers. Main warehouse activities and cost drivers are shown in Table 1.

3. Results and Discussion

The aim of this article is to use activity-based costing as a management method in a logistics service provider with regard to the cost management. The basic advantages of qualitative research are the detailed description and insight into the study of the issue, in addition it responds well to local situations and conditions and can search for local causal connections. The use of an activity-based costing method will be presented on a real case study based on the processes used in the decision-making process of a particular company.

The chosen logistics provider ensures transport services for many customers. In addition to transport, it also provides other logistics services. Such as activities related to warehousing, receipt of goods including their inspection, warehousing according to customer-required systems, or delivery of material and its transportation directly to the customer's production lines.

In recent years, logistics service provider (LSP) has been using a new approach to logistics warehousing cost calculations in connection with increased competition in the provision of logistics services. From the entire calculation system, it uses only preliminary calculations and, within the framework of the calculations, serves to support pricing decisions (for price negotiations, for price advocacy, for deciding whether LSP is interested in accepting the order, whether due to limited warehousing capacities for LSP interesting). The calculations always reflect customer requirements (the specific type and scope of service provided). There is a single cost structure in the calculation of the cost of warehousing (see Table 2). The calculation unit is always one product that customer requires to warehouse.

Calculation costs are structured to accommodate all customer requirements for the service provided.

The calculation includes the items: personal costs, handling equipment, transportation costs, facilities costs, information technology costs, other costs, operating costs and eventually overtime costs.

The LSP has monthly personal costs calculated per worker in a particular job position. In addition to wage costs, welfare costs, statutory insurance and liability insurance, costs include protective equipment, training, contributions to cultural and sporting events, and other company benefits.

Assignment of costs to handling equipment is based on customer requirements for product warehousing and necessary handling equipment that need to be handled with the product. The allocation of transportation costs to order is based on the fact that the LSP has the cost per km and the number of kilometres travelled by the various means of transport per month assigned transportation costs. The allocation of facilities costs is based on a cost per square meter and adequate warehouse equipment. Costs associated with information technology (IT) are focused on printing labels, printer traffic, cartridge costs, costs of IT connection, costs of maintaining IT and costs of communication.

Other costs consist of 100% external warehouse maintenance and the other costs include unexpected costs, which may be costs associated with the delay of the start of production or with the unexpected situations that may arise. Assignment of costs to operating is based on floor tape labelling in warehouse, operation margin in 1% and corporate margin in the height of 10% and the last item is insurance (liability).

Table 2

Logistics Cost Calculation of Warehousing and Other Logistics Services

Volume of the Product					
120000 / Year	#		Price Unit	Price All	
	Unit #	Unit €	Price/Month	Price/Year	per Product
PERSONAL COST					
Sequencing operators	1	6,50 €	3 978 €	47 736 €	0,398 €
Forklift truck drivers	1	7,20 €	4 406 €	52 877 €	0,441 €
Warehousing operators	1	6,10 €	3 733 €	44 798 €	0,373 €
Team leader - Resident	1	9,00 €	1 377 €	16 524 €	0,138 €
Social resources, Food vouchers	1	100,00 €	100 €	1 200 €	**0,010 €**
TOTAL PERSONAL COST			**13 595 €**	**163 135 €**	**1,3595 €**
HANDLING EQUIPMENT					
Forklift - Bidder - Extern, Rent/Month all include	1	820,00 €	820 €	9 840 €	0,082 €
Others Movement Equipment	1	300,00 €	300 €	3 600 €	0,030 €
Maintenance - Equipment	70%	1120,00 €	784,00 €	9 408,00 €	**0,078 €**
TOTAL HANDLING EQUIPMENT			**1 904 €**	**22 848 €**	**0,1904 €**
TRANSPORTATION					
Stuttle Extern Warehousing - (one day)	1	55,00 €	1 650 €	17 325 €	**0,144 €**
Truck drivers	1	8,00 €	4 896 €	58 752 €	**0,490 €**
Maintenance - Transport - Truck	8%	55,00 €	4,40 €	52,80 €	**0,000 €**
TOTAL TRANSPORTATION			**6 550 €**	**76 130 €**	**0,6344 €**
FACILITIES					
FG - Sequence Warehousing m2 - extern	2050 m2	2,70 €	5 535 €	66 420 €	**0,554 €**
FG - Sequence Area m2 - preparation	180 m2		486 €	5 832 €	**0,049 €**
FG - Empty	450 m2		1 215 €	14 580 €	**0,122 €**
FG - Full	250 m2		675 €	8 100 €	**0,068 €**
OFF m2	120 m2	3,70 €	444 €	5 328 €	**0,044 €**
Building maintenance	-	40,00 €	40 €	480 €	**0,004 €**
Facilities cleaning	-	850,00 €	850 €	10 200 €	**0,085 €**
TOTAL FACILITIES			**9 245 €**	**110 940 €**	**0,9245 €**
INFORMATION TECHNOLOGY (IT)					
IT - Labeles - container 1x	1	295,00 €	295 €	3 540 €	**0,030 €**
IT - Labeles small - Tanks 1x	1	185,00 €	185 €	2 220 €	**0,019 €**
Printer Zebra 2x	2	255,00 €	510 €	6 120 €	**0,051 €**
Cartridge	1	105,00 €	105 €	1 260 €	**0,011 €**
Print out	1	120,00 €	120 €	1 440 €	**0,012 €**
Comunication equipment - Mobile telephone	2	39,00 €	78 €	936 €	**0,008 €**
IT - Connection	1	711,00 €	711 €	8 532 €	**0,071 €**
Maintenance - IT	100%	294,00 €	294,000 €	3 528,000 €	**0,029 €**
TOTAL INFORMATION TECHNOLOGY			**2 298 €**	**27 576 €**	**0,2298 €**
OTHERS					
Maintenance - External warehouse	100%	95,00 €	95,00 €	1 140,00 €	**0,010 €**
Unexpectedly cost	1	500,00 €	500 €	6 000 €	**0,050 €**
TOTAL OTHERS			**595 €**	**7 140 €**	**0,0595 €**
OPERATING COST					
Rack Labelling, Floor Layout - floor tape, labelling	-	500,00 €	0 €	0 €	**0,000 €**
Operational margin in %	1%	100,00 €	1,00 €	12,00 €	**0,000 €**
Corporate margin in %	10%	100,00 €	10,00 €	120,00 €	**0,001 €**
Insurance/liability	1	225,00 €	225 €	2 700 €	**0,023 €**
TOTAL OPERATING COST			**236 €**	**2 832 €**	**0,0236 €**
OVERTIME COST					
Overtime - daily	1	9,50 €	10 €	114 €	**0,001 €**
Overtime - afternoon	1	11,00 €	11 €	132 €	**0,001 €**
Overtime - night	1	12,00 €	12 €	144 €	**0,001 €**
Overtime - holiday	1	13,00 €	13 €	156 €	**0,001 €**
TOTAL COSTS			**34 423,0 €**	**410 601,0 €**	**3,422 €**

Source: author

4. Conclusion

The chain of logistics activities ensures the smooth running of the production process and logistics costs are associated with each logistics activity. These costs are not negligible items that affect to a large extent the overall profit or loss of

an enterprise. The need to monitor costs in terms of logistics activities is a prerequisite for identifying rationalization measures in logistics activities and optimizing the logistics costs of an enterprise.
In order to ensure the synchronization of the individual logistics processes, the availability of the information needed for the individual managerial levels, the assessment of the work of the employees, feedback from the customers and the flexible operation in the event of deviations from the financial plan, in today's competitive environment, provided the required information to the users, i.e. the management of the company. This article showed the possibility of using activity-based costing as the case study in the selected logistics service provider with regard to the warehousing.

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SUSTAINABLE DISTRIBUTION LOGISTICS OF RETAIL CHAINS

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Abstract: Distribution logistics of retail chains is very specific, because the network of retail chains is usually very extensive and there are many constraints for distribution of goods, for example time windows of central warehouses (depots) and stores for loading and unloading, more deliveries within the same day to stores or distribution of objects of reverse logistics from stores to central warehouses. There are many flows between stores and central warehouses, for example product flows, information flows, financial flows, reverse flows etc. Sustainable distribution logistics should respect three pillars of sustainability, there are: economic, social and environmental pillars. Sustainable distribution logistics of retail chains should investigate the possibilities of streamlining with consideration to the pillars of sustainability. The article will focus on the distribution planning tools which are being used for planning of distribution logistics for retail chains. There are some algorithms of graph theory, for example: Vehicle routing problem with pickup and delivery with time windows. The aim of the article will be to find an algorithm for this type of exercise which will respect all defined constraints and pillars of sustainability for distribution logistics of retail chains. The algorithm will be simulated on a specific network of retail chain as a case study.

Keywords: distribution logistics, retail chain, vehicle routing problem, sustainability.

1. Introduction

The popularity of retail chains has grown in recent years among customers. Many retail chains have hundreds of stores and many central warehouses (depots). Demands on transport infrastructure and transport system as a whole are increasing. The intensity of traffic grows in the surroundings of individual stores, not only thanks to customers but also through the distribution logistics. The same applies for the surroundings of the central warehouses (depots) because hundreds of suppliers supply every day central warehouses and central warehouses deliver goods every day to hundreds of stores. It is also widely known that transport and distribution have a negative impact on the environment. This makes it necessary to pay maximum attention to distribution logistics. At the same time, greater emphasis is placed on sustainability issues through three pillars of sustainability and especially on the negative impacts of transport and distribution on the environment from the perspective of the environmental pillar of sustainability.

2. Theoretical Background of the Sustainable Distribution Logistics

Sustainable logistics is a research area developed since the 1990s according to Wiederkehr et al. (2004). Davis and Barekat (2002) stressed the terms like eco-logistics because these terms were increasingly used to define a sustainable environmental logistics. Schulte (1999) described sustainable distribution or sustainable distribution logistics as any means of transportation of goods in logistic chain with lowest possible impact on the environment and society. The term distribution includes according to the author the whole distribution process from storage, order processing and picking, packaging, improved vehicle loadings, delivery to the customer and reverse logistics. Sustainable distribution is based on three pillars: environmental pillar, economic pillar and social pillar. Faccio and Gamberi (2015) perceive logistic activities as the necessary condition for the harmonious growth of every urban area, even if they are also the main cause of pollution, noise and accidents. The rapid development of the demand for urban transportation has a negative impact on urban surroundings and on the environment (Wang et al., 2014). Faccio and Gamberi (2015) defined four groups of key players in the field of distribution logistics there are: retailers (stores etc.), carriers and warehouse companies, residents (inhabitants) and administrators (at national, regional and local levels). Karakikes and Nathanail (2017) stressed the importance of the urban distribution of goods because it is the main component of sustainable transport networks and one of the main contributors on traffic congestion and environmental pollution in the cities and agglomerations. Matsumoto et al. (2017) mentioned sustainable distribution or sustainable distribution logistics which considers both facility for distribution supply chain and also the transportation. Authors further emphasized the associated negative environmental impacts of distribution logistics and the need to use quality planning tools for distribution logistics. New challenges have been observed in models of vehicle routing problems which considered basic tools for implementing sustainable distribution channels in urban areas (Carrabs, Cerulli and Sciomachen, 2014).
Retail chains have usually a very extensive network which consists of depots (central warehouses) $D_1 \cdots D_n$ and customers (stores) $C_1 \cdots C_n$. The stores are supplied directly from direct suppliers $SD_1 \cdots SD_n$ or indirectly from depots. The depots are supplied from indirect suppliers $SI_1 \cdots SI_n$. Direct flows of the goods and indirect flows of the goods are depicted in the Fig. 1. Stores produce reverse flow especially transport units (pallets, crates, boxes etc.). These transport units are returned directly to the direct suppliers or indirectly to the indirect suppliers through the depots. The diagram of the distribution and reverse logistics of retail chains are depicted in the Fig. 1.

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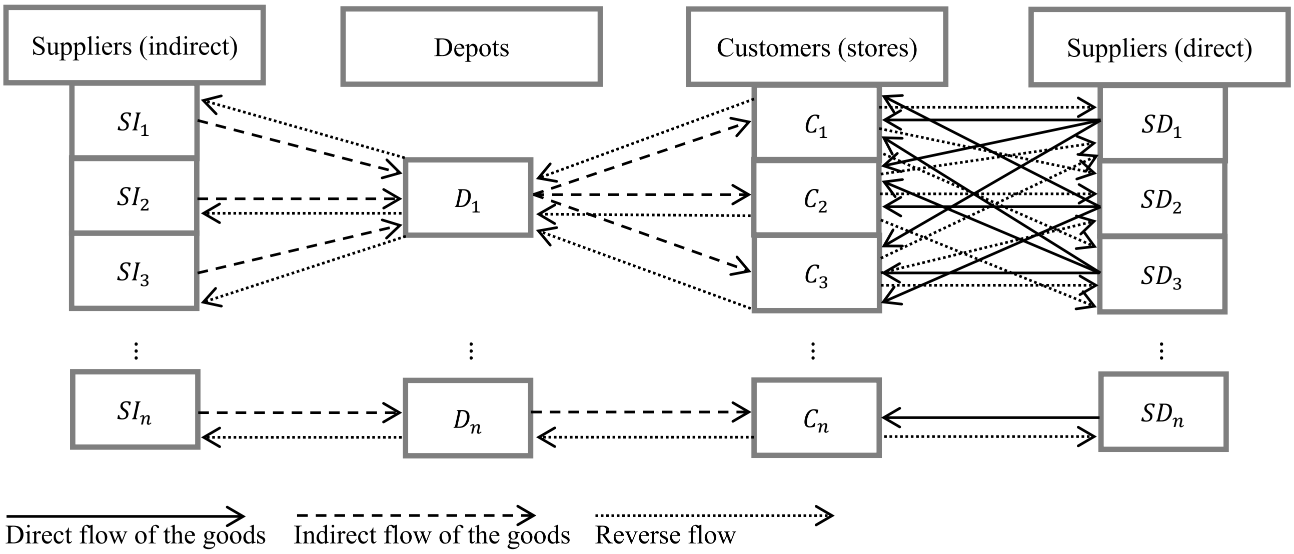

Fig. 1.
The Diagram of the Distribution and Reverse Logistics of Retail Chains
Source: authors

3. Methods and Data

Methods and data are presented in this chapter. The algorithm of heuristic method for Vehicle routing problem with pickup and delivery with time windows is presented firstly. Then VRP Spreadsheet Solver is paid attention because this Microsoft Excel Workbook is used to solve a case study which is theoretically described at the end of the chapter.
Algorithm of heuristic method for Vehicle routing problem with pickup and delivery with time windows according to Desaulniers *et al.* (2002) uses these types of variables: binary flow variables x_{ijk}, time variables T_{ik} (specifying when vehicle k starts the service at node $i \in V_k$) and variables L_{ik} giving the load of vehicle k after the service at node $i \in V_k$ has been completed. The formulation of Vehicle routing problem with pickup and delivery with time windows according to Desaulniers *et al.* (2002) is as follows formulas 1-15.

$$min \sum_{k \in K} \quad \sum_{(i,j) \in A_k} c_{ijk} x_{ijk} \tag{1}$$

subject to

$$\sum_{k \in K} \quad \sum_{j \in N_k \cup \{d(k)\}} x_{ijk} = 1 \,;\ \forall\, i \in P \tag{2}$$

$$\sum_{j \in N_k} x_{ijk} - \sum_{j \in N_k} x_{j,n+i,k} = 0 \,;\ \forall\, k \in K, i \in P_k \tag{3}$$

$$\sum_{j \in P_k \cup \{d(k)\}} x_{o(k),j,k} = 1 \,;\ \forall\, k \in K \tag{4}$$

$$\sum_{i \in N_k \cup \{o(k)\}} x_{ijk} - \sum_{i \in N_k \cup \{d(k)\}} x_{ijk} = 0 \,;\ \forall\, k \in K, j \in N_k \tag{5}$$

$$\sum_{i \in D_k \cup \{o(k)\}} x_{i,d(k),k} = 1 \,;\ \forall\, k \in K \tag{6}$$

$$x_{ijk}\left(T_{ik} + s_i + t_{ijk} - T_{jk}\right) \leq 0;\ \forall\, k \in K, (i,j) \in A_k \tag{7}$$

$$a_i \leq T_{ik} \leq b_i;\ \forall\, k \in K, i \in V_k \tag{8}$$

$$T_{ik} + t_{i,n+i,k} \leq T_{n+i,k};\ \forall\, k \in K, i \in P_k \tag{9}$$

$$x_{ijk}\left(L_{ik} + l_j - L_{jk}\right) = 0;\ \forall\, k \in K, (i,j) \in A_k \tag{10}$$

$$l_i \leq L_{ik} \leq C_k;\ \forall\, k \in K, i \in P_k \tag{11}$$

$$0 \leq L_{n+i,k} \leq C_k - l_i;\ \forall\, k \in K, n+1 \in D_k \tag{12}$$

$$L_{o(k),k} = 0;\ \forall\, k \in K \tag{13}$$

$$x_{ijk} \geq 0;\ \forall\, k \in K, (i,j) \in A_k \tag{14}$$

$$x_{ijk} binary; \forall k \in K, (i,j) \in A_k \tag{15}$$

The linear objective function (1) minimizes the total travel cost. Constraints (2-3) impose that each request is served exactly once and by the same vehicle. Constraints (4-6) characterize a multi-commodity flow structure and ensure that each vehicle k starts from its origin depot $o(k)$ and terminates its route at its destination depot $d(k)$. Compatibility requirements between routes and schedules are handled by constraints (7) and (8) are the time window constraints. For each request, constraints (9) force the vehicle to visit the pickup node before the delivery node. Constraints (10) express the compatibility requirements between routes and vehicle loads, while (11-12) the vehicle dependent capacity intervals at pickup and delivery nodes. The initial vehicle load is imposed by (13), and no negativity and binary requirements are given by (14-15). Constraint sets (3) through (15), as well as the objective function, are separable for each vehicle $k \in K$ (Desaulniers *et al.,* 2002).
The algorithm for Vehicle routing problem with pickup and delivery with time windows is solved in the Microsoft Excel workbook "VRP Spreadsheet Solver" which is an open source unified platform for representing, solving and visualizing the results of Vehicle Routing Problems. VRP Spreadsheet Solver uses public Geographical Information Systems (Bing Maps) and metaheuristics. The author of the "VRP Spreadsheet Solver" is Güneş Erdoğan and its scientific area covers exact and heuristic optimization methods, ambulance location problems, traveling salesman problems, vehicle routing problems and scheduling problems (Güneş, 2018).
Güneş Erdoğan and other co-authors are the authors of the following scientific articles, for example A Note on a Polynomial Time Solvable Case of the Quadratic Assignment Problem (Güneş and Tansel, 2006), A Branch-and-Cut Algorithm for Quadratic Assignment Problems Based on Linearizations (Güneş and Tansel, 2007), Ambulance Location for Maximum Survival (Erkut, Ingolfsson and Güneş, 2008), Computational Comparison of Five Maximal Covering Models for Locating Ambulances (Erkut *et al.,* 2009), The Traveling Salesman Problem with Pickup and Delivery and First-In-First-Out Loading (Güneş, Cordeau and Laporte, 2009), Scheduling Ambulance Crews for Maximum Coverage (Güneş *et al.,* 2010), The Attractive Traveling Salesman Problem (Güneş, Cordeau and Laporte, 2010), The Traveling Salesman Problem with Pickups, Deliveries and Handling Costs (Battarra *et al.,* 2010), A Branch-and-Cut Algorithm for the Non-Preemptive Capacitated Swapping Problem (Güneş, Cordeau and Laporte, 2010), Formulations and Branch-and-Cut Algorithms for the Generalized Vehicle Routing Problem (Bektaş, Güneş and Ropke, 2011), Modelling and solving an m-location, n-courier, priority-based planning problem on a network (Güneş, Tansel and Akgün, 2012), Metaheuristics for the traveling salesman problem with pickups, deliveries and handling costs (Güneş et al., 2012), The Orienteering Problem with Variable Profits (Güneş and Laporte, 2013) and Exact Algorithms for the Clustered Vehicle Routing Problem (Battarra, Güneş and Vigo, 2014).
The case study will be used for application of Vehicle routing problem with pickup and delivery with time windows in the real retail chain. The case study is the method of the qualitative research based on the study of one or a small amount of situations for application of the findings for the similar cases according to Nielsen, Mitchell and Nørreklit (2015).
The case study data represent the data of the real retail chain in the Czech Republic, but this case study is limited to just one depot (central warehouse) which is located in the Praha-východ and the case study is limited for the one round of distribution within the day. The visualization of the depot and customers (stores) is in the Fig. 2.

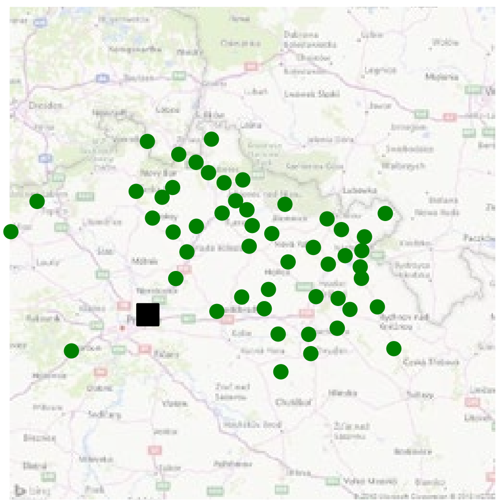

Fig. 2.
The Visualization of the Depot and Customers (Stores)
Source: authors with use Güneş (2018)

Location of the depot, locations of all 50 customers (stores), latitudes, information about start and end of time windows which must be respected, number of pallet space for pickup and delivery (one pallet space represented one standardized euro pallet) are in the Table 1.

Table 1
Locations, Latitudes and Time Windows of the Depot and Customers 01 – 50

Location	Type (depot / customer)	Latitude (y)	Latitude (x)	Time window		Pickup (pallet space)	Delivery (pallet space)
				start	end		
Praha-východ, CZ	Depot	50,1274131	14,6221731	00:00	23:59	---	---
Bělá pod Bezdězem, CZ	Customer 01	50,5012122	14,8041817	03:30	05:00	9	22
Benátky nad Jizerou, CZ	Customer 02	50,2908525	14,8234317	05:45	07:00	9	13
Beroun, CZ	Customer 03	49,9638233	14,0719964	05:15	06:30	3	9
Broumov, CZ	Customer 04	50,5856611	16,3318097	03:30	07:00	8	13
Česká Lípa, CZ	Customer 05	50,6855131	14,5376417	04:00	06:00	3	9
Česká Skalice, CZ	Customer 06	50,3946689	16,0427625	04:45	05:30	11	18
Dobruška, CZ	Customer 07	50,2920133	16,1600131	04:15	06:15	9	16
Doksy, CZ	Customer 08	50,5647128	14,6555250	03:45	07:00	8	9
Dvůr Králové nad Labem, CZ	Customer 09	50,4317219	15,8140211	04:30	07:30	10	13
Frýdlant, CZ	Customer 10	50,9213944	15,0797406	05:00	08:00	9	14
Holice, CZ	Customer 11	50,0660114	15,9858997	05:00	07:00	8	24
Hořice v Podkrkonoší, CZ	Customer 12	50,3660903	15,6318339	04:00	06:30	5	7
Hradec Králové, CZ	Customer 13	50,2092283	15,8327683	05:30	06:30	5	16
Hrádek nad Nisou, CZ	Customer 14	50,8527897	14,8445472	06:00	07:00	8	22
Hronov, CZ	Customer 15	50,4798497	16,1819714	05:45	07:00	0	13
Chlumec nad Cidlinou, CZ	Customer 16	50,1544031	15,4602619	05:15	06:45	8	7
Chrastava, CZ	Customer 17	50,8169256	14,9688361	03:30	06:15	7	23
Chrudim, CZ	Customer 18	49,9510922	15,7955758	04:00	07:00	4	19
Jablonec nad Nisou, CZ	Customer 19	50,7243075	15,1710772	04:45	07:30	9	6
Jaroměř, CZ	Customer 20	50,3561958	15,9213644	04:15	08:00	8	24
Jičín, CZ	Customer 21	50,4372261	15,3516250	03:30	05:00	10	12
Liberec, CZ	Customer 22	50,7699972	15,0584492	04:00	06:30	11	16
Lomnice nad Popelkou, CZ	Customer 23	50,5306247	15,3734103	04:45	07:00	9	9
Městec Králové, CZ	Customer 24	50,2071808	15,2975814	03:30	07:00	11	11
Mimoň, CZ	Customer 25	50,6586886	14,7247361	04:00	06:00	8	21
Mladá Boleslav, CZ	Customer 26	50,4113514	14,9031850	04:45	05:30	0	15
Mnichovo Hradiště, CZ	Customer 27	50,5272047	14,9713353	04:15	06:15	11	22
Most, CZ	Customer 28	50,5030069	13,6361742	03:45	07:00	0	19
Náchod, CZ	Customer 29	50,4167044	16,1628883	04:30	07:30	9	20
Nová Paka, CZ	Customer 30	50,4944939	15,5150317	05:00	08:00	6	17
Nové Město nad Metují, CZ	Customer 31	50,3439522	16,1515464	05:30	06:00	8	6
Nový Bydžov, CZ	Customer 32	50,2415025	15,4908206	06:00	06:30	10	6
Pardubice, CZ	Customer 33	50,0385383	15,7802056	05:45	07:00	1	11
Poděbrady, CZ	Customer 34	50,1424186	15,1188122	04:15	06:00	4	18
Přelouč, CZ	Customer 35	50,0398478	15,5603075	05:15	06:00	7	9
Rychnov nad Kněžnou, CZ	Customer 36	50,1628389	16,2748839	03:30	05:30	10	12
Semily, CZ	Customer 37	50,6019053	15,3355211	04:00	06:15	4	6
Stráž pod Ralskem, CZ	Customer 38	50,7028011	14,8010175	04:45	07:00	8	5
Tanvald, CZ	Customer 39	50,7373536	15,3058536	04:15	07:30	10	22
Teplice, CZ	Customer 40	50,6403975	13,8245072	03:45	08:00	0	23
Trutnov, CZ	Customer 41	50,5610067	15,9127036	04:30	05:00	2	5
Třebechovice pod Orebem, CZ	Customer 42	50,2009683	15,9922311	05:00	06:30	0	15
Třemošnice, CZ	Customer 43	49,8691186	15,5800239	05:30	07:00	9	6
Turnov, CZ	Customer 44	50,5872847	15,1568011	06:00	07:30	3	17
Týniště nad Orlicí, CZ	Customer 45	50,1513633	16,0776972	03:45	05:30	4	6
Úpice, CZ	Customer 46	50,5123742	16,0160675	05:45	07:15	2	14
Ústí nad Orlicí, CZ	Customer 47	49,9738744	16,3936106	05:15	06:15	2	15
Varnsdorf, CZ	Customer 48	50,9115439	14,6182350	03:45	07:00	5	17
Vrchlabí, CZ	Customer 49	50,6269681	15,6093742	04:30	07:30	10	23
Železný Brod, CZ	Customer 50	50,6427400	15,2540775	05:00	08:00	8	7

Source: authors

VRP Spreadsheet Solver applied these limited conditions for this case study: one depot, fifty customers, the fastest route in Bing Maps, the average vehicle speed was set to 70 kilometers per hour, homogenous car fleet with maximum capacity thirty three pallet space, hard time windows type, service time in depot was one hour and customer service time was half an hour.

4. Results

Results of the vehicle routing problem with pickup and delivery with time windows for the case study are presented in the Table 2, there are twenty three vehicles with defined routes to the customers. Every vehicle starts and ends in the depot. The number in brackets indicates the number of pallet space for pickup and delivery in the depot and for each customer. The vehicle 17 serves only one customer (40), other vehicles serve from two to three customers. Three customers serve vehicle number 3, 4, 16, 18 and 21. This is the optimal solution according to entered inputs with the use of VRP Spreadsheet Solver.

Table 2

Solution of the Case Study With Individual Routes and Information About Pickup and Delivery

Vehicle	Route (pickup/delivery)				
Vehicle 01	Depot (33/0)	Customer 29 (9/20)	Customer 04 (8/13)	Depot (0/17)	
Vehicle 02	Depot (32/0)	Customer 07 (9/16)	Customer 13 (5/16)	Depot (0/14)	
Vehicle 03	Depot (33/0)	Customer 36 (10/12)	Customer 45 (4/6)	Customer 47 (2/15)	Depot (0/16)
Vehicle 04	Depot (31/0)	Customer 34 (4/18)	Customer 16 (8/7)	Customer 32 (10/6)	Depot (0/22)
Vehicle 05	Depot (31/0)	Customer 01 (9/22)	Customer 08 (8/9)	Depot (0/17)	
Vehicle 06	Depot (29/0)	Customer 49 (10/23)	Customer 37 (4/6)	Depot (0/14)	
Vehicle 07	Depot (33/0)	Customer 27 (11/22)	Customer 24 (11/11)	Depot (0/22)	
Vehicle 08	Depot (31/0)	Customer 10 (9/14)	Customer 48 (5/17)	Depot (0/14)	
Vehicle 09	Depot (33/0)	Customer 06 (11/18)	Customer 42 (0/15)	Depot (0/11)	
Vehicle 10	Depot (30/0)	Customer 05 (3/9)	Customer 25 (8/21)	Depot (0/11)	
Vehicle 11	Depot (28/0)	Customer 28 (0/19)	Customer 03 (3/9)	Depot (0/3)	
Vehicle 12	Depot (29/0)	Customer 39 (10/22)	Customer 50 (8/7)	Depot (0/18)	
Vehicle 13	Depot (30/0)	Customer 11 (8/24)	Customer 43 (9/6)	Depot (0/17)	
Vehicle 14	Depot (33/0)	Customer 35 (7/9)	Customer 20 (8/24)	Depot (0/15)	
Vehicle 15	Depot (29/0)	Customer 17 (7/23)	Customer 19 (9/6)	Depot (0/16)	
Vehicle 16	Depot (32/0)	Customer 41 (2/5)	Customer 46 (2/14)	Customer 09 (10/13)	Depot (0/14)
Vehicle 17	Depot (23/0)	Customer 40 (0/23)	Depot (0/0)		
Vehicle 18	Depot (31/0)	Customer 21 (10/12)	Customer 31 (8/6)	Customer 15 (0/13)	Depot (0/18)
Vehicle 19	Depot (33/0)	Customer 22 (11/16)	Customer 44 (3/17)	Depot (0/14)	
Vehicle 20	Depot (30/0)	Customer 18 (4/19)	Customer 33 (1/11)	Depot (0/5)	
Vehicle 21	Depot (33/0)	Customer 12 (5/7)	Customer 30 (6/17)	Customer 23 (9/9)	Depot (0/20)
Vehicle 22	Depot (28/0)	Customer 26 (0/15)	Customer 02 (9/13)	Depot (0/9)	
Vehicle 23	Depot (27/0)	Customer 38 (8/5)	Customer 14 (8/22)	Depot (0/16)	

Source: authors

The visualization of the solution for twenty three vehicles and routes is presented in the Fig. 3.

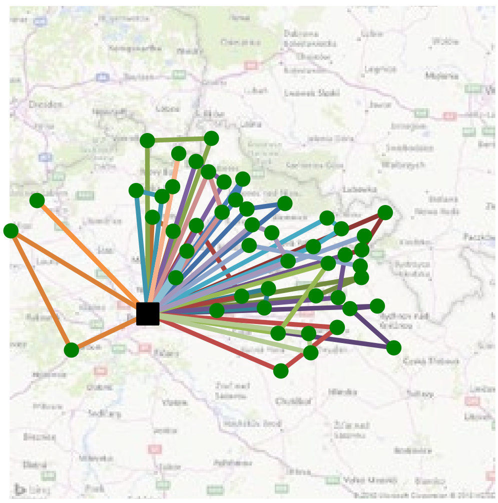

Fig. 3.

The Visualization of the Solution (Twenty Three Vehicles)

Source: authors with use Güneş (2018)

5. Conclusion

In the future can be expected a further increase of traffic intensity due to population growth and population's increasing demands on mobility. The growing boom of e-commerce will lead to greater pressure on distribution logistics and the rising popularity of retail chains, rising sales and higher sales volumes increase the demand for distribution logistics of retail chains. On the other hand, it is necessary to emphasize the need to reduce the negative impacts of transport. One of the potential to reduce the negative impacts of distribution logistics is to use efficient planning tools to optimize the distribution logistics of the retail chain.

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OPEN ACCESS INTERMODAL TERMINALS FOR GREENER LOGISTICS SERVICES

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Abstract: The paper builds upon prior research on the potential for the greening of transport and logistics services on the Polish market. The shift from road to rail has often been put forward as the most favourable measure to meet the environmental goals. Although the Polish intermodal transport (rail-road in particular) has been steadily growing, compared to other European countries and taking the existing infrastructure into account, its share could be higher, and the rate of its growth could be faster. Therefore, we conducted a Delphi study to identify the barriers to the development of intermodal transport in Poland. Issues concerning intermodal terminals were consistently indicated as one of the main obstacles, thus becoming the primary focus of the paper. Using the Delphi method, we further determined that the main problems with intermodal terminals are insufficient number and non optimal spatial distribution, inadequate technical standards (IT and equipment in particular) as well as issues with ownership and management structures. The latter are elaborated to a greater extent, showing that the open access to terminals is crucial to ensuring better utilisation of intermodal terminals and further development of rail-road transport. We also present the ongoing process of making the access to terminals open to all railway undertakings, what activities have been taken and what are the experiences so far. The findings are not limited to the Polish market, but have broader implications and can help in understanding the phenomena found in other transport and logistics markets, especially those still developing or less mature.

Keywords: intermodal transport, intermodal terminals, open access terminals, green transport, green logistics.

1. Introduction

The transport and logistics (T&L) industry is a considerable source of negative externalities and its contribution to GHG emission is also substantial. In the face of global environmental problems and climate change every effort (of countries, companies, individuals) towards the greening of T&L services is needed in order to meet targets implied by national or global agreements on preventing air pollution.

Recent studies by Klopott and Miklińska (2017a and 2017b) on the state of greening of the T&L services in Poland revealed that the process of "greening" is at the very early stage of its development and its pace is unsatisfactory. Authors identified the scope and types of green initiatives and practices implemented by logistics services providers (LSPs) on the Polish market and examined the factors behind the (non)implementation of green solutions. They also focused on the purchasing phase and explored the correlation between green requirements of customers, if any, and the readiness of logistics providers acting in Poland to satisfy such needs. These studies revealed, among others, that (Klopott & Miklińska, 2017a and 2017b):

- there is a rather low green awareness among stakeholders of the T&L market in Poland,
- the demand for green transport and logistics services is not noticeable,
- there is a shortage of green initiatives on the Polish market implemented by logistics services providers (LSPs),
- there is a lack of readiness (organisational, technical, as well as financial) to fulfil the green requirement of LSPs' customers,
- influence on the environment as a buying criterion is a factor of no or very low significance,
- the green criterion is not considered by LSPs when choosing a subcontractor, unless it is expressly required by the customer,
- only a small number customers noticed the potential for intermodality and requested reducing the share of road transport in favour of railways,
- LSPs rarely encourage their customers to choose a greener transport mode and to take advantage of intermodal solutions.

These findings cannot be disregarded, considering the projected rapid development of the Polish T&L market and its high share in the total EU market (e.g. in 2015, this market was ranked as 7th biggest in Europe (Kille et al., 2015)). Especially interesting are the findings regarding the intermodal transportation. Indeed, despite the potentially favourable conditions, the share of intermodal transport in Poland is disappointingly low and road transport is still predominant. There are many reasons and explanations as to why the modal shift has not yet occurred, and the issue concerning intermodal terminals is one of them. Therefore, the aim of this paper is to highlight the status quo of intermodal terminals in Poland and to present the ongoing process of making the access to these facilities open to all railway undertakings, in order to foster better utilisation of terminals. This is important to ensure the growth of intermodal transport share and, thereby, the development of green logistics services in Poland.

2. Intermodal Transport in the Greening of T&L Services

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Transport operations account for a large share of logistics systems' emissions (Eng-Larson&Kohn, 2012). According to the European Environmental Agency, the EU transport sector is still responsible for 46% of total EU-28 emissions of NO_x and constitutes a rising source of GHG emissions that in 2015 exceeded 1990 levels by 21% (EEA, 2015). On a global level, the international trade-related freight transport had a carbon footprint at around 1600 Mt CO_2 emissions from fuel burn in 2015, and it is projected that, along with rising volumes of transported cargoes, CO_2 emissions could increase by 120% by 2050 if no reduction measures are taken (OECD/ITF, 2017). The road freight transport was responsible for a large portion of these emissions (at around 40 %) (OECD/ITF, 2017).
Within the array of suggested measures to make transport and logistics greener, and to reduce their environmental impact, is a shift to intermodal transportation (e.g. McKinnon, 2008; European Commision, 2001 and 2011; Eng-Larson & Kohn, 2012). The potential of a modal shift from road transport to less polluting modes has been raised by European politicians since the late 1990s. The modal switch was presented as a promising way to reach the target reductions in CO_2 emissions from transport operations agreed under national and international agreements (see e.g. European Commission, 2001).
However, despite political ambitions and substantial EU financial support (with a flagship Marco Polo programme), transport statistics do not mirror these efforts and only a minor progress has been observed. Road transport continues to dominate the transport market in Europe, accounting for nearly 75 % of the total inland tonne-kilometres performed, while rail transport for a little above 18 % and inland waterways for about 6 % (Eurostat, 2016). The share of road and rail transport (28 EU countries) has remained almost unchanged since 2009: road transport decreased by 2.2 %, while rail transport recovered slightly, increasing by 1.5%, compared to 2009 (Eurostat, 2016). There is a number of explanations as to why the intermodal transport has not yet achieved a desired share, with the low quality of intermodal service supply and demand inertia being among the most commonly cited (e.g. McKinnon, 2008; Eng-Larsson & Kohn, 2012).

3. Intermodal Transport in Poland

3.1. General Overview

Since 2007, the intermodal transport (rail-road in particular) in Poland has been growing steadily, although the pace of its development is unsatisfactory. The total volume of transported cargo increased from 4,8 million tonnes in 2008 to 14,7 million tons in 2017 (UTK, 2018), which represents the growth at CAGR 13,2 %. In 2017, for the first time in history, the total volume of cargo transported by rail operators surpassed 1 million of intermodal units, mostly containers, thus marking an increase of CAGR 10,9 % from 2008 (Figure 1). Nevertheless, the share of intermodal transport in overall railway freight transport remains very low, accounting for 4.53 % and 8.8 % (measured by transport output) in 2011 and 2016, respectively. It needs to be emphasized that the related European average (by transport output) was at 17.6% already in 2010 (UTK, 2012, 2017). Nevertheless, the number of rail carriers (rail undertakers) has been consistently increasing: from 6 in 2007, 9 in 2012, to 18 in 2017 (UTK, 2018).

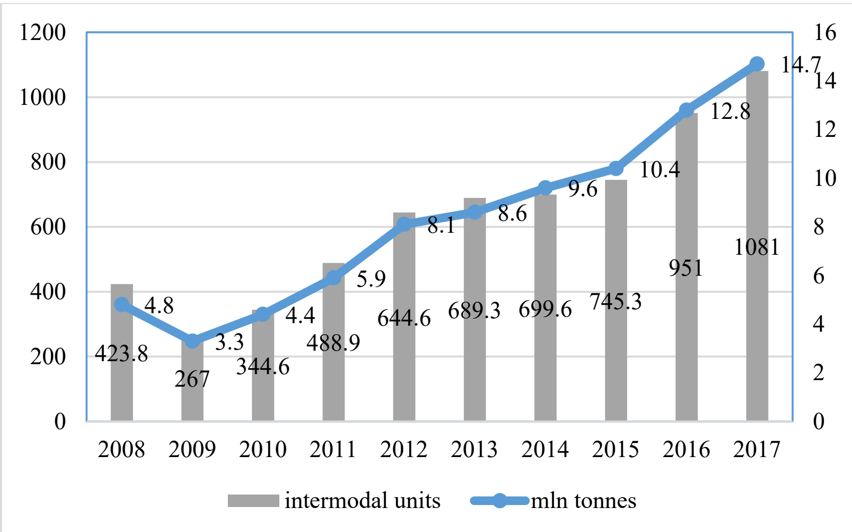

Fig. 1.
The volumes of intermodal freight transport in Poland over the period 2008-2017 (in million tonnes and number of intermodal units)
Source: own elaboration based on the Office of Rail Transport data (UTK, various issues)

At present, there are 19,330 km of railway lines in operation (fourth rank in Europe), of which 62% are electrified (higher than European average for 22 EU countries - 54,6%) (IRG-Rail, 2017). However, the length of railway lines has been significantly reduced within the past 20 years, and ca. 4 755 km of railway lines have been withdrawn from operation (Miklińska, 2017). About 98% of railway networks are standard gauge lines (1435 mm), while approximately 2% are wide track (1520 mm). The average density of railway lines in 2016 amounted to 6,1 km/100km^2 (CSO, 2017). The majority of railway lines (95,8 %) are managed by the main infrastructure manager, PKP PLK (IRG Rail, 2017) who provides conditions for rendering services in intermodal transport (being responsible, e.g., for modernisation of railways and imposing charges on rail carriers).

Although the Polish intermodal transport has been steadily growing, compared to other European countries and taking the existing infrastructure into account, its share and the rate of its growth are disappointing. As mentioned above, Poland has a sufficient length of railway lines (9,4 % of all European railway lines in 24 EU countries), but the share in total volume of cargo transported by intermodal transport within the EU (measured by transport work) was only 3,56 % in 2011. To compare: Germany accounts for 18,9 % of railways in length, but its share in intermodal freight transport is considerably higher (about 13 times as high), going above 47,53% in 2011 (UTK, 2013; Eurostat, 2016; IRG Rail, 2017). Therefore, there are reasonable grounds to believe that further and faster development of intermodal freight transport in Poland can potentially be achieved, and solutions to support its growth should be sought.

3.2. Main Barriers to Better Utilisation of Intermodal Transport in Poland

In order to identify the barriers that hinder satisfactory utilisation of intermodal transport in Poland, an empirical study using the Delphi method was conducted (Considering the limited length and the main purpose of the paper, an in-depth elaboration of the study, its methods and research proceedings have been omitted). The Delphi method can be used to help identify problems and their potential solutions, in forecasting, in decision-making, as well as to set goals and priorities (Dalbecq et al., 1986), being a suitable technique that allows to aggregate expert opinions on a given topic. 16 experts were chosen to participate in the study, in such a way as to reflect opinions of different stakeholders related to the transport and logistics market who are involved (directly or indirectly) in the intermodal operations. The coefficient of variation was used as a measure of consensus as well as stability, and, as suggested by English and Keran (Van der Gracht, 2012), its value at or below 0.5 was established as a cut-off point, indicating the acceptable degree of consensus (no need for additional round). Finally, the Delphi process was divided into three rounds: Round 1 took place early October, Round 2 - mid-November, and Round 3 - late November and early December, all in 2017.

The experts achieved a very high level of agreement for a number of factors hindering better utilisation of intermodal transport in Poland. Those with the highest scores of consensus were listed below and divided into seven groups for more clarity. These groups were: liner infrastructure, nodal infrastructure, rolling stocks, transport policy, market & organisational issues, costs & prices, awareness & cooperation.

Linear infrastructure:

- The poor condition of railway infrastructure, being a consequence of years of neglect (and inherited after the period of the centrally planned economy). It is only in recent couple of years that rail infrastructure has been modernized and its condition is slowly but systematically improving, although it still lags behind Western European standards.
- Investments in road infrastructure (increasing density of motorways) have improved conditions for road freight services.

Nodal infrastructure:

- An insufficient number and nonoptimal spatial distribution of intermodal terminals in Poland to ensure growth of intermodal transport in different parts of the country and on different routes.
- An inadequate technical standard of many intermodal terminals. It refers, especially, to the limited handling and storage capability, stacking and handling yard pavement, length of railway trucks, handling equipment.
- The fragmented ownership and management structures of intermodal terminals is an impediment to coordination of intermodal services.
- The lack of non-discriminatory rules with regard to access to intermodal terminals to all railways undertakings.
- Uncoordinated process of development of intermodal terminals. As a result, there are some locations where there were too many of them (all were under-performing).
- The lack of dedicated IT systems coordinating utilisation of inland intermodal terminals.

Rolling stocks:

- There is a lack of appropriate rolling stocks, while the condition and age of the existing ones is very poor.
- In particular, there is a lack of special locomotives of relevant parameters dedicated to the intermodal transport, as well as a lack of a special railways wagons.

Transport policy:

- In the long term, the lack of consistent and coherent policy as well as the lack of a comprehensive vision with regard to intermodal transport development; empty promises in the national strategy for transport development, which did not translate into action.

- The lack of stability of policy of intermodal transport development (e.g. with regard to financial support (subsidies) for intermodal alternatives; no one knows whether it will continue or not).
- The lack of competent and continued (i.e. regardless of changing central governments) administration body responsible for development of intermodal transport.

Costs & prices:

- Too high track access charges paid by railway undertakings; the level of these charges is considerably higher compared to road transport as well as to track access charges in other countries.
- The price for intermodal carriage is not attractive for shippers, and, as it is the main criterion for choosing the mode of transport – intermodal is at a disadvantaged position.
- Intermodal "subsidies" (rebates) are too low to counterbalance the cost differences between modes (rail-road); the selections of beneficiaries of intermodal "subsidies" is arguable, and it is a consequence of a lack of a clearly defined meaning of intermodal transport (and intermodal terminal as well).

Market & organisational issues:

- The lack of sufficient flows of goods that may enforce the use of intermodal transport.
- The quality of intermodal services is insufficient; to some extent this is a result of the condition of linear infrastructure (speed limitations; limited permissible axle load; too slow timetable speed).
- The lack of proper organisation of road feeder services to and from intermodal terminals.
- Railway carriers fail to adapt to contemporary market structures as well as to customer demands.

Awareness & cooperation:

- The environmental awareness is almost non-existent, except some global LSPs; the eco-awareness diminishes against the issues of costs and profitability.
- Reluctance of different stakeholders to cooperate and the lack of mutual trust.
- Mental barriers and habits, reluctance to changes among various stakeholders, which are not always rational.

The issues concerning intermodal terminals in Poland have been consistently indicated among the main obstacles, and therefore, they require further elaboration.

5. Intermodal Terminals in Poland and the Issue of “Open Access”

Over the past years, the number of intermodal terminals in Poland has increased to more than 30; on average, there is one terminal per 10,000 km^2 of the country’s area. In Western European countries, this figure is higher, at 4.2 terminals per 10 000 km^2 (in Germany more than 4, in Belgium over 7, and in the Netherlands over 11, per 10 000 km^2) (UTK, 2012 and 2016). As mentioned previously, Delphi panellists indicated problems with the spatial distribution of these terminals, also pointing to the inadequate technical standard of many of them. Indeed, a significant number of intermodal terminals in Poland, especially older ones or recently modernized, fail to meet Western European standards, making it impossible for them to handle larger flows of containers or other intermodal units. A diverse ownership structure of intermodal terminals in Poland constitutes a significant obstacle in their effective utilisation. These terminals are owned or managed by various entities; in Poland by: intermodal operators, railway carriers, infrastructure managers, operators of sea container terminals, companies with more shareholders, and others. A similar situation exists in other European countries (UIRR, 2016). The issue of terminal ownership is also directly linked to their funding, as various entities have access to various sources of financing. This may result in uneven terminal development on a national scale. An UIRR report emphasizes that: “The diverse ownership and financing background of transhipment terminals mean that they constitute a unique category of transport infrastructure” (UIRR, 2016). Therefore, intermodal terminals should be of special interest. Without their sufficient number and spatial distribution, as well as without open access provided to all operators, further development of intermodal transport will be jeopardised. Hence, it is necessary to take all possible actions leading to a better utilisation of existing facilities, but also in line with the EU policy. Already in the EU White Paper 2011, it was stressed that: „Infrastructure shapes mobility. No major change in transport will be possible without the support of an adequate network and more intelligence in using it” (European Commission, 2011). Although this statement refers to the mobility of people, its meaning can be extended to freight terminals and cargo transport. The intelligent utilisation of the existing intermodal terminals may be facilitated with the policy of "open access" in place.

The issue of "open access" as a response to problems related to the utilisation of intermodal terminals is not suggested only by Delphi panellists, but it is also the opinion of specialists from the European intermodal sector. In a 2014-2015 UIRR report, we read: “The lack of a European definition for "open access terminal" - ideally contained in legislation, as well as the conditions that they must fulfil, creates an uncertain situation as today each Member State may, or may not, set different requirements. Subsequently, CT stakeholders must "learn" the conditions from terminal to terminal and from country to country (…) The differences in the conditions of accessing terminals are emerging as an obstacle to devising new CT connections” (UIRR, 2015, 11).

In order to redress this situation, some steps were initiated at the EU level in 2017. Then, a new regulation regarding service facilities was adopted, i.e. the Commission Implementing Regulation (EU) 2017/2177 of 22 November 2017 on access to service facilities and rail-related services. It constituted a kind of general terms also for freight terminals and other categories of rail service facilities. These rules must be complied with by 1 June 2019 (UIRR, 2018). In Poland, new solutions regarding access to the railway infrastructure facilities have been proposed by the amendment to the Rail Transport Act of 2016, which came into force in 2017 (Act, 2016). The facilities listed in the Act include, among others, freight terminals and hence also intermodal terminals.

A question arises as to what conditions must be met for a railway undertaking to obtain access to an intermodal terminal and how is this access regulated in Poland. In accordance with the provisions of the abovementioned Act on railway transport, the manager of the service infrastructure facility prepares its statute, which specifies whether the facility is intended to be shared or not. The facility may not be shared only when it has not been in use. Rail carriers, including those from other Member States, have access to infrastructure facilities on equal and non-discriminatory terms. In order to acquire the right to access an infrastructure facility (e.g. an intermodal terminal), a railway undertaking must conclude an agreement with the terminal operator, specifying the rights and obligations of both in the scope of the services provided. Further, the operator of the facility also develops Regulations for access to the facility, in which the terms of making the terminal available, technical conditions, and the amount of charges are stipulated, among others. These Regulations must be published on the operator's website. The national register of the service infrastructure facilities (including intermodal terminals) is maintained by the President of the Office of Rail Transport (ORT - Polish abbreviation UTK) and it contains information about the owner of the facility, the facility manager and the operator, the railway network to which the facility is connected, as well as the scope of services (Act, 2016). Currently (July 2018), 37 intermodal terminals are listed on the ORT website (Table 1), along with a map of terminals (and other service facilities) in Poland (Fig. 2) (terminals marked by blue boxes) (UTK website, 2018a).

Fig. 2.
Map of intermodal transport facilities in Poland
Source: UTK website, 2018b <http://www.utkgik.home.pl/mapa_obiektow_kolejowych/>

In reference to the data presented in Table 1, it should be added that there are substantial differences between terminals regarding lifting and handling equipment. The biggest intermodal terminals, especially those located in seaports, are very well equipped, such as with: Shore to Ship Super Post Panamax Cranes, Shore to Ship Post Panamax Cranes, Rubber Tired Gantry Cranes, Internal Movement Vehicles, forklifts etc. However, there is still a lot of terminals (13 out of 37) characterized by a very basic handling equipment, e.g. with just Reach Stackers (sometimes only 1 or 2 of them); in the case of three terminals, there is no information on the ORT website regarding the handling equipment that they use.

Considering the specificity of intermodal transport in Poland, equipment of terminals and services offered concern, mainly, the handling of containers, but also, to a lesser extent, swap bodies, big bags, iron ore, grain or dangerous goods.

The biggest and most modern are terminals provide a bigger range of services and more regular connections to other intermodal facilities. Apart from basic services such as loading and discharging or storage of containers, these terminals offer: the stuffing and stripping of containers, warehouse services, customs clearance, weighing (VGM/SOLAS), container repairs, depot services, and last mile delivery services. Some of them work on a 24-hour basis, 7 days a week, and some on business days only (7 a.m. to 3 p.m. or later), holidays excluded (UTK website, 2018a; Terminals Catalogue 2018). Basic information about intermodal terminals are gathered in Table 1.

Table 1
Intermodal terminals in Poland

No	Name of the terminal	Owner/manager	Total area/the current maximum annual transshipment capacity/storage area	The number and size of railway tracks for loading and unloading
1.	BCT – Baltic Container Terminal Ltd.	International Container Terminal Services, Inc.	66,2 ha/1 200 000TEU/ 20 000+storage yards for 6500 cars	3x675m 2x300m
2.	Gdynia Container Terminal S.A.	Gdynia Container Terminal S.A./ HPH GROUP, CK HUTCHISON HOLDINGS	19,6 ha/636 000TEU/ 2 536 slots for 20ft/ max storage capacity 112 000TEU	4 tracks, 520m 3 tracks,638m
3.	Deepwater Container Terminal Gdańsk	DCT Gdańsk S.A.	71 ha/3 000 000 TEU/ 55 000 TEU	4x618m
4.	Gdański Terminal Kontenerowy S.A.	Manager: Gdański Terminal Kontenerowy S.A.; owners: Port Gdański Eksploatacja S.A.; PKP Cargo Connect Sp. z o.o.	6,7 ha/70 000 TEU/ 4 000 TEU	2x257m
5.	DB Port Szczecin Sp. z o.o.	DB Port Szczecin Sp. z o.o.	12,7 ha (56,6ha DB Port Szczecin)/120 000 TEU/3 500 TEU	3 041m
6.	OT Port Świnoujście – Terminal Kontenerowy	OT Port Świnoujście Sp. z o.o.	20 ha/70 000 TEU/ 2 000 TEU	1 200m
7.	Ostsped Szamotuły Terminal	Owner and manager: Ostsped Intermodal Spółka z o.o. Spółka Komandytowa	- / - / 1 000 TEU	900m
8.	Loconi Intermodal Terminal Kontenerowy Poznań	Loconi Intermodal S.A.	1,6 ha/ 40 000TEU/ 1 000TEU (including 600 depot)	1x350m
9.	Container Terminal Poznań Franowo - PKP CARGO CONNECT Sp. z o.o.	Owner and manager: PKP CARGO CONNECT Sp. z o.o. (until 31.12.2015 r. Cargosped Sp. z o.o.)	2,8ha/117 000 TEU/ 1 800 TEU	2x610m
10.	Polzug HUB Terminal Poznań	Owner: HHLA; manager: Polzug Intermodal Polska Sp.z o.o.	16ha/385 400 TEU/ 1 500 (depot)	4 x 610m; 1x 610 m
11.	Centrum Logistyczno-Inwestycyjne Poznań II CLIP Logistics Sp. z o.o.	Clip Logistics Sp. z o. o.	10ha/ 75 000TEU/ 8 000TEU	1 527m
12.	PCC Intermodal – Terminal PCC Brzeg Dolny	PCC Intermodal S.A.	9ha/110 000TEU/ 2 464 TEU	2 x 650 m + 2 x 650 m
13.	Schavemaker Kąty Wrocławskie	Schavemaker Invest Sp. z o.o.	5ha/75 000TEU/2 700TEU	764,5m
14.	Loconi Intermodal Warsaw Terminal	Owner and manager: Loconi Intermodal S.A.	6,8ha/100 000TEU/ 2 000TEU	1x580m 1x460m
15.	PKP CARGO CONNECT Sp. z o.o. Warszawa Container Terminal	PKP CARGO CONNECT Sp. z o.o. (untill 31.12.2015 r. Cargosped Sp. z o.o.)	3ha/77 000TEU/1 200TEU	1x320m
16.	Polzug Terminal Kontenerowy Pruszków	Owner: HHLA; manager: POLZUG Intermodal Polska Sp. z o.o.	4,46ha/96 000TEU/ 1500 TEU (depot)	1x300m; 1x100m; 2x250m
17.	PCC Intermodal – Terminal PCC Kutno	PCC Intermodal S.A.	11ha/250 000TEU/ 4 000 TEU	4x700m; 1x700m
18.	Erontrans Stryków Container Terminal Erontrans Agencja Celna Sp. z o.o.	Owner and manager: Erontrans Agencja Celna Sp. z o.o.	1,6ha/16 000TEU/2 000TEU	1x320m
19.	Spedcont Łódź Container Terminal	Spedycja Polska SPEDCONT Sp. z o.o. w Łodzi	9,2ha/80 000TEU/ 6 000TEU	2x400m
20.	Łódź Chojny Container Terminal	Manager: Loconi Intermodal S.A.	2,14ha/70 000TEU/ 2 000TEU	1x600m
21.	Container Terminal Radomsko	Owner/manager: Loconi Intermodal S.A.	6,41ha/80 000TEU/ 2 500 TEU	1x600m
22.	Erontrans Radomsko Container Terminal Erontrans Agencja Celna Sp. z o.o.	Owner and manager: Erontrans Agencja Celna Sp. z o.o.	1,2ha/ 10 000TEU/ 2 000 TEU	1x320m
23.	PCC Intermodal – Terminal PCC Gliwice	PCC Intermodal S.A.	5ha/150 000TEU/ 2900TEU	4x650m
24.	PKP CARGO CONNECT Sp. z o.o. Gliwice Container Terminal	PKP CARGO CONNECT Sp. z o.o. (untill 31.12. 2015 Cargosped Sp. z o.o.)	6,5ha/ 128 000TEU/ 1 800TEU	2x410m
25.	Polzug Terminal Dąbrowa Górnicza	Owner: HHLA; manager: Polzug Intermodal Polska Sp. z o.o.	16ha/233 600TEU/ 1400TEU (depot)	3 x 625 m; 1 x 100 m; 1 x 400 m
26.	EUROTERMINAL SŁAWKÓW	„Euroterminal Sławków" Sp. z o.o.	91ha (4ha container terminal)/284 810TEU/ 3500 TEU	7 x 700 m (concerns UTI services)
27.	Brzeski Terminal Kontenerowy - KARPIEL Sp. z o.o.	KARPIEL Sp. z o.o.	10,5ha/108 000TEU/ 5 000TEU	6x366m

No	Name of the terminal	Owner/manager	Total area/the current maximum annual transshipment capacity/storage area	The number and size of railway tracks for loading and unloading
28.	PCC Intermodal - Terminal Kolbuszowa	Owner and manager: PCC Intermodal S.A.	- /16 000TEU/400TEU	1x510m (PKP PLK SA)
29.	Lublin Container Terminal LTK Intermodal Sp. z o.o.	Owner and manager: LTK Intermodal Sp. z o.o.	2,5ha/13 000TEU/ 2500TEU	1x600m
30.	EUROPORT Małaszewicze Duże	Owner and manager: EUROPORT Sp. z o.o.	13ha/80 000TEU/ 1 300TEU	standard track -500 m; wide track 1520 mm – 500 m
31.	PKP Cargo Centrum Logistyczne Małaszewicze	Owner and manager: PKP Cargo S.A./PKP Cargo Centrum Logistyczne Małaszewicze Sp. z o.o.	14,06ha/223 380TEU/ 1872TEU	track 1520 mm-1766 m in total; standard track-1746 m in total
32.	Terminal T1 Żurawica (container railway)	PKP CARGO Centrum Logistyczne Medyka – Żurawica Sp. z o.o.	0,8ha/23 800TEU/60TEU	5
33.	Terminal T2 Medyka (container railway)	PKP CARGO Centrum Logistyczne Medyka – Żurawica Sp. z o.o.	1ha/20 000TEU/3TEU	3
34.	Container Terminal Siechnice	Owner: Rail Polska sp z o.o. Manager: Baltic Rail AS	10ha/50 000TEU/ 800 TEU	2x600m
35.	Container Terminal Włosienica	Owner: Rail Polska sp z o.o.; manager: Baltic Rail AS	10ha/ 50 000TEU/ 780 TEU	400m
36.	Rail Terminal Rzepin	Owner and manager: Rail Terminal Rzepin sp. z o.o.	1,6ha/ 40 000TEU/ 500TEU	2x200m 2x400m
37.	ANDREX LOGISTICS TERMINAL CHRYZANÓW	Owner and manager: Andrex-Logistics Andrzej Konończuk	6ha/ 180 000TEU/ 3 000TEU	2x660m

Source: own elaboration based on: UTK website, 2018a, Intermodal terminals, <https://www.utk.gov.pl/pl/dostep-do-infrastruktur/dostep-do-infrastruktur/mapa-obiektow-infrastru/terminale-intermodalne>; Terminals Catalogue 2018.

How does the implementation of new legal provisions work in practice? Operators of intermodal terminals in Poland, in accordance with legal provisions, were required to publish the terminal regulations on their websites by 9th December 2017 and most of them have fulfilled this obligation. Moreover, they were also obliged to submit the facility to the register of the President of ORT. According to information provided by representatives of ORT during the intermodal conference held in Gdańsk in April 2018, there are still managers who have failed to submit their facility or have provided incomplete information (Kozłowska UTK, 2018). The process of creation of the register of infrastructure facilities continued until the end of June 2018 and it currently contains information about 37 intermodal terminals (UTK website, 2018a).

It should be emphasized that the President of ORT ensures the non-discriminatory and equal treatment of carriers by terminal operators. In the case where e.g. the Regulations of a particular facility do not meet the requirements of the Act, and this fact results in difficulties for the railway carrier to obtain access to the terminal, the carrier may submit a complaint to the President of ORT (UTK website, 2018a).

6. Conclusions

Intermodal transport in Poland develops slowly but steadily. However, it is difficult to specify to what extent exactly stakeholders take advantage of the existing potential in order to utilise the intermodal alternative on a larger scale and offer more environmentally friendly T&L services. The findings derived from the Delphi study confirmed that there are still a lot of obstacles hindering the desired development of this market and intermodal terminals are among the most important ones.

A large number of terminals in Poland differs unfavourably from standards met in Western European terminals, requiring substantial improvements (and, in consequence, a significant financial contribution). It is also necessary to undertake other measures, e.g. based on a wider cooperation on the intermodal market participants, which could lead to a better utilisation of terminals in the future.

Recent changes in the policy regarding intermodal facilities and making them "open" are an example of such measures. Given that the lack of open access to terminals was considered problematic by all Delphi panellists and achieved a high score of consensus, it may be assumed that this measure, although taken with much delay, was welcomed with enthusiasm by the intermodal transport stakeholders. The process of making terminals in Poland open is ongoing, but this is only the first step on the long road to improvement and results are difficult to forecast. Undoubtedly, however, a change in perception with regard to this issue can be observed.

It also must be recognized that potential development of intermodal transport may also bring new challenges for intermodal terminals, as rising cargo handling volumes would require further improved cooperation and dedicated IT solutions.

The findings of this study are not limited to the Polish market, but have broader implications and can help in understanding the phenomena occurring in other transport and logistics markets, especially those still developing or less mature.

It would be interesting to investigate in the future the influence of the new "open access" policy on operational performance measures of terminals (e.g. changes in handling volumes, number of connections/calls, number of rail undertakings with access to terminals), as well as to research to what extent it could influence the process of greening T&L services.

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CONTROLLING TIME COMPONENT OF LOGISTICS ACTIVITIES AT DELIVERY POINT USING STATISTICAL PROCESS CONTROL

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Abstract: In goods delivery process there are lots of activities such as: order processing, order preparation, transport, control of the delivered goods, etc. In this paper, process of goods handover at the delivery point was analysed in detail. Analysed data was collected from a logistics provider, who is supplying markets at the gas stations, for a period of 22 days. During these days, provider had 1783 deliveries. Based on duration of certain activities it was concluded that the most savings can be achieved by optimizing delivery time. Main cause for longer handover is the large number of order lines, as well as quality and quantity controls. Efficiency of this process is crucial since saving time during this process, saves cost as well. In order to determine whether process is statistically controlled, in this paper, Statistical Process Control (SPC) was used. When delivering, goods are placed on pallet which must be checked at the delivery point. Processes of quality and quantity control are done simultaneously with goods handover, and were also analysed. Process was controlled in most of the analysed days, except one when handover time was longer than usual and influenced on process to go over the control limits. Determined day when uncontrolled process occurred was than analysed in detail. Some corrective-preventive actions in order to improve delivery process are also defined. Based on the results it can be concluded that the proposed methodology is very useful for improving process time.

Keywords: Statistical Process Control, control chart, unloading time, quality control, quantity control.

1. Introduction

Distribution process besides picking is one of the most intense and most demanding processes since lots of resources in terms of people and vehicles are required. Unlike picking process, distribution is characterized by the fact that it allows direct contact with the customers, which based on this process can create perception of the quality of the provided service, since everyone wants the right goods, in the right amount, in the right place and in the right time. Based on previous sentence it can be concluded that time component is one of the most significant in distribution process. For this reason monitoring distribution time component is of great importance, since the delay in distribution causes a number of problems such as complaints, the dissatisfaction of the customer, additional costs, creating wrong perception of the service quality and others.

Distribution is characterized by a series of interconnected and conditioned activities and processes. These processes are receipt of the order and processing of the same, issuance of the picking order, preparation of goods and delivery of the goods to the customer. Monitoring realization time of the above mentioned processes is of great importance if increased efficiency of the process and cost savings are desired. In this paper, distribution times from the retailer's distribution centers (DC) to the stores on gas stations were observed. The observed times were then analyzed using a control chart to determine on which days an uncontrolled process occurred. After the application of the control chart for all observed days, the same was applied for the day that was uncontrolled to determine when the uncontrolled process occurred during the day. Reasons for the longer distribution time can be numerous and will be analyzed in this paper.

The paper is organized as follows. In first chapter a problem description is provided. In the next chapter tools for time controlling were analyzed. In the final chapter results of the analyzed problem are provided as well as prepositions for the process improvement. At the very end of the paper final conclusions and directions of the future research have been made.

2. Problem Description

The distribution process represents a link between ordering and goods delivery, which is realized through its channels. A distribution channel can defined as a system of individuals and organizations aimed at directing the flow of goods and services from producers to the consumers. Depending on the relationship between the seller and the buyer, there are different types of distribution channels. The basic type of distribution channel is a direct channel where there is no intermediary between the manufacturer and the end consumer. This type of distribution channel represents the shortest and simplest form of product distribution. Mostly smaller and more frequent deliveries are realized through this type of channel. The next type of distribution channel implies the participation of distributors in distribution process through manufacturer's network. The characteristic of this type of channel is that manufacturer has a certain amount of final products in stock in their distribution centers, from where it is then transported to the retail. It is important to note that deliveries to the distribution center are carried out with larger vehicles of higher capacity with homogeneous load while distribution is carried out with vehicles of less capacity. The disadvantage of using this type of channel lies in the fact that all logistics resources are owned by the manufacturer. As a mediator, beside distribution network of the manufacturer, the distribution network of seller can be present, which is the third type of distribution channel. This type is identical to the previous one with only one difference, and that difference is that all logistics resources are owned by

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the seller. The disadvantage of this type of channel is reflected in lower dedication in core business by the seller. The fourth type for intermediary has wholesalers which are purchasing products from manufacturers and then selling them to the retailers. In order to eliminate lack of the third type of distribution channel a 3PL provider is introduced as an intermediary who carries out logistics activities for the manufacturer. The advantage of this type of channel is reflected in the fact that a logistics provider can perform distribution at a lower cost. The last type of channel as a intermediary has a broker. This type is rare and is mostly used in trading channels (Andrejić, 2015).

As previously mentioned, subject of this paper is distribution of the goods to the markets on gas stations. The distribution process itself is organized as follows. Before the distribution process there are certain processes that precede and must be realized in order to realize the distribution process. Namely the entire process begins by customer sending its order in accordance with its needs. Upon receipt order is processed and picking order is issued. After picking the goods are loaded and are distributed to the end-users. The described processes are shown in Figure 1.

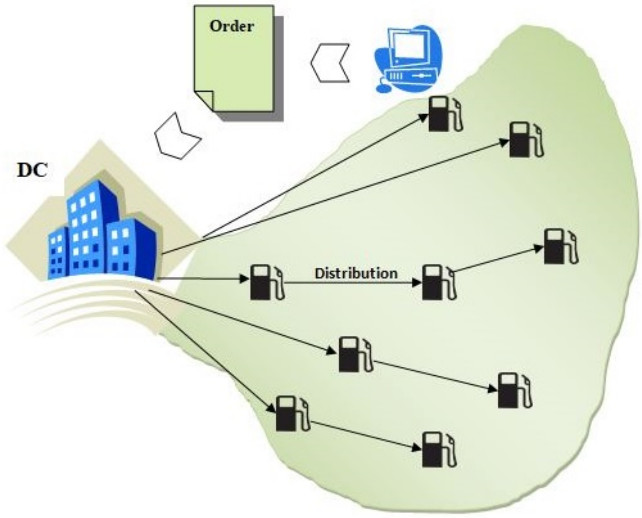

Fig. 1.
Distribution process

In the analyzed case, it can be concluded that this is a type of distribution channel where the network of the seller appears as an intermediary. In this case, the goods are being delivered from 5 DCs to 300 markets on gas stations. In the process of delivery 100 vehicles of different categories and capacity are used.

3. Tools for Time Control During the Process of Delivery

The tools for monitoring certain distribution processes are numerous, however in most cases the statistical process control (SPC) is used in the literature where the process capability indices are calculated and the control chart is used to visualize the uncontrolled process. In logistics, control chart can be used to monitor numerous parameters, both time as in this case, as well as other parameters. A common goal in all these different applications is to improve the process and to make it more efficient. Thus Sousa et al. (2017) applied SPC to improve the production process and thereby improve product quality. By applying these tools, the authors came to the conclusion which are the main causes of product quality variation. The SPC can also be used to determine capability of certain processes (Kilibarda and Andrejić, 2014). Costantino et al. (2015) applied SPC and control charts to improve inventory replenishment in supply chain thus lowering uncertainty and improving supply chain performance. In this paper SPC and control charts were also used since the aim of the paper was to determine if and when uncontrolled process occurred, and to determine capability of delivery as well.

3.1. Statistical Process Control (SPC)

Statistical Process Control (SPC) represents tool used to determine process capability, in order to improve quality of the product thus lowering cost of the production lower quality products or damaged ones. Three methods are used to determine process capability: diagram of dispersion, control charts and index method used to represent process capability. Applying the SPC determines whether the process is statistically controlled or it is necessary to apply some of the corrective-preventive actions in order to improve process. Diagram of dispersion and control charts give a graphic representation of the process control using control limits, given that if the process is within the control limits, then it is also controlled. Otherwise it is uncontrolled process that needs to be monitored and improved. In contrast to these methods, the index method examines the ability of the process over a set of indexes such as:

- Potential Capability index - Cp;
- Process Capability index - Cpk.

Relationship between these two indexes is shown in Figure 2.

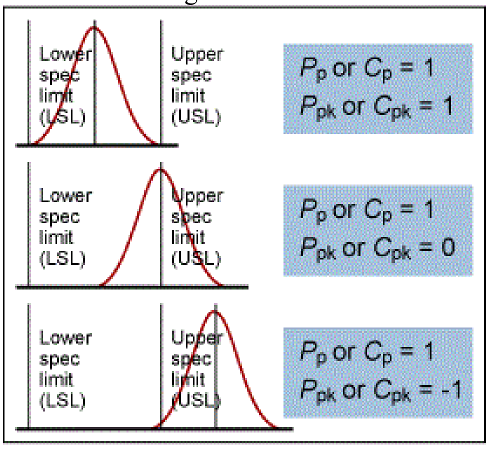

Fig. 2.
Relationship between Cp and Cpk
Source: (*Berardinelli, 2018)*

It is important to note that when calculating the Cp and Cpk indexes, following conditions must be met: the observed sample is large, normal distribution of the sample, the process is stable. When these conditions are not met, the obtained data are not valid.
Cp and Cpk indexes in this paper are calculated using formulas (1) and (2) shown below. Based on formula (1) it can be concluded that Cp index was obtained by dividing the difference between the upper (UCL) and the lower (LCL) control limits by 6σ. Sigma in the formulas represents a standard deviation that is counted for the observed sample. In the case of Cpk index a minimum value is obtained, either as a fraction of a difference between the upper control line and mean value divided by 3σ or as a difference between the mean value and lower control line divided by 3σ.

$$Cp = \frac{UCL-LCL}{6\sigma} \quad (1)$$

$$Cpk = \min\begin{cases}\frac{UCL-\bar{x}}{3\sigma}\\ \frac{\bar{x}-LCL}{3\sigma}\end{cases} \quad (2)$$

Based on the value of Cp and Cpk, process can be:
- Cp < 1 – process should be redesigned
- Cp around 1,33 – process should be controlled
- Cp > 1,6 – process is non-critical

3.2. Control Charts

As already mentioned, control chart is one of the way of showing process capability. A control chart can be defined as a chart used to determine how the process changes over time. This chart consists of 3 lines, which represent the upper control limit, the mean value and the lower control limit (Pajić *et al.,* 2018). If a process that is being monitored by its value exceeds the control limits, then the process is considered statistically uncontrolled and needs to be improved.
When analyzing the processes, a wider tolerance zone was first used, where the lower and upper limits were determined on the basis of 3σ, after which the zone of tolerance with the limits determined on the basis of 2σ was used. When it comes to a wider zone of tolerance, all processes are within the limits, which implies control, but when observing narrower tolerance zone, the days with uncontrolled processes were observed. The obtained average values are shown on the control chart. On the basis of these values, the values of the upper, lower control limit as well as the mean value and standard deviation were determined. In determining the upper and lower control limit, the 2σ approach was used, for the above mentioned reason. This means that the value of the upper control limit was obtained as the sum of the mean value and standard deviation multiplied by 2. The lower control limit was obtained as the difference between the mean value and standard deviation multiplied by 2. Observing the control chart in order to determine an uncontrolled day, it was determined that this was on the 18th day when the delivery lasted longer than usual, which led to the appearance of an uncontrolled process (Figure 3)

Fig. 3.
Delivery times per days

Based on Figure 3 it can be seen that besides 18th day, the process was out of the control limits and on the 17th day, but it was not observed considering that it went over lower control limit, which means that this is even better result, i.e. shorter delivery time than lower control limit.

4. Results

In this paper, times of goods handover in the markets on the gas stations were analyzed. The data was collected from retailer who provides logistics activities to the markets at the stations and a total of 1783 handovers during 22 days were analyzed. In order to determine on which day(s) the uncontrolled process occurred, control charts were used. The values on the control chart were obtained as the average time of all realizations during that day. The number of realizations as well as duration of each varies depending on the day (Figure 4).

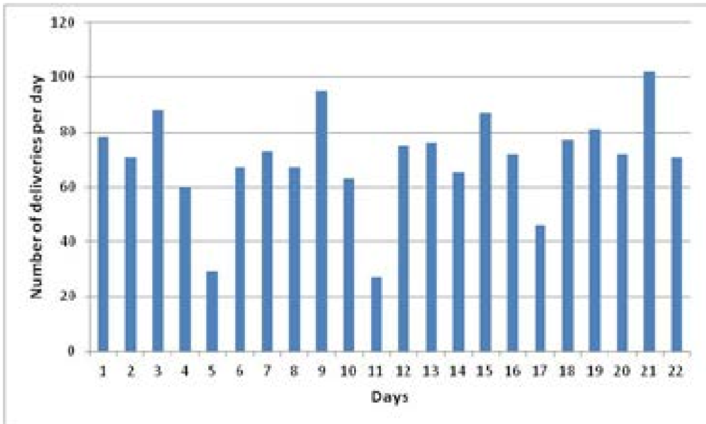

Fig. 4.
Number of deliveries per day

When comparing Figures 3 and 4, it can be seen that even though the 18th day is not the most affected day by the number of deliveries, it was still the day which was uncontrolled. In order to determine the capability of the process, Cp and Cpk indexes were calculated according to the formulas shown earlier in the paper. Based on these formulas, the following values were obtained: Cp=1.28 and Cpk=1.28, and based on these results, it was concluded that the process should be controlled (Kilibarda and Andrejić, 2014).

After defining the day that was statistically uncontrolled, the same was analyzed in detail. Given that there were 72 deliveries on that day, the total number of deliveries was divided into three charts, each containing 24 delivery times (Figure 5). And in this case the control limits are determined in the manner described earlier. However, in order to obtain the relevant value of the standard deviation used to calculate the control limits, the entire sample was taken into consideration and based on it the standard deviation was calculated and then applied to all three charts. In this way it was achieved that the value of the standard deviation is identical, since otherwise the value would be different in all three charts and obtained data would not be relevant.

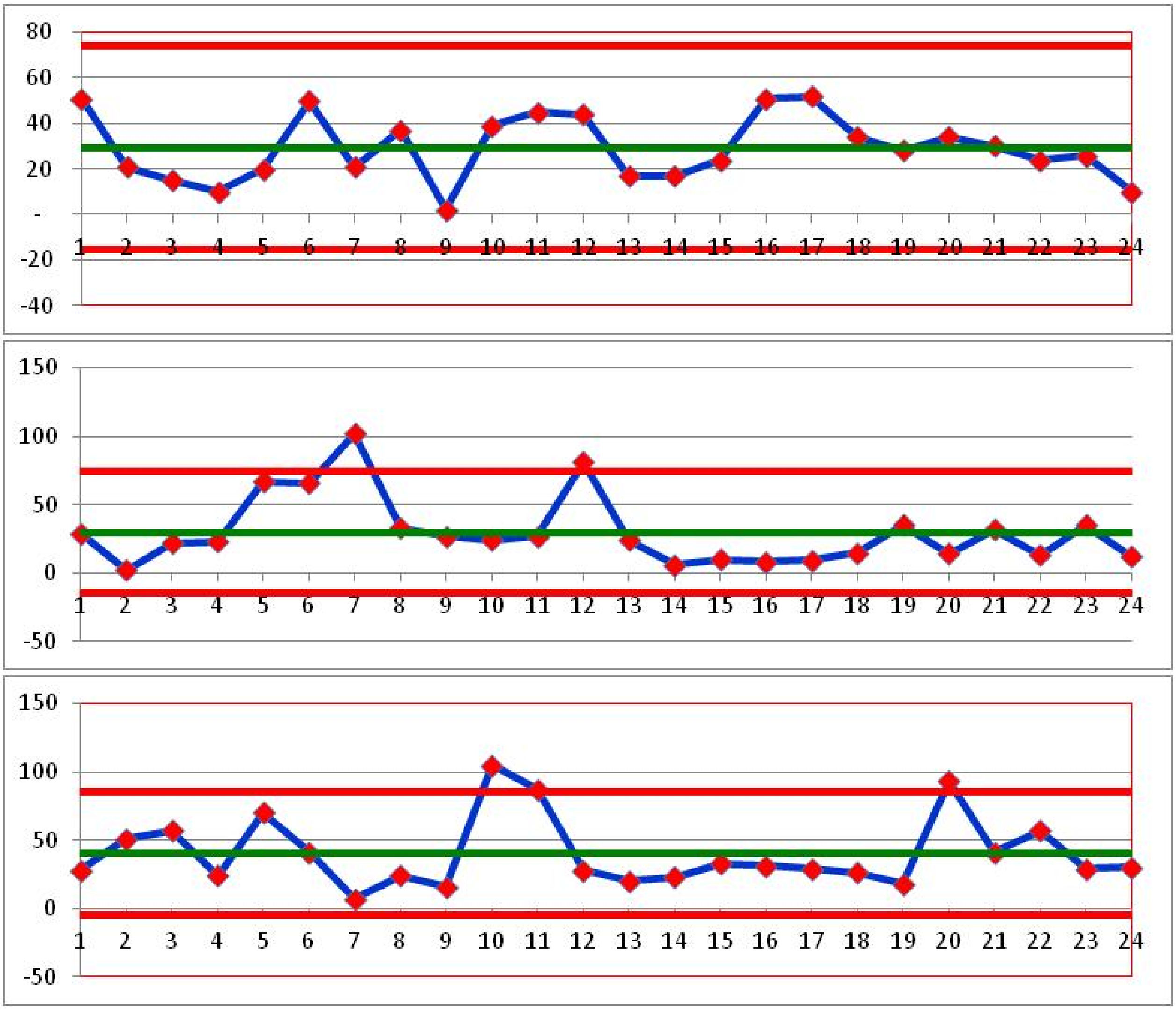

Fig. 5.
72 deliveries during the uncontrolled day

Of the total number of crossing over control limits on the displayed control charts, in two cases, crossing occurred in the morning hours (9:30 am and 10:09 am) while the remaining three occurred in the afternoon hours (13:51, 14:30 and 16:01 pm).

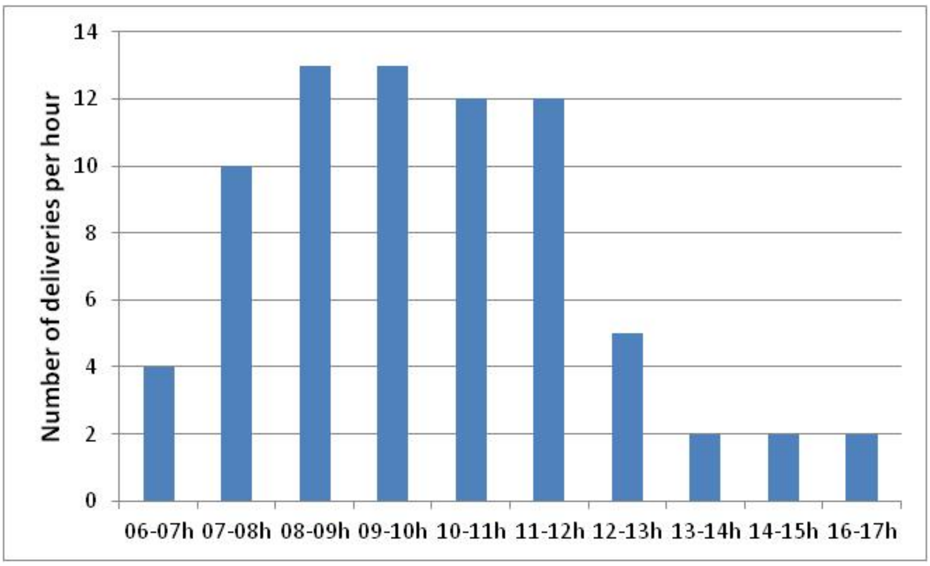

Fig. 6.
Number of deliveries per hour on the uncontrolled day

The reason for this may be the fact that there is a greater demand in the afternoon hours than in the morning hours, as confirmed by Figure 6 from which it can be seen that although there were much less deliveries in the afternoon hours than in the morning hours, the afternoon ones lasted longer. Also during the handover of goods, the presence of the employees of the gas station is necessary since the quantitative and qualitative control is carried out. Qualitative control refers to the shelf life of the product, while counting delivered products represent quantitative control which lasts longer. The reason for the long quantitative control is in fact that gas station stores require smaller quantities of products (often less than the unit of packaging). Another reason for the increased delivery time may be the crowd at the gas station itself, and as the presence of the workers during unloading is necessary, this may result in extended delivery time.

As a potential corrective measure in this case, the delivery time frame may be defined, in order to carry out delivery in periods of the day when the smallest crowd is at the station and when there are a greater number of workers who could receive the delivery. Also another solution can be night delivery in order to avoid crowds and thus speed up the delivery process. Reducing the duration of the quantitative and qualitative control could be achieved by using boxes that would be closed after picking and which could not be opened until the moment of the receipt of the goods, using a seal or a padlock. In this way, for any disagreement in quantity and/or quality retailer would be responsible, which would speed up the acceptance of goods at the gas stations thus shortening the delivery time.

5. Conclusion

Based on the analyzed case the importance of monitoring the time of certain logistics activities during the process of goods delivery can be seen. By reducing the time of realization of certain activities, many savings can be achieved, both in time and in costs. In order to determine the process control as well as the assessment of capabilities, control charts and statistical process control (SPC) were used. During the observed 22-day period, only one uncontrolled process occurred, which was then analyzed in greater detail. This more detailed analysis actually refers to the observation of that day to the hour level in order to determine in which moment during the day the uncontrolled process occurred, i.e. when the delivery lasted longer than usual. Only one day was uncontrolled, which speaks of the quality of the logistics service provided by the retailer. Finally, certain corrective and preventive measures that could be implemented to improve the delivery process are proposed.

Future research could be conducted in several different directions. The first direction relates to the research of new technologies (vehicles without drivers, drones, etc.) that would perform more frequent and less deliveries. The second direction refers to exploring the possibility of applying advanced information achievements and better linking of all participants of the supply chain. At the very end, there is a study of the human factor and the elimination of errors that arise as a consequence of the mentioned factor.

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LOGISTICS CENTRES IN POLAND FROM THE PERSPECTIVE OF EUROPEAN STANDARDS – STATUS QUO AND DEVELOPMENT OPPORTUNITIES

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Abstract: For several decades, the Logistics Centres (LC) (also known as freight villages) have constituted an important element of the logistics systems in numerous countries. In Europe, there are over 240 facilities of this type. In each country, we can observe certain specificity of the Logistics Centres. It refers to the terminology and the applied organizational and legal solutions, as well as the number of premises. Despite some differences, the European LC have been developing based on a common set of criteria promoted by EUROPLATFORMS (related, *inter alia*, to the service offer, issue of intermodality and managing entity). Thanks to their attributes, the Logistics Centres satisfy the requirements of the sustainable development of transport. Many stakeholders in Poland have already shown interest in the Logistics Centres. At present, Poland is one of the most desirable logistics locations in Europe. However, we can observe here only several typical Logistics Centres where small share of modern warehouse space is located (today, in Poland, the resources of commercial space amount to more than 13 million square meters). Therefore, the aim of this paper is twofold 1) to present the current state of Logistics Centres development in Poland and analyse to what extent they meet the European standards 2) to identify determinants for the development of Polish Logistics Centres. In order to fulfil the main objectives of the paper a review of literature as well as analysis of statistical data, reports, documents published by the governmental agencies, real estate agencies and consultants have been conducted. In addition, comprehensive content analysis of websites, newsletters of Logistics Centres in Poland has been performed. The paper provides characteristics of the Logistics Centres existing in Poland, taking into account, *inter alia*, their structure, organizational and legal form and service offer. Factors affecting the development of LC in the Polish seaports and inland have been indicated. The paper also includes SWOT analysis of the Logistic Centres in Poland. The conclusions resulting from the analysis may constitute guidelines for other countries where Logistics Centres are planned and developed.

Keywords: logistics centres in Poland, freight villages, sustainable transport development.

1. Introduction

Logistics Centres are transport and logistics infrastructure facilities which have constituted important elements of macro-logistic systems of numerous European countries for several decades. In some of them (e.g. in Germany) LC were build in the second half of the 1990s. In Poland, the issue related to their development appeared in discussions of theoreticians and practitioners almost at the same time - at the end of the 1990s. At that time, the first significant planning works began. In 2000, the analysis results were published indicating the location for six Logistics Centres in the country (situated at the intersection of the existing and planned infrastructure of various modes of transport) (Krzyżanowski, 2000, 17). It must be mentioned that Poland at that time was at the beginning of economic transformation and development of market economy. The lack of modern warehouses in the country and the development of TSL market and trade represented opportunity for LC development, generated demand for such facilities. At the same time, due to years of negligence, in the country there were almost no highways, there was a shortage of railway lines of proper standard and intermodal terminals. The ownership issue of numerous plots of land was also problematic. In the country, the bodies of local government were only brought into being and there was a shortage of good practices and rules regarding Public-Private Partnership. Till today, only a few Logistics Centres have been established in Poland, and they meet the European standards to various degree. The present stage of LC development in Poland has been affected by numerous factors of different nature. In time, new determinants have occurred and will provide the direction for LC development in Poland. They will be specified further in the article.
The aim of this paper is: to present the current state of Logistics Centres development in Poland, analyse to what extent they meet the European standards and to identify determinants for the development of Polish Logistics Centres. The author has already conducted research on the concept of Logistics Centres (Miklińska, 2008), selected problems related to LC (Miklińska, 2015a), and the development of LC in the Polish seaports (Miklińska, 2015b). Today, after several years and subsequent changes which provided new requirements, it was decided to extend research and perform analysis of the current state of LC in Poland. In order to fulfil the main objectives of the paper, a review of literature as well as analysis of statistical data, reports, and documents published by the governmental agencies, real estate agencies and consultants have been conducted. In addition, comprehensive content analysis of websites, newsletters of Logistics Centres in Poland has been performed. The paper also includes SWOT analysis of the Logistics Centres in Poland.

2. European Standards and Attributes of Logistics Centres - Literature Review

In particular European countries, to define logistics facilities which constitute the subject of analysis in this paper, the following concepts are used, e.g.: freight villages, Güterverkehrszentren, Interporti. Despite terminological differences, in the development of European LC we can indicate some common features. They include a set of general criteria – attributes. They have been included in the most popular, in reference literature, definition of Logistics Centre concept

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(earlier - freight village) provided by EUROPLATFORMS: „A Logistics Center is a center in a defined area within which all activities relating to transport, logistics and the distribution of goods – both for national and international transit, are carried out by various operators on a commercial basis. The operators can either be owners or tenants of buildings and facilities (warehouses, distribution centres, storage areas, offices, truck services, etc.), which have been built here. In order to comply with free competition rules, a Logistics Center must be open to allow access to all companies involved in the activities set out above. A Logistics Center must also be equipped with all facilities to carry out the mentioned operations. If possible, it should include public services for the staff and equipment for the users. In order to encourage intermodal transport for the handling of goods, a Logistics Center should preferably be served by a multiplicity of transport modes (road, rail, sea, inland waterway, air). To ensure synergy and commercial cooperation, it is important that a Logistics Center is managed in a single and neutral legal body (preferably by a Public-Private-Partnership). Finally, a Logistics Center must comply with European standards and quality performance to provide the framework for commercial and sustainable transport solutions" (EUROPLTFORMS EEIG).

Under this definition, as well as other studies of the said organization (EUROPLATFORMS EEIG, 2015, 4), the main features of LC have been distinguished: multi-stakeholder approach, defined principles regarding LC property (usually, ownership or lease), open access, multimodality, modern LC facilities, management body (preferably PPP), cooperation of entities within LC, achieving synergy effects, compliance with sustainable transport requirements. The requirements LC should meet have been analysed further in reference literature. Recently, numerous publications have been dedicated to the issues of green solutions in LC – the issue of greening LC (Altunaş&Tuna, 2013, 59-80) and their sustainable development (Baydar, Süral, Çelik, 2017, 1214). The issue of Logistics Centres location and methods to determine them has been analysed as the idea of fundamental importance for the success of LC (Kayikci, 2010, 6297; Özceylan et. al., 2015, 38). Moreover, reference literature provides numerous mentions on synergy effects achieved, e.g. in German LC (Winkler&Seebacher, 2012, 399-410), significant attention is also devoted to the structure of entities managing these LC (Nestler&Nobel, 2009, 332-333). Furthermore, already in the 1990s, city-logistics projects completed with the participation of LC constituted a significant area of interest in Germany; it was the hallmark of those centres (ISL&LUB Consulting GmbH, 2010, 4). Over the years, under the changes in environment the Logistics Centres have been facing new requirements. Today, the challenges ahead of them include: digitalization, e-mobility and introduction of autonomous vehicles (DGG, 2018).

The previously specified attributes constitute a very general set of criteria. In the case of each country detailed solutions are determined by the existing economic and legal conditions or technical and technological ones, e.g. conditions within transport infrastructure. It is difficult to enumerate unambiguous requirements and technical standards LC should meet. Under the document developed by EUROPLATFORMS we can indicate particular regularities in the development of LC in Europe. In 28 EU countries there are ca. 240 LC, and countries with the largest number of them include: Germany (35 LC), Spain (33 LC), France (26 LC) and Italy (21 LC) (EUROPLATFORMS EEIG, 2015, 16). The average area of the European LC amounts to 108 ha; however, their size in particular countries is very diversified and fluctuate from several to even several hundred hectares (EUROPLATFORMS EEIG, 2015, 16). We need to mention that LC from Italy, Germany and Spain rank among the top ten in the European LC from 2015 (ISL&DGG 2015, 5). It is worth focusing on Germany – a country which ranks first in Europe regarding the number of LC. In this country the total area of LC amounts to 6,132 ha, which generates the average size of LC - ca. 175.2 ha (EUROPLATFORMS EEIG, 2015, 16). The German LC are also characterised by multi-stakeholder approach since already in 2010, in all facilities there were ca. 1,300 enterprises (there are on average 37 enterprises per one LC) (ISL&LUB Consulting GmbH, 2010, 4). From the perspective of meeting the principles of sustainable development it is important that all German LC have direct access to the infrastructure of at least two transport modes, and 20 of them are trimodal LC. Furthermore, in almost all LC or in their vicinity intermodal terminal is located. In this respect, data of all European LC is not so optimistic. The majority of LC meet the requirement of multimodality, 100 LC have direct access to two modes of transport, 105 LC – to three and 15 to four transport modes. We also need to indicate that 20 LC from among the 240 specified in Europe have direct access to the infrastructure of only one transport mode. The location of the majority of European LC complies with the location of key nodes of the Trans European Transport Network (EUROPLATFORMS EEIG, 2015, 18-50).

3. Requirements and Determinants for the Development of Logistics Centres in Poland

From the initial plans till today, only several typical Logistics Centres have been established in Poland (they are characterised in Table 1). Their development has been affected by numerous factors, mainly economic and geopolitical ones related to international trade, development of the national transport system, including mainly the development of linear and nodal transport and logistics infrastructure. Significant factors have been indicated below.

As mentioned before, the construction of LC was planned in Poland only several years after the beginning of political and economic transformation and development of market economy. Economic relations changed and new trade partners became important. Before the transformations of 1980, the main trade partners of Poland included: Soviet Union, Federal Republic of Germany, East Germany and Czechoslovakia. Already after the transformations significant change was observed; at that time, the countries with the largest share in trade with Poland included (in 2000) Germany, Russia, Italy and France, and recently (2016) they include, in the import of goods: Germany, China and Russia, and in export: Germany, Great Britain and Czech Republic (Central Statistical Office, 2008 and 2017). Such fact affected the change in the directions of cargo transport and the new requirements regarding the location of nodal infrastructure facilities. In Poland, as in other European countries, the change was affected by the development of globalization and offshoring – moving the production to Far-East markets. Today, e.g. thanks to geographical location, Poland, by means of trade with China, as well as location on the cargo transit route constitutes an important European point on the map of New Silk Route - One Belt One Road (OBOR) Initiative. The fact provides opportunity for intense cargo handling and may generate the need to establish another modern LC in the future. While discussing global cargo transport we need to indicate that today over 80% (by volume) and over 70% (by value) of global trade cargo is carried by sea; the volume of containerized cargo transport has still been increasing (UNCTAD, 2017, 1-12), which generates requirements also for the Polish seaports and LC located in these ports.

Taking account of infrastructural requirements, we need to indicate that in recent years the situation in transport infrastructure in the country has been improving. In the case of road transport – in 2000 in the country there were 250 000 km of hard surfaced roads, in 2005 - 254 000 km and in 2015 already 420 000 km. Moreover, we need to indicate that in 2000 there were only 358 km of highways, in 2005 - 552 km, and in 2015 – 1 559 km. In the case of railway infrastructure the situation regarding the length of tracks deteriorated since in 2000 there were 22 560 km of tracks in operation, in 2007 – 20 107 km, and in 2016 – 19 132 km (Central Statistical Office, 2008 and 2017). We need to emphasize that since 2000 nearly 3 500 km of tracks were taken out of operation, due to lack of financial resources for their modernization. However, at the same time numerous main rail roads were modernized, which contributed to improving the situation on important transport routes. In relation to the opportunities for LC development, in particular trimodal ones, we also need to pay attention to inland waterway transport. In Poland, this mode of transport is characterized by extremely low share in the total volume of transport and amounts only to ca. 0.3% related to the weight of transported cargo. The situation results, *inter alia*, from infrastructural negligence. Over the last several decades, the length of waterway recognized as navigable has decreased - in 2000 there were 3 813 km and in 2015 – 3 655 km (Central Statistical Office, 2008 and 2017). Unfortunately, the majority of inland ports are also in poor technical condition. One of few exceptions can be found in Gliwice port, located at the Oder River, which constitutes part of Silesian Logistics Centre (Table 1); similar situation can be observed in Szczecin.

In recent years, various stakeholders take actions supporting the development of intermodal transport in Poland. From 2008, the volume of railway intermodal transport increased from 4.8 million tons to 14.7 million tons in 2017; moreover, more and more railway carriers decide to handle such transport (in 2017 there were already 18 of them) (UTK, 2018, 2). However, the share of intermodal transport (measured by transport performance) in the railway sector amounts only to 8.8% (in 2016); to compare - in Germany in 2015 it is 37.9% and in Switzerland 50.7% (UTK, 2017, 6). Therefore, there is still significant potential for development.

Today, in Poland there are over 30 intermodal terminals. The experience of many European countries proves that close vicinity of terminals inland as well as those located in seaports constitute one of the main factors affecting the LC location. Therefore, attention should also be paid to the development of sea container terminals in Poland. Over the last several years, some new facilities of such type have been established and their role has strengthened, and even the world largest sea-going container vessels call at one of them, namely Deepwater Container Terminal (DCT) in Gdańsk. Recently, we can observe significant increase in the volume of containerised cargo handling in the Polish seaports. In 2000, 448 655 TEU was handled in total, in 2012 already 1 656 927 TEU, and at the end of 2017 - 2 384 785 TEU (at the above mentioned DCT 1 580 508 TEU) (Matczak&Ołdakowski, 2010; Rozmarynowska-Mrozek&Ziajka, 2018, 4). At each of the three largest Polish seaports there is a Logistics Centre, although each developed as per slightly different model (Tab.2). Unfortunately, too few LC are established in seaport hinterland area, connected with intermodal terminals already located in that area, to play the role of dry ports, e.g. as per German model (Olah&Nestler&Nobel&Popp, 2017, 2). In conclusion, over the past years the situation regarding the development of transport infrastructure in Poland has improved. For several years, significant efforts regarding the construction of new infrastructure and modernization of the existing one focus on facilities located along two core network corridors TEN-T in Poland: Baltic-Adriatic and North Sea-Baltic.

One of the main factors affecting the current position of LC in Poland involves the development of modern warehouse space market. Warehouse facilities constitute basic elements of the European LC. Unfortunately, in Poland modern warehouses are predominantly located outside the typical Logistics Centres. It results from the fact that during the construction of warehouses the Logistics Centres in Poland failed to provide such opportunity due to their low number. Therefore, the question arose why typical LC in Poland were not established although it was known there were needed and there were plans for their locations. The factors which caused such situation were numerous, e.g.: lack of financial resources, issues with the development of linear transport infrastructure (leading to LC), ownership issues regarding land and transfer of ownership, lack of optimal regulatory solutions and good practices regarding PPP (the first act enacted as late as in 2005, and another in 2008). Therefore, what was the history of the development of modern warehouse space market? We need to indicate that still in 1996 in Poland there were virtually no modern warehouses. Over several years, the situation changed significantly. It happened thanks to a number of factors generating demand for modern warehouses, *inter alia*: development of chain stores in Poland, development of logistics services market and in recent years the development of e-commerce market, with rather low labour costs and costs of warehouse construction. As a result of those and other determinants, at the end of 2017 market resources reached ca. 13.5 million m^2. On the Polish market, there are warehouses of the largest global and European developers (e.g. Prologis, Panattoni, Segro, Logicor and Goodman) (JLL, 2018). As mentioned before, in the years of dynamic development of the modern warehouse space market, there was (and still is) a shortage of Logistics Centres and developers located their warehouses in places of their choice. Therefore, a significant number of modern warehouse space in Poland fails to meet the

requirement of multimodality – most of warehouses have access only to road transport infrastructure and fails to have direct access to intermodal terminals. From the perspective of sustainable development of transport it is very unfavourable. We also need to indicate that locating warehouses outside typical LC makes it impossible to include them into IT systems, connecting various users, e.g. similar to Port Community System (Marek, 2017, 457). It also limits the possibility to achieve synergy effect, which is possible in typical LC thanks to the cooperation between enterprises.
However, we need to look to the future. Today, Poland is one of the most wanted logistics location in Europe (Prologis, 2017,1); significant increase in warehouse space is predicted. Together with the construction and development of another LC it would be possible to locate the newly built warehouses within the structure of LC. There is no doubt that the development of warehouse space market and potentially also LC will be affected by new determinants, at least the ones resulting from the need to build warehouses for e-commerce customers, where warehouses must be located closer to final clients as well as more and more important warehouse automation.

4. Characteristics of Logistics Centres in Poland

As indicated above, the criteria for distinguishing logistics centres from among other logistics facilities are not precise. Consequently, the nature of existing facilities is disputable and, therefore, in some countries it is difficult to indicate the actual number of LC. In Poland, there are several areas and facilities (e.g. in Mszczonów and Żurawica-Medyka) that develop into typical LC. While discussing the stage of development of Logistics Centres in Poland, the author provided characteristics of facilities specified as LC in the publication of EUROPLATFORMS, 2015, which include: Pomeranian Logistics Centre, Logistics Centre in Port of Gdynia, Logistics Centre in Port of Szczecin, Silesian Logistics Centre, Multimodal Logistics Centre CLIP Group, Euroterminal Sławków. Moreover, one additional facility was analysed - Wielkopolska Logistics Centre, which, according to the author, features important attributes, making it possible to recognize the facility as Logistics Centre (and is recognized as such in literature -Lipińska-Słota, 2008- and in practice). The analysis was conducted mainly under information provided by Logistics Centres (on their websites and in publications). Due to limited length of this study, the author selected and presented several main groups of LC features (Table 1), crucial from the perspective of European LC concept. They include attributes which enable presenting the stage of development of particular LC in Poland and their comparison.

Table 1
General Information on Logistics Centres located in Poland

Logistics Center	**Location / surface**	**Transport modes / intermodal terminal**	**Management body/ management function**	**Entities operating within LC, their specialty / type of LC services**	**Additional information**
Pomeranian Logistics Centre	in the northern part of the country, by the Baltic Sea, in the vicinity of the Port of Gdańsk and Deepwater Container Terminal (DCT); 9 km from the centre of Gdańsk; the total area of LC ca. 187 ha in area, on area of 110 ha Goodman developer will build warehouses of 500. 000 m^2	road/rail/sea - direct access to DCT, near A1 highway, S6 and S7 express roads, near intermodal terminal at DCT and railway infrastructure	Gdańsk Economic Development Agency (InvestGDA) (100% City of Gdańsk) – total area of LC; warehouse facilities managed by Goodman developer	dominant are warehouse leaseholders in LC from logistics sector; high-tech industry, petrochemical, cosmetic industry	near Tricity – ca. 1 million inhabitants – large market
Logistics Centre in Port of Gdynia	in the northern part of the country, in Gdynia, by the Baltic Sea, in the Port of Gdynia; LC covers the area of ca. 30 ha incl. ca. 20 ha for planned manoeuvre and storage yards;	road/rail/sea - direct access to Baltic Container Terminal (BCT) and Gdynia Container Terminal (GCT) (Port of Gdynia), 40 km to A1 highway, 6 km to S6 expressways, near intermodal terminal at BCT, access to railway infrastructure	Port of Gdynia Authority S.A. (PGA S.A) (shareholders: State Treasury about 99%, Municipality of Gdynia 0.2%, other shareholders)	warehouses (developer - PGA S.A) leased by: Logistics Service Providers, customs agencies and other entities, in LC also industrial properties of other enterprises from various sectors	new intermodal terminal planned within LC
Logistics Centre in Port of Szczecin	in the northwest part of the country, by the Baltic Sea, within the Port of Szczecin near DB Port Szczecin Container Terminal; LC 20 ha in area – internal infrastructure built by port authority; new operator – developer from Waimea Holding group will build warehouses of total area of 45 000 m^2	road/rail/ inland waterway- 8 km to A6 highway and E-65 road – access to railway infrastructure C-E59 and E-59	Waimea Logistic Park – Szczecin Seaport - developer under agreement will manage warehouse facilities	within LC there are several entities from various sectors, additionally bonded warehouse will provide services, Duty Free Zone, logistics services and light manufacturing	recently warehouse market of this region is developing dynamically
Silesian Logistics Centre JSC (SLC JSC)	in south of Poland, in Gliwice - the largest and most universal inland waterway port in Poland; at the beginning of Oder River Waterway; SLC area is divided into two parts 47 ha in Gliwice and 12.58 ha in	road/rail/inland waterway - close to intersection of A1 and A4 highways, access to railway infrastructure, station Gliwice Port and inland waterway Gliwice Port;	Silesian Logistics Centre JSC - Shareholders: Gliwice City (77.78%), DB Cargo Polska S.A. (20.55%),	SLC JSC provides services for: dangerous goods, mineral fertilizers, industrial, neutral and paper goods, food products and	LC located attractive for OBOR Initiative; the new class A warehouse is bimodal –

Logistics Center	Location / surface	Transport modes / intermodal terminal	Management body/ management function	Entities operating within LC, their specialty / type of LC services	Additional information
	Gliwice Sośnica, 59.58 ha in total; total storing area in five class A warehouses equals 28 000 m2	intermodal terminal (area of 5 hectares and capacity of 2.900 TEUs) managed by PCC Intermodal	OT Logistic S.A. (1.32%), other (0.34%)	containerized cargoes; Duty Free Zone and Customs Agency	available for road and rail transport;
Multimodal Logistics Centre CLIP Group	in the central part of the country, near Poznań, at intersection of two TEN-T corridors, North Sea – Baltic and Baltic – Adriatic; LC warehouse facilities include six warehouses A class of total area of 300.000 m^2, another under construction	road/rail- LC located close to S5 expressway and A2 Berlin–Warszawa highway, at E20 railway; near intermodal terminal – total area of terminal 10 ha and storage area 4500 TEU, equipped with dedicated IT system	logistics centre is part of Clip Group	Clip Group offers: logistics and storage services; bonded warehouse services; road and railway transport services; services for containerized cargo; Operator - STS Logistic-services for automotive industry	Member of EURO-PLATFORMS; 15th place in the ranking of European LC; regular transport to/from China within OBOR Initiative
Euroterminal Sławków	in the south of the country, on the outskirts of Silesia Agglomeration; the main part of logistics facility is intermodal terminal of 90.28 ha in area; from 2008 high storage warehouses of 8 000 m^2 were built	rail/road- -direct access to Broad-Gauge Line LHS (1520 mm) of ca. 400 km towards East; connection with CE30 and CE65 lines, road connections: to highways: A1 - 8 km, A4 -10 km, to E40 road - 5 km, intermodal terminal – handling capacity, 284 000 TEU/year	Euroterminal Sławków Sp. z o.o.- shareholders: CZH S.A., PKP Cargo S.A. and PKP LHS Sp. z o.o.	handling of containers, semitrailers and other types of cargo (loose, liquid); services: forwarding and storage (bimodal warehouse); comprehensive customs services – Customs Agency	in 2008 Euroterminal Sławków began the construction of International Logistics Centre
Wielko-polska Logistics Centre	in the central part of the country, LC has the area of 100 ha separated for business activity	road - (unimodal LC); close to intersection of A2 highway and road no 25; railway terminal at E20 railway line in preparation	Wielkopolska Logistics Centre Konin – Stare Miasto S.A.; stakeholders: City of Konin, Stare Miasto municipality and 13 private companies	within LC there are industrial facilities for companies of various sectors; LSP provides forwarding services (road and sea), warehouse and customs services; construction of custom-made warehouses, lease of class A warehouses	one of the first LC in Poland (2001)

Source: own elaboration of the author based on: Port Gdańsk. 2018. http://www.portgdansk.pl; Clip Group. 2018. http://clip-group.com; Gdansk Economic Development Agency. 2018. http://investgda.pl/pcl; Port of Gdynia Authority S.A. 2018. https://www.port.gdynia.pl; Silesian Logistics Centre JSC. 2018. https://scl.com.pl; Wielkopolskie Centrum Logistyczne Konin-Stare Miasto S.A. 2018. http://www.wcl.pl; Port Szczecin-Świnoujście. 2018. http://www.port.szczecin.pl; „Euroterminal Sławków" Sp. z o.o. 2018. http://www.euterminal.pl; Terminals Catalogue 2018; Goodman, Warehouse Space…; ISL, DGG 2015, Positioning and Establishment….

Due to limited length of this study it is difficult to analyse in detail the specificity of each LC indicated in Table 1. With reference to the European standards, we need to indicate that in terms of the number of LC in the country, taking account of the area of Poland, their number is lower than the number of LC in countries of similar area. Whereas, referring to the volume of LC we can indicate that particular LC in Poland, in terms of volume, does not differ from the standards observed in other countries. The largest LC in Poland covers ca. 180 ha and the smallest, several hectares. Taking account of the principles of sustainable development, we need to indicate that apart from one facility, all Polish LC are serviced by at least two modes of transport and two are trimodal. Almost all LC in Poland have access to intermodal terminal. In the facility which fails to provide such solutions, the terminal is already planned.

The service offer of Polish LC is very diversified. In each of them there are mainly handling and storage services as well as a wide offer of forwarding and logistics services. We can also observe certain specialization of services in some LC, for example these located in seaports, near container terminal. They handle containerized cargo carried in international transport. The services rendered by LC in Poland result from the activities of enterprises who run their business activity in LC and, as it is in many cases, rent warehouse space in LC. In some cases, services are rendered by the LC main operator and its leading entity.

With regard to the issues of entities managing the Polish LC, it is difficult to indicate only one model. In some cases, this is the operator as well as the owner and manager of warehouse facilities. At the same time, we need to remember that in some cases, the entity has a complex structure of shareholders including, *inter alia*, railway carriers, city and private entities (e.g. Silesian Logistics Centre) or city, municipality and private entities (e.g. Wielkopolska Logistics Centre). Thanks to such solutions in some cases we can conclude that Polish LC take the form of PPP.

In publications on the activities of Polish LC it is difficult to find any information on cooperation projects between enterprises in LC, on typical City Logistics projects with the participation of LC, or on many green solutions in LC (on the Polish market of logistics services such solutions are already in place – Klopott&Miklińska, 2017). In other countries, e.g. German LC, we can find numerous examples. One of the reasons for such situation in Poland, apart from those related to particular enterprises, may include lack of organization of national character connecting Polish LC and defining significant cooperation projects supporting innovation programs, following the German model of DGG. There is no doubt that such organization should be established.

3. SWOT Analysis of the Logistics Centres in Poland and Conclusion

The previous analyses on factors affecting the actual and future stage of LC development in Poland lead to conclusion providing that they involve areas of different nature. The following, simple SWOT Analysis for Logistics Centres in Poland, instead of conclusion, indicates strong and weak points of LC in Poland and opportunities and threats for their development.

Table 2
SWOT – Analysis of the Logistics Centres in Poland

Strengths	**Weaknesses**
- favourable location of existing LC relative to infrastructure of basic modes of transport and TEN-T, - location of LC in places of high demand for their services, - good condition of transport infrastructure leading to LC, - multimodal character of LC and access to intermodal terminals of almost all LC, - developing service offer of LC, - PPP-related solutions in LC.	- too small number of LC in the country, - uneven spatial distribution of LC in the country, - numerous modern warehouses in the country outside LC, - lack of cooperation projects in LC and poor awareness of their advantages, - lack of significant number of green solutions in LC.
Opportunities	**Threats**
- central location of Poland in Europe and high demand for modern warehouses in Poland, - improved transport infrastructure in Poland and its development within TEN-T corridors, - development of intermodal transport, - increase in the number of PPP projects in the country, numerous good practices of PPP, - development of sea container terminals in Poland, - development of cargo transport within OBOR Initiative.	- construction of new warehouses outside typical LC, - increase in attractiveness of warehouse markets of neighbouring countries, - lack of sufficient interest among enterprises to locate their activities in LC, - lack of current plans for LC development in Poland, - lack of dedicated organization supporting the development of LC in Poland, - changes in economic conditions and trade relations.

Source: own elaboration of the author

The history of Logistics Centres development in Poland was not easy. It involved difficulties common in many countries that went through political and economic transformations and where market economy was established much later than in many neighbouring European countries. Due to negligence in infrastructure, lack of financial resources and first of all unstable formal and legal conditions, today there are only few typical logistics centres in the country. Other countries, in terms of area only slightly larger than Poland have over twenty or thirty LC. Due to unfavourable conditions, in the period of dynamic development of the modern warehouse space market there was a shortage of LC in Poland, where such warehouses could have been located. It is predicated that the resources of the Polish warehouse market will double in the nearest future; therefore, there are opportunities to build some of them in LC and construct another facilities of such type in Poland. We need to emphasize that in 2015 one of the Polish LC – CLIP Group in Poznań succeeded and was ranked 15th among the European LC (ISL&DGG 2015, 5); it is also a member of EUROPLATFORMS. Such good examples regarding Polish LC give hope for their further successful development.

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PROBLEMS REGARDING INTERMODAL TRANSPORT IN THE DANUBE REGION

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Abstract: With the efficient use of intermodal transport for solving the issue of sustainable development and environmental protection, one of the main goals of the international community has been realized, and therefore, it is an important factor in the economy functioning. Apart from these areas, the problems of intermodal transport also reflect on the problems of functioning and connecting globally and locally, and it is important to study, treat and solve them. By reviewing and analyzing national strategic documents, the key problems of intermodal transport in the Danube Region were identified. The areas that needed greater attention were identified, the biggest problems of a different nature (financial and non-financial) were highlighted, as well as those that were not recognized. By analyzing the identified problems, the space for more effective and efficient definition of priorities and measures for solving the shortcomings in the system is opened for the purpose of overall economic development.

Keywords: intermodal transport, problems, Danube Region, national strategic documents.

1. Introduction

National strategic documents are different plans created with the aim of development a certain area within a specific period. They contain defined goals and measures for their realization. For improving the area, it is necessary to identify the problems and link them to the purposeful and targeted actions in order to solve them. This paper presents an analysis of strategic documents that directly or indirectly refer to transport, i.e. intermodal transport (IT) in the Danube Region (DR) countries. The aim of the analysis is to identify the key problems described in the plans - the existing shortage requiring intervention.

The identification of critical areas (the greatest number of problems, the biggest obstacles to the functioning of the system) helps decision-makers to define the proper measures, actions, and direct them to solving the problem. The slightest progress in the area that boosts the problem will be significant. In addition to providing an overview of IT issues, this paper focuses on areas that require greater attention, and are often common to many countries. At the same time, it identifies issues that are not included in the plan, and exist in everyday business. Separating the problem is necessary given the constraints of the different resources and the effectiveness of the proposed actions.

The main goal of IT is applying different modes of transport in order to reduce overall costs and improve the quality of services. Savings in energy, costs and time, less environmental pollution, and other positive effects of IT applications gain increasing attention in developed European countries (Caris et al., 2013). The goals of a competitive and efficient European transport system (EC, 2011) can only be achieved by more intensive development of IT (Zečević et al., 2017). Solving IT problems increases its efficiency and enables its higher market share, and thus the growth of the economy in general. The unit increase in the share of intermodal transport gives rise to the third degree of the unit value of GDP/capita (FTTE, 2018).

The Danube region encompasses 14 countries (EC, 2010), which are mutually different from the aspect of socio-economic indicators, representation and quality of IT, volume of flows and its treatment. Based on these characteristics, in order to analyze the situation in different parts of the Danube region, the countries have been grouped into functional micro-regions (FTTE, 2018).

2. The Biggest Obstacles to Intermodal Transport

In the analysis of the national strategic documents in DR countries, the 43 problems have been identified. Their representation in different countries differs and is the greatest in the strategic documents of Croatia (MoSTI, 2014), Serbia (MoCTI, 2008, MoCTI, 2015), Ukraine (Dornier at all, 2016) and Moldova (GovMD, 2013), while it is the least in the documents of Austria (Lakatos et al., 2015; BMNT, 2002; MBVIT, 2011a; BMVIT, 2011b) and Germany (BMVI, 2010).

The biggest obstacles to IT development are the problems that directly affect the potential user. They relate to subsystems, elements of the IT system (intermodal units, transport means, transport infrastructure, terminals and terminal networks, operators, service providers, organizations, telematics), regulation and institutional framework. The problems that have the strongest impact on the development of IT make 41.72% of the identified ones, and are shown in Table 1.

Table 1
The most important problems of IT in strategic documents of Danube Region countries

Problem	Participation in	The number of

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	all identified problems (%)	countries in which it was recognized
Lack of information and communication technologies (ICT)	5.69	12
Railways	4.74	10
Lack of (appropriate) terminals	4.27	9
Obsolescence and lack of vehicles	3.79	8
Time of travel	3.32	7
Unregulated law in the field of intermodal transport	2.84	6
Outdated technology in terminals	2.84	6
Customs formalities and offices	2.37	5
Permitted axle pressure (min. 22.5 tones/axle)	2.37	5
Connection of other hubs	2.37	5
Institutional framework	1.90	4
Sailing conditions	1.90	4
Delays at border crossings	1.90	4
Connection of city terminals/hubs	1.42	3

The outdated vehicles, especially those in rails and in water transport, are common problem faced even by the developed countries. These assets are more expensive than road ones, which compensate for their longer lifespan and permeability. It is not a rare situation that there cannot be found the required number of R rail truck, intended for the transport of intermodal units, in the European network. In addition to transport vehicles, the lack of intermodal transport units (ITUs) was also observed. Besides, there is a significantly smaller number of ITUs owned by a service provider (they are mostly owned by a sender/recipient of goods). In this field there is a considerable space for saving and improving efficiency.

Constraints at border crossings can be conditioned by the duration of customs formalities, but also by traffic density and volume. Customs formalities can be complicated (require additional documentation, etc.), but using the advanced information systems, implemented in a short period. The procedures and organization of the intermodal transport chain, especially in the system involving the railways, can have a greater share in the time structure of the chain (up to 60%), starting from the period of performing transport.

Problems at border crossings, congestion and waiting (according to the measurements in Serbia, in road traffic up to 4h (Republic of Serbia, 2017)) and complicated procedures (railway bill of loading (CIM) demand more attention and information than a bill of loading in the road transport (CMR)) and significantly obstruct the functioning of IT. According to the European Agreement on Important International Combined Transport Lines and Related Installations, AGTC (UN, 2010), retaining on the borders for compositions from ITU should not be longer than 30 minutes, the procedure should be simplified and should enable fair competition between rail and road transport.

The problem of legislation relates to the unregulated business and working conditions of operators in IT. In some countries, stimulating measures for this branch of economy are clearly stipulated (BMVIT, 2018), as well as are restrictions and permitted concessions to operators. The undeveloped IT in DR is also confirmed by the fact that hardly any strategic document treats this area as a separate entity. Ministries dealing with transport issues, mainly IT area, in an organizational sense, add it to the railways. This is also an issue of the institutional framework.

The institutional framework implies different authorities, societies, coordination agencies and national and international issues in the field. They can play an important role on the international scene; they can provide significant support to operators on the international scene, but also lead, improve the business conditions and perform promotional and other activities, everything in the favor of IT development. Such authorities or societies may be the first point of contact to a foreign company which wants to deal with the provision of IT services or claims this service in another country. Also, vice versa. The least such an institution can do is to provide useful information and guidance that will lead to the development and greater representation of IT with its promotion. The lack of institutions is mostly reflected in the low representation of IT technologies in the transport market, lack of awareness of its abilities, ignorance of the system, but also the lack of an adequate supply of services.

3. Critical Areas and Nature of the Problem

All identified problems of DR countries (43 problems) have been grouped in 16 areas, according to the type and character. Their number (in all DR countries) is shown in the table 2. Regardless the area of belonging, the problems can be divided into financial and non-financial. Solving problems of a financial nature requires significant investments (for example, the development of a transport infrastructure or intermodal terminals). Unlike them, the problems of a non-financial nature can be solved with much less money invested.

Table 2
Number of problems per area

Area	Number of problems (all countries)
Business	45
Transport infrastructure	36
ICT	22
Finance	20
Ecology	14
Projects	13
Terminal	11
Border crossings	9
Terminal network	9
Vehicles	8
Workforce	6
Law	6
Institutions	4
International cooperation	3
Politics	3
Flows of goods	2
Total	**211**

Over one fifth of all identified IT problems in DR is related to business problems. These problems are non-financial ones in their nature, and account for 48% of all financial problems. Typical representatives of the business problem are the unbalanced market, bad practice in companies, poor resource utilization and non-transparent business, primarily of the national railway operator. Apart from business problems, the significant problem of non-financial nature is the lack of plans for development/investment in intermodal transport (3.32% of the total identified problems).
The bad practice of companies, as the biggest problem, in addition to the non-liberalized market, refers to the following: irrational use of resources and their allocation; lack of cooperation between companies; inefficient choice of supply and placement of products; railway operators who do not endeavor in a competitive fight (where, regardless relatively good transit time, much is lost in initial/final operations), and also other companies that do not run their business efficiently, effectively and ecologically (EEE, Efficiently Effectively Ecologically). An irrational and inefficient business includes the insufficient use of available resources, mainly in the area of railway circuits and resources in terminals. This problem was observed separately from bad business since the latter can be in the scope of the first one, but not necessarily. The non-financial problem, identified in eight DR countries, is also the non-liberalized market. This refers primarily to services in rail transport, where the primacy is usually given to a national carrier holding the monopoly. Besides, problems of the non-liberalized market also relate to unequal conditions of access to the services of some logistics centers, intermodal terminals, and it is considered that the market is not "free", i.e. that, under the same conditions, the services are not available to all potential users. It is clear that a large share of problems has business-to-business relations, but insufficient participation of qualified staff also plays a big role.
Service offer (identified as a problem in three countries) refers to inadequate, non-existent or poor service offered by logistics providers or carriers, primarily in the rail and water transport. It can be the result of lack of understanding of market needs, inadequate competition (because companies do not compete for a "piece of cake") or company ignorance. This problem has been identified in Hungary (MoTTE, 2007; MoTTE, 2014), Croatia (MoSTI, 2014) and Moldova (GovMD, 2013). The problem may also be related to the absence of a complete range of services, or the absence of VAL (Value Added Logistics) services, especially when involving rail transport in the intermodal chain (specifically prominent in Hungary (MoTTE, 2007)). This problem is conspicuous in Moldova, as there is a lack of appropriate intermodal topics (GovMD, 2013). The situation has been additionally made difficult by the bad influence of the national railway operator, which was previously described.
The problems of financial nature make up 52% of identified problems in national strategic documents of DR countries. Typical representatives are traffic infrastructure (17.06%), intermodal terminals (5.21%), terminal network (4.27%) and vehicles (3.79%). The problems directly related to these IT subsystems make around 30% of identified problems. In addition, significant financial problems are related to ICT (7.59%). In order to solve the lack of funds in the budget, traditional approaches are mainly used. These are additional roadside payment charges, excise increase, external costs and likewise. Alternative approaches, such as the development of different forms of public-private partnership (PPP) (e.g. in the Czech Republic, MoT, 2014) or concessions (e.g. in Bosnia and Herzegovina, MoCT, 2016), are significantly lower in use and in plans.
The strategic documents of the more developed countries are dominated by problems that require significant financial resources (Germany - 89%, Austria - 80% of identified problems). Of those non-financial nature in Germany, PPP is allocated, and in Austria, insufficient resource utilization. Non-financial problems make up the majority of identified problems in Ukraine (65%), Hungary (64%) and Serbia (60%).

4. Situation Across Micro - Regions

Given that DR countries differ significantly in terms of their economic characteristics, the level of development and application of IT technologies, and for the purpose of comparative analysis of the problem, their grouping was carried out in three Danube micro regions (DMR):

- DMR 1: Austria, Germany and Slovenia;
- DMR 2: Czech Republic, Slovakia, Romania, Hungary, Moldova and Ukraine;
- DMR 3: Bulgaria, Croatia, Bosnia and Herzegovina, Serbia and Montenegro.

The number of problems identified in strategic documents by DMR varies, among other things, due to the varying number of countries that they cover. Only 12.80% of the total identified problems are in DMR 1 countries, of which 2/3 are in Slovenia. The rest of the problems have been almost evenly distributed in DMR 2 (94 problems) and DMR 3 (90 problems). Transport infrastructure and business issues are the most critical areas for the number of identified problems in all three DMRs (table 3). In DMR 1, problems related to terminals (especially the problem of outdated technology in terminals) are distinguished, DMR 2 issues related to ICTs and projects, primarily IT development plans, and in DMR 3 problems related to finance.

Table 3
Areas and problems across DMRs

Areas of problems	DMR 1		DMR 2		DMR 3	
	No. of problems	Frequency (%)	No. of problems	Frequency (%)	No. of problems	Frequency (%)
Business	4	14.81	23	24.47	18	20.00
Transport infrastructure	7	25.93	16	17.02	13	14.44
ICT	3	11.11	10	10.64	9	10.00
Finance	3	11.11	5	5.32	12	13.33
Ecology	3	11.11	5	5.32	6	6.67
Projects	0	0.00	9	9.57	4	4.44
Terminal	4	14.81	5	5.32	2	2.22
Border crossings	1	3.70	3	3.19	5	5.56
Terminal network	1	3.70	4	4.26	4	4.44
Vehicles	0	0.00	4	4.26	4	4.44
Workforce	1	3.70	1	1.06	4	4.44
Law	0	0.00	2	2.13	4	4.44
Institutions	0	0.00	2	2.13	2	2.22
International cooperation	0	0.00	1	1.06	2	2.22
Politics	0	0.00	2	2.13	1	1.11
Flows of goods	0	0.00	2	2.13	0	0.00

By analyzing the problems in micro regions from the aspect of the necessary investments for their solving, it can be concluded that financial problems dominate in the DMR 1 (77.78%), while in the other two micro regions, non-financial problems have a slight advantage (DMR 2 - 51.06%, DMR 3 - 52.22 %) (Figure 1).

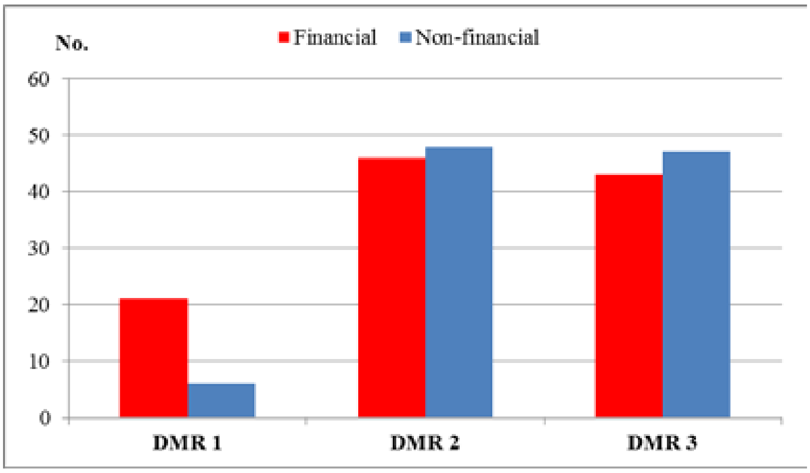

Fig. 1.
Non-financial and financial problems in micro - regions

In addition to the previously described business problems, corporate transparency has also been recognized in six, mostly less developed countries. The resolution of the problem is perceived as the adoption of the rules that will "force" companies and authorities, mainly the state, to make more transparent operations that will provide insight into their availability of resources, employment of new employees and similar (MoTMA, 2010).

Representatives of the problems in the field of transport infrastructure are railroads, travel time (caused by poor infrastructure) and connection of hubs (it can also be treated as a problem in the terminal or terminal network area, but it is closer to a particular area of the infrastructure since it directly refers to the connection, primarily railways). Railway transport makes most of the problems in the field of financing - financial sustainability of railways, financing of railway rolling stock and non-profitability of railway companies.

The lack of ICT systems has been recognized in all DR countries except in Bosnia and Herzegovina and Ukraine. Application of the European Rail Traffic Management System (ERTMS), River Information System (RIS), Intelligent Transport Systems, and the New Computerized Transit System (NCTS) have been mentioned. Since digital, e-logistics is the most important component of competitiveness, the applying of these, often expensive, systems does not belong to the VAL service domain, but is the necessary one. It is important to note that it is not enough to provide ICT support to individual modes of transport, but also more importantly - to ensure the connection between them, i.e. coordination, information sharing, response, synchronization and mutual cooperation.

The issues of a non-financial nature that are often neglected are those related to the law and the institutional framework in the field of IT (together, they make up less than 5% of identified problems). Intermodal transport requires the same treatment as other types of traffic (road, rail, water or air), since it represents a system for itself. If the EU goals are sustainable development, greater use of environmentally friendly forms and transport technologies, then the development of all individual aspects, should be in the function of IT. The law and regulations need to be updated and adapted to the needs of society in order to preserve the environment, but without imposing unjustified obstacles and restrictions on the work of the operator.

When it comes to critical areas for IT development, it is also necessary to mention the problems that are specific or omitted in the national strategic plans. Among the specific problems, there are the lack of projects for addressing bottlenecks, the lack of research and studies (recognized only in Hungary (MoTTE, 2007; MoTTE, 2014) and the lack of freight transport centers (FVs), as the largest form of logistics centers (Zečević, 2006) (identified only in Bulgaria (MoTITC, 2010)). Although they have been rarely recognized as problems of IT development, the mentioned problems are consistent in a much larger number of countries, especially developing countries. The problem of using subventions (therefore, subventions exist) is recognized only in the Czech Republic (MoT, 2014) and Hungary. Similarly, the problem of centralized railway management was identified only in Slovakia (MoTCD, 2016) and Serbia (MoCTI, 2008; MoCTI, 2015).

The number and category of problems that exist, but were omitted in the strategic documents, vary by country. However, at the level DMR 3, among others are the following: the use of subventions and the connection of city terminals, projects addressing solving bottlenecks and the impact of the national strategic operator. In the DMR 2, no novelties were found regarding the maintenance plans and the lack of FVs, space in the ports, and the lack of skilled workers. Germany and Austria as the most developed countries of the DR have the least IT problems, but in Slovenia, as a DMR 1 member, they are not identified, and there are problems of lack of FVs, IT development plan, navigation conditions and obsolete and insufficient vehicles.

5. Conclusion

Knowing the problem enables the setting of targeted actions and more efficient and effective realization of goals. Without identifying the problem, it is not possible to remedy the deficiencies and improve the situation, which can lead to multiple resource spending, prolongation of the moment of benefits realization and their reduction, and generating

losses in terms of failure to meet requirements in the areas that would otherwise have priority. In order to maximize the benefits and efficiency gains, while defining the problems, it is necessary to determine the priorities for solving. The risk of problems is increasing if it is not recognized, as a result of lack of attention and knowledge of the situation.
Research into strategic documents has shown insufficient knowledge of IT systems and inadequate treatment of areas in most DR countries. Critical areas of the whole region are business problems, transport infrastructure and ICT, of which at least the last two can be treated in a similar way, or have similar solutions in different countries. Examples of interventions in the field of transport infrastructure would be, among others, the removal of bottlenecks and modernization of railways, the stimulation of the reuse of industrial tracks, in which case the connection with ports is justified, and also with all categories of logistics centers.
In general, it can be concluded that better knowledge and promotion of IT systems, especially in countries in which it is not satisfactory, would bring significant benefits to both providers and service users. It is important to note that IT problems are not only at the operational level (such as the choice of means and/or proper use of the system) but also at somewhat higher levels (where the emphasis is on cooperation, networks, terminals and services, awareness raising), to the level of institutions and regulations.

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MODELLING SECURITY OF INTERMODAL TRANSPORT BY APPLICATION OF PETRI NETS

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Abstract: The security of intermodal transport (IT) depends on the level of security of all links of the intermodal transport chain (ITC). The basic element of the IT system is the intermodal transport unit (ITU). ITU is a token, and its movement through the intermodal network makes a dynamic change in the system. An analysis of a secure IT system that is complex, dynamic, and targeted towards a particular goal requires the modelling of the structure and the transfer of units in the chain links. These analysis can be performed using Petri nets which is a convenient tool for displaying a complex system and validating the characteristics of its subsystems. This security modelling approach allows you to see the functioning of the ITC in a real environment.

Keywords: intermodal transport, intermodal transport chain, security, modelling, Petri nets.

1. Introduction

Intermodal transport (IT) is a very complex process, involving multiple modes of transport and different participants with different interests and goals. The security of an uninterrupted transport chain, or end-to-end security, is one of the key problems IT is facing with. Achieving a certain level of security, or protecting the system from stealing goods or vehicles, attacking drivers and illegal transport of people and goods, are the constant challenges that all participants in the continuous transport chain face with. The intermodal transport chain (ITC) is exposed to illegal activities and the risk that the intermodal transport unit (ITU), transport vehicles or traffic infrastructure will be exposed to crime or used by terrorists and become the object of a terrorist attack. Weaknesses are becoming increasingly apparent at connecting points of different modes of transport - intermodal terminals. In order to protect them, various security checks of transport means and ITUs are undertaken. In this paper, using Petri net, a sub-module of unobtrusive checks was developed in the intermodal terminal in which there is ITUs transfer load.

2. Petri Nets and Intermodal Transport

Petri Nets are recognized as a convenient, direct and efficient tool for modelling, analyzing and evaluating systems with discrete events. They give graphic and mathematical support to simulation, quantitative and qualitative analysis and system synthesis (Dong & Chen, 2001). They can systematically display all activities, shared resources, synchronized or parallel processes, etc. (Murata, 1989; Peterson, 1981). Numerous possibilities of application have influenced the development of various types of Petri nets: ordinary, black and white, colored, weather, stochastic, modular, etc. In an uninterrupted transport chain, IT is included in the category of systems with discrete events. The behavior of a complex system, such as the IT system, can be described on the basis of the system state and the change in the application of Petri nets. Although Petri nets can not present the complexity of operations in IT, their graphic aspect gives some advantages in displaying and testing the model. Cities represent resources, capacities or conditions, while crossing represent the flow and activities in the terminal. Tokens represent the ITU or the means by which the factory units are transported. ITC is a chain of events, and each link of a chain is a place of potential threat to security and safety. Since all chain links are not as secure and safe as possible, the Petri nets method provides the ability to identify critical points and control discrete chain activities.
By reviewing the literature, a large number of papers were observed with Petri nets for modelling logistic systems and intermodal terminals as a system with discrete events. The application of the stochastic Petri net is common in the process description in intermodal terminals (eg, Fischer & Kemper, 2000; Gudelj et al., 2010), modelling and analysis of logistic systems and chains (e.g., Labadi et al., 2008; Chen et al., 2005; Chen et al., 2003; Chen et al., 2002). There are also numerous examples of the implementation of the Petri net planning and resource managemen, the assessment of operational perfomances, the level of efficiency, and the identification of bottlenecks of the intermodal terminal based on the corresponding system performance indicators (e.g., Di-Febbraro et al., 2006; Dotoli et al., 2006; 2010; Dotoli et al., 2014; Cavone et al., 2017). Time Petri Nets have proven to be a good tool for analyzing logistic systems (eg. Labadi & Chen, 2010) and assessing the performance of the intermodal transport net (Boschian et al., 2011).

3. System Description

Most of the trade that is being realized by ITCs is repeated. These chains include large and well-known operators working on predictable templates and which customs can easily control. In order to secure customs chains, customs should be familiar with terrorist operatives, false companies, zones of action and certain threats.
Efficiency of ITC implies unhindered flow of goods without stopping and slowing down ITU trends. In each of the links of the continuous intermodal supply chain (road transport at short distances, in the initial and final phases of the

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chain, intermodal road-rail terminal, rail transport, port container terminal, maritime transport) there are certain tools and measures to reduce the security risk. Every measure and intervention to increase security in the chain should be well thought out. The number of manual interventions and the duration also. Each additional minute for the processing time of the ITU would be problematic due to their number in the supply chain. In order to avoid duplication of operations in the chain phases and shorten the timing of customs operations, security enhancement measures should be integrated and located at intermodal terminals. This would not only shorten the timing of the chain realization, but would also reduce the risk of the possibility of using ITU for illegal purposes. Intermodal terminals are an important link on the transport route of goods from the manufacturer to the consumer and represent the so-called 'Black spots', places of increased risk for the security of the intermodal supply chain. Since security is more endangered when the ITU is stationary, or when it is waiting for loading, overloading or unloading, the goal is for processes in the intermodal terminal to run fast.
In all chain links, periodic checking of the security system should be carried out, in order to detect weak points. In accordance with the checks, but also technological development, the unit review procedures are also proposed and proposes the application of new, economically acceptable technologies.

4. IT Graphical Security Model

The paper presents the application of Petri nets for monitoring the secure movement of ITUs (tokens) in a complex, stochastic and dynamic ITC system. Petri net of complex systems is obtained by joining Petri nets of its subsystems. Merging can be accomplished by joining common sites of the Petri subsystem nets, which would mean that subsystems share resources; and by merging common transitions of Petri nets of the subsystem, which would mean that the subsystems change with the occurrence of the same event.
In the intermodal supply chain, different modes of transport and various intermodal terminals are included. All the links of the complex ITC system (sub-systems) can be presented to Petri nets as sub-modules. Given that subsystems share resources such as ITUs (container, interchangeable transport court, etc.) and a vehicle (truck, railway wagon, ship, etc.), Petri net of systems is obtained by merging common sites of Petri subsystem nets. Connection points are also the points of transport of ITU from one way to another.
In order to increase ITC security, each sub-module (chain link) can have an ITU security sub-module. The sub-module of the unobtrusive internal ITU test in the road-rail intermodal terminal is shown in Figure 1. A container loaded on a road vehicle is transported to the terminal where the checking of accompanying documents is carried out at the entrance gate. The vehicle then goes to the zone of the security check where an unobtrusive method - scanning and gamma rays – is used for checking possible presence of unauthorized content (people, radioactive materials, etc.). The procedures vary depending on the results of the scan test. If the control result is positive, the container is opened and the visual inspection of the interior is performed. If everything is correct, the container is closed, sealed, and directed to loading. Transitions t4 and t5 (Figure 1) allow adjustment of the time so that the scanning process can only be performed during the terminal working hours. The NetDraw program, version 3.4.2-10.9.15, was used to view Petri nets.

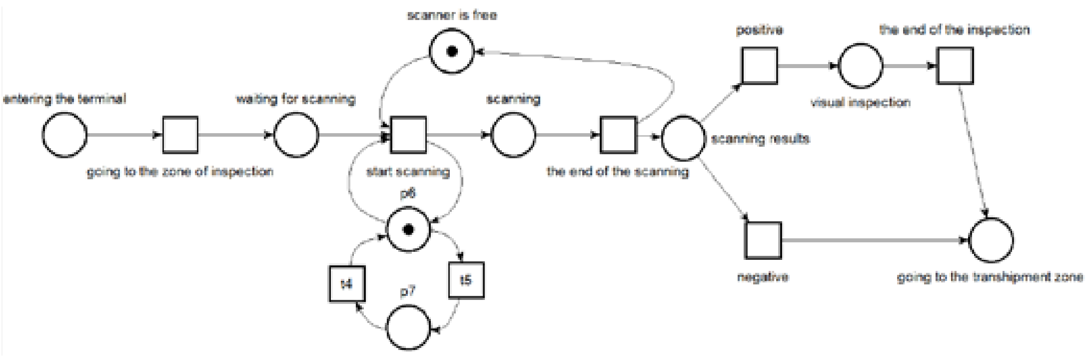

Fig. 1.
Sub-module of unobtrusive ITU checks
Source: (Čabrić, 2017)

Figure 2 shows the complex ITC system obtained by joining Petri nets of the subsystem (chain link) with a submodel of unobtrusive check in the rail-road, intermodal terminal.

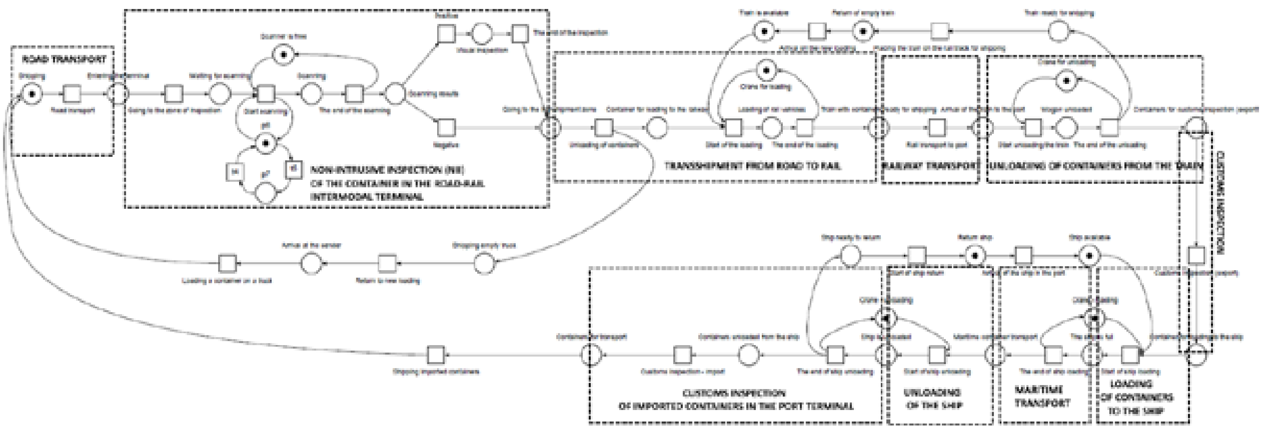

Fig. 2.
Sub-systems of the complex ITC system (Čabrić, 2017)

5. Modelling the Procedure of Unobtrusive Checking

The ITU that moves through the ITC can be treated as secure or as a potential threat, i.e. as a 'trojan'. The term 'trojan' is used as an association to the Trojan Horse which is run by a corporation established with the intent to deal with illegal, terrorist, and similar activities. When incepted, the corporation works in accordance with the law for a long time, until it has gained the trust of the customs, the police and other competent authorities, and then switches to illegal actions in the international transport of goods.
It is considered that the ITU is secure when, in accordance with national rules and international agreements, all participants in the processes of packing, loading, sealing, transhipment and shipping carry out the procedures related to increasing the level of security of the intermodal transport chain of supply. In accordance with international standard ISO 17721, after loading of goods, the ITU is closed and sealed with a unique identification number. If one of the following codes and standards apply in the ITC:

- ISPS code (security or ship, port and port equipment);
- Standard SAFE (developed by the World Customs Organisation, facilitates customs processes and procedures);
- CTU code (security during loading, CTU security seals - information document IM9),

and if all participants, and therefore providers of services, are granted the status of an authorized economic entity, one can speak of a secure intermodal supply chain. The status of an authorized economic entity is obtained by checking through certain procedures applied by the Member States of the European Union.
The security of the transport chain is based on efficient risk management based on the exchange of information between participants, in order to create a synergy of customs administrations and joint efforts to combat illegal activities in the supply chain. By establishing an adequate system for collecting information about ITC participants, the security check of the ITU is strengthened. The objective is, based on the information gathered, to separate potentially dangerous and potentially safe ITUs, which will reduce the security risk, thereby increasing the ITC security.
The discovery of ITUs with unauthorized content (migrants, chemical and biological weapons, explosive devices) is based on previous information, so the place of dispatch of goods, or the starting point of ITC has a special significance. Timely identification of the ITUs with a security risk recognized at the starting point of the chain makes it impossible for its arrival to intermodal and port terminals. In addition, checking the unit at the beginning of the chain makes it possible to know what is going through the ITC before the shipment arrives at the destination. By detecting problematic shipments and preventing their arrival at the end of the chain, Europe's internal security and the security of international trade are increasing.
Modelling the security of intermodal transport in the way that the ITU is viewed as certified or safe, and as a possible trojan, can be done with the CPN Tools, the tool for modelling colored Petri Nets. The tool provides the ability to check the layout of the terms involved in creating the code that defines the form of the net 'step by step'. A quick simulation allows the management of colored Petri nets, and the addition of a time component enables simulation of the time Petri nets. Complete and partial conditions can be analyzed, and standard results and reports contain information about the properties of Petri nets, such as limitation, liveness, reversibility, covertability and persistance.
An example of a colored Petri Net, made using the CPN Tools, as a submodel of an unobtrusive security check in the terminal, is shown in Figure 3. Let us assume that, at the entrance of the scanner ('Entrace scanner'), there are two types of units (UTIs in the figure): A – 'trojan', potentially dangerous, has a certain level of safety hazards, and B – 'certified' safe. Units range from 'Entrance Scanner' to 'Choice' where the type check is performed, after activating the 'Select' switch that is operated by 'Traffic_light' by turning on the light at the traffic light. By identifying the unit type, UTI is defined. After identifying the type, the unit is directed to one of two processes. Units that carry the attribute 'trojan' go for further checks (scanning, sealing, opening the door, visual inspection of the interior, measuring the level of CO_2 in the interior, etc.). Units that are based on previous information are considered safe, carry the attribute 'certified' and continue to move through the ITC. When the time component of the time is introduced, the colored Petri grid passes

into the time-colored Petri net. Assuming that the movement of the unit from the 'Entrance scanner' position to the scanning site takes 3 minutes, and the process of marking/assigning the unit to 'certified' or 'trojan' takes 8 minutes, then the activation of the passage is not current, but is timed by the length of the process.

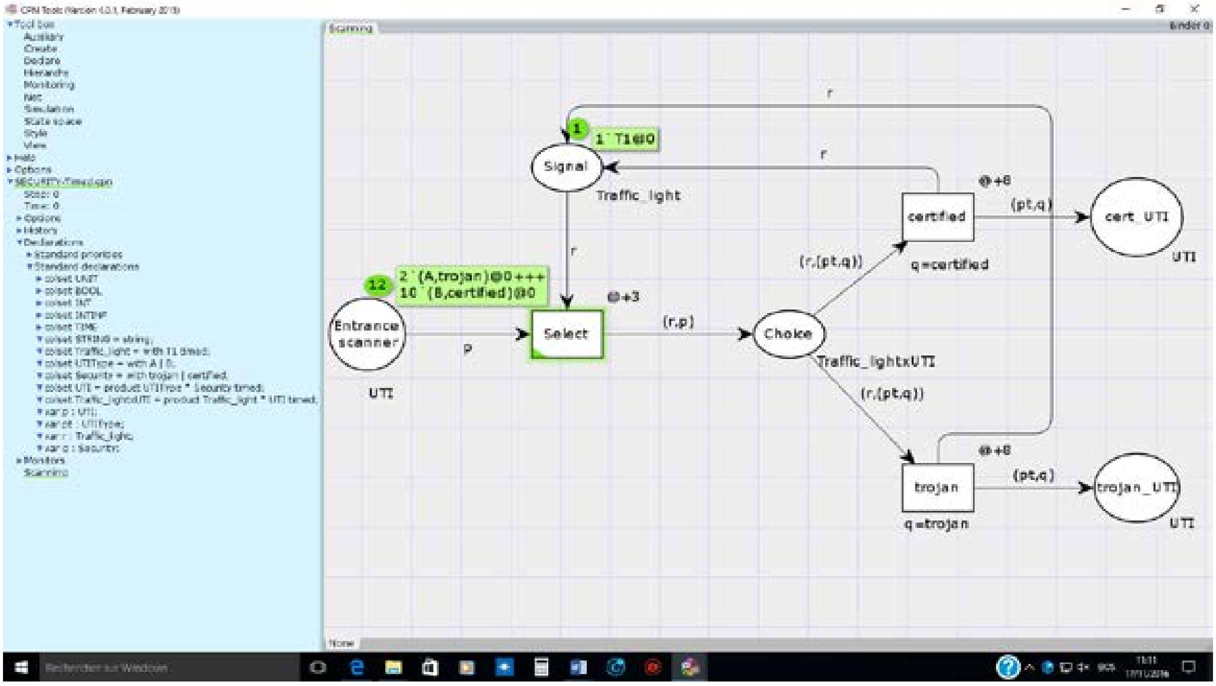

Fig. 4.
Modelling security for coloured Petri Nets using the CPN Tools (Čabrić, 2017)

6. Conclusion

Complex systems require the development and application of efficient methods and tools for their planning, optimization and management. Petri nets, as a graphic-mathematical tool, are suitable for modelling and designing various types of dynamic, discrete and distributed systems.

Planning and management in the intermodal transport chain, as a complex and dynamic system, requires simultaneous and comprehensive monitoring of all subsystems that are linked by the chain. The paper presents the possibility of modelling the security of the chain using Petri nets. Petri nets of systems are created by joining the common sites of Petri nets of his subsets. It is possible to develop sub-modules of ITU security checks in each of the subsystems. Considering that the danger of compromising security is greatest at the points of crossing different types of transport, the paper presents the model of unobtrusive security check in the road-rail intermodal terminal using the time-colored Petri nets. Terminals take all measures of directing ITU subject to security checking procedures at the very entrance, and before shipping from the terminal, latest.

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DEVELOPMENT OF THE CENTRAL EUROPEAN LOGISTICS PORTAL

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Abstract: CELP - The Central European Logistics Portal has solved the problem of a complete solution for editing and trading a system of international logistics portals over several years. Within this research study, team focused on the correct definition of the scope and utility values of the managing editorial system. The needs of the content management system have been defined as the providing information content, the booking of paid portal content, the economic system of cross-billing of business activities, the marketing support of individual logistics portals involved, the emphasis on the importance of mutual communication between editorial offices and the automation of shared content. After work on individual input analyzes of national logistics environments, the team proceeded to design the portal structure and to program the target SW itself. In the last phase of the project, the research team focused on supporting the basic logistics portal by developing native mobile applications that have enabled portal users to access the daily access to daily information from a logistics environment. The entire project has been implemented within the framework of the Eureka International Program and has been supported through the Ministry of Education of Youth and Physical Education of the Czech Republic.

Keywords: Logistics, Information Portal, Data Exchange, Sharing the Information.

1. Introduction

The project responded to the situation within logistics sector in Central Europe and to the absence of an integrated logistics information center for collecting, sorting, storing and distributing proven and up-to-date information from the logistics field. Outcome of this project *The development of the Central European Logistics Portal* should take over the role of this logistics center in Central Europe. The uniqueness of this solution consists in its operability, timeliness and, last but not least, integrity. The result of the project is to unify SW platform which allows research users to identify and maintain logistics information on the basis of research findings of entry constraints in individual participating countries by involving individual national logistics information portals in an integrated European multilingual environment.
This solution contributes to the greater competitiveness of logistics companies, their greater cooperation and the awareness of logistics users about the most suitable solutions for their needs and enables to make a decision to managers of individual companies based on correct and comprehensive information in the field of logistics processes. The solver position on the Czech and European market has given the assumptions not only for the successful solution of the project, but also for the commercial success of the solution results. The application of the solution results has been applied in the market in a partial way already during the project solution. The use of solution results has already been used in the verification process, first of all, with existing local customers using other information channels offered by the solution, and subsequently, with new transnational customers who will be able to make full utilization of the project European dimension (Bartuska *et al.,* 2016), (Kampf *et al.,* 2017).

2. The Central European Logistics Portal

The purpose of the project has been to research and develop the comprehensive European Information Logistics Portal, which addresses by the mutual information exchange among each other in the field of logistics, logistics processes and all elements of the logistics chain in the European region with an emphasis on the development of this sector in the Central European micro-region. This information is especially important for the optimal planning the logistics processes across 3PL logistics companies, transport companies, production plants, retail chains and other entities that are implementing the principals of logistics services. This information exchange is related to transport securing the logistics needs of individual entities, the safety of the operators involved in the logistics chain and the economic benefits of the entities using the portal services. Furthermore, it will actively contribute to the mutual cooperation of the already neglected logistics sector, to its development and to raise awareness of such an important sector of the national economy in the context of entire Central European region development (Buková *et al.,* 2016), (Kubasakova *et al.,* 2014). Advantages of the solution are, as follows:

- the proper up-to-date information for which the portal operator guarantees in one place,
- expertise,
- interconnection the industry news with the current offer of advertisers and particular database:
  - logistics providers,
  - carriers,
  - safe suppliers.

The portal, as a result of the project solution, serves:

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- to logistics operators for trade with given suppliers of the sub-logistics services in a region, which are not known well enough by them, and thus allows for a greater security of their own investments in the Central European region,
- to suppliers of equipment and technology for individual logistics chain members in order to be able to verify the existence of the given entity in the country, including the core credit rating of customers and other suppliers,
- to logistics customers, in a field of partners suitability assessment to meet their logistics needs in other European countries.

The portal is oriented towards top and middle management of the above-described companies in their decision-making process and for a broad logistics audience that provides free access to the latest logistics information in their country and other European countries. In this respect, the Central European Logistics Portal (CELP) has a positive impact on the logistics training development, and thus enables schools providing logistics education to access the most up-to-date information in the field, to the latest technological innovations, but also to raise awareness and involve their students in the production professional information within the portal.

In the future, individual involved national portals will be operated in the form of franchise using software support in this project of the developed communication environment, which ensures the editorial activity of the portal and the data transfer between the individual national portals that will be involved in the system. A properly set environment allows for simpler information exchange between the transnational part of CELP and individual national portals, which also contributes to linguistic multifunctionality, where the transnational part of CELP is implemented in English mutation and individual national portals are operated and will be operated in combination of English mutation and national language mutation.

It also allows direct verification of the logistics entities reliability incorporated into the portal through any national portal, or directly through the transnational part of CELP. The precondition for the target state after the completion of the project is to involve as many national portals as possible. It will be possible on the basis of established communications platform after the completion of all the project phases. The gradual engagement speed of the other national portals will depend on the business potential of the given field and the choice of a suitable partner for the franchise CELP. As part of the project outcomes, it is not only to reach readers and customers with the help of a web service (it is meant by the network of the news portal visible and readable on computers), but also its transmission and visibility on mobile devices (Jurjens, 2005), (Lizbetin *et al.,* 2016).

Status after the end of the project is depicted in Fig. 1.

Fig. 1.
Status after the end of the project
Source: Authors, based on the final report of the project

3. Project Objectives and their Accomplishment

The main partial objectives of project are summarized in following Table 1.

Table 1
The main partial objectives of project

Title	Start the solution	Ending the solution
Analysis, research and development of the application platform /environment and the content management system	10/2015	12/2015

Title	Start the solution	Ending the solution
Implementation, construction and launch of the portal for the web environment and implementation and putting into operation of individual national versions of the portal	01/2016	12/2016
Research and development of mobile applications and routine operation, including the connection of databases to national registers	01/2017	12/2017

Source: Authors, based on the final report of the project

3.1. System and Data Analysis

At this phase, the research team analyzed all the key conditions and circumstances that are important and influence the way of the project solving. Within this framework, all the initial conditions of the project solution were determined; system architecture and individual modules were designed. A diagram of classes emerges from the described links in process analysis. Further, a data model was developed and the system platform was defined. Data with respect to the HW project support was collected and analyzed. The HW demand of the SW was determined and the individual HW components required for long-term sustainability of the project were defined. At this phase, data and information was also associated, described and analyzed with regard to the communication and user environment of the project (Sýkorová and Čverhová, 2011).

3.2. Research and Development of Application Platform, Editorial System and Basic Application Modules

Already in the first year of the solution, the research team performed the preparation for programming and testing the the environment, the editorial system and individual application modules. Following the analysis, it was decided to start the administration modules development, news, users, business and marketing. Next year, the research team continued its work on implementing the portal in a web-based content management system and implementation and commissioning the individual national portals in a web environment. The results consist in platform/environment/editorial system, administration module, news module, module users, module store, marketing module, and user guide in the online application environment.

By these, work on an editorial and publishing system suitable for the administration of information portals in a web environment was completed. When implementing national portals, the research team conducted localization for individual language mutations. For each national version, national SEO (Search Engine Optimization) strategies and keywords for each environment were added. Following the implementation, the first phase of national portals testing was to carry out the communication testing national portals with the central transnational environment of the CELP.

Timing the individual objectives was spread over the second year of the solution. Researchers' capacities were regrouped according to immediate needs of solved partial requirements and within the determined objectives, analyzes of web environments and portal strategies including SEO strategies, communication environment test records, records of updating the programming documentation, and user manual were prepared.

Portal design for communicating with the web environment includes the following results (Bai, Y. 2011), (Chan, 2014):

- data model design,
- user interface design,
- specific address book and event calendar,
- programming documentation development.

Suggestions for national portals to communicate with the national web environment include the following result:

- Defined .po. and .mo. files containing translation for individual language versions of portals.

During the project solution, the researchers worked on partial requirements of internal procedures. To manage the programming documentation, cloud tools for managing GITHUB source code were used. The analytical documentation was kept in the prescribed form in the cloud of MS, its Office 365 - sharepoint and the document management server. UML data models for designing data structures and processes have been created and stored in the enterprise architect modeling tool (Rosenberg and Stephens, 2007).

3.3. Implementation and Design of Web Portal

In this sub-phase, the research team focused on web environment analysis, the design of a portal strategy including SEO strategy and keyword definition, the design of a graphical interface for the portal and the implementation and programming of the web interface portal in the new content management system.

In order to create a graphical interface for the portal in a web environment, a graphic template was defined and selected and the appearance of the website portal and the content portal were implemented and programmed.

The results were, as follows (Naumov and Kholeva, 2017):

- web site analysis, portal strategy development including SEO strategies and keyword definitions,
- portal graphical interface,

- portal implementation in the content management system.

At this phase of the project, a number of consultations were carried out. Based on these consultations, requirements and comments have arisen to the individual modules of the content management system and new requirements for plug-ins. Following the negotiations and evaluation of the comments, a comprehensive review of the proposed solution was carried out which altered the visual and enriched functionality of the application. The following plug-ins were added to the original solution:

- business directory,
- event calendar,
- advertising space.

Besides modifying and adding modules, it was necessary to solve the development team with more general features, including:

- logging,
- administration of the application,
- sharing content between individual portals,
- emailing portal messages,
- data synchronization.

Last but not least, the graphic design and portal layout was made. This proposal was converted to HTML5 with the necessary functionality. The research team focused on debugging the portal and applications for most of the IE9, IE10, IE11, Firefox, Safari, Opera, Chrome and Edge browsers, a responsive three-column look, a page load speed of 2.63 seconds; page size 1.42 MB; number of requests 93. AJAX search service and Google analytics support also were implemented by the team.

After successful implementation of the CELP transnational environment, the research team focused on research on national environments, selection of national portals operators, research and analysis of the communication environment, programming the communication environment between the transnational CELP environment and national portals. The testing communication environment functionality, the testing operation and the debugging portal were followed. During solving the Eureka project, the scope of involving national environments in the project, and thus all the works on national environments, were determined to be national portals:

- Czech,
- Slovak,
- Hungarian,
- Polish.

As a result of this phase, four national portals for web-based environments were put in place according to individual locations. Unlike solutions in a transnational environment, the following features were developed, programmed and complemented based on a series of consultations in each of national environments (Bradford, 2012):

- communication between portals,
- sharing published content among portals,
- sharing the advertising space and placing it among portals.

The graphic design and its functionality were implemented in the editorial system and the result was shown, first of all, in the transnational environment of CELP and its website www.eurologport.eu. The pages were successfully tuned and run in trial mode.

3.4. Research and Development of Mobile Applications and Routine Operation, Including the Connection of Databases to National Registers

In the last year of the project, works on the project solution continued with the native mobile applications development for the largest and the most important mobile operating systems. During the mobile applications development, the research team emphasized native development using modern technologies and standards and a simple, user-friendly environment with easy control. The analysis of individual national environments for the use of national general registers, their use for determining the creditworthiness of the involved entities and the mutual communication of the individual portals and their links to the individual national portals was carried out in parallel. At the end of the project, works to run the whole solution into routine operation were made. From this phase on the project participation, the following partial objectives were obtained (Sklar, 2016), (Tupas et al., 2016), (Williams et al., 2015):

- mobile environment analysis,
- mobile app testing records,
- new registry module,
- records of updating the programming documentation,
- a processed user guide,
- a final technical report.

Results of this phase formed the prerequisites for the successful project sustainability and its further development within the business and strategic options of the investigators.

3.4.1. Research and Analysis of the Mobile Environment

This phase had the aim to describe all the key conditions and circumstances that were important to influence the development of CELP's mobile applications from an analytical point of view. Within this phase, all uniform starting conditions of the solution were determined. A uniform process and functional diagram was created for all mobile applications. Also, a single data model was developed and mobile app platforms were confirmed. This phase was also intended to gather, describe and analyze data and information with respect to the communication and user environment. The result was to process analysis in printed and electronic form in the structure described above in this chapter.

3.4.2. Development of Native Android and iOS Apps

First of all, the solution analyses and specification were done. In addition, graphical design of individual screens (GUI) and communication protocol (API) were made. Implementation itself and application programming were performed. At the end of this phase, the team tested mobile apps, debugging and releasing them on Android Market and the iTunes/App store for free download. The results of the phase were, as follows:

- native Eurologport for Android,
- native Eurologport application for iOS.

Applications have been successfully tuned and run in trial mode. The Eurologport Android mobile app selling page on Google Play is illustrated in Fig. 2.

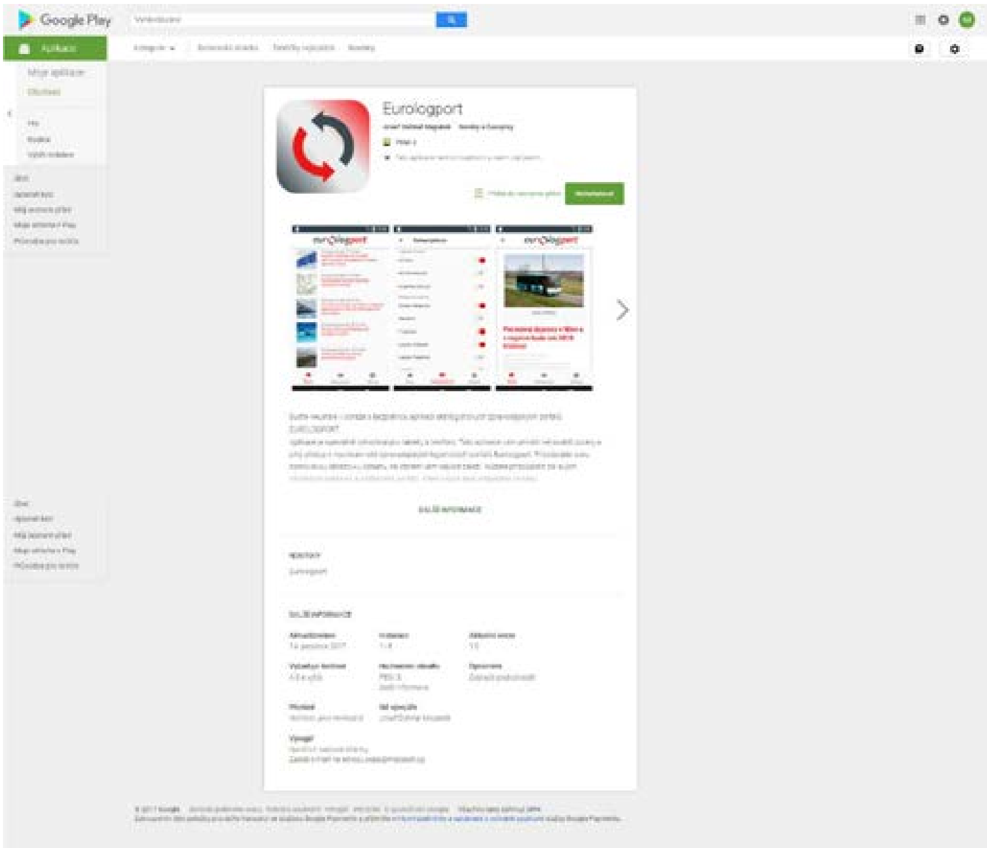

Fig. 2.
The Eurologport Android mobile app selling page on Google Play
Source: Authors, based on the final report of the project

3.4.3. Bindings of the Databases to the National Registry

First of all, the research team prepared user workstations and streamlined communication with real IS users. In addition, an analysis of the national legal restrictions for entries into public registers, the development and programming the communication interface between the CELP application modules and the national registers were carried out. Trial operation with selected system users represented the completion of this phase of the solution. A number of consultations were conducted at this project phase and, based on these consultations, a number of requirements and comments were developed for each module of the registry module. The registry was programmed to display information both in the application and on individual portals, such as viewing information for the corporate directory plug-in reader. In the first phase, it was programmed for existing portal sites. The results were, as follows:

- enhanced registry module in the application for individual portals,
- linking and validating information entered into the corporate directory with each relevant national registry,
- view information about validating data about the observed company in the corporate directory.

After the first phase, the next phase smoothly continued while it was intended to investigate the differences in other national environments, analyze the needs of programming the differences in national environments, develop and program a universal communication module for different national environments, specify the structures of the required databases for national portals. After programming the necessary connections, the research team proceeded trial operation and tuning of the universal national module. This phase represented a prerequisite for the subsequent operation of the information system itself. Module Registry was modified to make it easier to connect to other national and transnational registers (Polgar and Adamson, 2013), (Rajlich, 2011).

3.5. Launch into Routine Operation

At this phase, the research team focused on deploying the developed and tested solution in routine operation and verifying individual communication links. Within this phase, the final report of the project was processed as well. The objective was to implement the final integration and stress tests of the CELP information system designed in the project previous phases. From the authentication process, recommendations to modify individual functionalities to optimize the operation of CELP's information system and its transnational communication environment were made. The results were, as follows (Krásenský, 2010):

- prepared project final technical report,
- processed test protocols,
- documentation and records from authentication and testing operations.

3.6. Testing, Debugging, and Bug Fixes

During the project, the research team used and tested several of the following logical SW areas:

- programming verification of the SW and its parts in following areas:
    - platform,
    - content management system and publishing system,
    - applications,
    - web template and its components,
    - mobile application,
- user operational testing:
    - user application testing,
    - user web portals testing,
    - user mobile apps testing.

During testing, tools available in the SW environment were maximized. The cloud tools for managing GITHUB source code were used to manage and store the test documentation. Testing was performed in a group of the following experts:

- Josef Dohnal (Chief Programmer and System Architect),
- Lenka Dohnalová (Web Specialist),
- Michal Drha (Sales and Marketing Specialist),
- Jiří Kalenský (Logistics Specialist).

4. Discussion

Throughout the project, following systems and applications were gradually started to run in routine operation (CodePeer, 2013), (Fauzi, 2012):

- universal platform and editorial and publishing system for managing websites and applications,
- project applications,
- individual web portals for the Internet environment in the target markets of Central Europe, the Czech Republic, Slovakia, Hungary and Poland,
- mobile applications for Android and iOS operating systems.

All systems and applications have been deployed and run without major operational problems.

4.1. Universal Platform

The result was to design a universal programming platform for editorial and publishing systems and web applications including source codes (specimen, see Fig. 3).

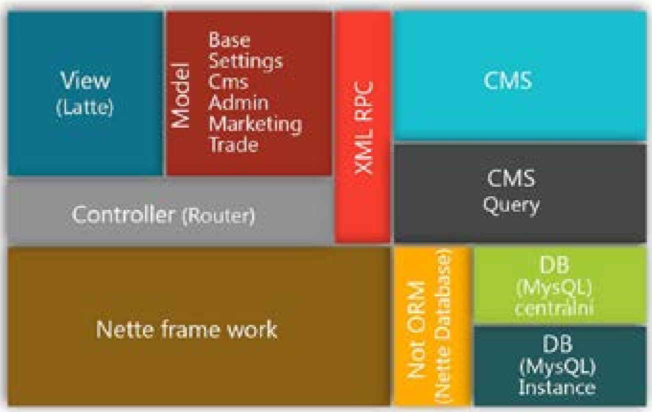

Fig. 3.
A universal platform for creating web applications
Source: Authors, based on the final report of the project

4.2. Editorial and Publishing System

The result was to design an editorial and publishing system suitable not only for the information portal administration processes in a web environment including source codes (Jurjens, 2005), (Kampf et al., 2017).

4.3. Project Applications

The result was to design web application including individual user modules for managing and running the application. The application has been implemented and running on individual web portals with the following path http: //www.eurologport.XX/elp/. During the project implementation, the application was implemented and installed in a transnational CELP environment, and in individual, national environments for the Czech Republic, Slovakia, Hungary and Poland on individual national domains of the Eurologport (specimen, see Fig. 4).

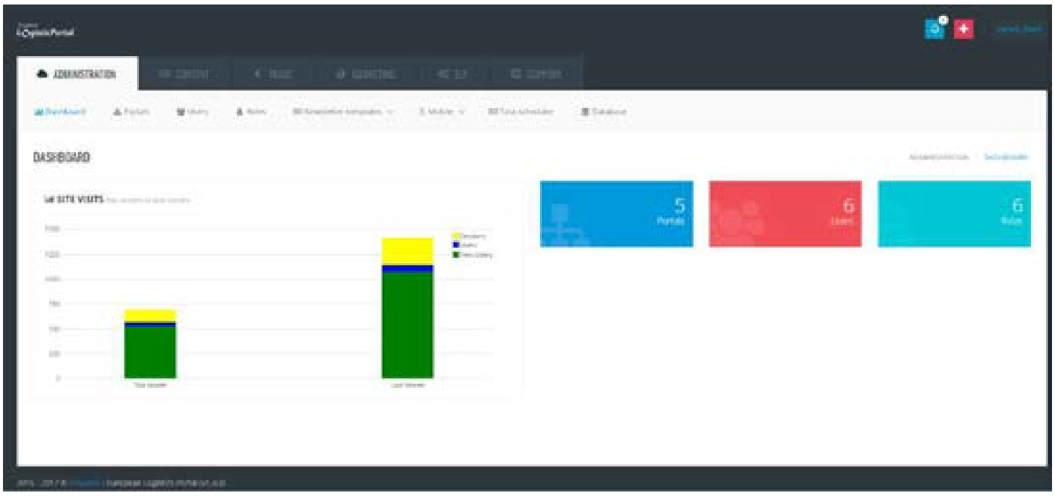

Fig. 4
Logistics portal Eurologport.eu application
Source: Authors, based on the final report of the project

4.4. Web Portals and Mobile Applications

Graphic designs and their functionality were implemented in the content management system. The result was implemented on the following websites: www.eurologport.eu, www.eurologport.cz, www.eurologport.sk, www.eurologport.hu and www.eurologport.pl. Webpages were successfully tuned and started in trial first, and then, in routine operation according to the project planned schedule.
The information system design has represented the result of all the project solution. A software solution for the content management system has been created to enable safe and seamless data exchange between national portals involved in the franchise project and the CELP - Central European Logistics Portal, including an operational and functional native

mobile application for the iOS and Android mobile operating systems. Implemented national information portals in the web environment represent other results.
The ultimate objective of the researchers was to develop such an information system that is capable of further research and development, and it is possible to respond to it, based on a modular structure in order to allow for its users, logistics, transport, forwarding and other companies to use it. It is brought to them in the form of validated up-to-date information from the field of logistics, and possibly, resulting cost savings based on logistics processes management arising from the correct input information (Buková *et al.,* 2016), (Chan, 2014), (Conger, 2012).
During solving the project, the research team worked according to the best practices used for other solved projects. Analytical and programming documentation has been stored in the cloud or on researchers' servers (McQuaid, 2015), (Sýkorová and Čverhová, 2011).

5. Conclusion

Works on the whole project were divided into three successively phases. The first phase included processing the initial analyzes for the correct definition of the designed logistics information portal final structure and related information system structures including its modular setting. At this phase, the solution involved parallel works of several groups of researchers, especially analysts, programmers, examiners, consultants and project manager. The editorial system architecture design and individual function models of the information system special modules were the most important results of this phase.
The objective of the second phase was to implement the web portal into the content management system and implement all the individual national portals into the web environment based on analyzes from the previous phase and based on the comprehensive detailed analysis of national environments. These environments mainly solved the selection of a suitable partner for the national portal operation, the content management system communication range between the national portal and the transnational CELP environment.
The CELP information portal design implemented and tested as well as its national version in the national web environments of the Czech Republic, the Slovak Republic, Hungary and Poland represented the results of this phase.
The objectives of the final phase project participation were the following activities: to analyze the mobile environment for effective work on programming of mobile application, the design of mobile applications for Android and iOS operating systems, the restriction analysis of the system possible connection to the national registers, the development of connection including trial operation with the selected Czech portal. Based on this testing, a particular solution to connect other national registers was prepared. During the project participation, the research team worked according to the best practices used for other solved projects. The analytical works were based mainly on data collection, data modeling, the system object-oriented design and the proposed system modular structure. All the planned objectives and project results have been successfully fulfilled.

Acknowledgment

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IMPACT OF CRM ON THE QUALITY OF THE NEW POSTAL SERVICE - BH POSTEXPRESS

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Abstract: Modern postal companies cover a complex area that is intertwined with communications, logistics and advertising, and its process activities consist of three phases: the process of communication, logistics processes and advertising processes. New concepts of decision support in decision-making postal-logistic traffic rely mainly on useful information and the application of various IT technologies (BI, SCM warehouses, ERP, CRM) used to avoid and predict unexpected events that are rapidly occurring on a dynamic postal market. Today's business cycles of modern postal operators are compressed, faster, contain more data, and a faster and more efficient decision-making system that represents the real competitive advantage of postal companies. Competent organizations aware that performance management processes and relevant flows of data, information and knowledge have a decisive impact on their success. The focus on postal service users, based on quality and timely customer service, is the basis for successful postal operators. The paper analyzes the impact of the call center as CRM tool on the quality of providing new postal service - BH PostExpress in PE BH POST Sarajevo.

Keywords: CRM -Customer Relationship Management), call center, BH PostExpress, customer satisfaction, business performance, quality.

1. Introduction

Under the conditions of deregulation and full liberalization of postal traffic, public postal operators are confronted with competition every day, which in every way tries to take as many services as traditionally provided by public postal operators.. In order to survive in the open postal market and respond to these challenges, public postal operators pay close attention to the quality of service delivery and the application of modern technologies to new and value-added services.The World Postal Union's Congresses of the past years pay special attention to the quality of services provided by postal operators. The quality of postal traffic is reflected in the quality of postal services. In order for the postal operators to provide quality service to their users they must properly plan, design and build the postal network to ensure the planned traffic capability. In this paper, we have come to know the essence of customer relationship management with the aim of improving the quality of postal services, all of which are based on the example of the call center business on the new postal service BH PostExpress in PE BH POŠTA.

Today, when markets become saturated, and competition is getting bigger and more serious, it is no longer easy to attract and even less retain users. Greater customer care and the development of long-term personalized relationships become the cornerstones of every business. The concept - "customer care" becomes the only correct solution if public postal operators want to survive and succeed on the postal market.

Customer relationship management takes more significant place in the company's business strategies, especially with postal operators where it is necessary to continuously communicate and share information with its users. The contemporary business of modern and successful companies is based on the Customer Relationship Management (CRM) concept. This is the concept of a newer date, which completely changes the current approach to customers, more focusing on them and their needs that are nowadays individualized, as opposed to far-reaching focus on service and sales. Technological innovations and especially development of information technologies and computer technologies, have led to changes in the lives of individuals, the world around us, and so on the business environment, which has caused changes in the way business transactions are performed and the customer's position change in the value chain.

The problem of developing and maintaining long-term relationships with consumers CRM analyzes deeper, taking into account all the internal and external elements that touch this problem. The purpose of the CRM concept is to enable a more efficient implementation of the set business strategy and goals through the consideration of consumer needs. CRM as a concept represents the alignment of business strategies, organization structures, behavior, collection, processing and use of information, in order to meet their needs at all touch points with customers and achieve business profit of company. This strategy, which puts the customer into the center of business events and activities, solves the institution's doubts about who their clients are, and which are the most valuable ones. In order to improve the quality of postal services, PE BH POŠTA introduces the new postal service BH PostExpress (fast mail). This is an added value service that enables the transfer of consignments to legal entities and individuals in the territory of Bosnia and Herzegovina.

2. A General Model for Quality of Postal Services

If the postal operator is able to properly define the quality of its services, it will be able to combine its economic interest and the expressed and undisputed customer requirements for a certain degree of quality. A good level of quality of postal services directly influences pricing policy, increases the interest of users for further use of services, or increases business performance of postal operators. Post Operators must properly plan, design, build postal networks and continually innovate their offer with new services so their offerings can meet the needs of their customers. The quality of postal

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services is seen as a common effect of several characteristics that all together determine the degree of user satisfaction. In order to adapt to the needs and demands of its users, postal service providers should look at quality first and foremost from the customer's point of view..

Postal operators in an increasingly liberalized market are striving to provide an acceptable level of postal network quality for users at minimal cost, and in that case achieve the maximum possible financial impact, taking into account the more effective strategic planning, design, construction and maintenance of the postal network. The user's quality-related observations point to the effects rather than the causes. That is why the postal operator aims to strike a balance between the quality of services which users needs and the quality of services whose strategic planning, design, implementation and maintenance needs to be the most economical.

Measures leading to quality improvement can be classified as:

- Availability of postal units and means;
- Availability of capacity;
- Efficiency in the connection process;
- Continuous innovation and introduction of new service and value added services;
- Knowledge of each level of organization for quality management;
- Innovative program to achieve the anticipated quality of services;
- Strengthen internal marketing within the company.

The main objective of the postal service quality model is to provide a detailed description of the characteristics and parameters related to the quality of service from the point of view of operator, user and manufacturer of necessary service equipment. This model should combine features and service parameters related to the development, design and exploitation.

The general model of quality of postal services can make:

- Provision of the postal operator with the necessary technical equipment or the ability to rent and install certain technical equipment that provides the desired type of service;
- Automation of equipment on which the user can handle independently to achieve the desired service;
- Availability of the service - the ability of the operator to enable the provision of the service at any time required by the user;
- Reliability of postal service delivery - probability that there will be no interruption during the service period that could permanently terminate the requested service;
- Incompatibility of service - users' resistance to the interference that occurs when connection is established.

2.1. Quality as a Survival Factor in the Postal Service Market

The need to reduce inventory in the overall supply chain and reduce delays in the process of distributing material goods directly affects the increasing complexity of postal traffic. New challenges such as globalization, liberalization and privatization of the postal sector, the necessity of incorporating into European integration processes, and demands for high-quality traffic services create a new ambiance of postal operators' business, which requires innovative approaches to business in order to strengthen the postal operator's position on the liberalized and open postal market. Postal operators in modern society must necessarily improve their efficiency and competitiveness by simultaneously reducing their resources to survive in the market of modern technologies.

Postal operators depend and will increasingly depend on the integrity, reliability, security and applicability of information systems and processes and data in the organization as a whole. The information gained from the available data of postal system through Data mining is the basis for guiding both the reactive and proactive future behavior of the postal operator. Therefore Postal operators have to listen every day to customers and adapt their services and operations to their needs and requirements, not neglecting their public service role as well. The focus on postal service users, based on quality and timely customer service, is the basis for successful postal operator operations. The requirements for quality of postal services include a hierarchical organization processes based on the user principles that relate to (accountability, security, planning, accuracy and reliability, information, availability of mobile capacity, after-sales service), followed by the use of high technology transport equipment supply chain as well as a postal process management system with the use of modern information technologies based on management practices.

Today's business cycles of modern postal operators are compressed, faster, contain more data and a faster and more quality decision-making system that represents the real competitive advantage of postal companies. Traditional postal services can no longer provide the prosperity of this system, but new services and new markets with new technical and technological achievements are needed. Postal operators must be paid to particular attention to the quality of the services they provide. Under the conditions of unfair competition to which postal systems are exposed, improvement of quality is set as a basic competitive advantage. That is why the European Union has mandated the standards of universal postal services that the public operators of other European countries follow and apply depending on the level of their development and capabilities.

2.2. Quality in the Strategies of the World Pact's Congress

Over the last twenty years, various factors have influenced the postal sector to re-examine its role in the communications market. The combined action of direct and indirect competition, privatization, liberalization, separation of operator and regulatory functions, user demand for better and more reliable services, and new technologies, convinced postal sectors to change their operational and financial strategy to remain competitive.
Developed European postal operators rapidly reach enviable standards in upgrading postal services as well as redesigning business processes by applying business intelligence to improve business efficiency and survival on a liberalized postal market. The application of business intelligence does not only include the full range of postal services, but also the framework for all the management, logistical processes that take place within the operator. The focus on postal service users, based on quality and timely customer service, is the basis for successful postal operator operations.
One of the elementary indicators of the economy's impact on postal activity is the level of consumption that is expressed in the number of postal shipment per capita per year. Analyzing competition on the postal market, it has been shown that the basic strength of postal sector is in its ability to monitor service and quality control "from the beginning to the end" based on powerful information systems and the application of their technologies.
The Universal Postal Union has defined the basic principles that a postal operator should apply if it wants to successfully counter market competition:

- Get acquainted with the market in which it operates (user needs, competition, new service, etc.);
- Meet customer needs in all aspects and adopt the concept of total quality for all offered products and services;
- Automate the technology and service management offered on the market.

The main goals of the Strategy adopted at the XXV Universal Postal Congress are:

- Improve the interoperability of the international postal network;
- Provide technical knowledge and expertise in the postal sector;
- Promote Innovative Products and Services;
- Promote sustainable postal sector development.

Postal Traffic has so far been concerned with quality through the assessment of the functioning of postal traffic and through improving the quality by changing the existing state of the organization in order to increase the effectiveness and efficiency of all activities and processes, in order to gain additional benefits for the organization and for its users. However, in the new business environment of postal sector, which comes with deregulation and liberalization, when it enters the process of continuous changes, a quality system must be established by establishing and maintaining the state of change in organizational structure, procedures, key and business processes and resources for quality management.
That is why for the postal sector the ultimate goal is to approach the Total Quality Management-TQM, which represents a broadly standardized, contemporary management approach for achieving quality goals. TQM is the process of system, accurate, complete and continuous changes in the management of the entire company with 218 quality aids in the direction of continuous improvement of overall business. TQM is based on ISO 9000 Series standards and represents a permanent and infinite process of improving overall performance across the company..
The basic principles of TQM can be expressed through the following processes:

- Continuous fulfillment of customer requirements to achieve its satisfaction;
- Continuously improving the overall performance of the postal organization;
- Continuous growth and development of postal organization with the satisfaction of all interested parties (owners, employees, society).

In order to provide quality in the company, it is necessary to make certain procedures and documentation. Acceptance solutions (guidelines, guidelines, models) for quality management through the quality system were provided by the ISO 9000 series. The quality system in postal traffic implies the determination of procedures to determine the requirements for characteristics of all service delivery processes, including marketing processes, service delivery as well as feedback that contribute to improving the quality of postal services. This also includes evaluations of the service performed by the user and the quality control of the implementation and efficiency of all elements of the quality system.

3. Competitive Benefits of Using CRM Methods Relating to Clients

Successful organizations know that performance management processes and relevant streams of data, information and knowledge have a decisive impact on their success. Such organizations note that performance management knowledge is the one that drives business and the most important knowledge of the organization.
CRM (Customer Relatioship Management) represents the integration of all business processes and technologies used to communicate with existing and potential customers and business partners across all available communication channels. CRM can be seen as a wider business strategy designed to reduce costs and increase profitability and efficiency by creating total loyalties for users. It represents every possible aspect of company interaction with its users, whether it is a sale or service. The basic objective of this business strategy is to personalize business with each user individually.
This means that every user will have a separate treatment and offer of those services that are most needed at the given time and which will only apply to him.

The beneficiaries have the opportunity to have available suppliers at all times of the day and at night, choosing and buying products or services, making inquiries and making payments without any direct physical contact, leaving their workplace or home. On the other hand service providers have the ability to provide twenty-four-hour online customer-tailored offerings that are available at any time, in every location, with consummate computer equipment.
The basic philosophy of the CRM concept in postal traffic is based on the claim that if a company has certain information about its user (what it wants, what kind of postal service it requires, what needs it meets, etc.) sales of such postal service will be much more successful and the user will be more satisfied. The most important CRM factor is timely and useful information.
This strategy, which puts the customer into the center of business events and activities, solves the institution's doubts about who their clients are, and which are the most valuable ones. Market and consumer access, marketing methods can no longer be implemented without the use of information-communication technologies, leading to significant changes in marketing, planning, strategy development and development. The CRM concept is a set of institution options, approach methodologies, and purposeful application of technology, enabling the commercial functioning of institutions. Through information-communication technologies, and especially the Internet, direct connection is made possible through the use of computer networks, supply and demand.
Using the CRM concept has multiple goals:

- detailed customer identification;
- segmentation of clients according to their needs and potential values for the institution;
- establishing quality and sustainable interaction with clients;
- creating an organization oriented towards the client;
- customizing products and services to customers and their needs.

The introduction of CRM does not represent the technological equipment and implementation of technical logistics in financial institutions, but changes in approach and thinking of all employees from top ranked managers to executive operatives. Today, this is the biggest problem and the key to the success of those who have decided to apply this concept. Customer Relatioship Management is a marketing process (marketing one by one) that directs the business orientation of an enterprise towards an individual consumer. Basically the CRM concept lies in a simple idea, which is "differently treated different consumers". The efficiency of the CRM process, which needs to be integrated through marketing, sales and through consumer relationship, implies:

- identification of factors that contribute to a successful relationship with consumers;
- developing practices in consumer relations;
- developing a process that will benefit consumers;
- formulation of issues that would best assist the solution of potential consumer problems;
- recommendation of solutions for consumers who have a complaint about the product / service;
- track sales as well as consumer support.

3.1. The Impact of CRM on Customer Satisfaction, Loyalty and Business Performance of the Postal Operator

An important reason for CRM (Customer Relationship Management) is that it enhances business performance by improving customer satisfaction and increasing customer loyalty, as shown in Figure 1. There is an appropriate logic of the model called the "satisfaction-profit chain ".

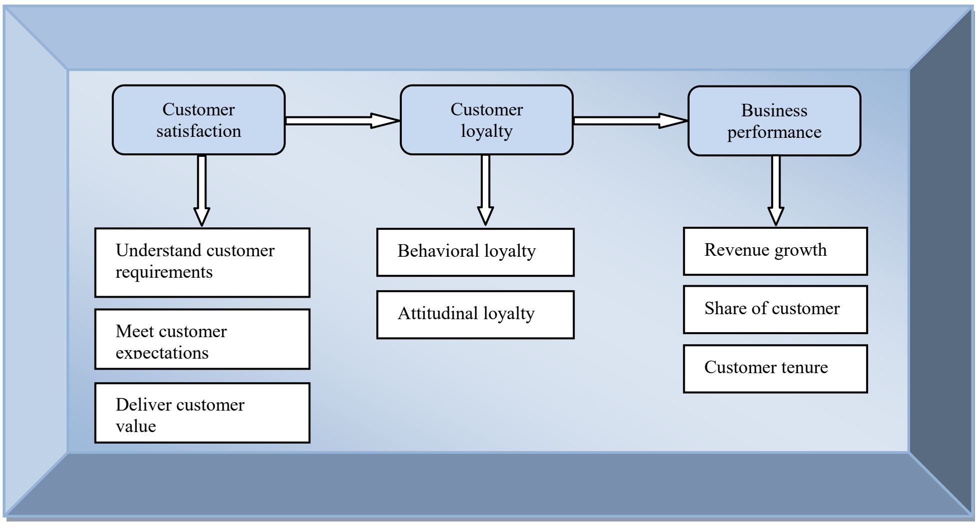

Fig.1.
The satisfaction– profit chain
Source: (Buttle, 2008), page 68-72

Satisfaction increases because customer insight allows companies to understand their customers better, and create improved customer value propositions and better customer experiences. As customer satisfaction rises, so does customer intention to repurchase. This in turn influences actual purchasing behaviour, which has an impact on business performance. We'll examine the variables and linkages between them. First we'll define the major variables of customer satisfaction, customer loyalty and business performance.

3.2. Customer Satisfaction

Customer satisfaction has been the subject of considerable research, and has been defined and measured in many ways. We define customer satisfaction as follows:
Customer satisfaction is the customer's fulfilment response to a customer experience, or some part thereof. Customer satisfaction is a pleasurable fulfilment response. Dissatisfaction is an unpleasurable fulfilment response. The 'experience, or some part thereof' component of the definition suggests that the satisfaction evaluation can be directed at any or all elements of the customer's experience. This can include product, service, process and any other components of the customer experience. The most common way of quantifying satisfaction is to compare the customer's perception of an experience, or some part of it, with their expectations. This is known as the expectations–disconfirmation model of customer satisfaction. This model suggests that if customers perceive their expectations to be met, they are satisfied. If their expectations are underperformed, this is negative disconfirmation and they will be dissatisfied. Positive disconfirmation occurs when perception exceeds expectation. The customer might be pleasantly surprised or even delighted. This model assumes that customers have expectations, and that they are able to judge performance. A customer satisfaction paradox has been identified by expectations–disconfirmation researchers. At times customers ' expectations may be met but the customer is still not satisfied.
This happens when the customer's expectations are low. 'I was expecting a shipment late and late. I'm unhappy!'
Many companies research customer requirements and expectations to find out what is important for customers, and then measure customers ' perceptions of their performance compared to the performance of competitors.

3.3. Customer Loyalty

Customer loyalty has also been the subject of considerable research. There are two major approaches to defining and measuring loyalty, one based on behaviour, the other on attitude.
Behavioural loyalty is measured by reference to customer purchasing behaviour. Loyalty is expressed in continued patronage and buying. There are two behavioural aspects to loyalty. First, is the customer still active? Secondly, have we maintained our share of customer spending?
In portfolio purchasing environments, where customers buy products and services from a number of more-or-less equal suppliers, the share of customer spending question is more important. Many direct marketing companies use RFM measures of behavioural loyalty. The most loyal are those who have high scores on the three behavioural variables: recency of purchases (R), frequency of purchases (F) and monetary value of purchases (M). The variables are measured as follows:

- R - time elapsed since last purchase;
- F - number of purchases in a given time period;
- M - monetary value of purchases in a given time period.

Attitudinal loyalty is measured by reference to components of attitude such as beliefs, feelings and purchasing intention. Those customers who have a stronger preference for, involvement in, or commitment to a supplier are the more loyal in attitudinal terms. Recently, researchers have combined both views into comprehensive models of customer loyalty. The best known is Dick and Basu's model, as shown in Figure 2.
These authors identify four forms of loyalty, according to relative attitudinal strength and repeat purchase behaviour. 'Loyals' are those who have high levels of repeat buying and a strong relative attitude. 'Spurious loyals' have high levels of repeat purchase but weak relative attitude. Their repeat purchasing can be explained by inertia, high switching costs or indifference. Latent loyalty exists when a strong relative attitude is not accompanied by repeat buying. This might be evidence of weakness in the company's distribution strategy, the product or service not being available when and where customers want. From a practical point of view, the behavioural definition of loyalty is attractive because sales and profits derive from actions not attitudes.
However, taking the trouble to understand the causes of weak or negative attitudes in customers can help companies identify barriers to purchase. It is equally true that knowledge of strong or positive attitudes can help companies understand the causes of competitor-resistant commitment. However, it is not clear from the Dick and Basu model whether attitude precedes behaviour or behaviour precedes attitude. Researchers generally accept that causation is circular rather unidirectional. In other words, attitudes influence behaviour, and behaviour influences attitude.

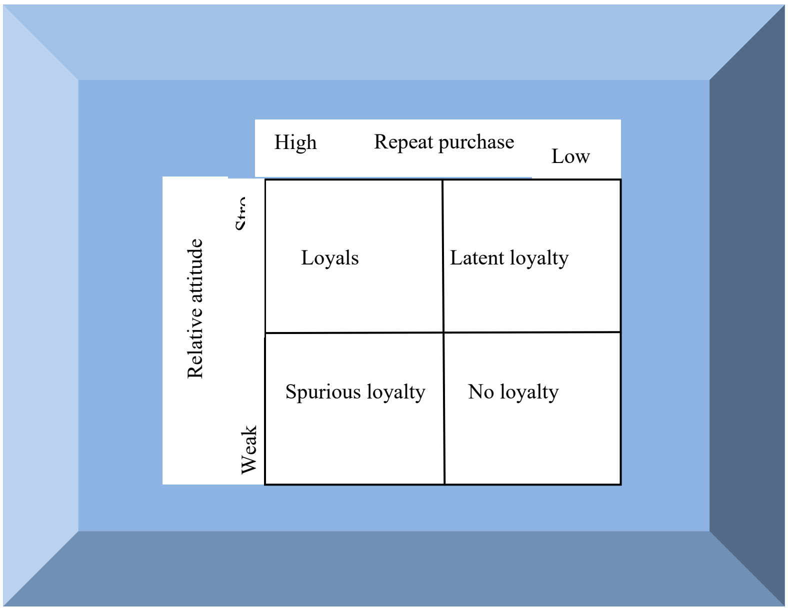

Fig. 2.
Two-dimensional model of customer loyalty
Source: (Buttle, 2008), page 68-72

3.4. Business Performance

Business performance can be measured in many ways. The recent trend has been away from simple short-term financial measures such as quarterly profit or earnings per share. Leading companies are moving towards a more rounded set of performance indicators, such as represented by the balanced scorecard. The balanced scorecard employs four sets of linked key performance indicators (KPI): financial, customer, process and learning and growth. The implied connection between these indicators is that people (learning and growth) do things (process) for customers (customer) that have effects on business performance (financial). Customer-related KPIs that can be used to evaluate business performance following a CRM implementation include: customer satisfaction levels, customer retention rates, customer acquisition costs, number of new customers acquired, average customer tenure, customer loyalty (behavioural or attitudinal), sales per customer, revenue growth, market share and share of customer (wallet). The balanced scorecard is highly adaptable to CRM contexts. Companies need to ask the following questions. What customer outcomes drive our financial performance? What process outcomes drive our customer performance? What learning and growth outcomes drive our process performance? The satisfaction–profit chain suggests that the customer outcomes of satisfaction and loyalty are important drivers of business performance.
Share of customer (share of wallet or SOW) is a popular measure of CRM performance. If your company makes a strategic CRM decision to serve a particular market or customer segment, it will be keen to measure and grow its share of the chosen customers ' spending. As indicated in Figure 2.8 , share of customer focuses on winning a greater share of targeted customers ' or segments' spending, rather than market share.

4. Packet-Courier Service BH POST EXPRESS

In order to improve the quality of postal services, PE BH POŠTA introduces the new postal service BH PostExpress (fast mail). It is an added value service that enables the transfer of consignments for legal and natural persons in the territory of Bosnia and Herzegovina.
The delivery of BH PostExpress services is transmitted from the reception site to the delivery time within the deadlines depending on the BH PostExpress type service for a fee, determined by the BH PostExpress Pricelist in the internal traffic. Consignments can be sent as individual, total consignments of a total mass of up to 50 kilograms and as a pallet of a maximum weight of 500 kilograms. Shipment may be with or without a marked value, and the maximum marked shipment value may be up to 5,000 BAM. The price of the service depends on the weight of the shipment and the time it will be delivered. A mass of up to 10 pounds and delivery on the same day costs 12 BAM, while it will cost 8 BAM within two days. A delivery of 150 to 200 kilograms, if delivered on the same day until 12 o'clock, would cost 80 BAM while within two days the cost of delivery would cost 65 BAM.
Users across the territory of BiH have four types of new service transfer available:

- today delivered, today handed down;
- today delivered, today delivered until 18 o'clock;
- today delivered, tomorrow delivered; and
- (D + 2) today handed over, delivered for two days.

The reception of BH PostExpress consignments is made on a call at the address of the user, or in the business premises of the sender and at the mail counter, every working day (including Saturday), from 08:00 to 18:00 on the call center number 1417.

4.1. Implementation of the Call Center in the BH Post Express Parcel/Courier Service

The Contact Center is a business system that combines voice and electronic communication with users, and modern data processing technology, enabling:

- adequate customer support;
- support for marketing activities;
- improvement, automation and increased sales of services;
- successful management of contacts with users;
- improve overall image of the company.

Physically, this is the place where a group of agents / operators manages a large number of incoming and outgoing calls/contacts with users, by phone, web site, email, etc. and routing requests to the Mail Centers through an appropriate application solution. Contact Center PE BH Post d.o.o. Sarajevo is a central place for customer care, through activities and activities that imply:

- provide relevant information on the services of PE BH POST in internal and international traffic;
- resolving reception, dispatch and delivery of mail and other services;
- receive announcements for BH Post express, ems and tg services.

The Contact Center is to be seen as an independent project that will enable business processes and tools to enhance Customer Relationship Management (CRM) and Public Relations (PR).
Implementation of the BH POST EXPRESS Contact Center is also an innovative approach in terms of increasing customer loyalty and implies an effort to design a business system that will enable unified and decisively defined technological delivery procedures for "BHPost Express", with simultaneous control and reporting, in order to redefine and correction of possible irregularities management.
The introduction of new BH POST EXPRESS services does not depend on the implementation of the Integrated Contact Center system, but this service uses the resources of the Contact Center and is an integral part of the order / announcement management, monitoring of consignments and providing information and complaints. The task is to ensure the same and sufficient quality of communication with the users, through the unified ways of answering the operator, and a precisely defined distribution information procedure in the open work order.
In order to achieve savings and optimize service delivery processes, a well-organized Contact Center should have been enabled:

- Easy ordering services;
- Receipt and delivery of consignments agreed on a precise location and the responsible user.

The implementation of this solution implies activities of integration of business / technology processes that will enable the monitoring of each individual shipment, from the moment of the shipment notification, to the physical delivery to the recipient. It is important to define the procedures and ways of acting agents in the Contact Center, and dispatchers at the Post Centers and other participants in the BH POST EXPRESS service process technology. Also, the BH POST EXPRESS Application Center solution has an integral unit / module integrated GPS tracking system .Global Positioning System), which enables proper route design and routing of vehicles, and optimizes and reduces the cost of fuel.

4.2. The Organizational Chart and Human Resources of the Contact Center in the BH Post Express Parcel/Courier Service

The Figure displays the Contact Center BH POST EXPRESS, which is an integral part of the Corporate Contact Center of PE BH POŠTA d.o.o. Sarajevo offers unified services such as BH POST EXPRESS, EMS and service telegrams, real-time process monitoring, control of delivery deadlines and stable point detection in the system.
BH POST EXPRESS parcel / courier services segments in the Contact Center:

- Contact CENTER BH POST EXPRESS - Centralized with operators, located at GPC, connected to the number 1417.
- DISPERSERS AND DISTRIBUTORS - Dispatcher, Dispatcher system and other technology vendors, as a BH POST EXPRESS service segment, by Mail Centers.

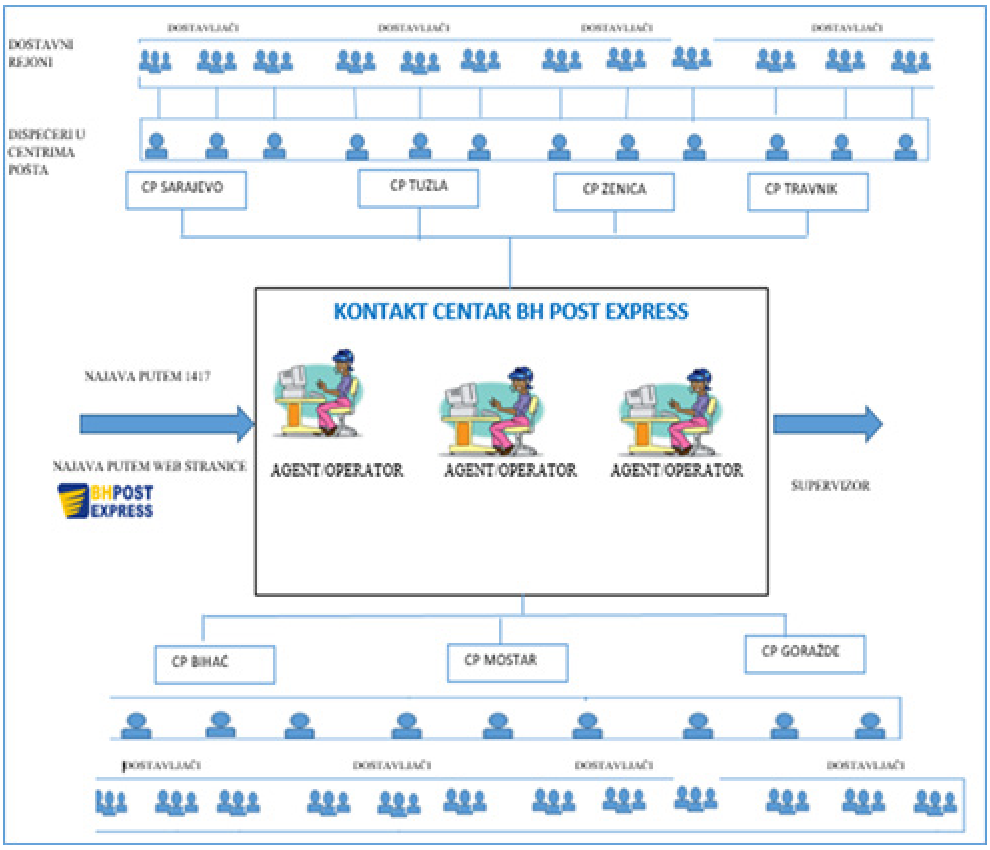

Fig. 3.
Organizational Scheme Contact Center BH POST EXPRESS
Source: BH Post Express distribution support in the area of Bosnia and Herzegovina, PE BH POST Sarajevo.

This approach to the Contact Center is an innovative approach as it enables full satisfaction of customer needs while providing unambiguous and precise procedures for dealing with BHPOST EXPRESS shipments, phone logs, reception at the address and counter and delivery thereof, simultaneous tracking of consignments, complete control and timeliness and quality control. Also, this approach enables optimal delivery and pickup processes, routing delivery vehicles through the integration of GPS systems into the Contact Center system.

AGENTS/OPERATORS – Of contact Center BH Post Express is located in GPC Sarajevo and has full capacity of three (3) agents. Computer Agents have BH POST EXPRESS agent applications and are applicatively linked to dispatchers in all Mail Centers.

DISPATCH CENTERS IN THE POINTS CENTERS – The second level or operator that receives the work orders / tags from the GPC Contact Center agents, and is organized by the couriers on the field. The organization of the Dispatch Center, Delivery and Postpaid Recipients is integrated with each Mailing Center for the part of the postal network for which the Post Office has jurisdiction. The BH POST EXPRESS Contact Center would communicate directly with users, avoiding the possibility of congestion and rejection of customer calls due to the small capacity of the Contact Information Center and Complaints Center at 1312.

EXSPERT IN GENERAL DIRECT OF POSTAL OPERATOR – The person who supervises the whole system and communicates with the other two postal operators. This person is in charge of all contacts and activities that require alignment with the other two postal operators and a person who knows the service of BH POST EXPRESS in all technological phases.

In addition to human capacities, in the work of the BH POST EXPRESS Contact Center, particular attention should be paid to the way of communication with users, the rules of unified behavioral procedures and the work of the Contact Center to avoid some of the most common errors in the Contact Center:

- the user waits for a long time on the line until the next operator is free;
- "Switching" users from one operator to another;
- low employee motivation.

4.3. Customer Communication Channels - Receipt of Orders

Contact with customers takes place through two communication channels:

- Telephone number 1417;
- Via contact form on the web page.

Reception of BH POSTA EXPRESS postal shipment can be made by calling at the address of the user or in the office of the sender. The BH POST EXPRESS Contact Center is announcing the announcement of the BH POST EXPRESS postal shipment take over from 8:00 am to 6:00 pm by phone number 1417. The reception of these postal shipments and the announcement of postal shipment relates only to the narrower areas of the towns of Bihać, Mostar, Travnik, Tuzla, Sarajevo and Zenica, including the larger users in the Sarajevo Post Office, and the headquarters of the Municipality of Ilidža, Hadžići, Ilijaša and Vogošće.

4.3.1. ANNOUNCEMENT VIA CALL ON 1417

Agent of Contact Centers BH POST EXPRESS receives a telephone announcement of the receipt of BH POST EXPRESS postal shipment at the address of the user or in the business office by entering the sender's information in the "BH POST EXPRESS Posting Diary" message via the Contact Center via Phone 1417 "according to the text of the form.

After filling out all the necessary information, the received work order/address is applied automatically and automatically to the dispatch center at the Post Office for which the announcement relates. Dispatchers in the Post Center perform the delivery organization in accordance with the best practice of optimizing work processes.

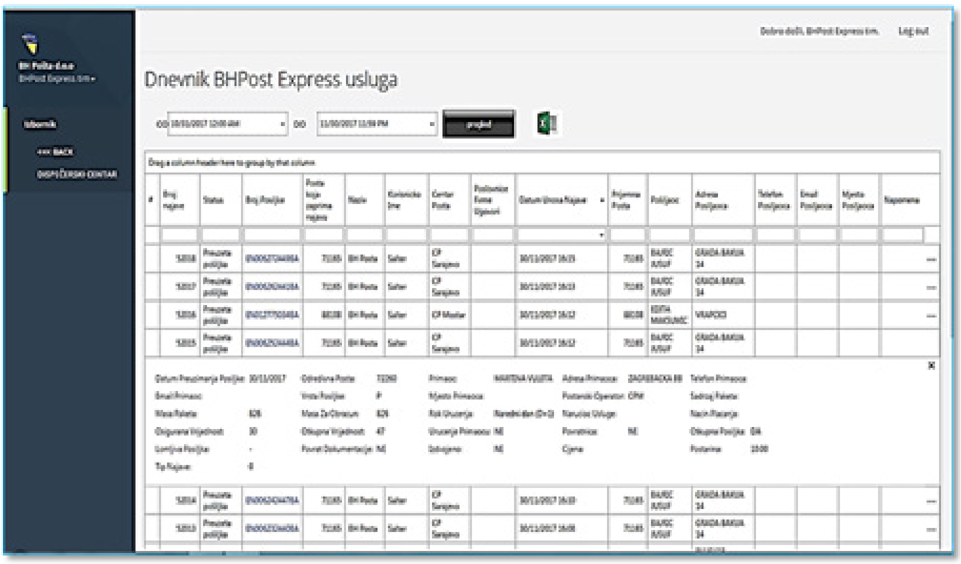

Fig. 4.
BH POST EXPRESS service diary
Source: (BH Posta, 2018)

4.3.2. ANNOUNCEMENT VIA CONTACT FORMS ON WEB PAGES

If the announcement is made through a web application, Agent of the BH POST EXPRESS contact center must verify the authenticity of the entered data by confirming the validity of the job order by calling the user and confirming the credibility of the entered data via the contact form. Contact form or order form BH POST EXPRESS through a website, will be defined in accordance with the technological solutions of the service, with all the necessary inputs for the service to be executed. Also, a form of contact (online calculator) in the form of a virtual assistant must have such features to maximize the user's convenience and to assist him in choosing the appropriate service (dimensions, speeds, delivery to the address etc.). Selection system, gets the ultimate price for that type of service you have chosen.

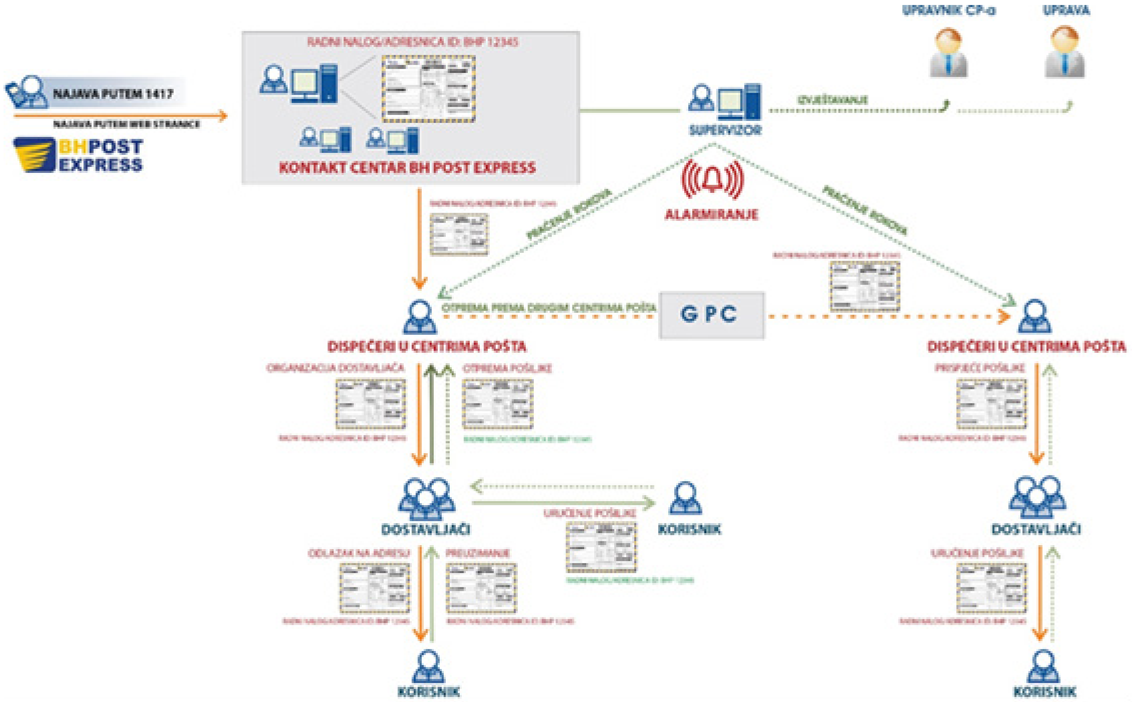

Fig. 5.
Information flow of Contact Centar and treatment of all participants in the service delivery process
Source: (PE BH POST, 2018)

Number 1417 is geographically linked to the Center Post Office, and it is necessary to make the necessary activities that will routed calls to the BH POST EXPRESS Contact Center at GPC. The intention is to have the complete platform of the Contact Center on VoIP technology, which would reduce costs and improve the routing capabilities of the Contact Center.

5. Conclusion

Quality in postal traffic today represents the postal operator's image, a powerful weapon against competition and a means to ensure progress and survival on a liberalized postal market. Quality is the right answer to the growing demands of users of products, goods and services. By ensuring the quality, each company ensures the satisfaction of the users, but also their own satisfaction, and the satisfaction of their employees, suppliers, and thus the entire community.
New challenges such as globalization, liberalization and privatization of the postal sector, the necessity of incorporating into European integration processes, and demands for high-quality traffic services create a new ambiance of postal operators' business, which requires innovative approaches to business in order to strengthen the postal operator's position on the liberalized and open postal market . Postal service users are increasingly demanding because they have a greater choice of a more favorable operator. By measuring customer satisfaction, we come to extremely valuable business information that enables us to plan and implement many important business moves. Knowing the satisfaction of the users, postal operators can react before they lose the market and before some weaknesses are reflected in their business. All these are indicators for the rapid improvement of the quality of postal services.
Quality should not be imagined as a morality - quality of postal services is a need that demands: quality planning, quality control, quality assurance and quality improvement to achieve the best quality of postal services.
In order to improve the quality of postal services with the concept of CRM, PE BH POŠTA introduces the new BH POST EXPRESS packet - courier service. BH POST EXPRESS is a value added service that enables the transfer of consignments for legal entities and individuals in the territory of Bosnia and Herzegovina. The BH Post Express services postal shipment are transmitted from the place of reception to the place of delivery within the deadlines depending on the type of BH Post Express service for the fee, which is determined by the BH Post Express In-Service Internal Price list. The reception of BH PostExpress postal shipment is made on a call at the address of the user, or in the business premises of the sender and at the mail counter, every working day (including Saturday), from 08:00 to 18:00 on the call center number 1417. Packet/courier service BH POST EXPRESS uses the resources of the Contact Center and is an integral part of the order/announcement management, tracking of consignments and providing information and reclamation. The task is to ensure the same and sufficient quality of communication with the users, through the unified ways of responding to the call operator, as well as the precisely defined information distribution procedures in the open work order, which directly influences the increase of the satisfaction and loyalty of the user PE BH POŠTE.

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MODELING FRAMEWORK FOR LAST-MILE LOGISTICS SERVICES

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Abstract: Last-mile delivery services are considered a critical part for e-shopping activity. Especially in urban areas rigorous planning is required by logistics service providers, due to uncertain demand, traffic conditions and geographical particularities. To this end, the main purpose of this paper is to measure consumers' most recent e-shopping experience to understand, study and evaluate consumer behavior towards delivery service attributes. A modeling framework is developed that includes consumers' characteristics, household characteristics, e-shopping characteristics, delivery service attributes and e-shopping motive. A survey was conducted in the city of Athens (Greece) and data were collected from 140 consumers who have a prior experience in online shopping and their replies were used to test the research model. The research findings pointed out that delivery service attributes are depending on the product type and value chosen as well as e-shop origin. E-shopping is mostly preferred by consumers to fulfil their utilitarian motives, and then to feel satisfaction. The most significant delivery service attributes were time of delivery, electronic notifications, delivery cost and return label. The results of this research can be used to the effective design and optimization of last-mile delivery service.

Keywords: last mile, e-shopping, delivery service attributes, consumer shopping behavior.

1. Introduction

The increasing trend of e-commerce has induced the transportation of small and fragmented shipments to be delivered at a specific point, and time as well as with additional service features based on consumer's requests. This type of goods' movement, from a transportation hub to a final destination which is either at consumers' home address or at a pick-up point, is called 'last-mile' delivery. Last-mile is the most complicated segment of the transport chain, as it involves adapted processes depending on geographical issues, cultures and habits of e-shoppers. Further to this, the share of costs related to the last mile, as part of the total transport costs, may range from 13% up to 75% of the total supply chain (Gevaers et al., 2009). Although this type of transport is traditionally performed by postal operators who distribute mail and other small shipments to people's home address, e-commerce generated changes in the patterns of last-mile deliveries in order to meet the so-called 'last mile challenge' of getting online orders to people with different needs in a specific geographical area with the most efficient way.

The importance of e-commerce and delivery services is one of the top five priorities of the European Union in order to promote e-commerce among European countries (Ecommerce Europe, 2016). Therefore, one of the most important categories of good practices within the context of e-commerce concerns the improvement of delivery service solutions in order to rationalize the last mile delivery. To this end online shoppers' attitudes and preferences should be the object of additional investigation to integrate their impact on shaping last mile operations. Understanding consumers' needs can be the key differentiator, for planning an efficient and sustainable last-mile delivery system not only for providers who have to organize transportation and retailing but also for the end-users who wait for delivery and choose to do e-shopping instead of in-store shopping. Delivery service can be used as a differentiated factor by e-retailers and win customers through customized delivery services.

In Greece electronic commerce has exhibited considerable growth during the last two years, and this upward trend is expected to continue in the forthcoming years. Three million Greek consumers perform online shopping spending an average amount of 1,600 euro whereas the Greek e-commerce sales reached 4,5 euro billion. One of the main reasons of the increasing trend of e-shopping is due to income reduction and the imposition of capital controls which made Greeks more price sensitive. The five top categories for online purchases are travel services reaching at 84%, followed by hotel reservations at 70%, electronic equipment and peripherals at 69%, entertainment tickets at 69%, and apparel and footwear at 62% (ELTRUN, 2018). The average value of an online order costs no more than 25€, it weights no more than 2kg and a great percentage of them can fit into a mailbox (IPC, 2017). Since economic instability is expected to continue and impact on Greek consumers' purchasing patterns and trends, the phenomenon of looking for product offers through e-shopping will continue to be the most important factor driving internet retailing in Greece.

Nonetheless, the organizational structure of last-mile delivery services provided in Greece, is still not so mature as is in other European countries especially like in northern European countries. For example, in the UK, or in Netherlands, alternative delivery methods such as pick-up points (PPs) and automated parcel stations (APS) equipped with lockers (Morganti, et al., 2014), have developed and provide more flexibility for consumers to collect their online orders. Having processed a field review about alternative options to home deliveries in Athens, there are the following three main alternatives:

- Delivery to physical stores: A smart business model was developed by 'Clever Point' which has organized delivery and return services of online orders through selected physical stores, like mini-markets, petrol stations or other convenience shops. On the one hand physical stores gain potential customers and on the other e-shoppers can choose the store that is more accessible to them. This solution can be developed further to other cities in Greece, depending on the success of the cooperation between e-retailers and physical stores.

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- Delivery to Parcel Stations at petrol stations: 'ACS' is a Greek courier company, which besides its own physical store network, has developed a parcel network with the cooperation of Shell Petrol Company throughout Greece. This network which is named 'ACS Smart points' consists of Automated Parcel stations which are installed in Shell's petrol stations. Consumers can receive and send their online order using these points, which are a safe place, operating 24 hours and 7 days per week throughout the whole year. In addition, consumers are informed through SMS and e-mail about the status of their online order.
- Postal offices: 'Hellenic Post' S.A. is the national provider of postal services in Greece, which has the most extended network throughout the country and is used by many national and international e-retailers to deliver online orders to end-users. Postal offices are a secure method that is used also for parcel returns, by many European e-retailers as they have proceeded with contract agreement with Postal Operators to offer this service for free to consumers.

The aforementioned delivery service methods to distribute online orders, depicts that in Greece the organization of last-mile deliveries is still under development and presents a great measurement challenge to investigate deeper and understand the demand side of this sector, that is the aim of this research to consider consumers' point of view.

The theme of last-mile deliveries and e-shopping has drawn a significant scholars' and practitioners' attention. There has been an extensive research about the issue of alternative delivery locations, like pick-up points, a very popular solution for parcel service providers as they can achieve very high first-time delivery rates (McKinnon, 2003; Xu et al., 2014; Morganti et al., 2014; Andriankaja, 2012; Stanislaw et al., 2015). Further to this, the issue of change in time of delivery was investigated as far as in what extent consumers have the option to choose a certain time-window to receive their online order (Campbell and Savelsbergh, 2006; Deketele et al., 2011; Agatz et al., 2011). To this end, there are many studies about influencing the consumer behavior to choose home delivery or pick-up point, based on the idea of changing delivery pricing, Agatz, et al. (2008). Other studies describe models about shopping trips within the context of comparing the benefits between e-shopping and in-store shopping (Mindali and Weltevreden, 2013). A significant number of studies in the fields of psychology, marketing, information systems and operations management have identified various factors that encourage consumers to shop online (Cheung et al. 2005; Darley et al. 2010; Monsuwe et al., 2004). Although, there has been an extensive research, less is known about consumer behavior and the impact on the concept of delivery service attributes for e-shopping. This paper aims to contribute to the fields of marketing and operations by identifying and describing this research gap and pointing out the need for future research. In consequence the research question that this paper is examining is the following.

What are the structures of e-shopping characteristics that lead consumers to increased preference to choose specific delivery service attributes?

Through these structures operational logistics managers and delivery operators (the supply side) will be able to gain a better understanding on customers' behavior how they are motivated to proceed with e-shopping and select specific delivery service attributes. More specifically the results of this research will be used to measure the significance of delivery service attributes with the scope to rationalize last-mile logistics services. However, there is another goal of this research, and this is to include practical experience to academic research and show that academic research can coincide with the interests of managerial practice. The survey conducted for this research took place in the city of Athens (Greece), where the greatest volumes of parcels are moving. The rest of the paper is organized as follows: section 2 reviews literature, section 3 explains the data collection and estimation, proposes the model framework and formulates hypotheses, and discuss research's results and section 4 concludes the paper.

2. Literature Review

The consumer delivery service system can be seen as a series of markets in which the desires of households and individuals (i.e. the demand side) are constrained by the opportunities offered to them (i.e. the supply side). More precisely, parcel delivery services for e-shopping is a kind of 'derived demand' originating from the direct demand for e-shopping. Consumers demand for a parcel delivery service, mostly not because they really need it but because they want to conduct e-shopping activity (Hsiao, 2009). Although the provision of delivery service for e-shopping is an issue between e-retailer and transport service provider, the services to be developed need to identify consumers' demand and especially under what conditions a customer is willing to pay for these services.

Consumers prefer e-shopping towards in-store shopping due to the higher convenience that it offers them, such as more product information and choices, the ability to compare products and prices and the potential to shop from any place at any time avoiding shopping trips. An important factor that determines the choice of e-shopping towards in-store shopping is the product type and value. Belonging to a particular product class has implications for the manner in which individuals gather information (Mindali and Salomon, 2007), purchase and choose delivery service type (Zhai, et al., 2016). Consumer products can be loosely categorized into three groups although a given product may have some qualities of two or all three of the groups (Chiang and Dholakia, 2003; Klein, 1998; Peterson et al., 1997). The first product type includes search products, which are those whose qualities a consumer can determine without any inspection prior to purchase, like books and CDs. The second category involves experience goods/ services, such as vacations and restaurants, as well as apparel and shoes which require actual experience prior to purchase in order to ascertain their quality. Last is the category of credence goods/services (e.g., legal and financial services) which require specialized knowledge, such that a consumer may have difficulties evaluating the quality even after consumption (Hsieh et al. 2005). The value and type of product, within the B2C market may be regarded as an explanatory variable that can determine the delivery service attributes chosen, like the speed (e.g. groceries), or request for value-added services (e.g. signature, cash on delivery, extra insurance, etc.).

Having chosen to proceed with online shopping and which product type to purchase, this decision relates with consumers' e-shopping motive, either to fulfill a utilitarian intention (functional or tangible) or hedonic (pleasurable or intangible) (Salomon, et. al., 2010). Depending on which motive consumers choose to shop online, they express different behaviors (Lim and Cham, 2015; Rohm and Swaminathan, 2004). Utilitarian motive refers to the desire to achieve some functional or practical benefit, whereas hedonic motive concerns an experiential need, involving emotional responses or fantasies. Sane and Chopra (2014), as utilitarian motives proposed, discounts, personal attention, membership, product quality, reasonable price, brands availability and product variety. These consumers who manage to purchase the product of their interest at a good offer, their utilitarian motive is realized and increased.

E-shopping incorporates, also hedonic elements, which have to do with emotional or experiential aspects of e-shoppers. Consumers aim to obtain hedonic value through arousal, playfulness, and positive affect from interacting with an online store (Bridges and Florsheim, 2008). Sane and Chopra (2014), proposed as hedonic motives status, branded products, ambience, relieve stress, enjoyment, mood improvement, hobby, exercising, store reputation, new trends. Consumers who are driven by their hedonic motives to shop online, they may select products which provide pleasure and influences positively their attitude, which in turn may positively affect the propensity of online purchases (Kim and Eastin, 2011).

In terms of delivery services, hedonic motives may lead consumers to choose a faster delivery service comparing with utilitarian motives which may concern to save travelling expenses to physical stores, thus, prefer a slower delivery service. However, previous researches have documented that online shoppers are driven by both utilitarian and hedonic dimensions, which together formulate the online shopping experience (Solomon, 1999; Childers et al., 2001; O'Brien, 2010; Overby and Lee, 2006) and influence online shopping decisions (Bosnjak et al., 2007). Both motives can be complementary and satisfy both needs (Holbrook and Hirschman, 1982; Ozturk et al., 2016), thus to influence consumers' decision-making regarding e-shopping which is directly connected with delivery services.

Apparently, e-shopping can be fulfilled by a delivery system that can satisfy both consumers' and retailers' needs. Having studied the academic literature and advised the delivery service provider's price catalogue, as well as e-shop's offered services, the below attributes synthesize the delivery service provided, and these are the following:

- Delivery point;
- Delivery time and speed;
- Track and trace;
- Value added services;
- Delivery price.

Delivery point is the first thing that consumers need to determine after completing e-shopping. They are two main options, either to provide an address that can be at home or at workplace or to choose to collect online order from a pick-up point if this option is provided by e-retailer. Pick-up points is an alternative solution to home delivery, like automated parcel stations, which can increase the consumer's willingness to pick up the goods instead of using home delivery. This type of service is widely offered to consumers in northern European cities, and is mostly provided by postal and logistics operators (Morganti et al., 2014). The critical issue that needs to be considered here, is that these points need to be close to living areas, such as close to consumers' residences, on the way to work, close to shopping centers, to public transport stations, close to parking and in secure locations. Iwan et al., (2016) analyzed the usability and efficiency of automatic collection points based on the postal company's experience in Poland and concludes that it seems to be the major direction in the near future, to evolve into more structured distribution channels to serve e-shoppers and aim for more consolidated shipments that is a sustainable solution for the environment.

The concept of time and speed of deliveries, that is the total time between order placement and delivery to consumer, is one of the main factors that impact on the choice of delivery service attributes. Parcel service providers, segment their price catalogue on delivery time into same day, next day, or two and more days, as well as delivery to specific time-slots and develop different logistical approaches (Huebner and Kuhn, 2016). Time of delivery is a determinant factor for delivery service, but also for online shopping. Consumer wish to deliver his/her online order immediately after completing e-shopping, thus the aim is to minimize the time that customers can wait to receive their online order. They may require time-based delivery service in order to control the trade-off between home delivery and pick-up point by being able to select a pre-defined delivery time slot in advance (Agatz et al., 2011). The issue of providing a specific delivery window implies that small delivery windows will produce the highest customer satisfaction. Agatz et al. (2008), proposed time alternative, like morning or afternoon timeframe, potential of deliveries on Saturday, to deliver to neighbor or to service points. Goebel et al. (2012) researched a service offered to consumer that is the choice of a pre-defined time slot and found that consumers who perceive a delivery service as more valuable are willing to pay more for that service. The more precisely the customer can control or select the desired time slot, the higher the cost for retailers. All in all consumers are willing to pay up to a certain amount of delivery fee and receive their order the same day, if it is a local e-shop, instead of waiting some days. Furthermore, consumers who perceive this convenience enhancing service as attractive, represent a market segment that has significant revenue potential. Miyatake, et al. (2016), studied, time windows delivery service and is suggested that in case of a second pre-arranged delivery service in which consumer will be absent, then he/she should pay an extra delivery charge as a penalty. This service can be applied successfully as long as there is a pre-arrangement between the service provider and the consumer, so as to

arrange home availability depending on working hours per week. By offering time-based delivery services may allow logistics service providers to invest in more convenient technological interfaces such as more frequent communication through sms or email.
Consumers get information regarding the order status of their electronic purchase, right after having completed their online order which informs them about the date and tracking number of order dispatch. Then consumers are directed to parcel providers' web site to continue with tracking. Track and trace are services based on automatic identification of the parcels' location and status by use of technologies such as RFID, barcodes, and are the most important services for e-shoppers. Electronic data for order status allow the customer to have the feeling of shipment control and arrange his/her presence at home at the time of parcel delivery. This feature has a significant impact on repurchase intentions (Cho 2015; Liao et al., 2010, Rao et al., 2011). However, in case of cross-border e-shopping, due to lack of information systems' interoperability between delivery operators, end-to-end track and trace is not guaranteed.
The price of delivery service, is another important factor in consumer's decision-making. Service delivery pricing, is known as the shipping fee, and reflects the costs of physically moving the product from one place to another as well as it reflects the value-added services that a consumer may have selected to receive his/her online order and these may involve delivery within a certain time, cash on delivery, extra insurance or any other personalized service. Although, delivery service is provided for free to consumers, when the online order is above a certain amount, this doesn't mean that shipping cost is for free, rather than the price of delivery service is included in the product. In consequence, the delivery price paid by the e-shopper to the e-retailer does not necessarily reflect the delivery price paid by the e-retailer to the delivery operator. As delivery service has a critical role to e-shopping, and affect retailer's and consumer's cost, it is better for e-retailers to clearly introduce the delivery price independent from the price of the items, (Miyatake et al., 2016). A significant factor to delivery price plays the geographical area, in terms of residence disparity as window deliveries in urban areas can be lower than standard deliveries within rural areas (Gevaers et al., 2014). Whereas some e-shoppers only care about paying a low delivery price, others are prepared to pay more for delivery in exchange for extra services, faster or more convenient delivery. Speed and cost are the two factors that are crucial to the success of last mile delivery (Chen and Pan, 2015).
Consumer behavior is influenced by all the above described factors throughout the decision process of e-shopping and delivery service. In addition, it counts the experience of the previous e-shopping activity, whether consumer was satisfied from the whole service provided (Chang, Wu, and Lai, 2010; Monsuwé et al., 2004), which if it was positive then will lead to repeat purchasing in the future (Monsuwé et al., 2004; Zhou et al., 2007). It should be mentioned, though that the majority of e-shoppers' purchasing experience is directly linked to the quality of the delivery service that the seller provides them. In consequence, delivery service can provide value to the total e-shopping process.

3. Methodology

3.1. The Proposed Model and Hypotheses

Based on the literature review, it is proposed an integrative model framework to understand what factors impact consumers to choose delivery service attributes to receive their online order (Figure 1). This framework provides the attributes of delivery service, as well as the links with consumer's characteristics, household characteristics, e-shopping characteristics and e-shopping motives.

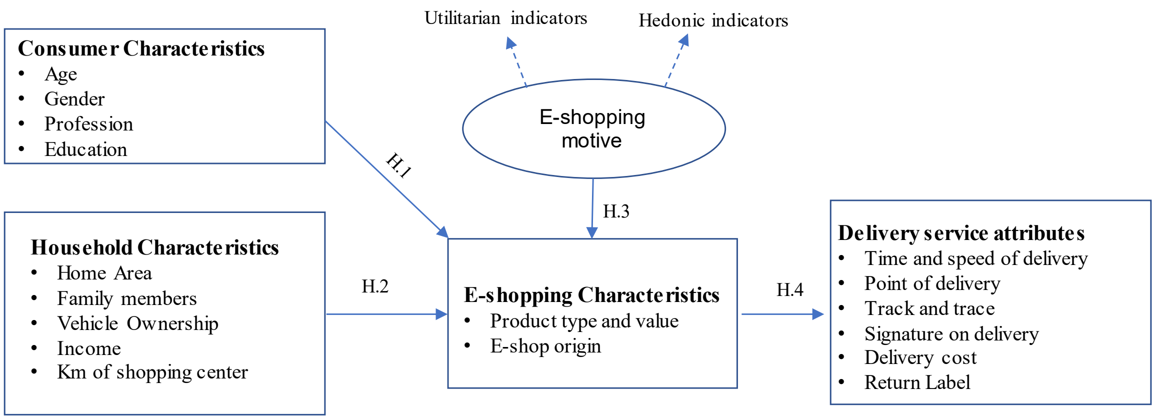

Fig.1.
Modeling Framework for last-mile delivery services

In this model, the effect of each of the variables was examined and four hypotheses for testing the relationships between the variables of the framework were formulated and produced. These are the followings:

- H1. E-shopping characteristics (product type and value, e-shop origin) are dependent to consumer characteristics (age, gender, profession, education)

- H2. E-shopping characteristics (product type and value, e-shop origin) are dependent to household characteristics (Home Area, Family members, Vehicle Ownership, Family income, Km of shopping center)
- H3. E-shopping characteristics (product type and value, e-shop origin) are dependent to e-shopping motive (utilitarian, hedonic)
- H4. Delivery service attributes (Time and speed of delivery, Point of delivery, Track and trace, Signature on delivery, Delivery cost, Return Label) are dependent on e-shopping characteristics (product type and value, e-shop origin).

An online survey was conducted to collect data on consumers' most recent e-shopping experience. Questionnaire was developed using Sawtooth Software, and disseminated through internet social networks. The survey took place in the period of March to May 2018 and data were then analyzed using SPSS statistical software package. The total number of valid questionnaires that were collected was from 140 respondents.
The table below presents the delivery service attributes and attributes' levels that were measured for this research.

Table 1
Delivery service attributes and levels included in the questionnaire

Index	Delivery service attributes	Attributes' levels
1	Delivery point	• at home • pick-up point
2	Time and speed of delivery	• Standard delivery (3-7 days) • Express delivery (1-2 days) • Next day delivery
3	Electronic notifications for status delivery	• Order status notifications (email/sms) from the transport company • Order status notifications (email/sms) from the e-retailer • Through special mobile application of the transport/courier company • Through the transporter's/ courier website
4	Value-added services	• Signature • Return label
5	Delivery cost	• Free delivery (e-shop offers it as a standard service) • Free delivery (the order value was above the limit to cover free delivery cost) • 1-3€ • 3-6€ • >6€

The results of the questionnaire showed that the gender distribution was 51% percent of male and 49% was female. The greatest age category, 42% falls in between 37-45 years old, whereas 27% who replied were in the age category between 27-36 years old. The majority of the respondents 70% were well educated as they hold an Msc or Phd degree while 74% have a full- time job. The top three categories of products purchased were apparel and shoes at 34%, then were pharmaceutical and cosmetics at 31%, electronic devices at 19% and pc equipment at 16%, whereas 54% of the online orders had a value between 31-80 euros. The greatest majority of e-shoppers 64%, shop from Greek e-shops.
The monthly household income was evenly distributed close to 20% for each of the four income categories, of 500-1,000€, 1,001-1,500€, 1,501-2,000€ and 2,001 -2,500€ whereas a slight increase 24% lies in the fifth income category of >2,500 €. In terms of geographical location, the greatest majority of consumers 86% live in the urban area of Athens, that is close to the city center, thus the distance to the closest shopping area is no more than 5km. Regarding vehicle ownership, almost everyone, 94% owns a car, while approximately 41% own a bicycle, too. Most of the respondents 28% live in a house with 3 members, whereas households with 2 or 4 members have the same percentage that was 24%.
Figure 2 below presents the delivery service characteristics that were selected by respondents, to receive their online order. Standard delivery method was chosen with great difference at 80% compared with the other two methods in terms of time velocity. The preferred point of delivery was at their home address at 63% and then at their office address at 29%. However, 53% of respondents reported that they received track and trace information from the e-shop and 33% from transport company. Half of the consumers 51%, didn't sign to receive their parcel. The greatest percentage of e-shoppers received their order with free delivery either as an option offered by the e-shop at 27% or due to the amount of order that was over the limit which provides free shipping at 33%. However, 17% of respondents paid less than 3 euros to receive their online order. Finally, a return label wasn't found by 44% of the consumers.

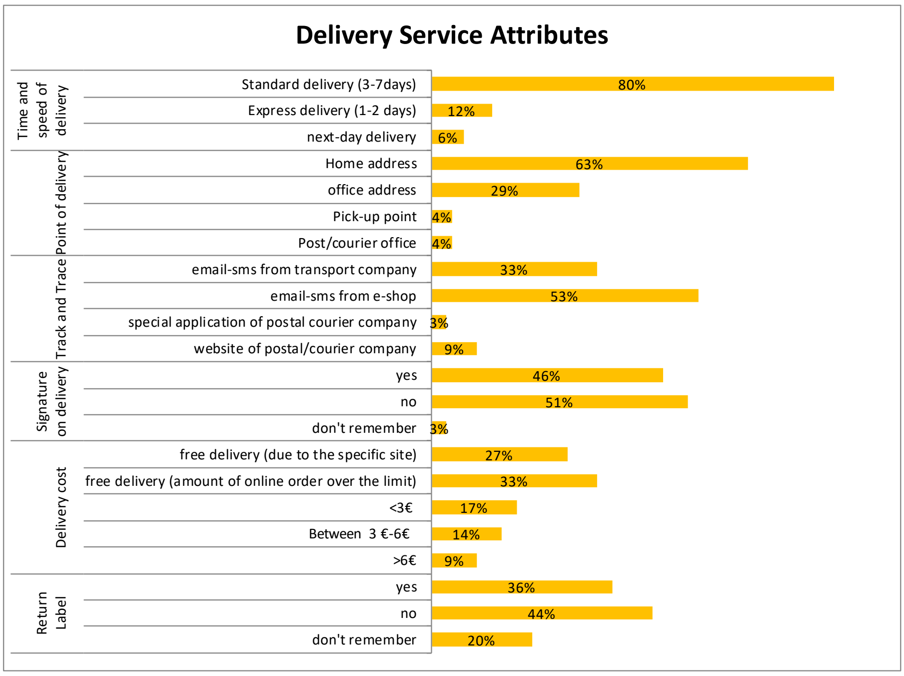

Fig. 2.
Delivery Service Attributes chosen to receive online order

As far as e-shopping motive is concerned e-shoppers have rated high at 53% 'the convenience that an e-shop offers them to shop any time from any place', as well as 'the detailed product information that they can find' at 24%. Further to the utilitarian motives, 39% of consumers replied that they 'feel great satisfaction when they find to shop products of the last trend' and 25% when 'they find offers and sales'.
Applying chi-square test it was tested H1. and it was found that, only three types of products were statistically significant with consumers' characteristics. These were pharmaceuticals and cosmetics (χ^2=6.801 and p=0.009), and apparel and shoes (χ^2=9.575 and p=0.002) which were statistically significant with gender, and more precisely with female as is the majority who shop these two types of products. The third type of product, is PC equipment (χ^2=4.859 and p=0.027) which was statistically significant with profession as well as e-shop origin (χ^2=13.327 and p=0.001). All other types of products and their value had no statistical significance with the consumers' characteristics.

Table 2
E-shopping characteristics vs. consumers' characteristics

e-shopping characteristics	**Age**	**Gender**	**Profession**	**Education**
Groceries	1.558 (0.459)	0.203 (0.652)	0.037 (0.848)	0.630 (0.427)
Pharmaceutical	2.199 (0.333)	6.801** (0.009)	0.321 (0.571)	0.007 (0.934)
Apparel and shoes	0.814 (0.666)	9.575** (0.002)	0.282 (0.596)	1.580 (0.209)
Office consumables	2.840 (0.242)	1.029 (0.310)	2.159 (0.596)	0.183 (0.669)
Kids products	5.448 (0.066)	0.501 (0.479)	0.643 (0.423)	2.294 (0.130)
Household product	5.205 (0.074)	0.686 (0.407)	2.210 (0.137)	0.358 (0.550)
PC equipment	1.880 (0.391)	2.933 (0.087)	4.859* (0.027)	0.145 (0.703)
Electronic devices	2.859 (0.239)	0.502 (0.479)	1.101 (0.294)	0.901 (0.343)
value (1-30 euro)	0.281 (0.869)	0.026 (0.873)	1.602 (0.303)	0.084 (0.772)
value (31-80 euro)	3.667 (0.160)	2.403 (0.121)	0.100 (0.752)	0.521 (0.471)
value (81-150 euro)	1.792 (0.408)	0.147 (0.701)	1.679 (0.195)	0.045 (0.833)

e-shopping characteristics	Age	Gender	Profession	Education
value (251-350 euro)	0.372 (0.830)	1.029 (0.310)	0.690 (0.406)	0.630 (0.427)
e-shop origin	6.382 (0.172)	2.873 (0.238)	13.327** (0.001)	0.017 (0.992)

*p<0.05, **p<0.01

As far as household characteristics' variables are concerned, none of them which have tested have shown statistical significance with any of the e-shopping characteristics, thus this model component is rejected and its variables can be measured again under a different category.

In order to test e-shopping motivation, with the products that were found to be statistically significant with consumers' characteristics, Mann Whitney test was applied, and the results are presented in the table below.

Table 3

E-shopping motivation in relation with e-shopping characteristics

E-shopping motivation	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Pharmaceuticals and Cosmetics				
Better control to my consumption habits	1518,000	6271,000	-2,614	0.009
The feeling of satisfaction finding products of last trend	1619,000	6372,000	-2.186	0.029
Apparel and shoes				
The feeling of satisfaction when I found offers and sales	1752,000	6030,000	-2.040	0.041
PC equipment				
The convenience to shop whenever I want from any place	956,500	7977,500	-2.139	0.032
The detailed product information that I can get	963,000	7984,000	-2.024	0.43

Reporting Mann Whitney test showed that there was a statistical significance (U= 1518,000, p = 0.009) between the utilitarian indicator 'Better control to my consumption habits' in relation with pharmaceutical and cosmetics product category as well as with the hedonic indicator 'The feeling of satisfaction finding products of last trend' (U=1619, 000, p=0.029). Following this, the hedonic indicator 'The feeling of satisfaction when I found offers and sales' with apparel and shoes product category was found to be statistically significant (U = 1752,000, p = 0.041). Regarding the Utilitarian indicator 'The convenience to shop whenever I want from any place' shows statistically significance (U = 956,500, p = 0.032) with PC equipment as well as with the 'The detailed product information that I can get' (U=963,000, p=0.043).

Concerning delivery service attributes relating with e-shopping characteristics applying chi-squared tests, the results are summarized in the table below.

Table 2

Results of Delivery service attributes towards e-shopping characteristics

Delivery service attributes	χ^2	*p*	E-shopping characteristics
Standard delivery (3-7 days)	6.117 4.193 7.546	0.013 0.041 0.023	Pharmaceuticals and cosmetics Apparel and shoes Country of e-shop
Next day delivery	5.818	0.016	Groceries

Delivery service attributes	χ^2	p	E-shopping characteristics
Electronic notifications for order status	10.233 9.153 25.803	0.037 0.027 0.001	PC equipment Product value (31-80 euro) Country of e-shop
Return label	10.933	0.027	Country of e-shop
Delivery cost	21.002 28.765	0.000 0.000	Product value (1-30) Country of e-shop

The above results show that next day delivery was applied only for groceries products, while products that were mostly preferred to be purchased by our respondents like pharmaceuticals and cosmetics and apparel and shoes, the issue of time delivery was not so significant as they have chosen the slowest method. The provision for electronic notifications was requested for PC equipment, a product type that was preferred mostly by men rather than by women. Goods that their value was in the value category of 1-30 euros, the issue of delivery cost was important, while for products' value that is 31-80 euros electronic notifications were important. What is interesting to notice is that delivery services, such as standard delivery method, electronic notifications, delivery cost and return label are all significant with the e-shop origin. Whereas point of delivery was not a significant factor with any of the e-shopping characteristics.

3.2. Discussion of Descriptive Statistics

The great difference between standard delivery method and express delivery shows that respondents are interested more in saving cost rather than time of delivery. Only for groceries next day delivery was an important issue and this can be explained as is a type of product that need frequent replenishment for a household and is a necessity.

Regarding point of delivery, online orders are delivered at consumers' place either at home address or at the workplace. There were very few choices for pick-up points, which shows that either this method is not provided by e-retailers at their e-shops or even if it is provided consumers can arrange successful home delivery. When consumers complete their online order, receive an order notification message and then it follows a message for the day of order dispatch which refers to the tracking number. Having received this tracking number, consumer usually diverts to transport provider's web page to track for order status. In this survey results have shown that respondents were receiving order status notifications from the e-shop rather than the parcel provider company. This can be explained that since the majority of e-purchases were performed in Greek e-shops, the delivery time was short, so since consumers were receiving a message notification about order dispatch, then they may not have continued tracking their items to parcels providers' web site, where shipping status is displayed. In case of an e-purchase from a foreign e-shop then order status notifications could be checked more frequently by consumers. A substantial last-mile issue in home deliveries occurs if a signature by the person stated on the parcel's address is required, as this element reassures delivery by a specific person. But, in this survey this characteristic doesn't seem to have a significant meaning, whereas it could be of high importance in case that the order is exclusively for personal use or the receiver doesn't want to know other family members about his/her online order. In case that signature is not of high significance, then order can be received by any other person who is at home, and avoid delivery failure. The top three product categories chosen were apparel and shoes and pharmaceuticals and cosmetics mostly by women, while PC equipment was most frequently purchased by men. This shows that gender plays an important role to product type as well as the profession. This finding comes to an agreement with Clemes et al., (2014) who states that gender has an influence on e-shopping behavior. The product value category of 1-30 euros was a preferred category by consumers, but it was found that delivery cost has a significant role. The option of free delivery can be offered to this type of value of products, in consequence this may be an issue for e-retailers to think and find a method to provide free delivery. Although household size impact on e-shopping activity and more precisely on the frequency (Zhou and Wang, 2014), comparing with singles who tend to do less online shopping (Farag et al., 2007), in this survey this model category didn't impact on e-shopping characteristics. The variables that constitute household characteristics will be measured under different category.

Consumers are more sensitive to receive electronic notifications as the value of product is rising. Consumers' motivation is an important element to consider and together with e-shopping characteristics and individual characteristics to develop customized delivery services. Most researchers focus on motives relative with product, in consequence there is an opportunity to examine deeper in terms of delivery services. Apparently, consumers from Athens, are motivated to shop online because of the convenience that e-shopping offers in terms of time, place and product information towards physical stores, and for finding sales and good offers as well as purchasing goods of last trend that these can not be found to physical stores. However, they are also induced to shop by hedonic motives, such as the desire to find the last trend in the desired products, so both motivations influence consumer behavior. These findings

concur with other researchers' that e-shopping motivation, can be driven either to maximize utility for practical reasons or to gain as much pleasure, (Kourouthanassis et al., 2008).
Country of e-shop is a determinant factor for electronic notifications, time of delivery, return service and delivery cost. Although the respondents in this survey have mostly purchased from a Greek e-shop (64%), the origin of e-shop whether concerns domestic e-commerce or cross-border, seems to generate different behavior for delivery service. This can be explained by the fact that local markets apply different marketing strategies for customer service. In addition consumers who shop from a local e-shop can access easier the e-retailer in case they meet any problems with their online order. Apparently, e-shoppers' attitudes and preferences should be the object of additional investigation to integrate their impact on shaping last mile operations. Knowing consumers' preferences will provide feedback to develop consumers' segments depending on their specific individual characteristics, motivations and e-shopping characteristics and provide a competitive advantage firstly to e-retailers and then to parcel providers.

4. Summary and Conclusion

In this article, it was attempted to examine e-shoppers' most recent e-purchase experience and define these components of e-shopping and motivation characteristics that lead consumers to choose specific delivery service attributes. The developed model framework provides an insight into the potential interactions between consumer behavior and logistics operational procedures of e-shopping so as to develop marketing strategies for different delivery service types provided to e-shoppers.
Based on these preliminary results, it can be assumed that e-shoppers choose to shop online mostly driven by their utilitarian motives, chasing for offers and discounts, and then from hedonic motives, gaining satisfaction of acquiring a product of the last trend. However, there is a place for further investigation, as the sample of this survey was taken from the city center of Athens, where shopping opportunities are to a very close proximity, whereas results can be different if consumers where living in rural areas.
These approaches are consistent with the aims of this paper in order to understand consumer behavior and how they react to delivery service attributes. These findings provide feedback to the supply side of e-commerce market, in order to develop specialized retail chains based on product type and value, develop their information systems concerning tracking and tracing, and the options of delivery service that the e-shop can offer to consumers. Last-mile networks need to be very agile, and provide an efficient delivery service system, that can offer various services and predict consumers' behavior. Future logistics models should focus on controlling the last mile distribution service quality rates of customer satisfaction.

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THE NEW APPROACH FOR THE POSTAL SERVICES USING CITY LOGISTICS METHODS

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Abstract: This paper focuses on the vehicle routing problems found in cities for goods distribution generally called as City Logistics which is a very discussed topic in recent years. Appropriate selection of the city logistics methods can help to remove the urban transport problems from the city with the constraints of space and with the need to clean the already damaged environment. That is currently, according to the research, one of the biggest problems for the big as well as for the small cities. The main aim for the area of City Logistics is to minimize the frequency of journeys of the supply vehicles in the cities, especially in the cities centers and by this minimization bring the environmental impact due to the added value of the service itself. Purpose of this paper is to explore the new city logistics problems and solutions and present some selected possibilities where the City Logistics services can be transferred to the postal services in the Czech Republic. One of the selected solutions is a consolidation of consignments at the spot of transshipment and then subsequently delivery of that consignment using a new approach. The paper itself can be divided into the three main parts. The first part focuses on the domestic as well as international research with an aim to bring a comprehensive overview of the City Logistics services. In the second part of this paper is an analysis of the current state of the City Logistics in the connection with the postal services. The new approach designed by the authors of this paper is in the third part.

Keywords: city logistics; postal services; consolidation of consignments.

1. Introduction

Currently, the ever-growing urbanization trend of large, medium and small sized towns is the object of interest not only for city logistics experts, but also for politicians and the public. The main reason for such attention is the negative economic, environmental and social impact of urbanization. Negative impacts include high congestion, noise, polluted air, vibrations and higher logistics costs in the city. While higher logistics costs are reflected in higher product prices, external effects in the form of polluted air and noise can cause various civilization diseases and generally a lower quality of life in the city. Tadić et. al. (2015) underlines that local authorities are aware of the importance of organization and control the current logistics chain situation in the cities, but most of the local authorities do not know how to minimize the negative impact of logistics activities on the economy, environment and quality of life in the city. According to the United Nations research, more than 54 percent of the population currently live in urban agglomerations. The prediction of the United Nations, according to which 66 percent of the population will live in cities by 2050, is alarming and there is a need to look for ways to ensure sustainable urban development. Tadić et. al. (2015) pointed out that besides the growth of the urban population, the trend of growing goods flows is continuing, which leads to increased activities of road freight and light commercial vehicles. Quak (2008) detailly described the negative impacts of growing trend of road transport, which are related to the economy (increases prices), society (damages to human health, accidents, noise and lower quality of life in the city) and environment (emissions and consumption of non-renewable energy). Witkowski (2014) characterized city logistics as a process of planning, implementation and monitoring effectiveness of people, freight transport and information flows in urban areas in order to improve the quality of life in the city. Tadić et. al. (2015) pointed out the role of transportation in city logistics, which consist in a reduction of the number of empty vehicle-kilometers and control the number, size and characteristics of the freight vehicles. All of it is to achieve a city logistics goal, which is to increase efficiency and minimalize the negative impacts of the logistics process and support the sustainable development of urban areas. All the authors outlined sustainability as a way to ensure economic, ecologic and social prosperity. Taniguchi et. al. (2013) outlined a need to create a balance between smart economic growth, transportation and cleaner, safer, quieter agglomerations and a risk of disaster due to global climate change. According to Brundtland (1987) sustainability can be characterized as a development that provides the needs of presents and do not compromise the ability of future generations to ensure their own needs. Russo (2010) described a worldwide Sustainable Development Strategy which aims to create a continuous long-term improvement in the quality of life by managing and using resources efficiently, developing economic and social sustainability in terms of efficiency and safety and environmental sustainability in terms of air pollution.

2. What Have We Learn About City Logistic so Far?

Nowadays attention is being paid to issues of sustainability all over the word, in some cities they have begun developing smart cities projects or at least their concepts for future realization. An inseparable part of the smart cities projects is city logistics, which is responsible for the logistics processes and the sustainable transport in the city. According to Taniguchi et.al. (2001) city logistics is "*the process for totally optimizing the logistics and transport activities by private companies with support of advanced information systems in urban areas considering the traffic environment, the traffic congestion, the traffic safety and the energy savings within the framework of market economy*". Kauf (2016) defined that a main city logistics task is to improve the quality of life in cities for their residents and ensure

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competitiveness of businesses located in the city. Russo (2010) outlined the importance of consideration of different interests before implementing city logistics measures, means an investigation of the relations and the interests of urban transport stakeholders. It follows from the above that it is necessary to perceive the concept of city logistics comprehensively and take into consideration the needs and objectives of all stakeholders. Pursuant to Taniguchi and Thompson (2014) the four main stakeholders are: shippers, freight carriers, administrators and residents.

Residents are the most numerous group of stakeholders, they are the one who create the commodity and the transportation flows in the first place. The more residents that live in the city, the bigger the demand in restaurants and the shops, which lead to increased transport flows. Another reason of increased transportation in the city is growing e-commerce, due to the fact that residents more often buy things on the Internet and require delivery as soon as possible. That' leads to an increasing number of freight vehicles in the city and lower loading factor. According to Demkes et. al. (1999) logistics providers trying to satisfy customer needs are more often focused on the effective time management instead of focusing on effective transport methods, which implies an increase of running vehicles and thus the vehicles-kilometers.

Logistics providers or freight carries represent another major stakeholder, which can influence the logistics situation in a city. Freight carriers are the ones who decide which type of freight vehicle is used for transportation, the one who arranges the routing for vehicles and the one who is responsible for the loading factor. The main problem is the different goals of city logistics and freight carriers. While city logistics is focusing on sustainability in terms of ecology and society, the freight carriers focus on their incomings. According to Tadić et.al. (2015) as a result of such discrepancy, freight carriers provide their services without needed coordination, in most cities urban freight transport is very inefficient, which means that the same amount of goods can be delivered with a smaller number of vehicles-kilometers, but with the same or even better quality of service. The studies show that logistics services providers are mostly small companies, which have a lower utilization factor of the vehicles cargo space.

Another group of stakeholders, which is according to Witkowski (2014) plays the most important role in the city logistics system is the administration or government. The main goal for the administration should be a sustainable development in the city and ensuring high living standards in social, economic and environmental issues. Autor Witkowski (2014) outlined the most important tasks for administration related to each issue. In social areas it is ensuring the safety of residents and education of residents about the protection of the environment. In the case of economics, the main goal is to reduce the costs associated with the movement of people and cargo and in case of the environment the main aim is to reduce emissions of CO_2 and NOx and noise reduction in the city. Tadić (2015) pointed out that the local authorities or administrations in European cities provide a lot of regulations and measures in order to increase consolidation, cooperation and coordination and thus raise the efficiency of the city's logistics. On the other hand, author outlined often inadequate decisions of authorities, which are made without the analysis of the existing situation, its surroundings and the impacts on the overall city's logistics system. Several authors (Allen et.al, 2000; Quak, 2008) agreed that often prohibitive and restrictive measures like restrictive measures concerning the load capacities of vehicles or time for accessing the selected zone in the city, has a negative impact on logistics activities, instead of making them more effective. Tadić (2015) underlined that restrictions and prohibitions in a city's logistics cannot be the solution itself, this requires a certain level of understanding of all stakeholders' activities and decision-making processes while considering the consequences for the entire system of city logistics.

The last group of stakeholders in a city's logistics system is the shippers, which represents different shops and restaurants as well as e-commerce retail. Shippers, in order to ensure high quality service for their customer and incomes for themselves, require the goods to be delivered on time. Often, they force the freight carriers to be punctual and implement a delay penalty, it leads to a non-efficient way of transportation.

Analysis of current city logistics situations and administrator initiatives shows that interaction between the private (freight carries) and public (administrations) sector is deficient, which leads to a lot of misunderstanding and failures of city logistics measures. The main problem is that administrations do not know enough about the problems related to logistic activities in the city and the freight carriers are unable to formulate requirements from the administrations in order to achieve a sustainable city logistics solution (Tadić, 2015). Dablanc (2007) characterized the whole situation as a slowly chancing process, where neither the freight carriers nor administration are willing to make progress, on the one hand the freight carriers are waiting for a right and supportive (financially) initiative from the government and the government, on the other hand, expected freight carriers to set up new logistics solutions, which will satisfy customers and environmental needs, but may not be profitable at all.

The main aim of city logistic is to find a new sustainable solution for transportation and supplying into cities which will be acceptable for all stakeholders. The key to success is based on cooperation and synergy effects generated by participants in the supply chain (Kauf, 2016). During the history of city logistics there has been presented a lot of city logistics methods and assumptions, focused on creating a sustainable city. For example, there are studies about urban logistic terminals, last mile management, different types of consolidation and a reduction in the number of trucks trips in the city. According to Taniguchi (2014) some of the elements are fundamental for creating a sustainable city logistics system. For example, innovative technology for information and communication, Intelligent Transport Systems, cooperation between the public and private sectors and changing the mind-set of logistics managers are some of them. Using information and communication technology (ICT) and intelligent transport systems (ITS) could help the shippers qualify their services by tracking vehicles with GPS, tracking freight containers or palettes, route planning to avoid congested roads based on digital maps and real time traffic information. ITS could also help to reduce operation costs, by reducing the number of trips (Nemoto et. al. 2001).

According to Gonzalez-Feliu et. al. (2013) the most difficult element is cooperation between the public and private sector. The main problem of public-private partnership is the conflict of interests where, on the one hand, is the private sector (shippers, freight carriers, shoppers), who wants to constantly improve the service for their customers, notably by more frequent and smaller supplies of goods. On the other hand, is the side of the administration, who want to coordinate the private sector activities to minimize the environmental and social impact of transport and create sustainable, liveable cities for their residents. The last fundamental element in creating a good city logistic system is, according to Taniguchi (2014), a change in the mind-set of logistic managers, mostly because logistics managers are the main players in urban freight transport systems. They are the one who makes the decisions about whether their company is going to provide a green city solution and educate their employees about sustainable cities and how they can participant or not. The main thought is that we cannot solve 21-century problems with 19^{th}-centure mindsets (Landry, 2012). But are the logistics managers the only ones, whose mind-set needs to be changed in order to create sustainable and livable cities?

2.1. City Logistics Current Situation and the Theoretical Measures

There are different types of city logistics management, which are focused on different management methods and city logistics schemes to arrange environmental, economic and social sustainability in cities all over the world. The key success factor in achieving city logistics goals in every city is a right combination of different city logistics schemes and management methods in order to create a synergy effect.

The first step in applying the best fitting logistics measures in a selected city is finding the current transport situation and the major relating problems in the city. Tadić et. al. (2015) outlined a problem with empty runs of vehicles in the cities due to geographical imbalance, unsuitability of the vehicles and problems with routing and scheduling the vehicles. Geographical imbalance exists due to current logistics organization, when most cities are supplying from logistics centers outside the cities, which increases the transport distance during the supplying and costs reverse empty runs of vehicles. According to Allen et.al. (2012) there are several factors that affect the extent and location of logistics activities for example population density, size and economic structure of the city, operational models and vehicle structures in the realization of flows. Significant impact on urban areas has supply chain organization, means locations of logistics centers, warehouse systems and spatial arrangements within the chain. Dablanc (2007) pointed out the problem with the regulation of city logistics situations, which is the same as 20 years ago, for example identifying the maximum size or weight of trucks authorized to deliver in city centers. Author Dablanc (2007) described a new model of restrictions used in some European cities, which focuses on Euro emission standards of vehicles and the loading factor. According to these restrictions just the latest vehicles and fully loaded trucks can enter the city center. Dablanc (2007) also characterized a problem with the age of vehicles, turns out supplying vehicles trend to be older than the rest of the fleet of the truck industry, which leads to higher environmental pollution in the city.

The second step, after defining the common city logistics problems, which seems to be the same in all cities in Europe and the world, is finding an appropriate city logistics solution. As it was pointed out before, there are a lot of city logistics methods focusing on different types of city logistics problems. Some of the city logistics methods were already applied in the cities and some of them are in the planning phase, it depends on the degree of difficulty and input needed to process the different methods. Less input needed methods like access control to cities are currently more common in cities than for example one of the most expensive measures like an urban consolidation center. On the other hand, the problem with urban consolidation centers (UCC) is very often mentioned in the thematic literature, several publications are focused just on this problem. According to Brawne et.al. (2005) UCCs can be defined as a logistics facility situated in the city center or close to the area, which is supplying from the selected UCC. The key requirements are to avoid the part load deliveries into urban centers and provide facilities like UCC to insure consolidated deliveries by appropriate vehicles (for example smaller vehicles using alternative fuels or bicycles) with a required level of load factor. Due to the requirements below using an urban consolidation center brings a lot of positive effects to the city, for example less pollution, noise and congestion. Moreover, UCC has a positive impact not just on city logistics, but also offering a possibility of value-added services for its users as well, the only question is if they are open for reconfiguring logistics activities or not. According to Gammelgaard et. al. (2016) the benefit for users of UCC has two parts, one is consolidation of different deliveries at the UCC, so the user only receives one delivery per day and the other one is the program of value added services, the range of which can be different due to requirements of users. Gammelgaard et. al. (2016) describes possible additional services as stockholding, pre-tail activities, order process, return logistics, home delivery or last mile solution. Stockholding is a commonly used additional service for UCC costumers, when shipments are not just consolidated and transported to the customer, but also stored for some period. It helps users (for example retails) improve space usage in the store and use of employees. Pre-tail activities often represent control of goods and making goods ready for shelves, for example price tagging. Home deliveries often connected with e-commerce, when UCC can arrange deliveries of goods straight to the final customer. UCC can also provide added service at the delivering place as unloading at the right place, unpacking or even putting goods on shelves in the store, so store personal can take care of the customer at the same time (BESTUFS, 2007). All these value-added services aim–to persuade stores or restaurants in the city to use UCC for their deliveries in order to achieve sustainable transportation in the city. Another value-added service which UCC can provide is reverse logistics. Efficient reverse logistics is very important in the aim to achieve city logistics goals. Nowadays reverse flows of packaged material or returned goods is a noticeable problem for efficient city logistics in cities. According to the Reverse Logistics Executive Council reverse logistics is a specialized segment of moving goods, which starts after the sale and after delivery to the customer. Anthony (2005) characterized reverse logistics as the process of returning finished products for replacement, repair, or credit. Reverse logistic according to the author is often very costly for retail or logistics providers, but at the same time represents a necessary part of maintaining an efficient supply chain. Efficient reverse logistics plays an important role not just in the cost structure of it provider, but also in efficiency of whole city logistics organization. Reverse flows of returned goods from customer are difficult to organize and often causes additional runs of vehicles with very low load factor. That leads to additional environmental pollution, noise and congestion in the city. As it was pointed out before, there are a lot of city logistics methods focusing on different types of city logistics problems, Taniguchi et. al. (2014) prepared a summary of city logistics management methods (Table 1).

Table 1
City Logistics management types

Management Methods	City Logistics Scheme
Traffic flow management	Constructing ring road, truck route, access control to cities, low emission zones, providing traffic information using ITS
Parking management	Truck only parking space, loading/unloading space on streets
Time management	Off-hour delivery, time windows for entering cities, time sharing between trucks and cars
Vehicle management	Low emission vehicles, optimization of vehicles routing and scheduling, road pricing, load factor control
Cooperative freight transport	Urban consolidation centers
Co-modal freight transport	Using passengers' cars or trams for delivery
Recognition	Recognition of green freight transport companies
Organization	Freight quality partnerships

Source: Taniguchi et. al. (2014)

2.2. City Logistics Measures through the Practical Knowledge

City logistics measures and systems are different for big, medium and small size cities, but it turns out that sharing information about experience with city logistics projects within the cities is a key to success. All over the word there are similar cities, which could share their ideas and help each other to receive the sustainability and liveability. It is crucial for international knowledge of city logistics, to know mistakes that were made and learn and get inspiration from them.
In 2002 the European Commission created a co-funding CIVITAS Initiative ('City-Vitality-Sustainability') for cities to network together and try to minimize the burden caused by urban freight transport and to create a cleaner and better place to live. Within the CIVITAS Initiative program, city-laboratories have been set up, were the various measures of sustainable transport have been deployed, tested and evaluated. The various number of measures were focused on different city logistics system like: alternative car use, clean fuels and vehicles, cycling and walking, logistics and goods distribution, mobility management, traffic management, public transport and access and parking management (civitas.eu., 2013). The CIVITAS initiative project has 5 phases, each phase included different cities and different implemented measures. Nowadays, the fifth phase named CIVITAS 2020 has continued, in which there are involved 17 cities and 3 living lab projects. Almost 70 cities participated of the CIVITAS initiative project during the first four phases. According to Rooijen (2014) and CIVITAS Elan final Evaluation report (2012) a lot of different measures were used in the EU cities, the most common were:

- an inner-city distribution center in order to create a new more efficient way of goods distribution,
- using an ITS to improve routes for good delivery by minimizing the number of routes or using real time communication to avoid congestion,
- using clean vehicles to minimize air pollution in the city.

Different cities involved in the CIVITAS project use different city logistics measures in order to adapt them in the most efficient way to the selected city. Next Table 2 represents success CIVITAS initiative project measures in cities across Europe (Rooijen, 2014).

Table 2
Successful CIVITAS projects

City	Measures and their implementation
Time windows in Iasi	Two times windows (one in the early morning and one in the afternoon) were implement in Iasi to optimize traffic flow in the city. Companies which use determinate time windows were awarded. The number of goods distribution vehicles decreased at peak hours leading to a better traffic throughput.
City distribution by Boat in Utrecht	In order to increase the use of water transport and to reduce the air emission, a zero-emissive electric boat was introduced to cover the supplies to a clients, shops, bar and

City	Measures and their implementation
	restaurant along the canal. The key result was the reducing of CO2 emissions by more than 38 tones.
Consolidation center and electric delivery vehicles in Bath	DHL company established consolidation center and use an electric vehicle for delivery into central Bath. New service was free for 15 months for business in Bath. Important result was decreasing number of trips to Bath and reducing CO2 and other pollutant emissions.
Low emission zone in Aalborg	The main idea was to create a low emission zones across the city to force distribution company to fleet renewal and use heavy duty vehicles complying with the latest standards.
Cargohopper in Utrecht	The electric Cargohopper is a multi-trailer 16 meter-long designed to fit into small street network of the city center. The multi-trailer has a capacity equivalent to 5 to 8 vans and delivers freight from a City Distribution Centre to the inner-city.

Source: (Rooijen, 2014)

During the CIVITAS initiative a lot of unsuccessful experiences were in the cities, but the important things are the suggestions and recommendations of how to avoid the same problems in futures projects. As it is turns out the most important conclusion from all projects across Europe is about the importance of partnerships between businesses, operators and authorities, which seems to be the key factor for the successful implementation of any measures (McDonald, et al. 2010). That's why the main innovation, which was outlined in the CIVITAS Elan final Evaluation report (2012) is the integration of measures from different policy fields into one comprehensive urban policy concept, for example stakeholder integration, institutional integration, policy integration, spatial integration, modal integration, cross-site integration and technological integration. Rooijen et. al. (2014) outlined that a very common urban freight logistics measure an urban consolidation center was planned during the project CIVITAS in a lot of towns, but almost none of the projects were successful. According to McDonald et. al. (2017) the main reason of failure was the insufficient partnership between the stakeholders. Taniguchi (2014) describes successful urban consolidation centers in the towns of Japan. Consolidation centers in Japan work on joint delivery systems, which means cooperation of freight carriers to jointly deliver and/or collect goods to and from customers using urban consolidation centers. The key reasons to create an urban consolidation center are the same in European countries and in Japan, like reducing the negative impact on the environment, reducing cost, number of vehicles and number of drivers. Author pointed out the different success factors for urban consolidation centers in Japan and in European countries due to different mentalities and customer habits. While the success factor according to Taniguchi for Japan's cities are good leadership, enthusiasm towards achieving goals and a business model to maintain joint delivery systems, in European countries the success factors are mind-set of balancing the economic vitality and the environment, core organization for management of urban consolidation centers and neutral carriers for operating the delivery. Of course, some of the factors are the same. For example, appropriate location for the urban consolidation center and sufficient use of consolidation center.

The objective of the article was to find out, among other things, the existing state of the city logistics under the conditions of the Czech Republic and to describe the Czech scientific publications related to the problem. Research of literature shows a lack of publication about this topic in the Czech Republic. Research in the Visegrád Group states (Czech Republic, Slovakia, Hungary and Poland) showed a lack of publication on urban logistics not only in the Czech Republic, but also in Slovakia and Hungary. In comparison to that of Poland, the problem of city logistics is devoted to several authors (Witkowski, Kiba-Janiak). However, the lack of any publication does not mean the complete absence of a city logistics project in the Czech Republic, for example the second biggest city in Czech Republic Brno was participating in the CIVITAS initiative project. The main objective of Brno's participation in CIVITAS ELAN was to improve the quality of public transport and to lead more people to use the services. Since the beginning of the project, Brno has equipped all ticket vending machines with a system that automatically alerts the control center to any defects, so it can be quickly resolved. In response to the aging population, Brno has introduced new low-floor minibuses that also allows easier access for wheelchair users. Brno also wanted to modernize its fleet of public transport to make it less polluting and more energy efficient. For example, in trams and trolleybuses, they installed a heating control system to optimize energy consumption (civitas.eu., 2013). Prague the main city of Czech Republic also participated in a city logistics project across Europe named SUGAR. SUGAR (Sustainable Urban Goods Logistics Achieved by Regional and Local Policies) aims to address the main city logistic problems like ineffective management of urban freight distribution, as a critical component of the overall urban transport system and a primary source of vehicle pollutant emissions. The main goal of the project is promoting the exchange, discussion and transfer of policy experience, knowledge and good practices through policy and planning levers in the field of urban freight management. The city of Prague's participation was about creating protected delivery zones, which aims to protect the historical center and create better conditions for flowing traffic. The project was achieved due to regulations based on the weight limit of trucks allowed to circulate in the historic center of Prague and setting parameters for delivery time windows in the city center. According to SUGAR (2011) the project was successful, the volume of trucks declined by 85% on the busiest routes, and traffic was transferred to more appropriate roads.

Dablanc (2007) pointed out two different, somewhat unusual measures in London and Barcelona, which helped to improve the city logistics situation. The first was about successful partnership between the logistics providers and the administration, where the two biggest carriers' organizations discuss the practical details of delivery organization with transport for London representatives on a regular basis. After a very conflicting discussion a compromise was achieved, for example, the level of the congestion pricing tax assigned to delivery trucks (£5 a day, the same as for car drivers). The second one described city logistics measures used in Barcelona, Spain, according to the author the administration of the city hire a freight motor squad to prevent illegal long-term parking. After this the leaner lines are being used for truck delivery, as zones for loading/unloading space during off peak hours and as parking in the night for residents.

3. Current State of the City Logistics in the Connection with the Postal Services

According to the European Commission, which is responsible for the efficient functioning and the legislature of postal services in Europe, postal services play a key role in an effective and dynamic market of businesses and EU citizens. The European Commission works on improving the quality of delivery and access to postal services. Official documents focused on postal services across Europe offers a lot of information about the significant role of postal services in the EU economy (the EU postal sector accounts for €91 billion or 0.72% of EU GDP), employment (about 1.2 million people were employed by universal postal service providers in 2013) and in e-commerce (the parcel sector is dynamically growing in terms of volume and plays an important role in the development of e-commerce). Over 6.4 billion items were shipped in 2011 (European Commission, 2011). But according to Dieke et al. (2013), between 2007 and 2011 the European letter post sector declined in terms of revenues and volume. Demand for traditional letter delivery has fallen significantly: since 2006, the aggregate mail volume declined by more than a quarter in advanced economies and more than halved for some posts. In recent years the decline in mail volume slowed to 4.2% in 2016 compared to 5.6% in 2015 (IPC, 2017). Another significant change in the postal services market is the large development of e-commerce, which has led to the changing of consumer behavior and growing demands for parcel delivery services. Worldwide people buy things online more than ever, Internet retail sales have risen 18% per year on average since 2006. In response, postal operators create clear and consistent strategies, looking to grow the parcels business and further enable e-commerce. Also posts operators are seeking growth in new business and geographical markets to diversify revenues and are focusing on cost control and innovation as competition heats up and customer needs evolve (IPC, 2017).
Furthermore, the postal services market has undergone another change, which was the full liberalization in 2012, after that changes in the national postal services providers have exposed the competitive pressure mainly on profitable markets such as the parcel delivery market. National postal operators in Europe reserved in the area of universal services for example letter mail and preserve the monopoly position in this market. However, it has become necessary to maintain a position in the growing parcel delivery market, where most of the competing companies apply the strategy of cream-skimming, i.e. offers its services only in the cities with the highest density and offers fast and frequent delivery through the distribution warehouses around the city. The situation has led to the fact that large number of trucks from different companies are daily circulating in Czech and European cities. The biggest issue is that the councils of the cities have no idea how many cars are going through the city every day and what impact it has on the environment and traffic situation in the cities. The situation can be symbolized with the scheme below:

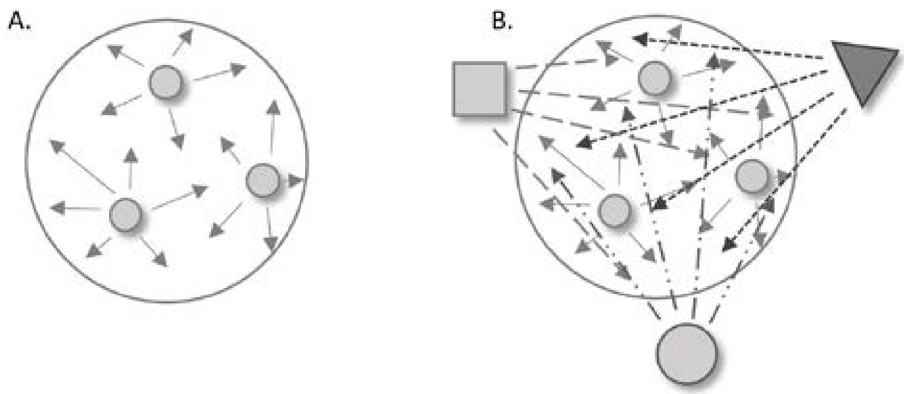

Fig. 2.
The supply chain situation in the city before then (A) and now (B)
Source: Author

Figure 2, Part A, illustrates the supply chain situation in the city before the e-commerce growth and liberalization, which means before the strong competition in the selected market, during this situation the national postal service provided the letter and parcel deliveries within the city. Now the situation has changed quite a bit (part B), the supplying cities arrange different transport companies from the distribution centre outside the city (triangle, rectangle and wheel), it leads to a bigger number of trucks in the city and chaos in city logistics, when transport companies in effort to achieve the greatest gain and take on a high competitive position offer more frequent transport by low loaded factor trucks. The e-commerce growth and the liberalization of the postal market consignments has caused in the cities the appearance of large number of private companies offering preferential parcel delivery services, which had lead to the need for changes to the national postal services provider in order to succeed in the new competitive market. The

European Commission's efforts to increase the efficiency of the postal sector, by opening the market to competition, has been accomplished. The are a lot of successful and efficient transport companies offers supply chain in the city, however it is looks like the side effect of liberalization and e-commerce growth was one big surprise for the cities and until now it is not clear how to solve this problem. The situation has persisted in many European cities since 2012 and it is one of the causes of such a wide interest in city logistics now. The main topic of this article is a suitable solution for the current situation particularly the inefficient position of national postal operators and unsustainable traffic in EU cities, especially in the Czech Republic. As was mentioned before, several authors dealing with the issue of city logistics perceive the lack of cooperation and communication between the private and public sector as the main cause of the failure of many projects in the field of city logistics. The scientific research and publications about this subject are focused on the possible ways how to ensure effective communication between two sides and force the private sector to respect the interests of single cities.

The main idea of the article lies in another view of the whole situation: why, in order to create sustainable city logistics in the cities, not directly cooperate with a more suitable partner? A partner who already has a network site, city-centre buildings, and transport facilities to meet the needs of customers primarily in the parcel delivery market (B2C or B2B) and will be willing to take into the consideration the requirements for sustainable urban development, particularly in the area of sustainable transport. It can be assumed, therefore, that a national postal operator, such as Czech Post, which is linked to the state (compensation for the provision of universal postal services) and for which, apart from private entities, constantly increasing profits at any price is not the main objective (due to historical development and the post-mortem position of the post office as a firm), could be more sophisticated and adapted to the underlying requirements on environmental, social and economic sustainability in cities.

Czech scientific journals do not offer a lot of papers dealing with the role of postal services in city logistics system, on the other side foreign transport journals provides several papers dealing with possible cooperation between the postal sector and the city logistics. According to the annual report (2017) Czech Post owns 3200 branch offices across the Czech Republic, has about 30 000 employees and transported about 341 848 packages in 2017, 20 % of all vehicles are vehicles using alternative fuels. Thanks to this Czech Post retained the position of leader in the package and postal services market. The below information shows that Czech Post has the resources to become a major logistics provider in cities in the Czech Republic. As was pointed out before the city logistics situation isn’t sustainable for the future, the councils of most cities don't even know how many vans from different logistics providers are circulating in their cities every day and how big an impact there is on the environment. So, partnership of logistics providers and councils is essential as never before, the Czech Post is a perfect candidate, because due to historical development it is the biggest logistics provider with resources and border networks in each city within the Czech Republic. But there is still the question of how to make this partnership work and what change in legislation may be needed?

During the literature search, it was found that the topic of postal services and its use in the city logistics sector is not very much studied. There is a big lack in European literature on this subject, especially in view of the decreasing number of letter shipments and the need to find a new direction for the use of large postal sector resources. The problem with the use of the postal sector for the purposes of city logistics is quite a matter of concern in the United States, where several distinctions on this topic came directly from USPS.

According to USPS (2016, a) there are already some projects between USPS and the cities in order to achieve “smart” cooperation, which aims to decrease traffic congestion, cut pollution and improve infrastructure. In achieving these goals data and analytics play an important role, the postal service with its ubiquitous network and its huge infrastructure of vehicles, post offices and mailboxes could help the local councils in the collection of multiple types of data, that could be used towards better management of city logistics and help to solve age-old problems like traffic congestion, poor air quality, and infrastructure maintenance. Some example of using such data comes from Boston, where the sensors on postal vehicles can record data about the smoothness of the ride and the location of the problem area. The representatives of a city, which gets the data through cloud identify potholes, monitor urban road maintenance and plan long-term investments in infrastructure. Another good example of using the postal vehicles and its vast infrastructure that crisscrosses the country daily is attaching sensors of air quality to the postal vehicles and making them mobile. By that postal services contribute to the health of cities inhabitants, the data from the sensors are automatically sent to the cloud and help the government save money, provide better targeted climate action plans and improve public health. The use of postal services in order to achieve city logistics goals is possible not only in the use of vehicles of the postal sector but also, for example, in using its space in the city.

Another area of cooperation between postal services and city logistics can be storage, according to USPS (2016, b) the boom of e-commerce has changed the fundamental aspects of warehousing. Available storage areas are at the lowest level since 2001 due to the growing demand for e-commerce retailers. A lot of big warehouses are built near the cities or major transportation infrastructure with the aim of getting the quickest possible transportation to the customer. On the other hand, demand in retail is looking to get smaller warehouses in urban city centers and aims to compete with major players on the market like Amazon and provide very fast delivery. According to the authors (USPS, 2016, b) with a vast network and available places like this the national postal operator can satisfy this demand and rent the places to the retail sector. In the research about Czech Post and its resources, has been find out, that exactly this model is working for Czech Post, which is offering their unused spaces for rent via Internet. On the other hand available warehouses in the city center could contribute to the transportation process of logistics provider, for example optimize the delivery window and radius for e-commerce orders. Use of this space in cities could be focused on efficient last mile delivery, which is the slowest and the most expensive part of delivery routes. The right use of warehouses in the center could not just contribute to the incomes and efficiency of logistics providers, but also on whole city logistics systems. Another use of national postal operators with a view of city logistics needs can be thought about reverse logistics. Contribution of national postal operators in organization of reverse flows in the city could be fundamental due to major network transportation within the city and available spaces in the city center, which could be also used for processing returns. According to the USPS (2016, b) the national postal operator in the US does not provide complete reverse logistics services. On the other hand, it does provide some returning for individual and business customers, for example Parcel Return Service (PRS), Merchandise Return Service (MRS), and Bulk Return Service (BPRS). While PRS provides an affordable returns solution for large volume shippers, including the first mile pick up, MRS enables merchants to provide customers with prepaid back-shipping labels that are only charged when parcels are scanned. And BPRS uses the advantage of postal services on small consignments to quickly return unified packages. USPS also decided to provide reverse logistics as a long-term goal.

4. Conclusion

The situation with traffic in European cities, especially in the Czech Republic, is alarming, efforts to achieve the sustainability by traditional methods of city logistics in most cities have failed or have not brought the desired effect. The major cause of failures seems to be the lack of communication, cooperation and, above all, the lack of understanding urban sustainability needs by private stakeholders. It looks like that, for the purpose of creating a functioning city logistics system in cities, there is a need to find a suitable partner, and to set more control of the traffic in the city. The system of control cannot represent just a list of restrictions, such as limiting the entrance of vehicles to city centers but should provide a way of creating a functioning city logistics system or smart city in the future. Currently, several publications describe the beneficial relationship between postal services and cities, where the postal sector thanks to the extensive infrastructure could help in achieving the goals of city logistics. This cooperation could be mainly used in the Czech Republic, where the postal sector's position is relatively strong. Another advantage of the use of the Czech Post for the needs of city logistics is the possibility of using the postal sites, which are already very extensive and includes attractive buildings in city centers throughout the whole area of Czech Republic. At present time, some of the Czech Post space isn’t sufficiently utilized, many valuable spaces are available for rent on the Internet. At the same time, those spaces can represent a great competitive advantage or help in achieving the goals of city logistics, especially while e-commerce is developing and the efforts of transport companies to meet the demands of the customer are growing. One of the effective city logistics systems that are currently used abroad and can be used with the conditions of the Czech Republic is urban consolidation centers, which is used for supplying cities. The shipments from UCC are delivered by alternative vehicles or are provided by alternative delivery ways such as a bicycle, or night delivery. The UCC system eliminates a large amount of supplies from different companies in the city, when private logistics providers are allowed to arrange transportation only to UCC, not in cities. The biggest challenge in creating a UCC is the selection of a suitable place and partner to ensure UCC operation and delivery within the city. On the basis of the presented analysis, it can be assumed that Czech Post could be a suitable partner for the UCC operation. As was already mentioned, Czech Post is a state-owned company that could take into account the city's environmental needs, on the other hand as a possible UCC brownfields currently belonging to Czech Post could be used. The launch of such a project would represent a new direction for city logistics as well as for Czech Post. The main challenge at the present time is the analysis of a solid possible solution and the necessary legislation based on the selected city.

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DEVELOPMENT TRENDS IN THE STRUCTURE OF SERVICES OF THE PUBLIC POSTAL OPERATOR IN SERBIA

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Abstract: A public postal operator represents some of the largest and most important infrastructures in each country. Since most postal markets are very competitive, there is a clear need for redefining and modernizing the existing service portfolio of public postal operator. Many researchers estimate that traditional postal services will lose their usefulness. However, this should be investigated based on the real data which is done in this paper. The next question is what is the role of new services based on electronic, Internet and communication technologies. This paper analyzes the development trends related to the universal service obligation and commercial services. The research is based on the ratio of the volume of services and achieved revenue in the case of public postal operator of the Republic of Serbia. Based on the conducted analysis, the operator could form an adequate business strategy.

Keywords: public postal operator, structure of services, revenue, strategy.

1. Introduction

The raising expectations of users and increasing competition on the postal market are some of the indicators of the necessary changes in the sector. In such circumstances, one of the most important questions for public postal operators is how to preserve the traditional postal services and to expand the current service portfolio with new services which would increase the profit and maintain a leading position in the market. To answer this question, a public postal operator (PPO) should analyze the requirements of the market, the needs of its users and the trends in volumes and revenues.
Observing the annual performance of the PPO in the Republic of Serbia over the past few years, it is noticeable that in 2016 the universal postal service (UPS) for the first time achieves lower revenue than commercial services. The share of UPS in the total postal services is still quite high; however, it is declining on a yearly basis. By reducing the volume of UPS, the unit cost per service is increased, which endanger the sustainability of the existing concept (RATEL, 2017).
Certain indicators show that services from the commercial domain are extremely profitable. The growing development of information and communication technologies leads to a reduction in the volumes of traditional postal services (especially letter post) and inevitably to increasing the cost of providing them. All this stipulates the need to redefine and modernize the existing service portfolio of PPO.
The paper deals with trends in the structure of services of the PPO in the Republic of Serbia. The time interval of four years, from 2013 to 2016, was taken into consideration. The aim of this paper is to examine the trends in both the postal market of the Republic of Serbia and the structure of services of the PPO which, in addition to reviewing the current situation, could contribute to the creation of new business strategies of the PPO from Serbia.

2. The Role and Importance of the Public Postal Operator and Postal Services in the Economic and Social Development of the Republic of Serbia

The postal services have a significant and specific economic function and they are one of the drivers of the development of economy and society. They are vitally important primarily for users and state functioning and this fact represents one of the reasons why postal services are considered as services of general economic interest. The postal sector in the Republic of Serbia, as part of the tertiary sector, is a significant element of economic and social development of the country. This is particularly evident having in mind that the postal services are not important just for the companies providing them, but also for other business, citizens and state institutions.
The efficient and high quality postal services have a great positive impact on the economy and society as a whole, especially in the transport sector. Postal services are very sophisticated services where the technical and technological innovations have been constantly implemented, primarily in the field of information and communication technologies. Accordingly, they represent an activity that, in addition to its own sustainable economic growth, can successfully support further economic development of Serbia. In addition to the economic value of postal services and networks, they also have an enormous social value by creating conditions for improving the lives of individuals or the entire society (Ministry of Trade, Tourism and Telecommunications of the Republic of Serbia, 2017).

Table 1
Participation of the public postal operator and the total postal sector in GDP (in percentage)

Year	Public Postal Operator	Total Postal Sector
2013	0.23	0.36
2014	0.25	0.38

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2015	0.25	0.40
2016	0.24	0.40

Source: Statistical Office of the Republic of Serbia

As can be seen in Table 1, the participation of the PPO as well as the total postal sector in the gross domestic product (GDP) of the Republic of Serbia has remained almost unchanged. The slight increase could be probably explained by an increasing degree of market liberalization in the segment of commercial services. Table 2 provides a support for the conclusion about the raising liberalization in the segment of commercial services. A significant increase in the number of postal operators on the market of the Republic of Serbia is noticeable.

Table 2

The number of postal operators in the Republic of Serbia (2013-2016)

Year	Number of Postal Operators
2013	47
2014	31
2015	36
2016	54

Source: RATEL, 2015; RATEL, 2016; RATEL, 2017; Public Transport Consult, 2018

3. The Postal Market in the Republic of Serbia

In this part of the paper, the postal market is considered from the aspect of UPS and commercial postal services, both in their volumes and revenues. It is noticeable that the volume and revenue of the UPS is registering a steady decline, contrary to commercial services where the volumes and revenues are gradually increasing. Figure 1 shows the relations between UPS and commercial services in the period from 2013 to 2016. A conclusion can be reached that there was a decrease in the relative number of USP volume compared to commercial services between the years 2013 and 2016. In 2013, the volume of USO was 89% higher than the volumes of commercial services. On the other hand this value decreased from 89% to 82.4% in 2016. The difference is even more significant in the relation between achieved revenues. In the year 2013 the revenue from UPS was higher for 6.2% compared to commercial services and four years later this revenue is smaller for 2.6% despite to the greater volume of UPS.

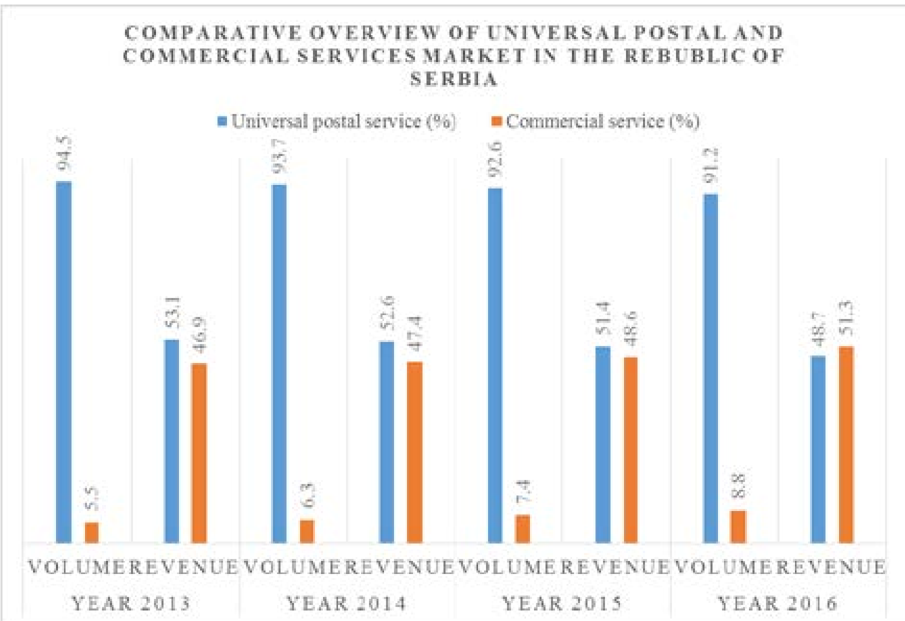

Fig. 1.

Comparative overview of UPS and commercial services on the market of the Republic of Serbia

Source: RATEL, 2015; RATEL, 2016; RATEL, 2017

3.1. Public Postal Operator and Competition

It can be noticed that the volume and revenue of the PPO have recorded a constant decline in comparison to the private operators where volume and revenue are gradually increasing. Private operators are providers exclusively of commercial services. Figure 2 shows that relative relation between the volumes of PPO and private operators in the considered period is going in favor of private operators. In the year 2013, we can notice a surplus for PPO of 92.4% in volumes compared to the private operators. However, in the year 2016 this surplus decreased to 87.8%. When it comes to the revenues, the trend is similar. In the year 2013, there was a surplus for PPO of 30.8% in revenue compared to the private operators. However, in the year 2016 this surplus decreased to 23.2%.

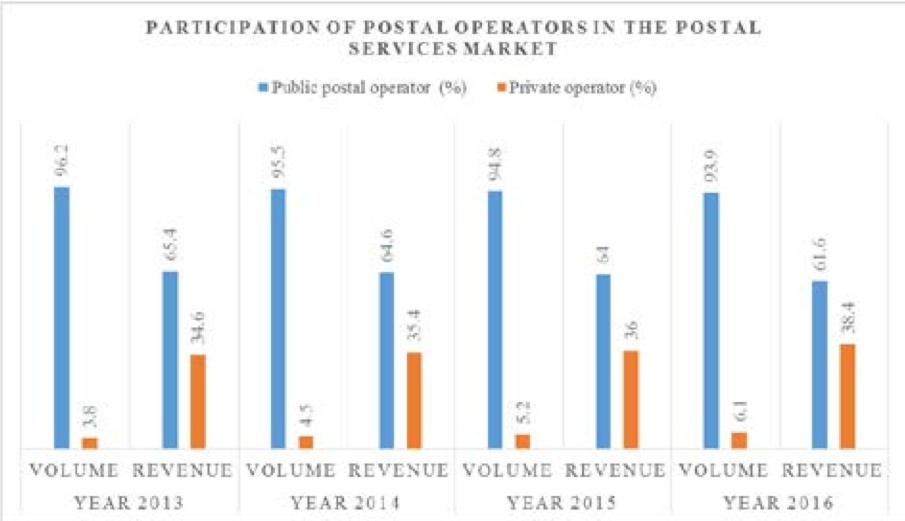

Fig. 2.
Participation of postal operators in the postal market
Source: RATEL, 2015; RATEL, 2016; RATEL, 2017

3.2. Structure of Services of the Public Postal Operator

In the structure of postal services performed by a PPO, the most dominant is UPS. As can be seen in Figure 3, the share of UPS in the total postal services of the PPO is relatively constant with a slight decrease in relative relation to other services. The main conclusion is related to Post Express – the courier and express service of PPO from Serbia. It is evident that this service has been rising during the years. Having in mind that the services in the field of commercial domain are highly profitable and that there is a high competition in this market, there are possibilities for further growth of these services of the PPO.
Figure 4 shows the trends in the structure of four types of services of the public postal operator in the Republic of Serbia. Those are:

1. Letter mail
2. Parcels
3. Post Express
4. Payment services

As shown in Figure 4, a decrease in the total number of letters is noticeable. In 2016, a decrease of around 27 million letters, or 8.85%, could be observed in relation to 2013. The decrease in the volume of letter mail has been steady since the beginning of the observed period and is the most vulnerable segment in the structure of services of the public postal operator.
Figure 4 also shows the downward trend in the volume of parcels by 2015, as well as a significant growth of express and courier services. This trend is primarily the result of the decline in the volume of parcels in domestic services.

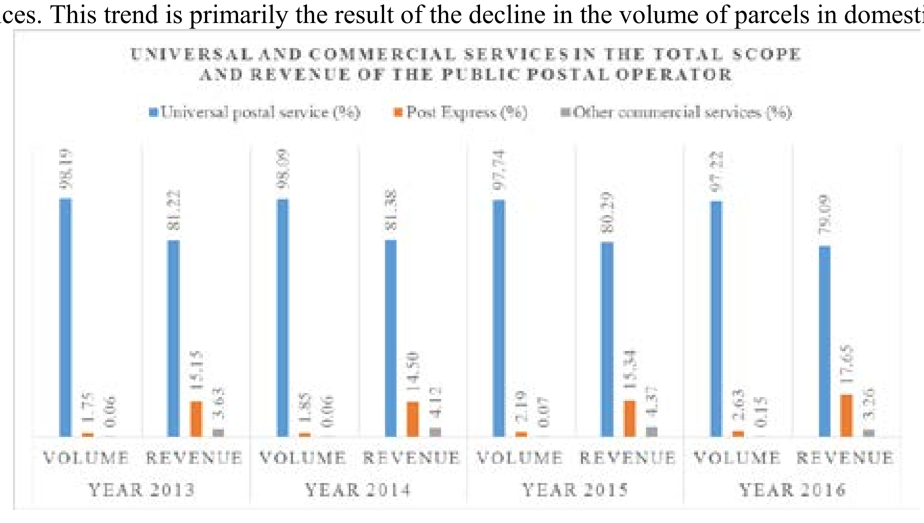

Fig. 3.
Universal and commercial services in the total volume and revenue of the PPO

Source: *RATEL, 2015; RATEL, 2016; RATEL, 2017*

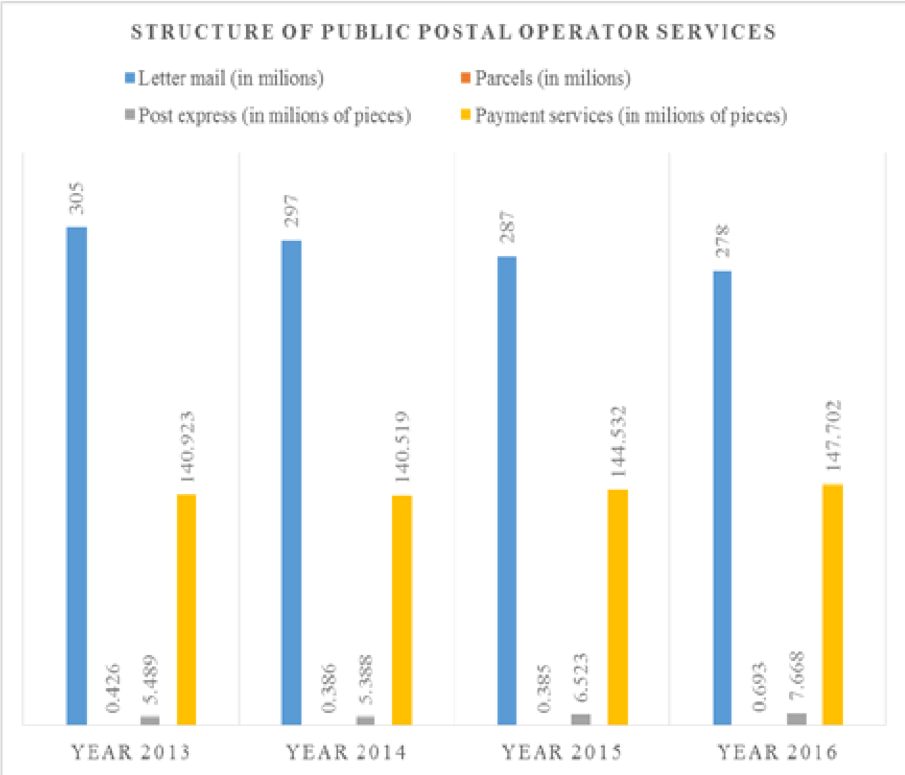

Fig. 4.
Structure of public postal operator services
Source: Statistical Office of the Republic of Serbia, 2018

For example, there is a decline of around 47,000 parcels from the year 2013 to 2014 or 12.53%, while in 2015 compared to 2014 there was a decrease of 2.74% or 9,000 packages. In 2016, in comparison with 2015, a huge growth of parcels in domestic services is recorded for the entire 94.67%. Related to the international parcel services, year-on-year growth in the volume of parcels is constantly reported, so in the year 2016 there were 21,000 packages more than in 2013, or 41.17% (Table 3).

Table 3
Volumes of parcels in domestic and international services (in thousands)

Year	Domestic Parcel Volumes	International Parcel Volumes	Total Parcel Volumes
2013	375	51	426
2014	328	58	386
2015	319	66	385
2016	621	72	693

Source: Universal Postal Union, 2018; Ministry of Trade, Tourism and Telecommunications of the Republic of Serbia, 2017

Observing the express items in Figure 4, it can be noticed that in 2014 there was a decrease of around 1.84% in comparison to 2013, or more precisely for about 101,000 items, while in 2015 and 2016, compared to 2014, this number increases. In 2015, this growth is 21.07% or 1,135,000 items, while in 2016 this amount was 42.32% or 2,280,000 items. In comparison to 2015, the number of express items increased by around 17.55% in 2016.
As in the case of express items, in the case of payment services there is a decline in 2014 compared to 2013 by about 0.29%, while in 2015 and 2016 the number of services is increasing compared to 2014 (Figure 4) . In 2015, payment services increased by 2.86%, while in 2016 they increased by 5.11% compared to 2014.

4. The Future of Postal Operators and New Services in the Postal Sector

The future of each postal operator is reflected, inter alia, in monitoring technological trends and innovations and adapting business and services to them. Thus, over the past years, the development of information and communication technologies has greatly influenced the postal sector. There could be three pillars notices in the further development:

- New models of the technological process,
- Implementation of new technologies to bring postal services closer to customers,

- New services offered by the postal operators.

New models of the postal process are mostly based on the use of artificial intelligence and robotics. The new solutions have a wide application in all stages of the technological process; however, some of the most important are in the field of mail processing, transportation and last mile delivery. Modern sorting facilities cannot be imagine without enormous automated machines and corresponding software applications for mail sorting. Autonomous postal vehicles that are able to partially or fully drive themselves have become already a reality in some countries (Čupić, 2017). When it comes to the last mile delivery there are various possibilities for the postal process optimization. For example, traditional delivery could be combined with autonomous drone delivery or by introducing a self-pickup service.
The pillars that are related to bringing postal services closer to customers and to introducing new postal services are very interconnected. One of the basic problems of PPO is how to finance the network of postal branches which should cover the whole state territory. There are various types of activities that could be implemented to enhance the usage of the extensive network and strong infrastructure (Dobrodolac, 2016); however, the self-service kiosks are very popular in order to cut the operating cost of buildings. Self-service kiosks have another important role as well; they significantly bring postal services closer to customers, first of all by 24 hour a day and 7 days a week service accessibility. When the use of smart phones and other communications technology is added to this system, even the new postal services appears.
There are many new convenient postal solution for the customers. Track and trace service has been already in use for year in almost all postal entities. Tracking shipments has significantly contributed to the increased quality of postal services. On the other hand, there are various mobile applications related to postal service. By installing and using them, the customers could pay the bills, get various types of information, such as about prices, terms of using services, the length of queues in various postal branches, etc.
Hybrid mail is a combination of traditional postal service and electronic mail. It represents a combination of state-of-the-art postal technologies and classic postal technology. The basic idea of hybrid mail is that the user, institution, or physical person sends information (e.g., bill, advertising message or similar) to the postal operator in electronic form, that such information is then processed, printed and packed in an envelope and that, as soon as possible, it is forwarded to the target group that the company, institution or physical person is addressing. Post of Serbia, as a public operator in the Republic of Serbia, has prepared expert teams for editorial and design services, preparation services, printing and envelope making services, tabular and rotary printing, personalized press, document insertion and graphic finishing. This service has not been fully utilized in the Post of Serbia; however by further development it could greatly revitalize some marketing services in the coming period, such as catalog sales and direct mail.
Inverse hybrid mail could be called a service where a customer gets their mail in electronic mailbox; however, it should be first transformed from physical to electronic form. In this way the recipients receives their mail in record time, while they can read it at their phones, computers, etc.
Modern technologies and the expansion of online business have caused the exponential growth of e-commerce. This growth is expected to be continued in the future. Due to the fact that postal operators, by means of goods delivery, already participate in particular systems of e-commerce, it is possible to even expand this kind of business for posts by forming their own virtual shopping center. Thus, in addition to goods delivery, the postal companies would organize the complete chain and provide the integrated services of e-commerce.
The use of e-invoices is constantly increasing. It is estimated that by 2020, e-invoices will become dominant in the countries of the European Union. The e-invoice issuer for each transaction saves an average of 6.5 EUR, the recipient as much as 10 EUR. In addition to the economic effect, this also contributes to the reduction of manual labor, the improvement of work procedures and the accuracy of data.
In addition to being a traditional leader in the postal and financial services market, a public postal operator should strive to become a leader in the high quality information and communications services market. For example, the PPO from Serbia became the first certification authority in the country.

5. Conclusion

Many traditional services are replaced by digital and this process is also evident in the postal sector. This process together with a high competition caused decline in volumes of mail for PPO in Serbia; however, the situation is similar in other European countries. In the recent years, the development of information and communication technologies has greatly affected the postal sector. Users massively switch to digital forms of communication. Also, the era of digitization in the modern world imposes the need to provide new services that are based on the digital platform.
The postal operators should use the advantageous of digitization to improve traditional postal services which would enable further development of the postal industry. For example, in the coming years, e-invoices will become the dominant form of invoice delivery, which will lead to a significant drop in traditional postal mail services. However, the posts could offer various mobile application to support this process and to remain present in this filed. Identifying the new trends is of particular importance for adequate market positioning.
The postal market in Serbia is to a certain degree liberalized, primarily in the field of express and courier services. Also, it is noticeable that these markets are heavily under pressure from the competition. The expected further continuation of the liberalization process as well as the expected further development of the market imposes the need for the public postal operator to increase its productivity and stability with constant optimization of business and development of new

services based on electronic, Internet and communication technologies. A remarkable trust from the users should be kept and this could be done also by offering new products and services, as well as by making these services as much convenient for customers as possible.

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RESEARCH OF MOTIVATIONAL MEASURES APPLIED IN LITHUANIAN TRANSPORT / LOGISTICS COMPANIES

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Abstract: In a dynamic society, everything is constantly changing, and there is no exception to motivational measures applied in companies, which cause a lot of problems for corporate executives. Most importantly, motivation is influenced not only by external factors, which are rather quick to notice, but also internal, personal ones that are noticed, and even more, it is difficult to assess. Employee motivation varies according to the situation, surrounding people and even the changing personal approach. This leads to the situation that long to apply the same motivational system can be inefficient. Therefore, managers, in order to ensure that employees' motivation does not diminish over time, has to choose a few motivational methods, to combine them and to change according to the situation. The article examines the theoretical aspect of motivation as a tool for better work efficiency, assessing its need for different career stages. And taking into account that in Lithuania the transport / logistics sector is one of the largest (according to the contribution to GDP), in practical part, it is assessed how people (working in this sector) are motivated and how it influences the performance of the company.

Keywords: Transport / logistics companies, motivation, tools, employees, career.

1. Introduction

Increasingly, in today's society, we hear about the promotion of action and does not matter at all what activity or age we are talking about. Motivation to work better is not a one-time phenomenon, the whole multitude of factors that are linked together in one huge system. Only mutually agreed motivational measures that are tailored to each individual's personal qualities and needs can help achieve the desired result - more effective work and better performance (Chai, Teoh, Razaob, & Kadar, 2017). The main incentives are wages, the ability to realize themselves, the possibility of career advancement, additional cash prize for the results achieved, microclimate, and so on.
Transport companies are no exception. The majority of corporate employees fairly easy to measure the results, so employees can easily be adapted to the material means of motivation (Hessler, Fisher, Polonsky, Bowyer, & Potter, 2018). Most of them have a certain amount of work for which receives wages, and all other compensation is frequently dependent on the results - from managers to find and fulfill orders, drivers of cargo transported or the number of hours worked and mileage.
The purpose of each employer is to achieve the best possible results in their field. The company's staff is the main engine, thanks to which companies generate high turnover, expand their business and gain market share (Vetráková & Mazúchová, 2015). Thanks only to good employees, the company can work successfully, but good employees invest themselves only by being motivated to do so.
The aim of the paper is to investigate the application of motivational measures in Lithuanian transport / logistics companies.
In order to achieve these objectives raised:

- To analyze the importance of motivational tools from a theoretical point of view;
- To investigate the influence of motivational measures on the performance of employees of transport / logistics companies.

Used methods:

- Analysis of literature sources;
- Quantitative research.

2. Motivation as a Tool for Better Productivity

The process of employee motivation in the company is the creation of a motivational system oriented to the behavior of the employee's behavior by directing it to the company in a useful direction by regulating the person's work capacity and promoting integrity and diligence (Matsukura, Shimizutani, Mitsuyama, Lee, & Ogawa, 2017). For this reason, in order to create an appropriate motivational system, the employer must set a set of criteria that have the greatest impact on employee motivation (Uvelius et al., 2017).
In order to create the most effective way of motivating a whole, a number of aspects must be investigated - the influence of motivation on the age of employees, their education, occupied positions and status at the workplace, the efforts of all colleagues and personal achievements and goals of the employees, their needs (Álvarez-García, del Río-

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Rama, Saraiva, & Ramos Pires, 2018). After analyzing these criteria, it is necessary to find out what impact the motivation system will have on employees' performance.
The main objectives for which it is designed motivation system associated with employee-effective promotion company microclimate improvement in order to increase employee loyalty and job satisfaction, workers' material and immaterial compensation for work management, career opportunities and personal qualities highlighting, using them for successful company development (Tziaferi et al., 2011).
A system of motivation can be effective only when the employer and employee set common goals, and the supervisor will convince the employee of the benefits of chosen motivation methods (Blomquist, Farashah, & Thomas, 2018).
The motivation measures are proposed to be divided into two groups:

- **Material** (direct and indirect). From the old order is established that the work carried out and the result achieved is rewarded. The most common form of remuneration is money. Direct measures of material motivation: salary, bonuses for merit bonuses for exceptional performance. Indirect material motivation means fixed payments for certain services, such as transport costs, catering, medical expenses, non-interest-borrowed loans (Smit, de Brabander, Boekaerts, & Martens, 2017). In Lithuania, this measure is very important for many, but due to the economic situation it is still difficult to detect.
- **Moral** (psychological) measures. The motivation to work more effectively is determined by achievements, relationships with the manager and cooperation (Bosch, Heras, Russo, Rofcanin, & Grau i Grau, 2018). Non-material motivational measures regulate employment, develop employment programs and so on. The need for material remuneration is expanded by connecting career opportunities, self-expression, recognition, leadership, and other criteria that promote employee motivation (Zheng, Baskin, & Peng, 2018a). There are a number of non-material motivational methods, in essence they all relate to the emotional state of employees. If the employer sees the employee's efforts in a timely manner and chooses motivation tools responsibly and appropriately, taking into account personal needs of the staff, for example, training, senior positions or more creative freedom, will have the opportunity to develop a loyal and dedicated worker. A worker who feels properly assessed will enjoy the pleasure of achieving better results that will bring success both at work and in personal life (Opriş, 2015).

Proper employee promotion is closely linked to successful company development - motivated employees are loyal to their workplace, thus avoiding employee turnover that affects the company negatively. New employees need to be trained and at the same time they cannot perform their work efficiently, resulting in worse results. The employees who are satisfied with their work and reward provide better quality services because they feel satisfied with their evaluation, hence the name of the company as a whole, and thus it becomes credible, well-known and allows you to attract new customers (Matsukura et al., 2017).

3. The Importance of Employee Motivation for a Career

Employee motivation is closely related to their career stages and this is a very important precondition for a successful business. Over time, not only the needs of employees change, but also their qualifications, and thus career opportunities, obviously, motivation is also changing and this is determined by a large number of factors.
In the new workplace, it is important for a person to have career prospects. If he sees that he will have the opportunity to raise the qualification and improve his financial and social situation, he will be motivated to do his job as much as possible (Strauss, Parker, & O’Shea, 2017). If the work is not viable, it is likely that the employee will not have the motivation.
The most important thing is that the employee feels and understand the importance of their duties. He also has to take responsibility for the results achieved - it is important how much he himself feels responsible for his work. And finally, the employee must understand the effectiveness of the work being performed. If a person feels all these stages - he will be more satisfied and more motivated to achieve better results.
States that the proper management of a career can achieve some benefits for both employer and employee (Blomquist et al., 2018):

- The employer - in planning career stages and processes, has the opportunity to develop highly motivated employees linking their work with the particular company's future. Such employees bring real benefits to the company - reduce employee turnover and increase work efficiency.
- A worker - is happy with the job and job he has, feels the satisfaction of the company, which makes it possible to improve skills and grow.

A common opinion prevails, material and non-material motivational methods will be most effective when, taking into account all factors, they will be coordinated with each other and continuously improved (Zheng, Baskin, & Peng, 2018b). It is important to combine them thoroughly, otherwise there may be negative consequences - less employee motivation and initiative. And it will directly respond to the company's performance.

4. The Results of Research

In modern transport logistics company improving of labor productivity it is an important part of the process. Many understand it as the corresponding components of the improvement: the new warehouse equipment acquisition, the purchase of new vehicles, a new route planning system, and appropriate investment in staff. The latter is given increasing attention because qualified, well-motivated personnel are able to effectively utilize both internal and external resources of the company. Therefore, in order to find out what situation in this matter is in Lithuanian transport / logistics companies, a quantitative study was carried out. An online survey was used to collect data. A questionnaire was first developed. The questionnaire was placed on the Internet with a request to answer only employees of the transport / logistics companies. When 100 questionnaires were received, the survey was stopped and was not publicly displayed. The purpose of the survey was to identify what measures motivate respondents (Fig. 1).

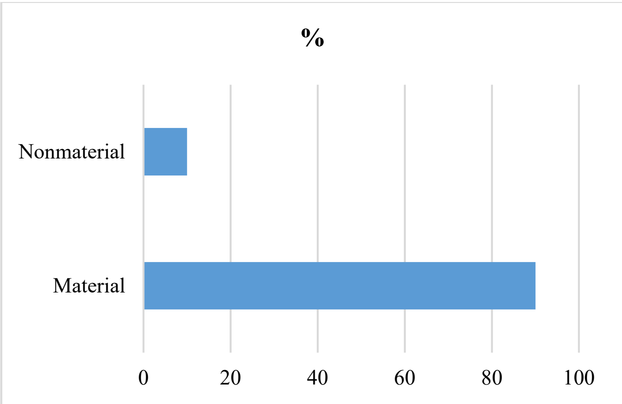

Fig. 1.
Identification of respondents' material interest

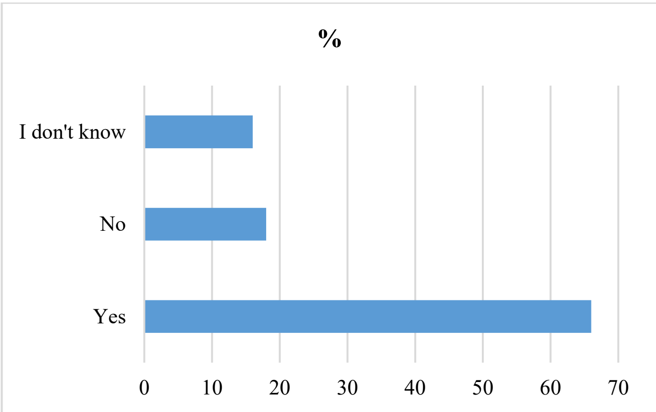

Fig. 2.
Application of motivational solutions in transport logistics companies

From Fig. 1 it can be seen that the most important incentive for staff motivation is the material component (90%). This is related to the employee's priority goals to earn a living, as the income level in Lithuania and in Western European countries is very significant. Based on Maslow's demand for pyramid principles, a person who satisfies his or her primary needs may seek other levels of personality development.
As Lithuania became a member of the EU, transport logistics companies had to increase their competitiveness and invest accordingly in their staff. Most logistics companies use one or another motivational tools (Fig. 2).
The majority of respondents (63%) indicated that their company had a system of employee motivation (material, incentive cognitive, beneficia), and less than one fifth of the respondents indicated that no motivational decisions are applicable or are not sufficiently explicitly declared to be understood by the worker their significance and importance.
Therefore, it is important to identify the need for respondents to work. What kind of work respondents' desires and how to describe? In Figure 3 are indicated the respondents' wishes what should be the nature of the work and how it can be reconciled with other needs of respondents.

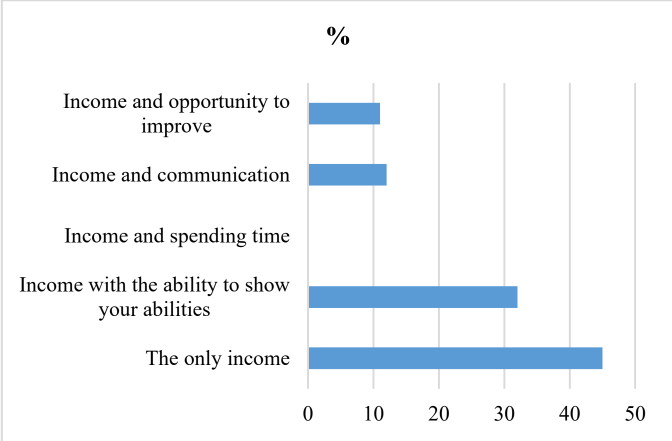

Fig. 3.
Identification of respondents' work as motivation and income

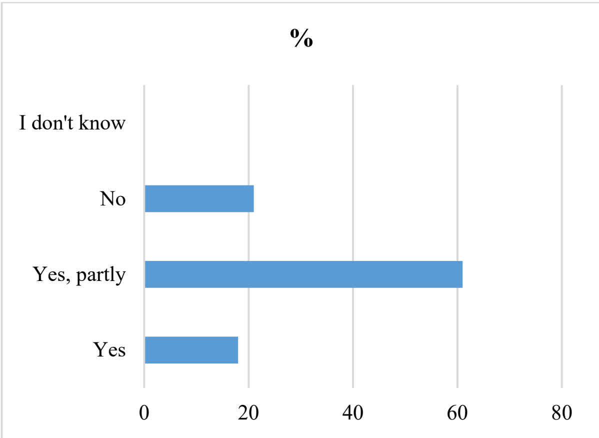

Fig. 4.
Motivation of respondents to achieve better work realization of professional needs results

The vast majority of respondents indicated (45%) that they would like to work as the sole source of income. This shows the need for respondents to focus on one job and not to distract from other work. It is important to note that none of the respondents mentioned work as a form of time spent, which testifies to the respondent's responsible attitude to the position they occupy. Another very important part of respondents (32%) seeks to show their both professional and personal abilities that can successfully be used for the interests of the company. Their motivation would be to get higher revenues based on the results achieved, i.e. seeking to directly transform their knowledge and leadership skills into material expressions of motivation - increased revenues. It is important for a person as a social person to communicate, communicate not only with his colleagues but also with other players in the logistics chain-clients, executors, intermediaries, etc. therefore 12% of respondents seek motivation through the opportunity to communicate and know other people. They see work not only as income, but also as a source of communication as a source of self-realization. Another part of the respondents (11%) seeks to improve, so they see the work not only through the material prism, but also the prism of self-improvement needed for gaining competencies at work.
Employees see the company's efforts and try to take advantage of it (Figure 4).
From figure 4 we see that the majority of respondents (61%) partially motivated to achieve better work results. This size indicates that the motivation system works in enterprises, but there are problems that need to be corrected in order to effectively realize the company's work. This fact is illustrated by the fact that one fifth (21%) of respondents indicated that they were not motivated to achieve better job performance. Therefore, the question arises whether the employer needs to implement a motivational system (Fig. 5)?

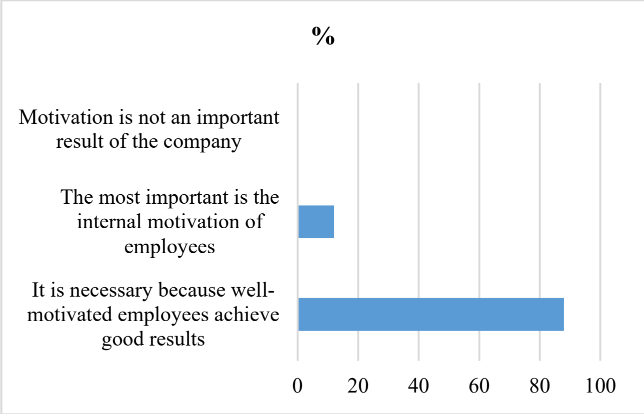

Fig. 5.
Respondents' opinion about the necessity of motivation

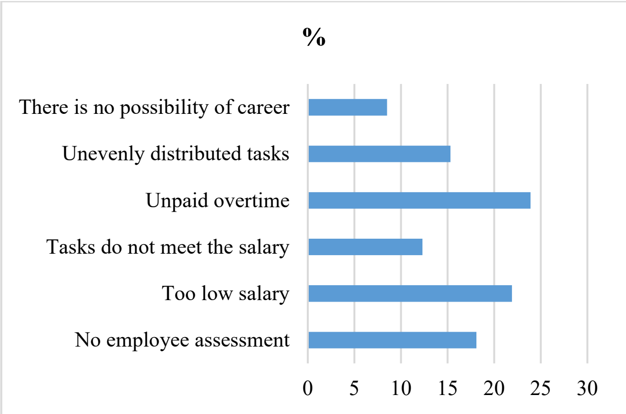

Fig. 6.
Indicators of motivation reducing

From figure 5 we see the opinion of the respondents on this issue. I would like to mention at once that none of the respondents indicated that motivation is not an important goal of the company. This suggests that motivation is not demanded among one fifth of respondents (Figure 4), but its importance is understood by all respondents. So it remains to be assumed that the motivation system must be, only somewhere it is perfect. Less than one fifth of respondents (18%) indicated that internal motivation of employees was important. These data are perfectly correlated with Fig. 3. the expectations expressed by the respondents about the nature of work (income and opportunity to improve). Both Fig. 3 and Fig. 5 that the respondents who are seeking perfection, motivate themselves and see themselves in the positions of a specialist and team leader. A similar percentage of respondents' opinion makes it possible to judgeThe vast majority of respondents (86%) openly declare that only well-motivated specialists will add value to the company and allow it to continue to develop. These results also correlate with Fig. 4 the data on the respondents' desire for better work results and how it affects motivation. Let's see what the total part of the answers (yes and partially) corresponds to Figure 5. The most popular response from respondents (it is necessary because well-motivated employees achieve good results). We can assume that respondents are motivated to seek better results of work, seeing the benefits of motivation will necessarily indicate its importance for the quality of the work performed. In this case, motivation becomes a good incentive to seek better job performance and to improve the respondents themselves.
Therefore, it is important to identify the criteria that reduce the motivation (Fig. 6) and which would improve the motivation (Fig. 7).

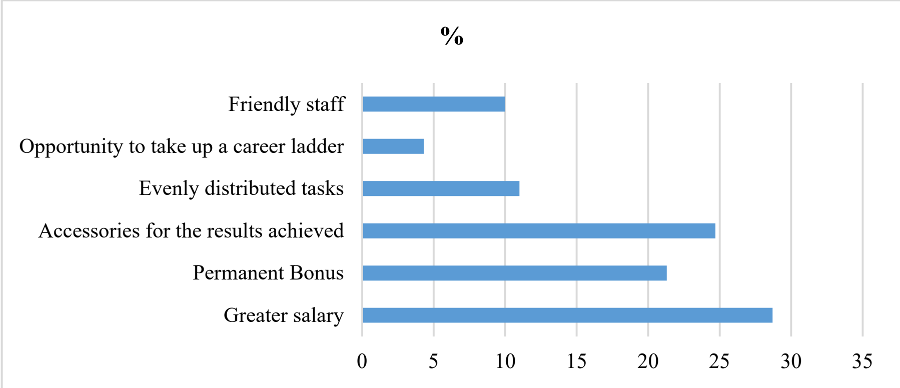

Fig. 7.
Indicators that improve motivation

The biggest motivation reducing indicators are: free overtime (24%), low pay (22%), non-staff assessment (18%), and uneven distribution of job assignments (15%). These data allow us to assume that transport logistics companies are using their employees, so we can see Figures 2 and 4 Described Negative Trends. In turn, what indicators would improve motivation? The most popular indicators would be: Greater salary (29%), bonus for the results achieved (25%) and permanent bonus (21%). As we can see, all indicators are related to material motivational methods, which correlate perfectly with Figure 1 data.
In order to determine the correlation between separated motivation measures have been drawn up in Fig. 8, which sets out all the motivation measures apply to the transport / logistics companies in Lithuania.

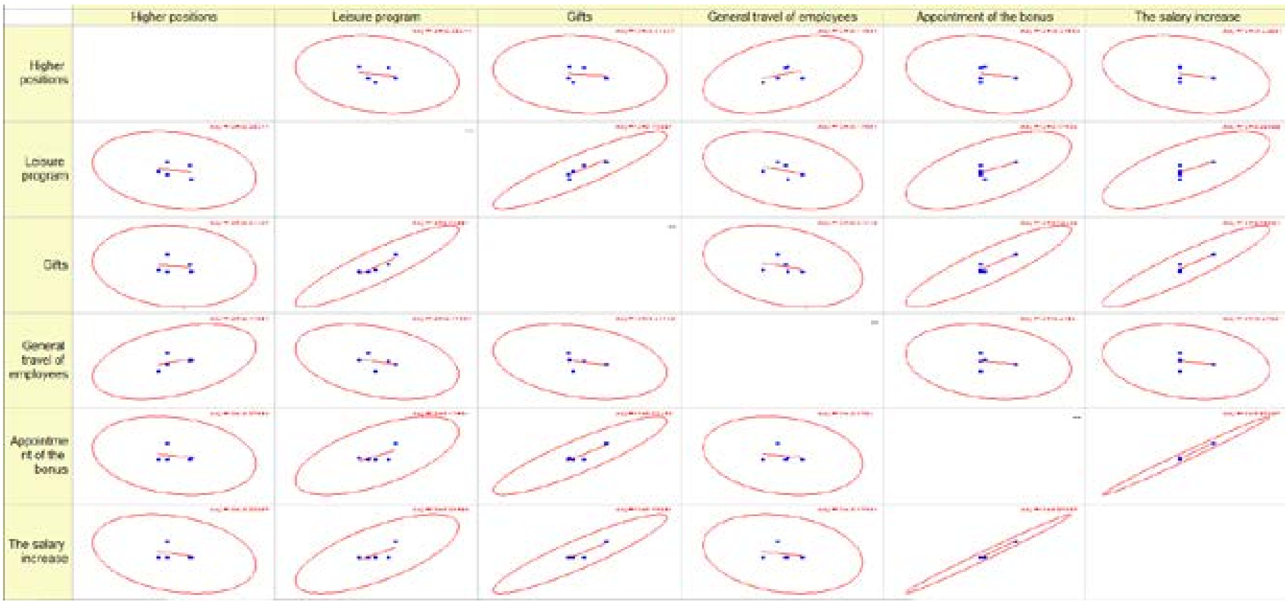

Fig. 8.
Correlation between different motivational measures applied in transport / logistics companies in Lithuania

Correlation relations confirm once again that the main source of motivation is the material motivation of respondents. We find that the strongest correlation relations are observed between the increase in salary and the award of bonuses (R^2 equal to 0.98), salary increases and gifts (R^2 is 0.79), between leisure programs and gifts (R^2 is 0.74).

5. Conclusions

1. After analyzing the possible motivational measures it became clear that individually they probably will not achieve the desired result. Managers should use a different motivation tool to create their entire employee-oriented system. Also, corporate executives should keep in mind that the motivation system is also "aging" and what motivates employees now can be completely ineffective after several years when their needs and attitudes will be met or changed.
2. Creating and applying a motivational system in the company makes it easier to create a loyal and responsible team, working for my colleagues and the company and striving to continuously improve and improve achievable results.
3. Employees in Lithuania are not motivated by higher positions because the difference in pay and the financial gain is inadequate and in the transport / logistics sector this trend is most noticeable when analyzing the

correlation relations of motivation measures, where, in all motivation categories, higher positions have a weak correlation (R^2 varies from 0,31 to 0,21).

4. In Lithuania, the best means of motivating employees is material - gifts, bonuses, and wages (the strongest correlation R^2 is between 0,98 and 0,74), o silpniausias, while the weakest ones, in terms of team mobilization measures, are general outings, leisure programs (observed there the weak correlation R^2 varies from 0,11 till 0,28).

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PREDICTION OF PAVEMENT RESPONSE UNDER VARIOUS SUBGRADE MODULUS

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Abstract: During past decades, the mechanical analysis became principal discipline in pavement design. As a tool for verifying mechanical effect on pavement and subgrade, finite element method (FEM) is often chosen. By employing FEM, it is easy to estimate the pavement structure's response and stiffness of subgrade. In terms of pavement rehabilitation the subgrade performance is of great interest since the pavement structure is the most expensive item of a highway construction project. The aim is to establish the relationship between the stiffness of subgrade, the pavement and their contact surface by using FEM parametric study with varying the subgrade stiffness. The parametric study will use; 1) 10-node solid element and triangular mesh with refinement at load applying area, 2) seasonal moisture variation, 3) comparison between Korean, Hungarian, and AASHTO design criteria.

Keywords: pavement response; finite element method; subgrade modulus; moisture effect.

1. Introduction

The trend in pavement design is changing. The past design principle was to use empirical guideline which had set up from the sites and engineers from their experiences. This empirical design principle is not considered accurate and makes the design conservative that is directly related to over use of material. During recent decades, there has been developments of correcting the design principle with applying mechanistic concept so that makes the design to be more realistic. For instance, Korea adapted the mechanistic concept and built its own Mechanistic-Empirical design method guide (MEPDG) and made about 67milion Euro discount on pavement construction cost per year compared to cost by empirical design principle (MOLIT, 2015). Mechanistic concept on pavement design is to convert the experiences from the site into design input variables. In the design input traffic load, environmental features, base/subgrade material properties in a correlation function form are included.
To enable Mechanistic-Empirical Pavement Design there are intense studies to choose effective tool to get mechanistic part of design; such as estimation of stress state, pavement responses, and constitutive equations. Representatively, Finite Element Method (FEM) is one of the most powerful tool for mechanistic design such as ILLI-SLAB, ILLI-PAVE, and EverStress FE. Along with those pavement analysis purpose FE software, the general purpose commercial FE programs (e.g. ANSYS, ADINA, ABAQUS) also become powerful tools for pavement analysis since these FE programs are useful with its user defined material model and the designers can code models what they want to analyze. Designers use FE programs to verify stress-dependent response of pavement structure with varying design parameters which they are interested in.
So far many studies focused on traffic loading among design inputs. Since the pavement is subjected to the environmental effects, most representatively temperature and precipitation is important to achieve structure's integrity during service life. In this paper the attempt to model the subgrade modulus by FE method is presented, mainly how to adopt moisture effect on the resilient modulus. Short comparison between Korea, Hungary, and the US design method on subgrade how they include moisture effect on their design method is shown.

1.1. Constitutive Equation of Subgrade

Subgrade displays a nonlinearity which is recoverable deformation from some part of plastic deformation under repeated loading (Duncan, et al., 1968). The term 'resilient modulus' is used to avoid confusion with 'stiffness' which describes force derived from a unit displacement whereas the resilient modulus includes recoverable strain (see the figure 1). Subgrade shows a stress-dependency on its modulus. There are intense researches tried to describe its relation.

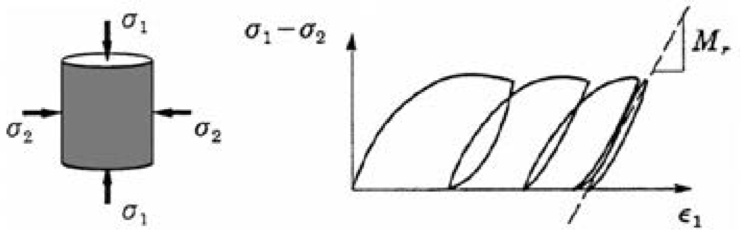

Fig. 1.
Triaxial Test and Resilient behavior of Granular materials

The stiffness of a material related to a resilient response can be written by this equation (1).

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$$M_r = \frac{\sigma_d}{\varepsilon_r} \tag{1}$$

This means a resilient modulus (M_r) is stated in terms of deviatoric stress (σ_d) divided by recoverable strain (ε_r). Based on this basic formulation intense researches supplemented additional terms which can capture full resilient behavior of subgrade.

Efforts to describe resilient behavior of the subgrade, the earliest model $\mathrm{K}-\theta$ (equation 2) arose by Hicks and Monismith (Hicks & Monismith, 1971).

$$M_r = k\theta^n \tag{2}$$

This simple model includes the mean pressure acting on the specimen (θ, bulk stress) which is raised to a power, n. From this simple form, many variations were developed by experts. Uzan found a non-neglectable effect of deviator stress on resilient modulus, and included deviator term into the model (Uzan, 1985). Later on Witczak substitute deviator term from Uzan model into octahedral stress and build Witczak-Uzan model (Witczak & Uzan, 1988). Thanks to octahedral is a three axes term this model is widely used in three-dimension FE modeling (equation 3).

$$M_r = \mathrm{k}_1 \mathrm{P}_a \left(\frac{\theta}{P_a}\right)^{k_2} \left(\frac{\tau_{oct}}{P_a}\right)^{k_3} \tag{3}$$

Where, k_1 , k_2 , k_3 are regression coefficient from triaxial test, τ_{oct} is octahedral shear stress ($= \frac{1}{3}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_1-\sigma_3)^2+(\sigma_2-\sigma_3)^2}$), and P_a is atmospheric pressure.

Those presented models are most well-known resilient models and still commonly used. Based on these constitutive equations researchers add some additional terms to make those equations reflect much more reality, like climatic effect such as the effect of temperature and precipitation.

2. Model and Method

2.1. International Practice: Hungary – Korea – US Approaches

In terms of mechanistic-empirical design of pavement structure, designers put the effort to make correlation model by collected data set from sites (empirical) and constitutive equations (mechanistic) for preparing a design guide. Each country develops their design guide which reflects on their regional characteristics, this chapter is about comparison between Hungarian, Korean, and US resilient guide.

Hungary currently uses the empirical method in the pavement design. The design guide does not consider the positive effect of subgrade modulus over 40 MPa (HMND, 2007); consequently it leads to overdesign of the pavement.

Korea prepared its mechanistic-empirical design guide (KMEPDG) in 2011 (MOLIT, 2011), and below equation is resilient modulus in the guide (equation 4) as a design input. The test method is from AASHTO T274-82, for the resilient modulus determination.

$$\mathrm{E} = k_1 \theta^{k_2} \sigma_d^{k_3} 10^{k_w(\boldsymbol{\omega}-\boldsymbol{\omega}_{opt})} \tag{4}$$

Table 1

Subgrade water content estimation model

Region	Subgrade water content estimation model (w)
Northern part	$\boldsymbol{\omega} = 23.54759 + 0.15216 \times \mathrm{temp} + 0.00070721 \times \mathrm{prec} + 0.17990 \times P_{200}$
Southern part	$\boldsymbol{\omega} = 21.84699 + 0.09598 \times \mathrm{temp} + 0.00064287 \times \mathrm{prec} + 0.9130 \times P_{200}$

Source: Ministry of Land, Infrastructure and Transportation (MOLIT, 2015)

Where, k_1, k_2, k_3 is model coefficients, ω_{opt} is optimal water content, ω is water content, k_w is model coefficient which reflects water content which is -0.1417 (for coarse grain material) or -0.0574 (for fine grain material). E_{opt} is the estimated subgrade modulus in an optimal water content condition. Subgrade water content is determined by an estimation model which contains monthly average temperatures, monthly accumulated precipitation and soil distribution. Water content estimation equation is suggested in table 1. Where, temp is monthly temperature (°C), prec is monthly precipitation (mm) and P_{200} is #200 sieve passing.

Even the water content reaches equilibrium, the water content can still deviate from equilibrium due to seasonal fluctuations in climate (Cary & Zapata, 2010). This fluctuation is taken into account in ω estimation in function of monthly average temperature and monthly precipitation. The authors indicate the correction ratio of M_r (equation 5) and M_{opt} which contains the degree of saturation as moisture effect on subgrade modulus.

Equation (5) is generalized resilient modulus estimation on AASHTO MEPDG and M_r determination test method is on AASHTO T 307 or NCHRP 1-28A (AASHTO, 2008).

$$M_r = k_1 p_{\mathrm{a}} \left(\frac{\theta}{P_a}\right)^{k_2} \left(\frac{\tau_{oct}}{P_a}+1\right)^{k_3} \tag{5}$$

P_a is normalizing stress, k_1, k_2, k_3 is model coefficients.

Those subgrade resilient modulus models on up part will be embodied as a user defined material property in ANSYS, on the following section 2.2.

2.2. Numerical Model

As a mechanistic tool for those constitutive relations from chapter 2.1, FE method is the most effective tool for pursuing reasonable solution. FE model is prepared by ANSYS and it was calibrated with multilayer program, Erapave. The model is constrained horizontal displacement at the sides, and both horizontal and vertical displacements were constrained at the bottom. Meshing is refined at the tire contact surface, and 50kN of static load is applied at the circular contact area with 150 mm radius. Solid 187 the quadratic 10-node element is chosen. A material property is given below on table 1.
Bottom locates over 18 radii of depth, and moving radially on the sides are constrained its facing axis over 12 radii from the center (Duncan, et al., 1968). Each layer is assumed to meet continuity condition that the layers are in contact with shear resistance fully active between them so that the layers act together as an elastic medium with a fully continuous with stress and displacement across the interface (Burmister, 1945).
Parametric study is conducted with varying moisture term according to climatic data of Seoul, Korea for the equation 4. By checking displacement vector sum, adjusted model size and determined the width a 8,000 mm to avoid boundary effect.

Table 2
Geometry, element type, and material property

Layer	Element	Poisson's ratio	Thickness [mm]	Young's Modulus [MPa]
AC	3-D, 10-node element	0.35	160	5,000
Base	3-D, 10-node element	0.35	200	500
Subgrade	3-D, 10-node element	0.35	10,000	E; M_r, *varying, and 40 for HUN method

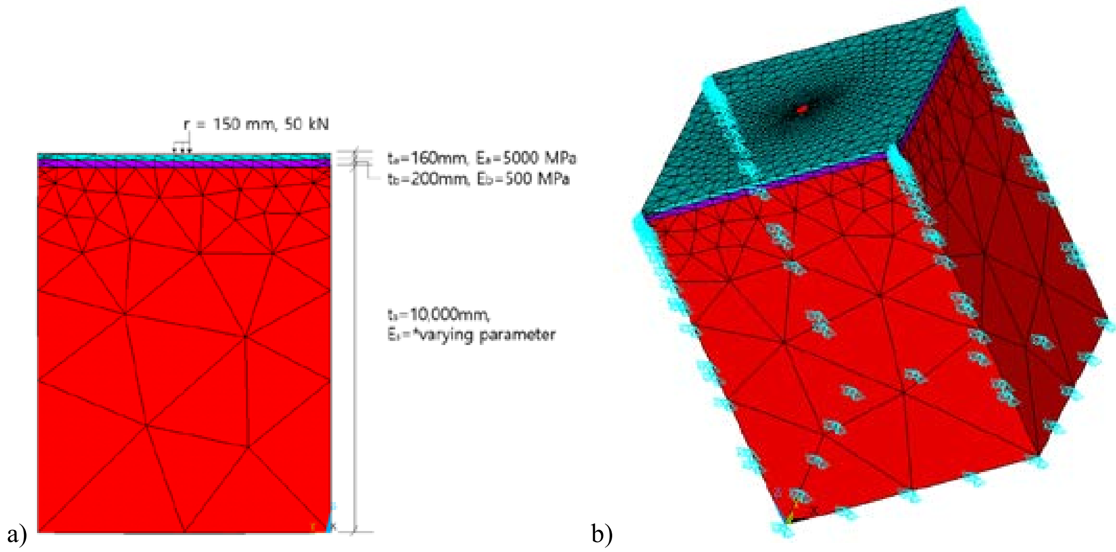

Fig. 2.
a) Geometry and material properties of each layer in meshed form, and b) boundary condition by ANSYS

Figure 2 is the numerical model after mesh and boundary set. Mesh is refined at the circular load applied area. Table 3 is input and output indication which were used in numerical study.

Table 3
Input variables and output of FE analysis

Input	ta, tb, ts	Thickness of asphalt, base, subgrade layer
	Ea, Eb, Es	Modulus of asphalt, base, subgrade layer
	ν	Poisson's ratio
Output	δ	Displacement of asphalt surface at the tire contact center
	ε	Tensile strain bottom of asphalt layer
	σ_z	Vertical stress at subgrade top

2.3. Parametric Study

Most of pavements lose its serviceability when they undergo premature rutting and fatigue crack. Those distresses happens when below criteria exceeds the limit;

- Displacement at center of the tire load;
- Strain bottom of the AC surface;
- Vertical stress state at the top of the subgrade.

Parametric study is conducted to see those responses which are directly related to serviceability. Strains at the bottom of asphalt layer is related to bottom-up fatigue crack, and vertical stress at the top of subgrade is related to rutting.

2.3.1. Influences of Water Content on Subgrade Modulus

To check the moisture effect on subgrade, the comparison between Korean MEPDG of equation 4 and American MEPDG of equation 5 was completed. Model coefficients can be found from table 4 and 5. Subgrade soil properties in table 4 is test result done by researcher of America with AASHTO T307-99 (Kim *et al.,* 2014) (AASHTO, 2012). For a fair comparison, the same soil properties were taken and calculated resilient modulus for each methods. The model coefficients on table 5 is calculated by correlation model guided in Korean Mechanistic-Empirical Guide (KEPDG) (MOLIT, 2015).

Table 4
Subgrade soil properties

ID	Percent Passing				OMC [%]	Maximum dry density [pcf]	Average regression coefficients for MEPDG			Soil classi-fication	Resilient modulus (M_r) [MPa]
	#10	#40	#60	#200			k_1	k_2	k_3		
9	84.2	37.8	17.6	6.2	11.9	119.3	1386	0.277	-2.499	A-1-b	85.551

Source: Prediction of subgrade resilient modulus using Artificial Neural network (Kim, et al., 2014)

The picked soil from the literature (Kim, et al., 2014) is #9 sample, the poorly graded sand. The soil properties on table 4 is results got from AASHTO T 307-99 test for resilient modulus. Accordingly the correlation model factor for water content term from Korean MEPDG is -0.147, and the other factors are shown in below (table 5).

Table 1
Korean MEPDG model coefficients

ID	Korean MEPDG model coefficient			
	k_w	k_1	k_2	k_3
9	-0.1417	171.812	0.262	-0.363

Confining stress is involved in resilient modulus as a hardening term (k_2>0) which makes modulus high whereas water content is involved as a softening term which hinders strength of subgrade (k_w<0). In the water content correlation model of KMEPDG, the monthly average temperature is also took into accounted. Thus, it is bit hard to verify the exact contribution of moisture and temperature on the subgrade modulus furthermore the k_w is negative and make water content have small contribution on the subgrade modulus (see equation 4).

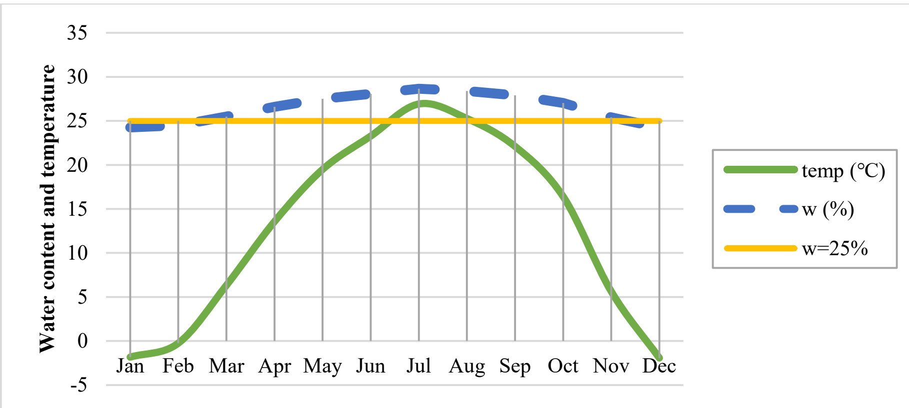

Fig. 3.
Monthly water content and average temperature distribution for the analysis, 2017 Seoul, Korea

Moisture related impact is only involved in the Korean MEPDG (equation 4) thus Korean climatic data is considered and applied in it. Results are shown in figure 4, the seasonal resilient modulus distribution of Korean MEPDG method is shown on the bar graph and MEPDG by AASHTO method in straight line. The resilient modulus on figure 8 is calculated under the condition that constrain stress is 13.8 kPa, deviator stress 41.4 kPa (AASHTO, 2008).

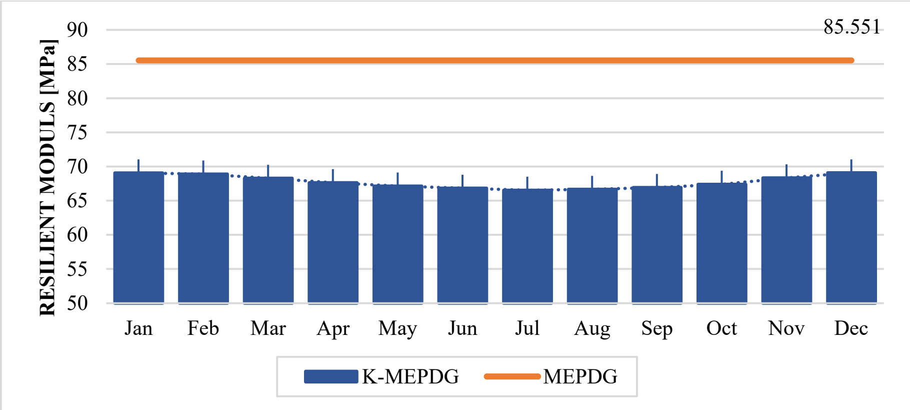

Fig. 4.
Resilient modulus by KMEPDG and AASHTO method

Figure shows the differences of 16~19 MPa between two design guides, and can say that almost 20% is involved in moisture content. Following is the responses with those resilient modulus.

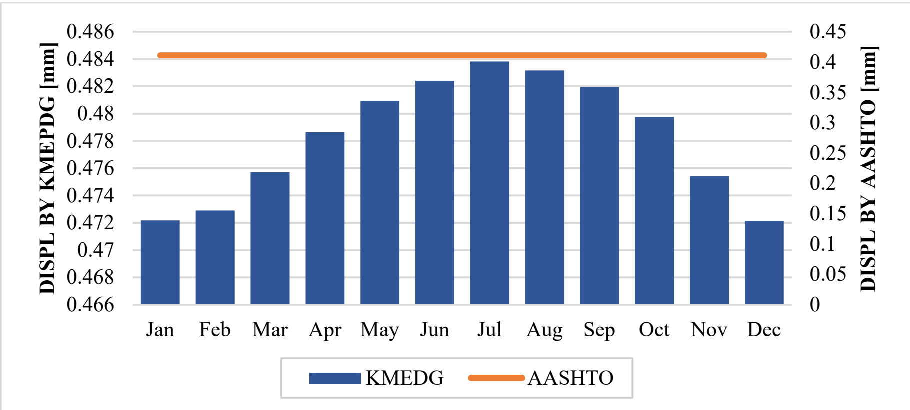

Fig. 5.
Displacement comparison at the center of the load [mm]

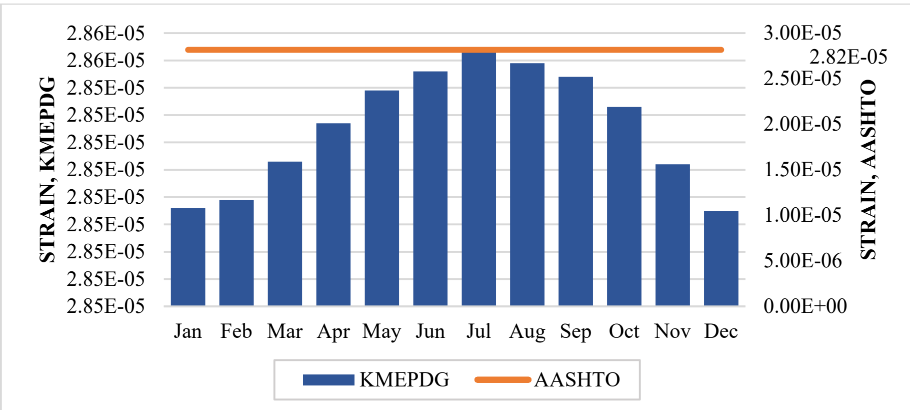

Fig. 6.
Strain on the bottom of asphalt concrete layer, at the center

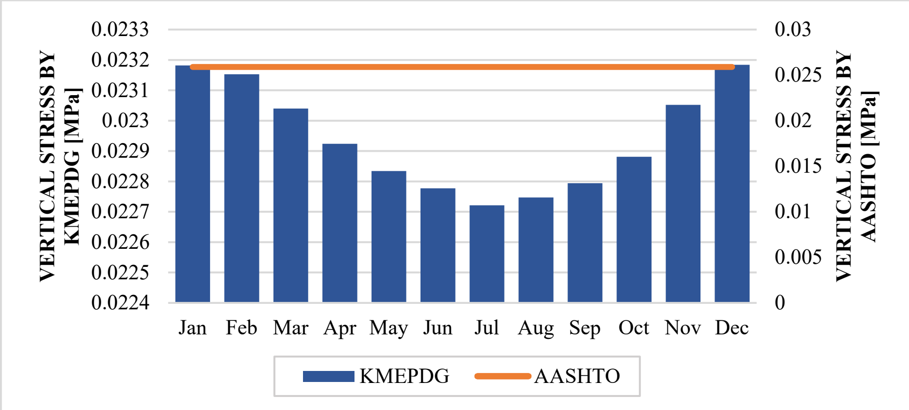

Fig. 7.
Vertical stress state at top of subgrade [MPa]

Figure 5, 6, and 7 shows the dependency of structural response on subgrade modulus. Those results describe that pavement maintenance requires more intervention during summer season.

2.3.2. Influence of Stress State

This part is to investigate pavement structure's response upon various stress state. In the Korean MEPDG guide, there is load combination for triaxial test for subgrade modulus (AASHTO, 2012).

Table 2
Testing Sequence for Subgrade Soil

Sequence	σ_c [kPa]	σ_d [kPa]	Sequence	σ_c [kPa]	σ_d [kPa]	Sequence	σ_c [kPa]	σ_d [kPa]	Sequence	σ_c [kPa]	σ_d [kPa]
0	41.4	27.6	4	41.4	55.2	8	27.6	41.4	12	13.8	27.6
1	41.4	13.8	5	41.4	68.9	9	27.6	55.2	13	13.8	41.4
2	41.4	27.6	6	27.6	13.8	10	27.6	68.9	14	13.8	55.2
3	41.4	41.4	7	27.6	27.6	11	13.8	13.8	15	13.8	68.9

Source: AASHTO T 307-99 test for resilient modulus (AASHTO, 2012)

According to AASHTO T307-99 selected two stress state, one is lowest stress state sequence number 11 and highest stress state sequence number 5.

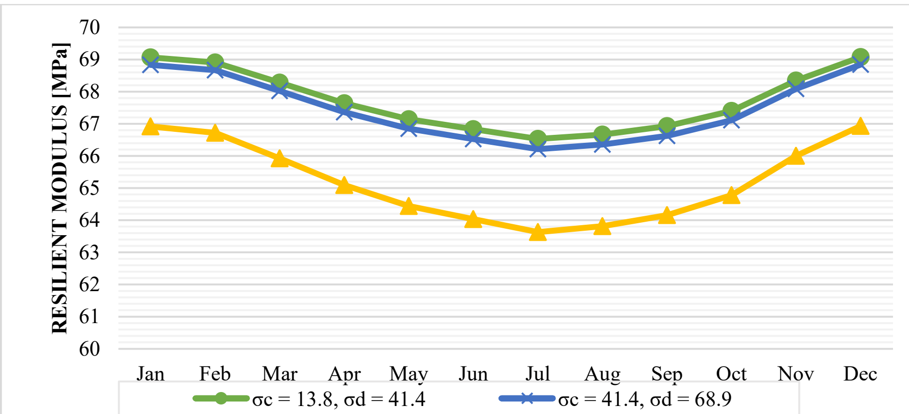

Fig. 8.
Monthly resilient modulus variation by KMEDPG under different load combination [MPa]

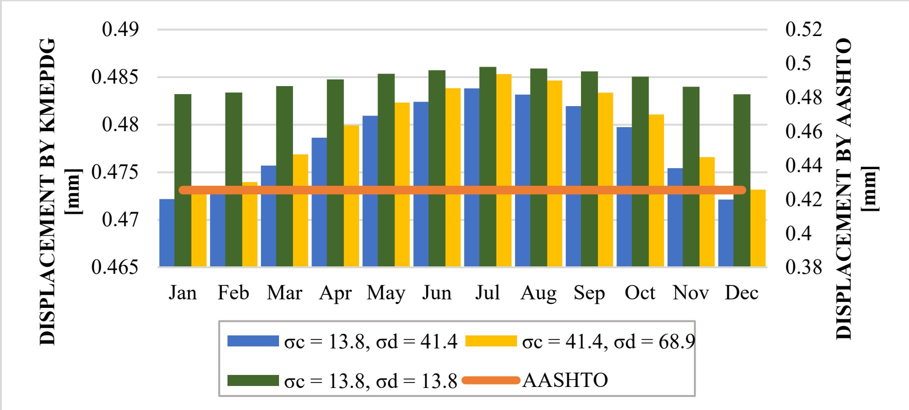

Fig. 9.
Monthly displacement estimation with comparison of K-MEPDG and AASHTO method [mm]

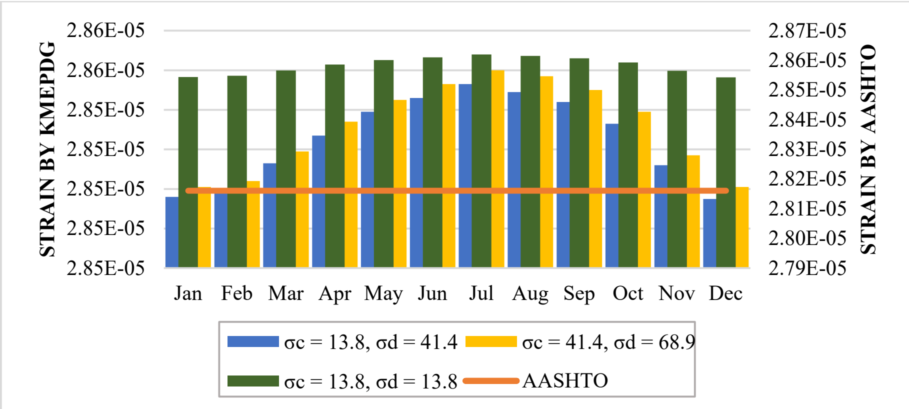

Fig. 10.
Monthly critical strain estimation with comparison of K-MEPDG and AASHTO method

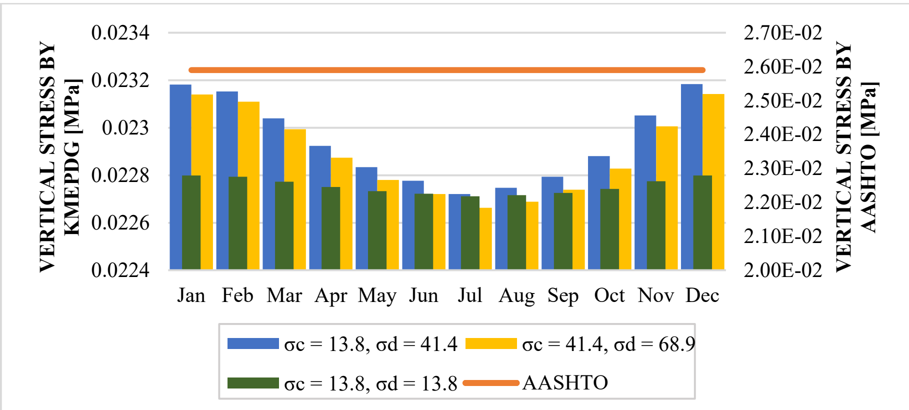

Fig. 11
Monthly vertical stress estimation with comparison of K-MEPDG and AASHTO method [MPa]

The strain has not significant differences both between different load combination and between Korean MEPDG and AASHTO MEPDG method. From figure 11, can see the stress resultant depends on deviator stress. The deviator stress on soil is induced by moving wheel load on the asphalt surface. Even with the static load was applied on numerical model the results produces the importance of moving load.

3. Discussion and Conclusion

Parametric study by employing ANSYS is performed to investigate environmental effect on the subgrade modulus. User defined element module could help to adapt varying subgrade modulus in the structural response analyses. It is a study of environmental factor which is represented as water content and temperature on subgrade resilient modulus.
Checking the pavement structure capacity which concerns the climatic effect is studied by comparing different countries' design guide. For the Hungarian guide, there is a slight chance of over use of paving material since it is using empirical design guide that does not consider any of climatic effect. Hungarian design method is bit underestimates the subgrade strength contribution on pavement responses. From the figure 4 to 7, can see that take consideration of

environmental effect cannot be neglected. A fluctuation upon monthly change as the water content and indirect temperature changes is presented. It draws the caution on keeping pavement structure's integrity has to consider the varying structural responses. In the later study will take into account an environment term with a factor from study of Cary and Zapata (Cary & Zapata, 2010).
Confining stresses statistically influence resilient modulus for granular soils. The results on the 8 to 11 figures a strain has not significant differences both between different load combination and between Korean MEPDG and AASHTO MEPDG method. Figure 11 shows a stress resultant dependency on deviator stress. The deviator stress on soil is induced by moving wheel load on the asphalt surface. Even with the static load was applied on numerical model the results produces the importance of moving load. It shows that in a static analysis if deviator stress is varied then the result can reflect moving traffic load.

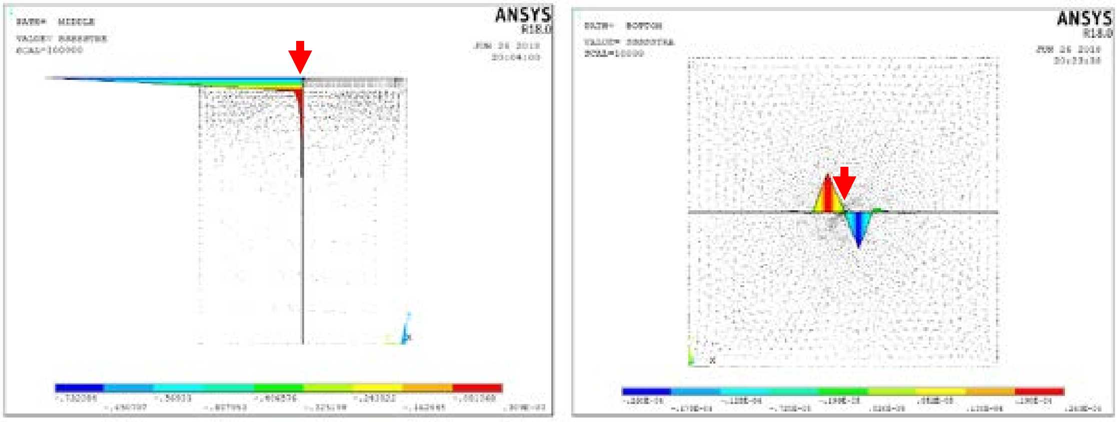

Fig. 12
Vertical stress distribution along the center-line of load (left); strain distribution underneath of asphalt layer along x-axis top view (right)

On the figure 12, the vertical stress distribution along z-axis and strain distribution along x-axis is shown and the red arrow means the center of load applied area. Those dots on the figure are nodes of numerical model. Most of the vertical stress resultant exhausts on the top part of subgrade. The strain is distributing symmetrically at the center of load. Interesting feature to highlight is that the peak occurs at the tip of perimeter. These mean that a pavement structure's performance is strongly dependent on subgrade and the permanent distress can be found along load applying perimeter.
To summarize;

- Empirical design method under estimates pavement structure's response;
- Pavement structure's performance strongly depends on subgrade's strength. Thus consideration of seasonal variation on the subgrade modulus for the exact estimation of whole pavement structure is important;
- Subgrade resilient modulus is varying upon season change. There is a trend, subgrade stiffens during winter time and softens during summer time. To ensure pavement structure's serviceability, there need a care during summer time;
- Permanent distress can be expected at the very tip of loading applying area. Position of this distress is not dependent on subgrade modulus.

Acknowledgements

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ASSESSMENT OF ROAD SAFETY FOR 2+1 ROADS WITH VARIOUS SOLUTIONS OF SEPARATING OF TRAFFIC DIRECTIONS

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Abstract: Researches conducted in many countries indicate that 2+1 roads significantly improve road safety. The studies on 2+1 roads focus mainly on the comparison of the safety performance for two-lane and 2+1 roads mainly considering a physical separation of the opposite traffic directions (cable barriers) or without any physical separation. In Poland, there are several scenarios of separating traffic directions, which include: horizontal markings (double solid line), horizontal markings with additional measures to improve road safety (low or high safety devices) and physical separation using cable barriers. As already reported, there is no description in the literature of the impact of all the above-mentioned scenarios on safety. Therefore, in order to assess the effectiveness of 2+1 roads and selection of the recommended configuration, it is necessary to quantify the impact of various scenarios of separating traffic directions on safety. The aim of the paper is to assess the impact of 2+1 roads on road safety, considering the various solutions of separating traffic directions on the basis of regression models quantifying the number of crashes considering also traffic and other variables. The quantification is carried out by calibrating a Safety Performance Function (SPF), based on the results of the inventory work, traffic flows and crash data. The effectiveness of the scenarios was estimated considering as base condition the horizontal marking with additional measures to improve road safety (high safety devices) and calculating the relative risk of the other scenarios in comparison with the base one. The overall results indicate safety benefit of implementing 2+1 roads in Poland, which can reduce severe crash frequency of 50% compared to two-lane roads. Furthermore, the present research work introduces a novel approach in 2+1 studies considering the safety effects of different separation of the opposite traffic flows based on SPF.

Keywords: road safety, 2+1 road, crash prediction model, safety performance function, cross-section.

1. Introduction

Road networks in the most countries are developed on the principle of a hierarchical network. Therefore, in road network is possible to distinguish sections with different: functions, road safety performances and cross-sections, usually based on speed and traffic volumes and composition. The greatest share in the road network are two lane roads, which can perform many functions, depending on the level of hierarchization of the road network. These roads, despite their versatility, have limited possibilities of traffic service and often do not provide a sufficiently high proportion of sections with the possibility of overtaking. As a result, the platoon increases by producing a lower level of service and safety performance. In this framework the implementation of additional overtaking lanes to improve performance on two lane roads can mitigate the problem. Depending on the constrain of the local conditions and to the final aim, one can use passing relief lanes or sections consisting of a series of alternating overtaking lanes, implementing the 2+1 roads typical configuration.

Literature review shows that 2+1 roads are characterized by a higher economic efficiency compared to four lane roads, filling the gap between two lane roads with limited overtaking possibilities and multi lane roads (*Kirby et al, 2014*).

German and Swedish experiences show that a 2+1 roads cross-section were not created as newly designed, but as low-cost means of improvement of 13-m two lane roads (with paved shoulders), It was introduced by a new horizontal marking method (Germany, Great Britain) and physical separation using cable barriers (mainly in Sweden). Data collected from different countries show that a 2+1 roads are designed for an average annual daily traffic of 4,000 - 25,000 vehicles/day (*Kirby et al, 2014*). However, considering the introduction of a three lane cross-section, the problems related to access control and demand for area to introduce interchanges, which will reduce the number of traffic disruptions should be considered. In the design stage, it is also necessary to consider possible problems with operation and to design a cross-section to ensure the possibility of carrying out maintenance works.

Besides, the effects on safety of the different configuration of the separation for the opposite traffic directions is still an open question. In Poland, there are several scenarios of separating traffic directions: horizontal markings (double solid line), horizontal markings with additional road safety measures (low or high devices) and physical separation using cable barriers (considering the Swedish approach). Unfortunately, in the literature there are not studies of the impact of all the above-mentioned scenarios on safety. Therefore, in order to assess the effectiveness of 2+1 roads and the selection of the recommended scenario, it is necessary to quantify the impact of different separations of traffic directions on safety.

The aim of the present research work is to assess the impact of 2+1 roads on road safety considering the various solutions of separating traffic in the two directions. The assessment was carried out on the basis of regression models quantifying the number of crashes considering road characteristics and traffic variables.

2. Literature Review

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Researches conducted in many countries indicate that 2+1 roads significantly improve road safety. The study on 2+1 roads focuses mainly on the comparison of the safety performance for two-lane and 2+1 roads with regard to the physical separation of traffic directions (cable barriers) and without such separation.

The main researches in the field of 2+1 roads are from Sweden. The report (*Bergh and Moberg, 2005*) presents the results of road safety analysis, including 2+1 roads. Conversion of wide two lane roads (13 m roadway width) into sections with a 2+1 cross-section with a cable barrier dividing the traffic directions turned out to be highly effective. Swedish research indicates a reduction of fatalities by 80% and seriously injured by 50%. The paper (*Vadeby, 2016*) presents the results of road safety research on 2+1 roads with a narrow cross-section in Sweden (9-10m roadway width), with a cable barrier). The analysis was conducted with a before-after study with a control group and an empirical Bayes correction (EB), by using models not calibrated on the dataset used for the safety evaluation. Additionally, for analyzed 2+1 roads, the speed limit was increased from 90 km/h to 100 km/h. Therefore, the assessment concerns the combined effects of the implementation of a 2+1 cross-section and the increase of the speed limit. The results of the analysis indicate a significant improvement in safety. The number of fatalities and serious injuries decreased by 50%, and the number of crashes with injuries by 21%. Considering only road sections (without access points), a reduction of 63% in the number of fatalities and serious injuries and a 28% in the number of crashes with injuries were estimated. There were no significant differences in the safety effectiveness of the narrow 2+1 sections compared to the previous analyzes of sections with a 2+1 cross-section retrofitted from 13 m roadway width.

The same in Germany, improving the road safety performance is one of the reasons for implementing 2+1 cross-sections, mainly as an alternative to wide sections of two lane roads (with paved shoulders). The paper (*Weber and Jährig, 2010*) describes the results of safety analyzes for 10 sections of rural roads with a high number of crashes. For road sections with hazardous overtaking maneuvers additional lanes for passing were introduced. In addition, for road sections where speed was the main cause of crashes speed cameras were installed. The research based on naïve before-after analysis estimated that the number of seriously injured was reduced by 50%, in 3 years of observations. The overtaking lanes combined with sections where overtaking is forbidden increase safety, improve level of service (travel time) and result in less aggressive behavior of drivers.

Harwood and John showed that the effectiveness of additional lanes for overtaking, evaluated by the reduction of all crashes is equal of 9%, but for crashes with fatalities is equal of 17% (*Harwood and John, 1984*). A later analysis (*Harwood et al., 2000*) led to the conclusion that the Crash Modification Factor (CMF) is greater and amounts to 0.75 for 2+1 sections. In the paper (*Park et al., 2012*) the road safety performance for 2+1 roads using EB method in the USA, was described. As a result of EB analysis, all crashes were reduced by 35%, considering only sections of roads without intersections. In the case of sections with intersections, this reduction was 42%. The results were developed at the assumed confidence level of 95%. Analysis of 2+1 roads in Texas (*Brewer et al., 2011*) leads to the following conclusions: on roads with traffic volume above 5000 vehicle/day the crash rate is lower than the average state crash rate (1.4 crash/VMT); the crash frequency is 29% lower than two lane roads in this region; severe crash frequency was estimated to be higher on 2+1 roads than on two lane roads although the average number of conflicts occurring on the analyzed sections is less than 1% of traffic volume.

The analysis of road safety for 2+1 roads was also carried out in South Korea (*Lee et al., 2010*). The 2+1 sections can noticeably improve safety for which similar results to European studies were estimated. The case study was conducted for two lane road with the highest share of fatalities due to road crashes in Korea – 78%, while in the country this share is on average 8%. In order to reduce the number of fatal crashes, it was decided to retrofit two lane road to the 2+1 road. The length of overtaking lanes is about 1-1.2 km. The crash data were collected for period before (1999-2007) and after (2007-2008) the reconstruction. It results from them that after the retrofitting of the section there were no road crashes. It means high efficiency in terms of improving road safety.

The 2+1 roads introduced with a barrier dividing the traffic directions, as an example of improving traffic conditions and road safety, were analyzed in Ireland too (*Gazzini, 2008*). The transformation of a two lane roads into the above-mentioned cross-section can result in the reduction of fatal accidents by 70-90%. This change brings a higher probability of increasing the total number of crashes, because of the occurrence of events related to the hitting in the barrier. Fortunately, it has been shown that these events are not hazarding for the health and life of road users. Although this scenario has a positive effect on safety, causes problems in the operation and maintenance of the road (the cost of maintenance increases due to the limited access to road).

An extensive report from New Zealand on the 2+1 road also addresses the issue of road safety (*Kirby et al, 2014*). The EEM (Economic Evaluation Manual) provides values for reducing the number of crashes when using an overtaking lanes: 30% - crashes related to overtaking over the entire length of the additional lane, 40 - 60% - head on crashes over the entire length of the additional lane, 15% - rear-end crashes over the entire length of the additional lane. After analyzing foreign examples of 2+1 roads with cable barriers and comparison them with the New Zealand traffic conditions, the expected reductions in road safety measures are as follows: fatal crashes by 48%, injured crashes by 33% and increase road collisions by 44%.

Studies in the area of safety for 2+1 roads have also been undertaken in Poland (*Cafiso et al., 2017*). The research included retrofitted sections of two lane roads to the section with an additional lane with length of approx. 13 km. The analysis was conducted for the years 2005-2013 excluding the year 2009 using the before after EB approach. Regression models were developed separately for sections: 2+1 (overtaking lane, conflicting and non-conflicting changeovers) and 2+1 with upstream and downstream sections. On the basis of statistical analysis, the value of the Crash Modification Factor was determined, In the first case it was 0.53 (only the section with an additional lane) and

0.96 (sections with upstream and downstream) in the second case. The results indicate a beneficial effect of introducing 2+1 roads in Poland on road safety, which can be as much as 50% compared to two-lane roads. Studies have shown that attention should be paid to the beginnings and ends of additional lanes, where access points often occur in for retrofitted sections. As a result, there is no positive impact of the change in cross-section on road safety (CMF is about 1). Similar studies were conducted considering surrogate measures of safety (traffic conflicts) *(Cafiso et al., 2018a, Cafiso at al., 2016)* to assess the effects of the additional lane length and conflict changeover length on road safety. This latter result not significant, while the optimum 2+1 segment length depends on the value of the average daily traffic.

3. Design of 2+1 Roads in Poland

In Poland, there are several solutions of separating traffic directions, which include the following: marking (double solid line), markings with additional measures to improve road safety (low or high devices) and physical separation using cable barriers. Unfortunately, there is no description in the literature of the impact of all the above-mentioned solutions on safety. Therefore, in order to assess the effectiveness of 2+1 roads and the selection of the recommended scenario, it is necessary to quantify the impact of various scenarios of separating traffic directions on safety. Solutions of separating traffic directions on 2+1 roads in Poland are presented in Fig. 1.

Marking (double solid line)

Marking with additional measures to improve road safety (low safety devices)

Marking with additional measures to improve road safety (high safety devices)

Cable barriers

Fig. 1.
Scenarios of separating traffic directions on 2+1 roads in Poland
Source: own source

4. Data and Method

The quantification of impact of scenarios of separating traffic directions on 2+1 roads in Poland was carried out by calibrating a safety performance function (SPF), which was developed using the results of the inventory work and crash and traffic volume data. As an independent variable describing road scenarios, the length of the segment L and the method of separation of traffic directions were analyzed. It was assumed that the model estimates the number of crashes on the road with a 2+1 cross-section and length L, which consists of the following elements: length of the additional overtaking lane and half of length of conflicting and non-conflicting changeovers. In a simplified manner, it was assumed that the length of the section is equal to the length of the additional lane + 250 m. There are four scenarios to divide the driving directions:

- P-4 – marking (double solid line),
- P-4+N – marking with additional measures to improve road safety (low safety devices),
- P-4+W – marking with additional measures to improve road safety (high safety devices),

- cable barriers.

The crash data from 2010-2016 from 11 sections of roads with a 2+1 cross-section consisting of 51 segments with different ways of separating driving directions were used in analysis. In total 662 crashes and PDO (property damage only) crashes were recorded on the analyzed sections. Crashes and PDO related to the way of separation of traffic directions including were considered which constitute the target group. Descriptive statistics for the data of crashes, traffic and 2+1 roads are shown in Table 1. Data cover the length of the 2+1 segment (*L*), the average annual daily traffic (*AADT*) and the number of crashes (*CRASH*) and PDO crashes (*PDO*). As an additional independent qualitative variable, describing the separation of traffic directions (*Sep*) was used.

Table 1
Descriptive statistics for 2+1 segments and crashes

	L [km]	AADT [Veh/24h]	CRASH [-]	PDO [-]	CRASH+PDO [-]
min	0.6	2088	0	0	0
max	1.9	18074	3	39	42
mean	0.964	8388.751	0.185	2.196	2.381
standard deviation	0.287	4311.965	0.479	3.805	4.009

Source: own source

To develop SPF model the generalized linear regression (GLM) modeling approach was used by calibrating the model on homogeneous segments (*Cafiso et al. 2018b*). The dependent variable was the sum of the number of crashes and PDO crashes (SPF) for 2+1 segment depending on the separation method to dividing the traffic directions. In the model, variables of traffic volume and length of the segment as well as a qualitative variable of the separation of traffic directions were used as independent variables, among which the previously described types of separation of traffic directions were distinguished. Statistical modeling was performed using a negative binomial distribution of the random variable of the number of crashes with a logarithmic link function as follows:

$$SPF = \exp(\alpha) \times L^{\beta} \times AADT^{\gamma} \times \exp(\delta_i \cdot Sep) \qquad (1)$$

where:
SPF – predicted number of crashes and PDO per year,
L – length of the 2+1 segment [km],
AADT – average annual daily traffic [veh/24h],
Sep – qualitative variable of the separation of traffic directions: cable barrier (a), marking P-4 (b), marking P-4+N (c)
$\alpha, \beta, \gamma, \delta$ – regression coefficients.
In the model the transformation of the independent variables *AADT* to *lnAADT*. and *L* to *lnL* was used

Based on a comparison of changes in the number of road crashes in depending on the type of separation the effectiveness of scenarios was estimated. It was done in a relative way, with reference to the separation using horizontal marking with additional measures to improve road safety (high safety devices) – P-4+W.

5. Results and Discussion

Regression coefficients in the SPSS software based on the performed regression analyzes were determined. All quantitative variables fulfil the requirements of statistical significance at the level of *p-value* <0.05. The final version of the regression model is presented below (designations according to formula 1):

$$SPF = \exp(-13{,}718) \times L^{0{,}714} \times AADT^{1{,}592} \times \exp[0{,}28 \times (a) + 0{,}175 \times (b) + 0{,}166 \times (c)] \qquad (2)$$

The categorical variable of the separation of traffic directions is equal 1, when it occurs, and the others types are equal 0. The graphical interpretation of the model in relation to the 1 km length of the segment with an additional lane (2+1 road) is presented in Fig. 2.

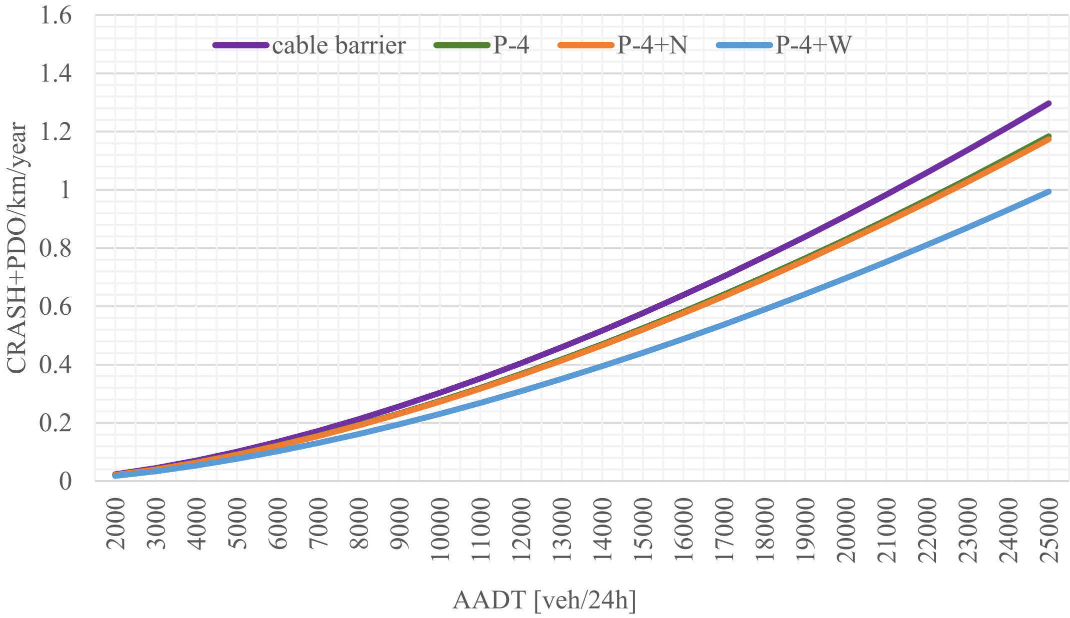

Fig 2.
The graphical interpretation of the model (2)
Source: own source

The presented model can be used to estimation the effectiveness of the separation of traffic directions based on a comparison of changes in the number of crashes. Based on this, the following conclusions can be made (considering the same value of AADT):

- the smallest number of crashes occurs for the P-4+W separation;
- for the P-4+N separation, there are 19.1% more events than for P-4+W;
- number of predicted crashes for the P-4+N and P-4 separations is similar. The difference between these solutions is not large, i.e. 1.1% more events for P-4 than for P-4+N, which is an unexpected result, taking into account the greater width of the separation for P-4+N on several sites);
- the greatest number of crashes occurs in the case of separation using cable barriers (32.3% more crashes than for P-4+W). However, it should be noted that these are mostly PDO crashes.

6. Conclusion

Literature review results a beneficial effect of 2+1 roads on road safety. The previously analyzed scenarios for the separating of traffic directions, described in the literature, included only the use of a 2+1 roads with road marking and with cable barrier. The introduction of 2+1 roads with different scenarios of separating traffic directions in Poland in recent years has allowed is pushing research for estimating their impact on road safety. The comparison of various scenarios for traffic direction separating was conducted in the present research work by developing a safety performance function. Comparison of various scenarios of separating opposite traffic directions indicate its influence on road safety. The results are in line with expectations and literature review and indicate the highest number of accidents on 2+1 roads with cable barriers. Despite the strongest effects on crash frequency, crashes occurrence on segments in which separation is made up by cable barrier have the lowest severity. The introduction of separation based on marking with additional measures to improve road safety (high safety devices – guideposts) is the safest scenario. It affects the changes of road perception. This such of separation has a similar impact on drivers' behavior to the physical barrier.

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MIX DESIGN OF BITUMINOUS BASE COURSES AND VARIATION ASSESSMENT OF INDIRECT TENSILE STRENGTH FOR SPECIMENS COMPACTED UNDER GYRATORY COMPACTION

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Abstract: The research focuses on the comparison of Indirect Tensile strength (UN EN 12697-23) and air voids content of bituminous specimens (UNI EN 12697-8) when the mix design is carried out by adopting the Marshall method (UNI EN 12697-34) and additional tests are carried out according to Italian Local Technical Specifications on road maintenance that require specimens prepared using Gyratory Compactor (UNI EN 12697-31). A total of 90 specimens were prepared of which 20 in first phase of mix design and the remaining to validate the solution. Different 4 HMA mixtures were prepared at different bitumen contents between 3.5% and 4.25% by total aggregate weight at 0.25% increments for bituminous mixture design solutions to define the optimum percentage of bitumen and Marshall Stability, Marshall Flow, Percentage of voids were in the first phase assessed. To validate the results, as discussed before, another set, outside the first one but reflecting its characteristics, was prepared and compacted under gyratory compaction. It was observed how the air voids content and Indirect Tensile Strength can change with the number of revolutions and the height of the specimen. This research may help to better understand that some Italian Technical Standard require for the acceptance of the mixture in situ.

Keywords: bituminous specimens, Marshall and gyratory compaction, indirect tensile strength.

1. Introduction

The expansion of production and market activities have caused a strong abuse of natural resources. The continuous and rapid growth of traffic demand together with the increase of permissible axial loads for road paving requires a higher quality of materials for the mixtures to be adopted. Due to high construction costs, research studies should focus on the correct design and choice of appropriate materials that can increase construction efficiency and at the same time extend the useful life of paving with reference to all the layers of which it is composed. In more recent years some specifications have been supplemented with performance-based parameters. The traditional requirements have been set empirically by correlating performance of pavements with volumetric design parameters. This approach is reliable when the materials in use and mixture types are relatively constant and enough evidence can be collected to correlate empirical properties to field performance. An ideal performance-based mix design would reflect pavement field performance and enable to evaluate mixtures for a specific climate and use application. This would allow optimizing material selection and proportions as well as introducing unconventional materials and technologies. Such changes nowadays are often not permitted because of the empirical nature of current mix design procedures. For these reasons performance-based specifications have the potential not only to improve pavement characteristics and extend service life but they can also help improve production technologies, increase cost effectiveness and minimize environmental footprint of asphalt production and paving. In particular the layers of which the same paving is composed must be set up and conducted on the basis of technical criteria to achieve and maintain in time some basic requirements, such as a) transmission capacity of vehicular loads to the subgrade; b) resistance to the phenomena of structural degradation; c) regularity and adherence of the viable surface; d) resistance to the freeze-thaw cycles; e) environmental sustainability.
With particular reference to the last of the five requirements, the phase of experimental research aims to provide claims and references for a package of mixture with only limestone material, evaluating the behaviour and the change of some mechanical properties such as Marshall Stability and Indirect Tensile Strength. In particular the research aims to evaluated ITS, for mixtures containing the optimum bitumen content not only compacted with impact compactor according to EN 12697-30 Standard but also with Gyratory compactor according to EN 12697-31 Standard.
Even if the much experimental analysis are based on superficial layers because these are in direct contact with road traffic it is important to evaluate the ITS parameter in particular for a base layer, because the mechanical characterization of the bituminous mixtures start from knowledge of the stress that take place inside the pavement due to induce load by road traffic overall for deeper layers.

2. State of Art

The expansion of production and market activities have caused a severe abuse of natural resources. The continuing rapid growth in traffic demands along with the increase in allowable axle loads necessitates higher quality of materials for the mixtures to be adopted.
In all the Technical Rules of the Contract, there is a lack of specific requirements and at the same time the difficulty of the scientific world to clearly indicate the link with the performance of the mixtures in use. Several studies and clear evidence of constructive practice have shown that, by reducing the voids in the mixture, the filler is able to perform

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important functions within the bituminous conglomerate, reducing thermal susceptibility and regulating the thickness and the mechanical properties of the mastic film. which covers the stone aggregate.
Research studies have shown that the strength of Hot Mix Asphalt (HMA) depends on several factors such as the type of filler used, aggregates and type and percentage of bitumen used. The significant importance of the use of fillers in bituminous conglomerates has been validated by numerous sector studies, among which the one conducted by Bocci and Giuliani, according to which the filler plays a fundamental role in the performance of bituminous conglomerate for road paving.
With their study Bocci and Giuliani have managed to derive the important experimental result of correlating the chemical characteristics of the filler and the adhesion capacity of the mastic.
In this regard, given the environmental and technological relevance of the study topic addressed, several researches have been conducted by environmental and transport organizations that refer to the use of recycled waste as a substitute material for calcareous filler, thus avoiding the further use of natural resources.
(Sangiorgi *et al.,* 2016) propose a different filler from the calcareous one from the study carried out on the evaluation of waste deriving from bleaching of clays for the production of porous asphalts with reference to the bound layers, such as wear, binder and base. Tests results are promising in terms of increasing of Indirect Tensile Strength, stiffness, and resistance to permanent deformations. Sangiorgi has shown that a negative effect on the workability of the mixture, depending on the design mixture and the type of binder, can be attributed to the high value of Ridgen voids , the percentage volume of intergranular voids referred to the density of a constipated specimen at dry with a normalized procedure with which it is able to provide an indirect evaluation of some fundamental properties, such as its mineralogical nature, the size distribution of the particles, their degree of angularity and texture.
Similar results have been obtained through the study of the application of coal waste powder CWP, conducted by (Modarres and Rahmanzadeh, 2014) showing an increase in Marshall stability, indirect tensile strength and the elastic modulus of HMA mixtures. However, the production of CWP for use in HMA requires incineration equipment that increases the total costs of the design of the mixture. Furthermore, the incineration process increases the total energy consumed and the environmental pollution.
(Chen *et al.,* 2011) focus more on the use of construction and demolition materials in bituminous mixtures, the possibility of partially replacing limestone filler in bituminous mixtures (HMA) with recycled brick powder. The experimental performed were indirect tensile tests, static and dynamic creep tests, water sensitivity tests and fatigue tests. The results show that the mixtures pre-pared with recycled brick powder have better mechanical properties than the mixtures with limestone filler. Thus, it is promising to use recycled brick powder as mineral filler in asphalt mixture both obtained by performing a Marshall impulsive energy compaction method.
Again with reference to the potential of fine aggregates recycled in powder form as fillers in the bituminous mixture, the same (Chen *et al.,* 2011) have focused their studies on the use of such materials for the base layers and foundation. The traditional Marshall procedure was used for the design of the mixture and from the results it was concluded that mixtures containing fine aggregates recycled in powder have an indirect tensile strength and a higher fatigue strength than the control mixtures.
(Akbulut *et al.,* 2012) for the first time investigate the use of granite sludge as fillers in bituminous mixtures assuming different quantities (0%, 2%, 4%, 6%, 8%) and using the Marshall method for each of the ratios the quantity was determined of optimal bitumen. Subsequently, Marshall mechanical and indirect tensile strength tests were performed for each of the samples. The results of the tests show that the use of granite sludge with an optimal ratio of 7.3% as filler in bituminous mixtures can improve the engineering properties of the mixtures in the wear layers, thus requiring a smaller amount of natural materials, such as aggregates and bitumen, and causing less damage to our environmental heritage. The present study is the first to have established the elements of the design of the essential filler in order to optimize the behavior of these mixtures.
More recently (Simone *et al.,* 2017) have conducted an interesting experimental work comparing the behavior of bituminous mixtures with different types of fillers, calcareous and waste glass powder, coming from the waste of goldsmith industries. To achieve a comprehensive approach, the tests have been divided in three phases: filler characterization, mastic rheology and mixture scale study. It has been found that this glass powder substitution has produced lower slip and greater stability following Marshall failure tests carried out in the laboratory. The choice of the granulometry was based on one of the gradation limits typical of the Italian specifications (ANAS) of the HMA mixtures for the surface layers, which was followed by the determination phase of the volumetric characteristics according to the UNI EN 12697-08 standard in addition to the analysis of the compaction curves obtained from the rotary press method to investigate the speed of workability. The samples were compacted with a rotational method to a N_{design} equal to 100. It can be said that the use of glass powder as filler not only allows the recovery and reuse of a waste material, but also allows to improve the performance in terms of resistance to permanent deformation in high temperatures.
(Sheng *et al.,* 2017) investigate the effect of phosphorus slag powder (PSP) and polyester fiber (PF) on the rheological properties of asphalt binder and performance characteristics of resultant mixtures. The PSP behaved effectively as a mineral filler such that it increased the binder viscosity resulting in enhanced mixture rutting resistance. The use of PF significantly improved the mixture resistance to low-temperature cracking and moisture damage as indicated by the flexural strain and tensile strength ratio results. They conducted indirect tensile tests in which two sets of samples were subjected to a split tensile test. Both conditioned and unconditioned samples were put in a water batch ad 25°C for two

hours. Based on the results, it appears reasonable to use PSP as a substitute for limestone powder, in conjunction with PF to achieve enhanced mixture performance characteristics.

(Topini *et al.,* 2018) suggest the use of two type of recycled fillers: Stabilized Bottom Ashes from municipal waste incinerators and Electric Arc Furnace Steel Slags. The results suggest, in line with the current specifications for binder courses provided by the Italian Road Authority-ANAS, that in certain conditions the investigated fillers increase the performance of the corresponding mixtures in comparison to standard (calcareous) filler. They investigated the failure properties using the Indirect Tensile Strength (ITS) test at 5, 20 and 40°C in line with the European specifications (EN 12697-23 2003). ITS decreases with increasing temperature and the voids content decreases for the two mixtures with recycled filler, as opposite to the behaviour of the mix with calcareous filler.

To guarantee sustainable construction, (Pérez and Pasandìn, 2017) investigated he reuse of construction and demolition waste (CDW) as recycled concrete aggregate RCA) for the manufacture of hot-mix asphalt (HMA) in place of natural aggregates, just like (Chen *et al.,* 2011). They used two types of bitumen: a conventional B35/50 and BC35/50, a crumb rubber modified bitumen. In according to EN 12697-12 standard, they evaluated the water resistance of the HMA after a series of eight cylindrical Marshall samples were compacted with 50 blows for face. At the optimum bitumen content, all of the mixtures presented air void percentages ranging between 4% and 7% and, in general, as RCA content grows, the tensile strength of dry and wet specimen decreases but only for mixtures made with BC35/50. In this regard, it is interesting to note that the heterogeneity of the RCA may effect the water resistance results.

(Sangiorgi *et al.,* 2017) presented another research that started from the idea that 100% RAP can be advantageously used in cold recycling technique for the production of bituminous mixtures for eco-friendly and durable pavements. The specimens were prepared with gyratory compaction (ASTM D6925). The volumetric characterization was then supported by the analysis of the air voids content of each specimen in according of EN 12697-8 standard and the static mechanical characterization included the Indirect Tensile Strength (ITS) both in dry (at 25°C) and wet conditions (EN 12697-12 standard). There is not a significant difference in terms of final density and air voids content between the two mixtures. As results of static and dynamic mechanical characterization, if CRM (Cold Recycled Mixture) shows the lower values its ITS and stiffness modulus are acceptable and higher than the limits imposed by most common Italian technical specification for Cold Mix Asphalt made of up to 30% of RAP. In addiction, the high presence of RAP within the mix does not modify the water susceptibility of the mixture if compared to traditional HMA, as it is confirmed by ITS test in wet conditions.

(Bressi *et al.,* 2016) studied the optimal dosage of bitumen in HMA because of the complexity of estimating the optimal average film thickness around the aggregates and satisfying as the same time the Voids in the Mineral Aggregates (VMA) requirements. HMA concretes with different binder contents were prepared and compacted using the Marshall hammer and gyratory compactor that simulates actual dield compaction and the particle orientation with laboratory equipment. They verified the mechanical characteristics with Marshall tests and Indirect Tensile Strength Test in comparison with the measurements. The ITS tests shows, as expected, different results for different temperatures: when the temperature increases the tensile resistance decreases. The optimal quantity of bitumen estimated by gyratory compactor is similar to that measured with the Marshall stability. The voids percentage that corresponds to the estimated bitumen quantity lies within the limits if the Marshall compaction is considered. It is just above the allowable range if the gyratory compactor ad Ndes= 100. The bitumen quantity estimated allows the production of asphalt mixtures that meet all the Swiss standard requirements.

3. The Case Study

The present study deals with the assessment of Indirect Tensile Strength for specimens compacted under gyratory compaction for the acceptance of the mixture in situ from the supervision of works, content only limestone materials for a base layer.

The research was divided into two phases:

- The first phase aims to define the optimum bitumen content for a base layer by a Marshall test according to EN 12697-34 standard, within the limits imposed by Italian Technical Standard.
- In the second phase was examined the behaviour of the same mixture, packaged by a Gyratory compactor according to EN 12697-31 standard, in terms of ITS according to EN 12697-23 standard, ITSR according to EN 12697-12 standard and air voids according to EN 12697-8 standard. For all test were analysed specimens with different height, where a first follows the ratio $\frac{h_{min}}{D} \in [0.66; 1.05]$ provided for Gyratory compactor and another required by EN 12697-23 standard where $h \in [35mm; 75mm]$, and a dense graded varying with Ndesign.

3.1. Materials and Method

Neat bitumen, limestone aggregate and limestone filler were used to produce asphalt mixes in this research. The neat bitumen had a penetration grade of 52 dmm at 25°C, a softening point of 49°C and a Frass of -9°C. The limestone materials is the product of limestone crushing and it is configured as a different size aggregate white in colour and characterized by an amorphous structure. The mix was produced in laboratory using different size of limestone adequately proportioned by volume in order to obtain a gradation curve fitting the reference envelope as EN 13108-1 standard, Technical Standard of the Southern of Italy and the restricted zone and the control points of the Superpave. Limestone gradation is reported in Fig 1. To evaluating the optimum bitumen content a Marshall test were carried out on a cylindrical specimens with 100mm diameter and an height of 63,5 ± 2,5mm according to EN 12697-34 standard. To evaluate the ITS the cylindrical specimen must be placed in the compression testing machine between the loading strips, and be loaded diametrically along the direction of the cylinder axis with a constant speed of displacement until it breaks according to EN 12697-23 standard. The indirect tensile strength is the maximum tensile stress calculated from the peak load applied at break and the dimensions of the specimen.

$$ITS = \frac{2P}{\pi DH}$$

Where:

- ITS is the indirect tensile strength, expressed in gigapascals (GPa), rounded to three significant figures;
- P is the peak load, expressed in kilonewtons (kN), rounded to three significant figures;
- D is the diameter of the specimen, expressed in millimetres (mm), to one decimal place;
- H is the height of the specimen, expressed in millimetres (mm), to one decimal place.

Besides to evaluate the behaviour and durability of the mixtures it has been applied the EN 12697-12 standard where the sample is soaked in a water bath for 48-72h at 40°C and then evaluated the ITSR according the following equation:

$$ITSR = \frac{ITS_{wet}}{ITS_{dry}} \cdot 100$$

Where:

- $ITSR$= is the indirect tensile strength ratio, in percent (%);
- ITS_{wet}= is the average indirect tensile strength of the wet group, in kilopascals (kPa);
- ITS_{dry}= is the average indirect tensile strength of the dry group, in kilopascals (kPa).

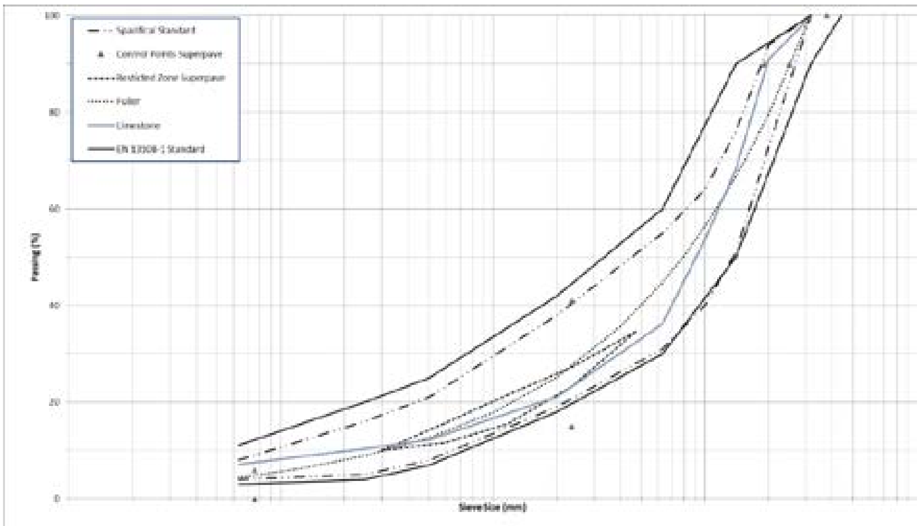

Fig. 1.
Grading curve of limestone materials

3.2. Mix Design

In this study, the Marshall method was used to determine the optimum bitumen content and prepare HMA according to the EN 12697-30 standard. For the reference mix (i.e. the mix that contained limestone powder as filler) 4 HMA mixes were prepared at four different bitumen contents between 3.5% and 4.5% by total weight of mixture at 0.25% increments (3.50%, 3.75%, 4.00%, 4.25%) according to the Italian specifications of the southern of Italy. In the specific case the diameter of each specimen is equal to 102.5 mm, while the quantity of mass used has been set at 1200 gr. Every specimen was compacted with 75 blows on each side. After the compaction phase, Marshall Stability and flow were determined according to the EN 12697-34 Standard. In Fig 2-3 the trend of the Marshall Stability and flow is shown as a function of the percentage of bitumen. It can be seen that with the increment of the bitumen the flows between the aggregates increase while the Stability tends to grow and reaches a peak value, that is the maximum value for the mixture under examination, then tends to decrease.

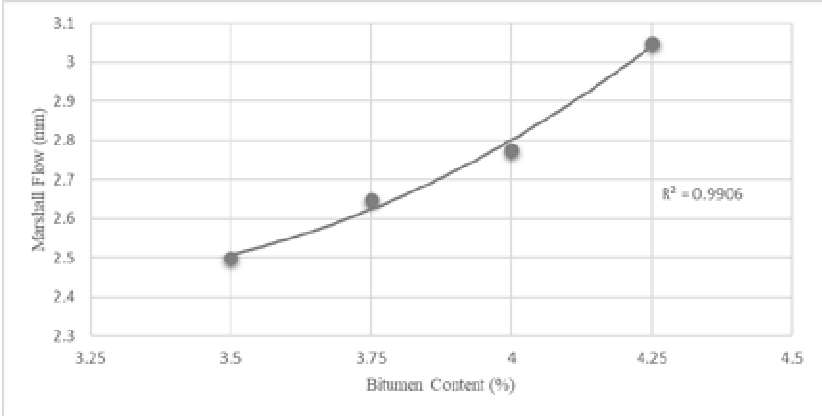

Fig. 2.
Variation of Marshall Flow with % of Bitumen

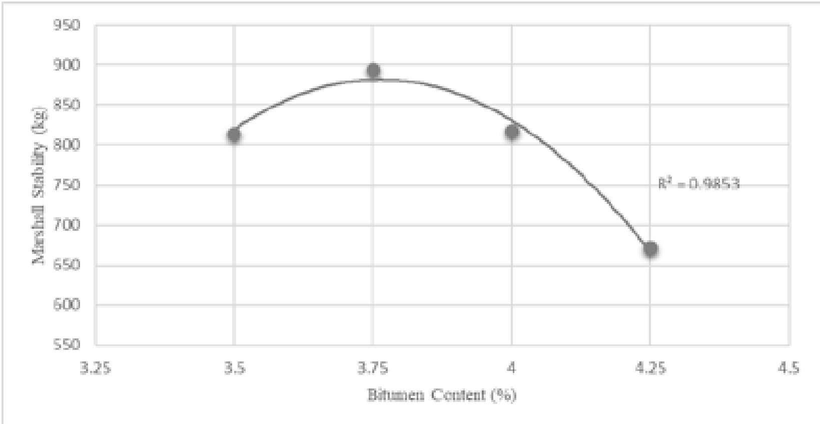

Fig. 3.
Variation of Marshall Stability with % of Bitumen

According to Italian Local Technical Specifications on road maintenance the percentage of bitumen must be between 4-5.5% it was choose an 4.00% bitumen content to which it corresponds a optimum stability value of 818 kg and a optimum flow value of 2.71 mm.
At the same time it's important determinate air voids content of bituminous specimens. The property of ''void filled with bitumen'' controls the plasticity, durability, friction coefficient, etc. of the mixes also provides a final bitumen film around the aggregate particle. So air voids content of bituminous specimens were determinate according to EN 12697-08 standard.

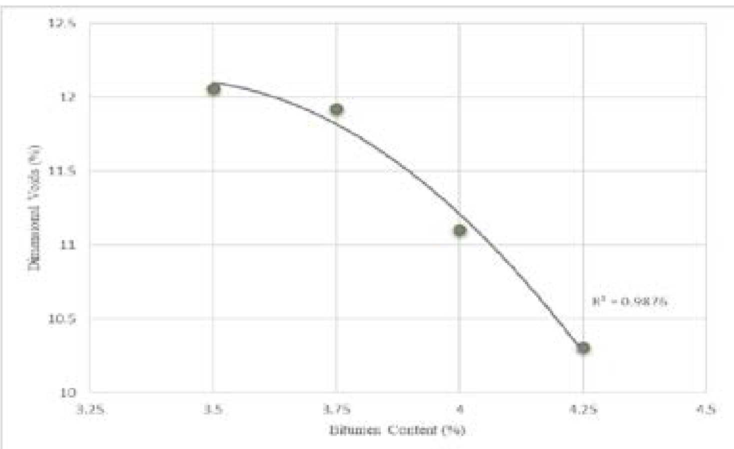

Fig. 4.
Dimensional voids

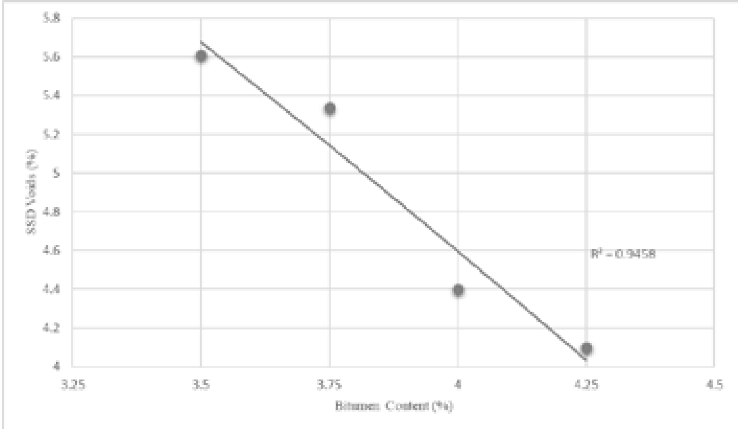

Fig. 5.
SSD voids

It's possible to notice from the results (***Fig. 4-5***) obtained that with the increase of the percentage of bitumen content present in the mixture in bituminous mixtures, the percentage of the dimensional and SSD voids decreases.
At an optimum bitumen content of 4.00% was observed a percentage of geometric and imbibed voids of 11.1% and 4.4% respectively. In ***Table 1*** is shown the results at the optimum bitumen content.

Table 1
Volumetric and mechanics parameters of the mix design

Bitumen Content (%)	SSD Voids (%)	Dimensional Voids (%)	Marshall Stability (Kg)	Marshall Flow (mm)
4	4.4	11.1	818	2.71

3.3. Evaluating of ITS and ITSR

After the optimisation phase, the mixture has been subject to a compaction according to EN 12697-31 standard to verify the ITS according EN 12697-23 Standard. But since the two standards shall require different height for the specimens two different height have been considered in the research. In particular, it was considered a height to fall within the range of ratio $\frac{h_{min}}{D} \in [0.66; 1.05]$ according to EN 12697-23 standard and a height $h \in [35mm; 75mm]$ according to EN 12697-31 standard. To satisfy the heights requirements by both standards different weight have been set, 4500gr for EN12697-31standard and 3000gr for the EN12697-23 in order to obtain the same level of densification achieved with Marshall compaction on the optimum mixtures. This was accompanied by a study on the assessment of N_{design} in compliant with the technical standard suggested. To validate the results obtained with Marshall test was fixed a N_{design}= 180 revolutions at which diametrical voids of gyratory compactor approximated the SSD voids of Marshall test and a N_{design}=100 revolutions where the SSD voids obtained with Marshall test are the same of those obtained with gyratory compactor. In ***Table 2*** are shown the total number of the specimens obtained.

Table 2
Sample obtained from Marshall compaction and Gyratory compaction

Label	Compaction Type	Height	N_{design}	N° specimens
MT	Marshall	h∈[63,5 ± 2,5]	-	7
G100A	Gyratory	hmin/D∈[0.66;1.05]	100	7
G180A	Gyratory	hmin/D∈[0.66;1.05]	180	7
G100B	Gyratory	h∈[35mm;75mm]	100	7
G180B	Gyratory	h∈[35mm;75mm]	180	7

The results obtained in terms of ITS are show in Fig 2. The ITS value for the G100B and G180B is the same while between G100A and G180A there is a difference of 4%. Moreover, look at SSD voids for all specimens (Fig 3) G100B and G180B have the same percentage of voids instead G100A and G180A shown a difference of voids of 3%. To evaluate the effect of moisture the specimens are soaked in a water bath for 72h at 40°C and than tested according EN 12697-23 standard after a conditioning at 25°C for 4 hours. The results obtained in terms of ITSR (Fig 2) show that there is no reduction of ITS for G180B but for the other there is a reduction of 14, 20, 22 and 30% respectively for Marshall, G100A, G180B and G180A.

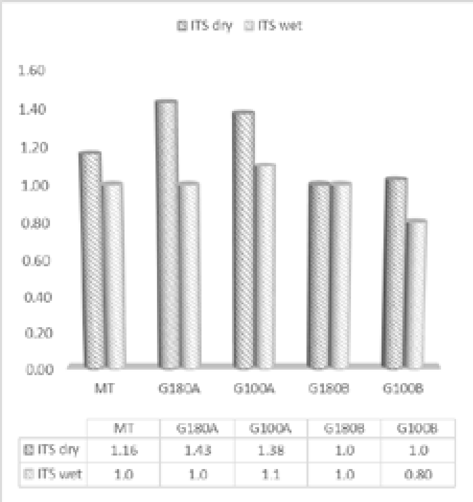

Fig. 6.
Loss of percent ITS after soaked in a water bath

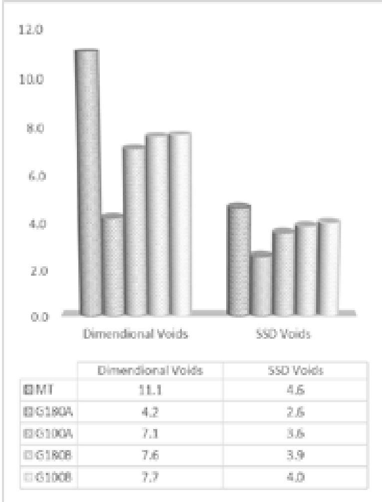

Fig. 7.
Relationships among geometric and imbibed voids in average values

4. Conclusion

Nowadays a control with Gyratory compactor carried out on the optimum of the mix is increasingly required by companies at the stages of lying of the mixtures with subsequent determination of volumetric and mechanics properties. Explanation on the specimen size that must be released is still undefined because between two references standard i.e. those for the gyratory compactor and those for the evaluation of ITS value, don't share the same opinion.
This present study had as purpose to achieve the optimum specimen size for the evaluating of the ITS parameter obtaining the same results in terms of voids for the optimum of the mixtures, obtained with Marshall test, with gyratory compactor. From the results it was concluded that between a N_{design} =100 and N_{design}=180 there aren't differences in terms of strength and since with regard to voids and ITS falls within the value obtained with specimen GB, it can therefore be said the determination of ITS value it can be assessment on G100B specimens.

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LABORATORY INVESTIGATION ON ADHESION PROPERTIES AND WATER SUSCEPTIBILITY OF BITUMEN-AGGREGATE SYSTEMS

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Abstract: Challenges concerning pavement engineering are nowadays mainly addressed to a low-cost and time-saving preservation of infrastructures. The need for innovative materials and technologies, combined with the necessity of guaranteeing adequate in-service performance, must face the growing distresses of pavements. Moreover, several works are not properly executed, due to inappropriate materials with not well-known properties. To this regard, the present paper focuses the microscopic mechanisms developed at the bitumen-aggregate interface in order to fully understand the bonding and adhesion factors that affect the asphalt concrete serviceability. Experimental tests were carried out to investigate surface texture of different kind of aggregates and its correlation with aggregate-bitumen adhesion strength. The external surface of aggregate was characterized in terms of microscopic structure using a 2D contact profilometer; then the bonding with different bitumens, also in the presence of water, was investigated through boiling water and peel tests. A 50/70 pen bitumen was selected to assess the adhesion characteristics with limestone, porphyry, basalt and steel slag aggregate. Samples were prepared both with smooth and rough aggregate surfaces (in order to simulate different physical conditions) and were characterized in dry and wet conditions. Experimental findings showed a strong correlation between the bitumen-aggregate adhesion and the different kind of tested aggregates. Such property seemed to be also influenced by surface conditions and bitumen-aggregate blending processes. In particular, bitumen-aggregate systems prepared with limestone and basalt manifested good water resistance, whereas the use of steel slag and porphyry led to worse performance, also according to roughness characteristics.

Keywords: adhesion, bitumen, aggregate, water resistance, surface roughness, contact profilometer.

1. Introduction and State of the Art

The construction of flexible pavements for road or airport infrastructures and the design of asphalt mixtures generally occur after specific project steps and material characterization. Once laid and compacted, asphalt concrete must ensure adequate in-service performance and durability, safety and functionality.
Actually, few transport infrastructures are now exhibiting critical behavior due to a bad design and construction; however, asphalt pavements are often subject to early deterioration.
A cautious design of pavement, correctly based on multiple factors such as traffic, climate, etc., requires the adequate knowledge of the materials' characteristics and their working mechanism. To this purpose, one of the most important aspects interesting asphalt mixtures is linked to the interaction between the binder (bitumen) and the lithic matrix (aggregate). Cohesion and adhesion constitute the principal actors determining the bitumen-aggregate affinity. "Cohesion" refers to the force linking the single molecular particles of bitumen. The forces connecting external particles of bitumen and aggregates is named "adhesion". The evaluation and the understanding of these forces and factors is a valid instrument for a proper mix-design of asphalt concrete (as example, for the choice of compatible types of bitumen and aggregates) aimed at durable asphalt pavements. In order to better understand these mechanisms, several tests and protocols have been implemented. Bitumen-aggregate adhesion depends on certain factors difficult to be controlled, above all during laboratory testing. Indeed, aggregate properties deeply influence the bond behavior with bitumen; chemical composition, surface texture (roughness and porosity), shape and size, external impurities affect aggregate characteristics and adhesion with binders. Also bitumen properties (as examples viscosity and chemical structure) impact on the adhesion forces. Bitumen content in asphalt mixtures is another important aspect, since binder film thickness (greater or smaller depending on the quantity) which cover aggregates contributes to the bonding strength. Bitumen modification (rheological alteration or polymeric addition) could add other sources of variability in adhesion. In addition, considerable external factors which interest this interaction have to be accounted: e.g. water presence, temperature, traffic (typology and intensity), human behavior (Graf, 1986). Quite a few researchers (Hefer et al., 2005; Masad et al., 2005) faced the problem, proposing different theoretical approach to explain the behavior of bitumen-aggregate link (e.g. theory of boundary layers, mechanical theory, chemical bonding theory, etc.). Humidity represents a crucial element because the presence of water causes the adhesion weakening and the possible stripping of the aggregate grains. Goel & Sachdeva (2016) published a study concerning many arguments about stripping phenomena within asphalt mixtures, defining the dynamic of stripping, its main causes and the specific tests required to its investigation. Also Pasetto et al. (2017) dealt with stripping and bitumen-aggregate affinity evaluating water susceptibility at mastic-scale and at mixture-scale with two different procedures. Literature reports multiple researches oriented to the appraising of affinity in the case of many aggregate types: Cui et al. (2014), Zhang et al. (2015) Paliukaité et al. (2016) and Pasetto et al. (2017) worked with limestone, marble, granite and steel slags, different kinds of bitumens and some adhesion promoters. Each of them concluded that promoters guaranteed sensible improvements in the adhesion quality (limestone and marble, characterized by similar chemical composition, resulted more basic with respect to granite and owned a better bitumen affinity – oppositely, more acid granite and steel slags displayed worse bonding attitude). Various studies (Lottman, 1982; Voskuilen et al., 1996; Airey & Choi, 2002; Zhang et al., 2017;

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Pasetto et al., 2017) were based on standardized testing methods; however, specific procedures addressed to the measurement of adhesion forces were generally lacking. Qualitative tests (Static-Immersion test, Rolling bottle test, Boiling water test, etc.) for the assessment of the adhesion degree were developed, and calculated mainly the residual bitumen percentage after tests, compared with standard prescriptions of standardized quantities (PATTI test, pull-off test, peel test, etc.); in certain cases, stress needed for the adhesion breaking was calculated.

2. Objectives, Experimental Set-Up and Tests

Since the surface texture and the wettability of aggregate are believed two of the principal factors influencing adhesion force, the objective of the present paper concerns the development of specific tests useful to evaluate such characteristics on different kinds of aggregate.
The secondary target of the work regards the behavior description of marginal materials (steel slags and secondary materials derived from earlier processes) able to ensure benefits related to environmental and economical savings (avoiding quarrying activities and use of natural aggregate). Depending on the aggregate type and shape, pull-off and peel tests were planned. Developed procedures differed from common utilized methods (which involve smooth-surfaced and regular-shaped grains) allowing the utilization of "not-treated" aggregates, preventing possible alterations in the natural surface texture and bonding attitude. Tests were carried out in different conditions to evaluate the effect on adhesion functionally to: aggregate nature, hygrometric status and surface texture. Such characteristics (described in the following paragraphs) are summarized in Table 1. Four different types of aggregate were employed: limestone, basalt, porphyry and steel slag. The binder consisted of a traditional bitumen, with a 50/70 dmm penetration grade. Two different hygrometric conditions were considered: a dry condition, based on the natural ambient humidity; a wet condition, based on aggregate soaking (before the binder application) for two days, that represents the needed time for the complete saturation of surface permeable voids. Surface textures were varied: for each aggregate type, smooth surfaces (by blade sawing) or rough surfaces (without treating aggregates) were prepared. Only in the case of steel slag, it resulted impossible to obtain smooth surfaces because of some issues encountered during the mechanical cutting. Experimental activities were structured in successive stages: firstly, surface textures of smoothed and rough aggregates were characterized through the high-resolution surface profiler, then wettability tests were executed on aggregate-bitumen blends. Further, stripping tests and peel tests (for the evaluation of adhesion force) were performed (Table 1).

Table 1
Experimental set-up

Aggregate type	Surface type	Dry condition	Wet condition
Limestone	smooth	X	X
Limestone	rough	X	X
Porphyry	smooth	X	X
Porphyry	rough	X	X
Basalt	smooth	X	X
Basalt	rough	X	X
Steel slag	rough	X	X

The high-resolution surface profiler consists in an equipment (Figure 1) for the determination of surface texture of materials, generally named as roughness. It is mainly composed of a high-sensible extremity, able to translate in the three principal directions (x, y, z) in order to record the roughness of the tested surface (a transducer converts movements in electrical signals). The used equipment owned a high-resolution interval of 16,000,000:1. The stroke of the extremity used in the work was equal to 15 millimeters either for smooth or rough tested aggregates. Digital surface reconstruction and 3D representation (Figure 2) required a sampling area of about 9 mm^2 (3 mm long on the x and the y axes). Two different cut-offs (i.e. the wavelength of the filter for the signals recording) were then imposed in the equipment: the first one equal to 2.5 mm for the analysis of greater ripples (regarding only some wavelengths), the second one equal to 0.8 mm for a more detailed evaluation. R_a, R_{sk}, R_{ku} and R_{sm} were the determined parameters. R_a is the arithmetic average of absolute distances of the roughness profile with respect to the mean line (line calculated with the least squares method, balancing the areas below and above the line and minimizing their separation). R_{sk} is the measure of the density function asymmetry referred to the mean line (in the case of $R_{sk} = 0$, the roughness profile coincides with a Gaussian distribution; when $R_{sk}<0$ a quasi-linear profile is obtained; if $R_{sk}>0$ several peaks can be detected). R_{ku} represents the profile peak density (if $R_{ku} = 3$ the profile follows the Gaussian distribution, if $R_{ku} > 3$ a rounded profile is detected, etc.). R_{sm} is the average distance between profile peaks above the mean line (peaks are the highest points in the profile, which separate a rising from a descendant segment).

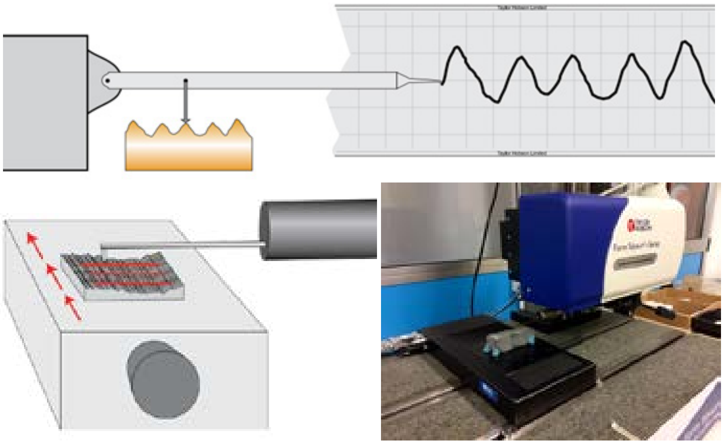

Fig. 1.
High-resolution surface profiler: equipment (right) and instrument functioning (left)

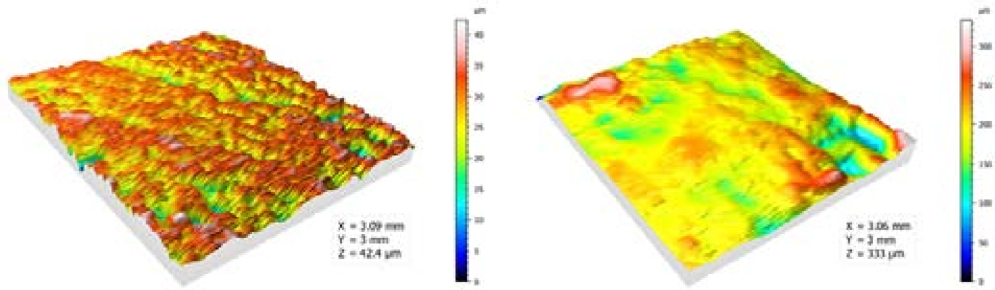

Fig. 2.
High-resolution surface profiler. Examples of 3D image: smoothed (left) and rough (right) limestone surfaces

The evaluation of the bitumen-aggregate adhesion in dry and wet conditions, as well as the analysis of wettability of aggregates by means of the Ancona Stripping Test (AST) proposed by Bocci and Colagrande (1993) were planned. The last is also adopted by EN 12697-11, except for the way of assessing final aggregate bitumen coverage. The procedure is based on the preparation of a blend of aggregate (60 g) and bitumen (3 g) mixed at temperature of 160 °C (Figure 3). When steel slags were used, proportions were changed using 75 g of aggregate in order to consider its higher specific weight and maintain an analogue blend coverage (volumetric properties). For AST, blends were placed in a 600 ml beaker with 200 ml of distilled water, laying the material in a suspended metallic net in order to avoid contacts with the beaker glass. The beaker was then placed in a greater one (of 2000 ml) containing 600 ml of boiling water. After 45 minutes, the material was extracted and cooled at ambient temperature, till the bituminous aggregate could be removed (Figure 3). Visual assessment of stripping percentage proposed by AST standard method was integrated by a Digital Imaging Processing (DIP) approach, implemented to separate residual areas of coated aggregates from stripped ones. In order to exclude further variables connected to ambient lighting and photo exposure, images of different samples were contemporary acquired in the same RAW format picture. DIP software allowed to adjust color palette to obtain representative stripping results, calculating pixel areas of coated and stripped portions (Figure 3).

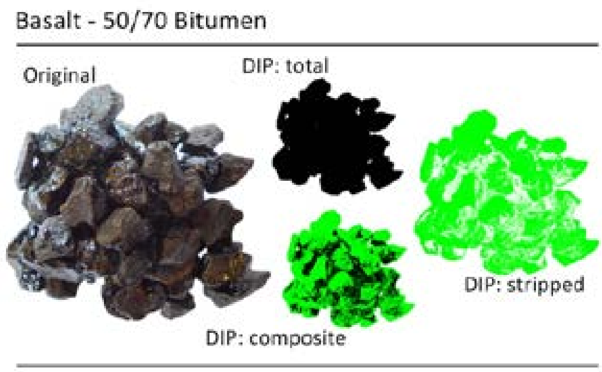

Fig. 3.
Example of blend before and after Ancona Stripping Test

Peel tests were already used in other researches (Zhang et al., 2016); similar operational procedures could be found in ASTM D6862-11 and EN 28510-1:2014 standards. A thick film of hot bitumen was placed on the surface of samples

(30 x 30 x 100 mm^3 size); suddenly, a 20 x 85 mm^2 rectangular aluminum stripe was then laid and bound to the sample. Each specimen was then cooled at room temperature for at least 30 minutes. An extremity of the aluminum stripe was bent in a perpendicular position (with respect to aggregate surface) to be clamped in the upper jaw of the machine used for the test execution (Figure 4). Figure 5 shows a sample at the end of this test.
Testing equipment was a universal machine composed by two jaws (Figure 4). In the lower one, a metallic shoe (able to shift in the horizontal direction) was interposed to clamp the sample and allow a traction force perpendicular (90°) to the aggregate surface (degrees of freedom of shoe adsorbed the non-perpendicular stresses). In the upper jaw, the aluminum stripe was clamped directly. Starting from the measured force F, the temporal evolution of vertical stress was determined for each sample. Punctual stress is calculated continuously as: $\sigma = F/A$, where A is intended as an infinitesimal constant area determined multiplying the stripe width for an infinitesimal length in the x direction, supposed equal to 0,01 mm (A value resulted constantly equal to 0,2 mm^2). Peel test speed was equal to 12 mm/min (as stated in ASTM D6862-11).

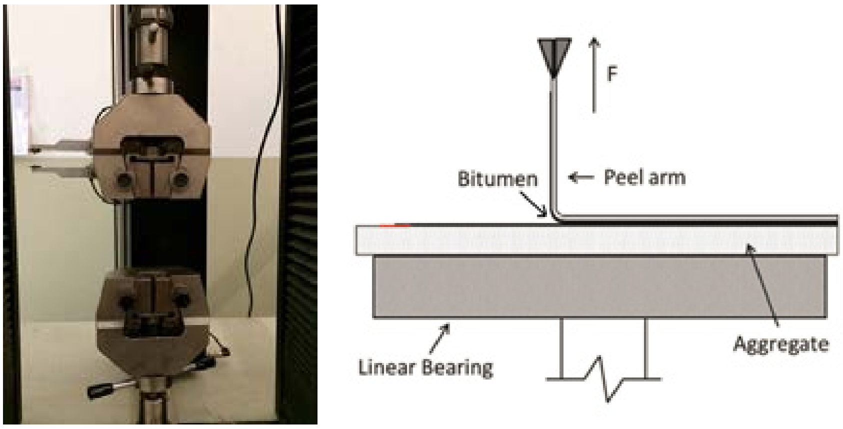

Fig. 4.
Peel test: machine (left), test setting (right)

Fig. 5.
Peel test results: dry smooth (left), wet smooth (right) limestone samples

3. Results and Discussion

Table 2 reports the results of physical-geometrical tests executed on aggregates to evaluate their main characteristics. Basic properties of used bitumen are described in Table 3. In general, all the aggregates showed rather low indexes. They seemed to match the requirements for bituminous mixtures stated by the main technical specifications for wearing courses. The best aggregate typology in terms of shape and flakiness indexes was the porphyry, but it exhibited a greater Los Angeles coefficient with respect to that of limestone or steel slag. Characteristics of bitumen seemed to be in line with typical properties of its class.

Table 2
Physical and geometric characteristics of aggregates

Aggregate type	Flakiness index [%] (EN 933-3)	Shape index [%] (EN 933-4)	Los Angeles index [%] (EN 1097-2)
Limestone	4	10	16
Porphyry	4	4	23
Basalt	7	6	14
Steel slag	5	6	12

Table 3
Basic properties of bitumen

Bitumen	Penetration @ 25°C [0,1/mm] (EN 1426)	Ring & Ball [°C] (EN 1427)	Ductility @ 25°C [cm] (ASTM D 113)	Elastic recovery [%] (EN 13398)	Fraas breaking point [°C] (EN 12593)
50/70	55	50	98	3	-6

Results from tests performed with the high-resolution surface profiler are presented in Table 4. Surface texture can be described through the parameters previously specified. Smoothed-surface samples presented almost similar R_a values: this proved that aggregate type minimally affected the surface roughness processed by the blade (cutting procedure furnished similar surfaces, regardless the aggregate type). Conversely, R_a values changed in the case of rough (untreated) surfaces. In this case, R_a values were always higher than those belonging to smoothed specimens. Roughness sensibly increased using basalt. Studying the sign of R_{sk} parameter, peaks trends of surfaces can be understood ($R_{sk} >0$ indicates greater peak presence, $R_{sk} < 0$ the greater presence of dips). Positive R_{sk} values were found for rough porphyry and basalt. As anticipated, also R_{ku} covers a key role in adhesion phenomena: recording R_{ku} values always higher than 3, all samples had jagged surfaces (in particular in the case of steel slag). R_{sm} parameters were quite high in all the situations, demonstrating a great distance from peak to peak and indicating that bitumens can show significant available spaces to develop adhesion (Table 4 reports that highest R_{sm} values were found with rough surfaces and cut-off of 2,5 mm).
Table 5 reports the results of the Ancona Stripping Tests. Residual bitumen quantity (%) and stripping (%) are indicated for each bitumen-aggregate combination. Examining material behavior, basalt and steel slag showed high percentages of stripping. Basalt suffered the stripping effects more than other aggregates, reaching a stripping percentage of 76,4%. Differently, limestone seemed to be a material particular resistant to this phenomenon. These behaviors could be justified by the chemical composition of materials. Indeed, limestone is a basic aggregate, thus hydrophobic; it do not contain silicon (SiO_2) but is full of calcium. For these reasons, it tends to assume a positive charge in presence of water and to generate salts with the functional groups of bitumen. These factors caused the better adhesive properties effectively recorded. On the contrary, porphyry is an acid aggregate, thus a hydrophilic material with a high content of silicon that, with water presence, generated negative charges responsible of mediocre adhesive characteristics. Analog behavior is attributable to steel slag due to a significant amount of calcium (despite silicon content was lower than that of porphyry). Different behavior of basalt (basic material) could be ascribed to a residual presence of impurities on the aggregate surface (before the blending with binder).
A graphical trend of tensile force related to time was built for each sample. Comparisons (Figure 6) were made fixing time to time texture conditions (smooth or rough) and hygrometry (dry and/or wet). It could be noticed that all aggregates in dry condition developed a good interaction with bitumen and good adhesion attitude; vice versa with wet cases (modest bitumen-aggregate adhesion). In general, comparing smooth (Figure 6a) and rough (Figure 6b) surfaces for the same material, the latter situation showed a greater (or similar) adhesive inclination. This finding could be expected considering that, generally, a rougher surface (with a huge number of asperities) should ensure more contact points, supporting the bitumen bond and causing the increase of the traction force needed for the separation. Overall, basalt (both smooth or rough samples) demonstrated force values greater than those of other aggregates. In wet condition, texture type (smooth/rough) seemed to affect the adhesion abilities to a limited extent. This can be ascribed to the fact that, in presence of water, the adhesion between aggregates and bitumen is mainly due to chemical affinity.
Figure 7 describes the tensile forces determined with Peel tests as a function of surface textures (in terms of R_a parameters) of all materials. Figure 7 shows mean R_a values for all the samples and stresses are calculated as mean of stress in the first 20% of test time. Figure 7a clearly depicts the different surface texture between smooth and rough samples; the increase of R_a values (increase of roughness) involved tension increments regardless the aggregate type. Despite a quite low coefficient of determination, tendencies shown in Figure 7a indicated that, as expected, stress increasing corresponded to roughness increments. Thus, a rough aggregate seemed to express a better adhesion with bitumen (with respect to a smoothed one). In Figure 7b the data of Figure 7a (dry samples results) and the wet samples results are presented and classified depending on the hygrometric condition (dry or wet). Dry samples (smoothed and rough) had a greater adhesion force with respect to wet ones and R_a seems to influence the degree of adhesion. On the other hand, R_a parameter did not affect the adhesion force in wet situations, probably because, with water presence, adhesion was mainly governed by chemical affinity, as demonstrated by stripping tests (AST).

Table 4
Results from high-resolution surface profiler

Aggregate type	Surface type	Cut-off [mm]	R_a (µm)	Rsk	Rku	R_{sm} (µm)
Limestone	smooth	0,8	3,80	-0,60	4,03	188,24
		2,5	4,57	-0,68	4,07	262,31

Aggregate type	Surface type	Cut-off [mm]	R_a (µm)	Rsk	Rku	R_{sm} (µm)
	rough	0,8	7,75	-0,49	4,64	317,81
		2,5	17,67	-0,48	3,64	1201,31
Porphyry	smooth	0,8	5,50	-0,34	4,40	230,19
		2,5	7,19	-0,88	4,83	389,80
	rough	0,8	5,63	0,15	4,21	508,12
		2,5	19,60	0,27	3,24	1982,22
Basalt	smooth	0,8	4,98	-0,49	3,65	189,76
		2,5	6,19	-0,68	4,08	269,28
	rough	0,8	9,98	0,04	4,07	446,11
		2,5	25,75	0,01	3,61	1439,15
Steel slag	rough	0,8	9,50	-0,74	8,39	387,30
		2,5	19,58	-0,62	5,68	1078,38

Table 5
Results from Ancona Stripping Test (AST)

Aggregate type	Residual bitumen quantity [%]	Stripping [%]
Basalt	23,6	76,4
Steel slag	32,7	67,4
Porphyry	60,8	39,2
Limestone	93,8	6,2

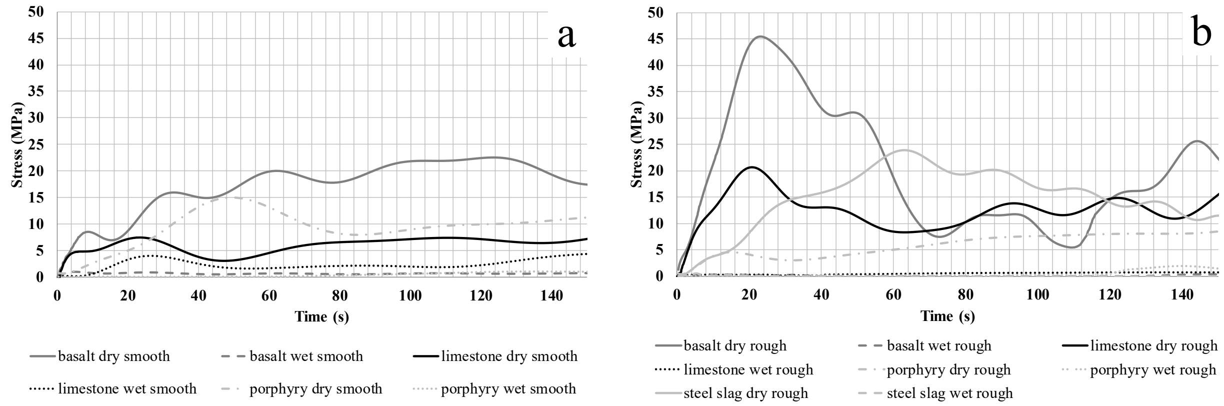

Fig. 6.
Peel test results: a) smooth and b) rough samples

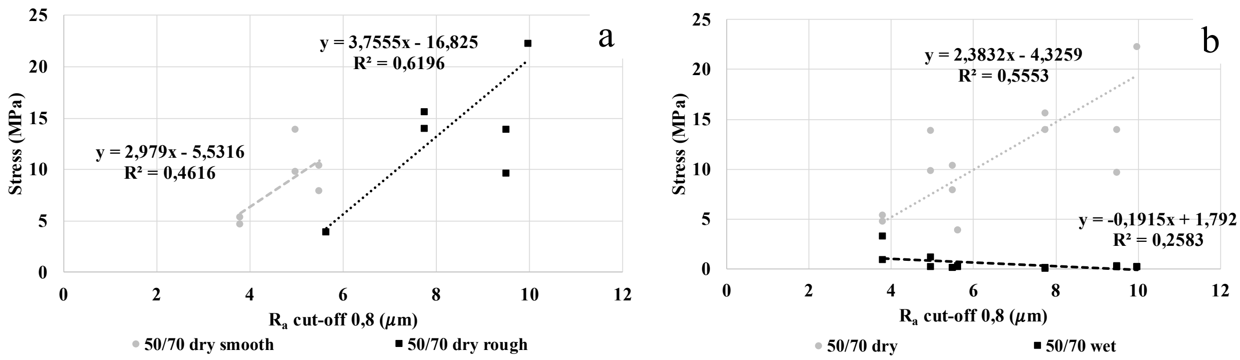

Fig. 7.
Correlations between stresses (MPa) and surface texture (in terms of R_a, in □m).

4. Conclusions

The present paper illustrates and discusses the study of physical-mechanical properties of aggregates and their influence to adhesion forces with binder. Specific emphasis was dedicated to the study of the surface texture through a high-resolution surface profiler. Stripping (through Ancona Stripping Test) and bitumen-aggregate adhesion (through Peel test) were also evaluated. Several factors proved to influence the adhesion between bitumen and aggregate; the proposed experimental activity tried to focus the attention on the correlation between surface texture, bitumen-aggregate affinity and the influence of humidity on the aggregate surface. Texture of different typologies of aggregate seemed to play a crucial role in the bitumen-aggregate affinity. Authors used an innovative approach, using a complex equipment (high-resolution surface profiler) to evaluate the surface texture of aggregates. In this way, more evident correlations between aggregate nature and bitumen-aggregate affinity were found. A univocal test procedure easily to perform (in terms of equipment complexity and time-consumption) can be suggested based on this approach.

By performing stripping and adhesion (Peel) tests, it was verified that different kinds of aggregates exhibited different behaviors: limestone showed the best affinity with bitumen, while other aggregates demonstrated less affinity. For Peel tests, executed in dry (with natural ambient humidity) conditions, best adhesion were detected for basalt (and porphyry to a lesser extent). Moreover, smooth aggregates always displayed modest adhesion attitude, whereas adhesive forces resulted significant in the case of using rough-surfaced grains. Adhesion values of wet samples were rather small (low bitumen-aggregate affinity with water presence). This seemed to confirm that water was the main actor in the development of adhesion, even attenuating effects of different surface textures (smooth or rough) of analyzed aggregates. In this case, bitumen-aggregate affinity became more important. In conclusion, the proposed experimental method resulted suitable for preliminarily evaluating the bitumen-aggregate affinity. Further detailed analysis to be developed can concern the increasing of variables, studying surface textures and affinities in function of different kinds of binders and surface parameters. Intrinsic variability of all the examined parameters resulted significant, thus a statistic-based validation of obtained results should be performed also to gain indication about the possible extension of physical quantities already accounted.

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PROPOSAL OF CORRELATION AMONG DIFFERENT SOIL BEARING CAPACITY PARAMETERS BASED ON AN EXTENSIVE TEST CAMPAIGN

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Abstract: Soil characteristics play a key role for design and construction of transportation infrastructures. Subgrades of pavements must be adequately designed and realized to face stress-strain fields due to vehicles, withstanding traffic loading during construction and service life and limiting deformations to prevent the pavement failure. The evaluation of the soil bearing capacity can be performed through different laboratory and in situ tests, both static and dynamic. Among the existing methods, Light Falling Weight Deflectometer (LFWD), static plate-bearing load tests (PBLT), Dynamic Cone Penetrometer test (DCPT) and California Bearing Ratio (CBR) tests can be cited. LFWD can be quickly used, being it a simple and portable equipment suitable for determining the stiffness modulus of the soil. Static plate-bearing load tests can be carried out to measure the elastic vertical displacements, obtaining the so-called modulus of reaction or modulus of deformation as a function of the plate diameter and the stress path. DCP is used to measure the resistance against penetration of a soil through a simple test. Then, such characteristic is generally correlated to CBR using empirical correlations. As known, the bearing capacity of a soil is strictly related to its degree of compaction. Given this background, an attractive aspect from a scientific and technical perspective concerns the correlation among different methods and parameters to determine a general approach in considering the different data available for the design and control of a soil layer. To this regard, the present paper shows the results of an extensive in-situ survey and laboratory experimentation assessing the bearing capacity of soils through the above-mentioned techniques: a huge data-base permitted the development of some correlations between the different static and dynamic data.

Keywords: bearing capacity, soil, in situ survey, laboratory experimentation, dry density.

1. Introduction and Experimental Approach

The availability of possible correlations among different bearing capacity parameters is essential for a better approach to the road design and construction. Bearing capacity measurements are often performed with a single technique, mainly depending on the available in-field or laboratory equipment; for this reason, the correlation of data deriving from different tools or methods is required, even if not always simple, given the complexity and the huge amount of physical variables involved in the measurement. Bearing capacity of soils (and, generally, unbound/bound granular materials for transport infrastructures) can be determined though several methods, using different instruments able to acquire different parameters. Principally, tests can be divided in static or dynamic ones. Static analysis generally considers the use of circular plates, loaded with heavy contrast weights (some standards require loads greater than 5 tons) and quite long loading procedures. Differently, dynamic tests usually imply advanced equipment that allows easy and timesaving surveys and tests. Both approaches can be used in field or laboratory tests. Among the existing in-situ tests, Light Falling Weight Deflectometer (LFWD) or Portable Falling Weight Deflectometer (PFWD), static plate-bearing tests and Dynamic Cone Penetrometer test (DCPT) can be cited. In laboratory, the California Bearing Ratio (CBR) test represents one of the most important solutions for the evaluation of materials' strength. The parameter suitable for the characterization of the bearing capacity varies according to the test: the dynamic modulus E_{vd} (MPa) is calculated with the LFWD, the California Bearing Ratio index (CBR, in percentage) can be estimated in field with the DCP tool or evaluated in laboratory with the CBR test, the reaction modulus k (MPa/m) and the deformation modulus M_d (also named static modulus, in MPa) are determined by means of a static bearing load plate test (the different parameter - k or M_d – depends on the size of the plate, loading steps and level). Several researchers analyzed benefits and drawbacks of such testing procedures and dealt with possible correlations of the parameters, validating experimental data and results (Ese et al., 1994; Loizos et al., 2003; Adam et al., 2009; Fleming et al., 2009). Frequently, studies found adequate relations analyzing the influence of variables which affect bearing capacity, based on soil grading, Atterberg limits, in-field specific weight, optimal Proctor density, natural moisture or optimum (Proctor) humidity content (Lim et al., 2014; Patel et al., 2013; Talukar, 2014; Sangiorgi et al., 2006). Correlations between static and dynamic parameters are substantially known. In 1995, the Institute for Transport Sciences of Karlsruhe (Gemany) elaborated a relation between dynamic modulus E_{vd} and static modulus M_d ("*Baksay formulation*") with the following equation: $E_{vd} = (0.52 \cdot M_d)+9.1$ (MPa). Tompai (2008) proposed efficient formulas to relate dynamic modulus of soils measured with the Light Falling Weight Deflectometer (LFWD) or similar instruments with the modulus derived from a static load plate, also comparing the findings with alternative correlations available in literature. Links between CBR index and static modulus were identified with empirical approaches by Rafiroiu (1971) and Jeuffroy (1967). Based on the analysis of various data from literature, Rafiroiu proposed two relations for the static elastic modulus E_{st} considering the average statistic distribution: $E_{st} = 3 \cdot CBR$ [MPa] for cohesive soils; $E_{st} = 5 \cdot CBR$ [MPa] for non-cohesive ones. CBR index of a compacted sample was measured in laboratory using the same density obtained in-field during static plate tests. Formulas were then validated trough an experimental survey with the determination of the static modulus of elasticity at the second loading cycle with a 30 cm diameter plate. Independently from the soil nature, Jeuffroy proposed the correlation $E_{st} = 6.4 \cdot (CBR)^{0.65}$, in MPa, even if a poor scientific background caused a weak reliability. Alternatively,

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Sargious found a correlation between the CBR index and the reaction modulus k; it was a bilateral-shaped curve, where the first part, for CBR values ranging from 2 to 30, was represented by the equation $k = 4.1+51.3 \cdot \log(CBR)$ [MPa/m], and the second one, for CBR from 30 to 100, was governed by $k = -314.7+266.7 \cdot \log(CBR)$ [MPa/m]. Depending on the soil type, Sangiorgi et al. (2006) proposed a relation between deformation modulus M_d and dynamic modulus E_{vd}, effective for M_d values higher than 50 MPa: $E_{vd} = (0{,}2 \cdot M_d)+(18{,}2 \pm 2{,}4)$. Also Kim et al. (2007) performed a lot of tests in order to identify a possible correlation between M_d and E_{vd}: in addition, they certified the significant cost save related to the substitution of the static plate tests with dynamic LFWD ones. Harison (1987) developed theoretical explanation for the linear log-log relation between DCP and CBR, conducting tests on clay-like, well-graded sand, and well-graded gravel samples prepared with standard CBR molds: moisture content and dry density parameters resulted key aspects for the CBR-DCP correlation. Truebe et al. (1995) evaluated the strength of a low volume road managed by the Forest Service in USA by means of the DCP, presenting a correlation between this apparatus and in-field CBR for unbound layers and subgrade. They furtherly reported the efficacy of DCP in the quick evaluation of strength properties. Interesting DCP-CBR relations were also published by Abdulrahman (2015). Wyroslak (2017) found other equations among the above described bearing parameters, depending on the state of surface layers of soil. Varghese at al. (2009) studied relations between LFWD, DCP and CBR parameters in order to define easy tools for the conversion of such physical quantities.

Given this introduction, the herein study presents the results of several in-situ and laboratory tests aimed at identifying some correlations between the main bearing strength parameters. Tests, described in more detail in the following paragraph, were executed within a vast unbuilt area of the Northern Italy, close to a major infrastructure. Inside this area, rectangular shaped, a reference central axis was identified: 3 alignments, parallel to the axis, were defined at a distance of 53, 75 and 105 meters on both sides (the northern and southern side are hereafter named “a” and “b” respectively). Perpendicularly to the reference alignment, 10 sections on the “a” side and 12 sections on the “b” side were drawn (at a distance of 200 meters one from the other) in order to define the location of the bearing tests. In some cases, the test sites were shifted some meters when ducts and pipes were detected close to the position. In the same area, some soil samples were taken to be analyzed in the laboratory. Figure 1 shows the layout of the test site (reference axis, “a” and “b” alignments, test and sampling sections). Since investigation required about two weeks of work, soil water content calculated with specific procedures was supposed to vary during the experimental campaign.

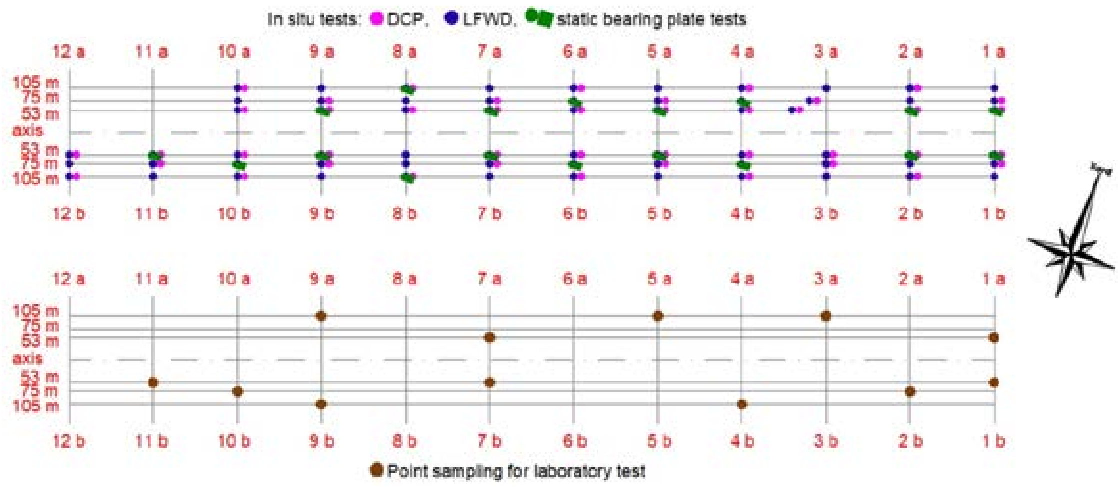

Fig. 1.
Tests and sampling area

2. Methods and Experimental Data

Data used for the present work were collected during in-situ and laboratory tests. In-field tests consisted in static and dynamic measurement of bearing capacity of soils: the more complex and time-consuming tests (depending on the equipment set up and the need of contrast truck machines) were carried only in some indicative sections (Figure 1); on the contrary, easier and faster tests (e.g. LFWD) were executed in all the sections. The following tests were carried out: Light Falling Weight Deflectometer (LFWD) tests, static plate-bearing tests, Dynamic Cone Penetrometer tests (DPCT) and sand cone tests. Light Falling Weight Deflectometer (ASTM E2835-11) allows the dynamic testing of soils and involves a quick procedure; for this reason it was used in all the sections: the output parameter of LFWD is the dynamic modulus E_{vd}. Static plate-bearing load tests (according to Italian standards, CNR 146/1992 and CNR 92/1983) were carried out only in some points, determining the deformation modulus M_d (300 mm diameter steel plate) and the reaction modulus k (760 mm diameter plate). DCP tests, performed in two replicates for all sections, allowed the estimation of the CBR index throughout a relation given by the US Army Corps of Engineering (ASTM D6951). Finally, sand cone test was used to determine the in-field specific weight of the soil (Italian standard, CNR 22/1972): tests were carried out only in some representative zones. Then, in the laboratory, collected samples were subject to grading analysis (EN 933-1 and EN 933-2) and Atterberg limit’s determination (CEN ISO/TS 17892-12); soils were classified according to the Unified Soil Classification System (USCS). Furthermore, Proctor specimens were compacted according with standards (EN 13286-2), adding the specific quantity of water corresponding to the pre-determined natural humidity. Part of the samples were tested suddenly after the compaction to calculate the immediate bearing index (IBI) (EN 13286-47); the other ones were subject to soaking 4 days (EN 13286-47) in order to evaluate swelling and CBR index after immersion.

Freeze-thawing tests were performed using an original protocol to evaluate the soil frost resistance: samples, after Proctor compaction, were sealed with plastic bags (to maintain humidity) and subject to freeze-thawing cycles. The samples were subject alternatively to freezing at -15°C, 50% humidity, for 12 hours and thawing at 20° C, 50% humidity, for 12 hours. The freeze-thawing cycle was repeated 6 days. After the 6th day, the samples were moved in a room at 20°C for 24 hours and then the compressive strength was measured.

Grading, Atterberg limits and water content are reported in Table 1. According to the USCS, the soil can be classified as "*silty sand, sand-silt mixture*" (acronym "*SM*"). Two samples coming from 1a and 9b sections were classified as "*poorly-graded gravel, gravel-sand mixture, little or no fine*" (acronym "*GP*") and "*inorganic silt and very fine sand, rock flour, silty of clayey fine sand or clayey silt with slight plasticity*" (acronym "*ML*"), respectively. Considering the classification prescribed by the Italian standard UNI 11531-1:2014 (based on the AASHTO classification), most of the specimens resulted as "*silty-sand soil*" ("*A2-4*" code). Table 1 resumes the results obtained for each test position. Table 2 and 3 summarize the in-field tests results, reporting the type of test and the corresponding parameter. Table 2, related to sand cone tests, shows natural soil moisture (%), bulk density (Mg/m^3) and dry bulk density (Mg/m^3). Table 3 shows plate-bearing load tests results (k, in MPa/m, and M_d, in MPa), LFWD moduli (E_{vd}, in MPa) and Dynamic Cone Penetrometer data (DCP in mm/blow and CBR in %). Table 4 summarizes the results obtained with laboratory tests: CBR index [%] after Proctor compaction, initial h_i and final h_f specimen height [mm] (before and after soaking, respectively), swelling Δh ($h_f - h_i$ difference), strength resistance before (R_C, in MPa) and after the freeze-thawing cycles ($R_{C\text{-}F/T}$, in MPa). The parameter (R_C - $R_{C\text{-}F/T}$)/R_C (in %) is used to evaluate the resistance variations after freeze-thawing cycles. In general, an overall consideration of results points out that studied soils have a discrete bearing capacity (for static plate and LFWD tests, bearing capacity was always measured 20 centimeters under the surface after the grassy topsoil removal).

Table 1

Grading analysis, Atterberg limits and classification results for in-field soil samples

	Sampling points												
	1a	**1b**	**2b**	**3a**	**4b**	**5a**	**7a**	**7b**	**9a**	**9b**	**10a**	**10b**	**11b**
Grading analysis													
Sieve size [mm]	**Passing [%]**												
2.00	94.0	99.0	93.0	99.9	97.0	82.0	96.5	94.0	99.0	99.9	100.0	97.0	90.1
0.4	46.0	82.0	72.0	92.9	85.0	71.0	88.8	81.0	89.0	97.5	92.0	87.0	81.1
0.063	4.0	27.0	16.0	40.4	30.0	15.0	27.9	7.0	25.0	56.0	41.0	23.0	33.4
Atterberg limits													
W_L [%]	22	17	23	18	18	17	19	19	19	19	17	21	20
W_P [%]	17	13	18	15	17	18	17	17	18	18	16	19	17
IP [%]	4	4	5	3	2	0	2	3	1	1	1	2	2
Classification													
USCS	GP	SM	SM	SM	SM	SM	SM	SM	SM	ML	SM	SM	SM
UNI	A1-b	A2-4	A2-4	A4	A2-4	A2-4	A2-4	A3	A2-4	A4	A4	A2-4	A2-4

Table 2

Sand cone test results: natural moisture and bulk density of soil

Sampling Points												
1a	**1b**	**2b**	**3a**	**4b**	**5a**	**7a**	**7b**	**9a**	**9b**	**10a**	**10b**	**11b**
Natural soil moisture [%]												
6.4	9.1	7.1	7.8	8.8	9.4	8.2	8.1	7.0	7.2	8.6	7.9	7.7
Soil bulk density with natural moisture content [Mg/m^3]												
1190	1540	1510	1310	1870	1510	1680	1660	1400	1480	1470	1720	1640
Soil dry bulk density [Mg/m^3]												
1050	1320	1310	1160	1620	1320	1450	1340	1230	1310	1320	1440	1380

Table 3

In field test results (from LFWD, static plate-bearing load tests, DCPT index and CBR by DCPT, respectively)

Sampling points	E_{vd} [MPa]	M_d [MPa]	K [MPa/m]	DCP index [mm/blow]	CBR (from DCP) [%]
1a	10.98	12.00	3.26	36.6	5
1b	15.23	21.33	---	12.9	22

Sampling points	E_{vd} [MPa]	M_d [MPa]	K [MPa/m]	DCP index [mm/blow]	CBR (from DCP) [%]
2a	15.12	14.56	1.64	21.2	16
2b	14.12	7.70	7.38	24.9	13
3a	9.93	---	---	22.7	9
3b	15.73	---	---	32.2	7
4a	8.98	16.25	9.43	29.6	7
4b	16.55	15.82	7.09	23.6	9
5a	11.68	36.63	8.79	18.7	12
5b	14.40	20.00	2.87	19.1	12
6a	11.20	27.69	7.21	23.1	12
6b	14.62	19.40	4.68	29.7	8
7a	12.15	22.56	4.66	24.4	9
7b	10.88	10.43	5.61	21.4	13
8a	17.77	16.76	15.67	26.6	8
8b	23.60	30.00	9.38	21.8	14
9a	21.62	10.32	7.75	27.0	18
9b	15.23	13.66	8.68	23.8	10
10a	14.67	---	---	18.4	19
10b	12.75	13.85	8.17	31.4	7
11b	13.98	20.13	6.62	18.6	12
12b	17.75	---	---	12.9	18

Table 4
Laboratory test results (IBI, CBR, expansion, frost resistance after freeze-thawing cycles)

Sampling points	IBI [%]	CBR [%]	h_i [mm]	h_i [mm]	Δh (=h_f - h_i) [mm]	R_C [MPa]	$R_{C-F/T}$ [MPa]	(R_C – $R_{C-F/T}$)/R_C [%]
1a	46	4	126.57	133.29	6.72	0.48	0.36	26
1b	15	27	124.51	127.25	2.74	0.38	0.29	24
2b	68	14	126.66	131.94	5.28	0.65	0.62	5
3a	51	38	124.99	126.77	1.78	0.73	0.64	12
4b	49	23	124.56	126.3	1.74	0.41	0.32	21
5a	58	32	124.38	126.62	2.24	0.45	0.27	41
7a	46	18	124.48	129.34	4.86	0.32	0.19	41
7b	34	24	124.58	128.17	3.59	0.27	0.27	1
9a	32	10	125.06	127.94	2.88	0.40	0.30	26
9b	61	8	124.18	130.61	6.43	0.52	0.49	6
10a	16	15	124.45	130.07	5.62	0.65	0.59	9
10b	48	31	152.62	128.49	2.87	0.46	0.29	36
11b	76	40	124.25	126.61	2.36	0.60	0.36	40

Values reported on Table 3 and 4 show a not good bearing capacity of the examined soils. Italian specifications for the construction of transport infrastructures introduce a classification based on parameter values. Soil investigated in this paper have: “middle” characteristics (CBR > 9% e k > 60 kPa/mm) if used as subgrade for road construction, “good” characteristics (15 % ≤ CBR ≤ 20 %) if used in airport safety strip or flexible pavement subgrade and “bad” characteristics if used as subgrade for railways or rigid pavement subgrade for airport infrastructures.
CBR indexes deduced from DCP tests and measured in the laboratory (after Proctor compaction and 4-days soaking) are sensibly different. Although literature reported that laboratory and in-situ (DCP) CBR values generally match (Sangiorgi et al., 2006), in this case a higher densification in the laboratory was observed and determined high CBR values if compared with those of in-situ samples; this was probably due to a low presence of fines and compactability characteristics. Table 4 also shows swelling results (height variation of samples confined in molds) after 4 days of soaking and the compressive strength (R_C) before and after freeze-thawing cycles ($R_{C-F/T}$). In general, soils seem to be

partially affected by freeze-thaw effects, with an expansion equal to approximately 5% and a compressive resistance decrease of 22%.

3. Developed Correlations

Considering the existence of several equations suitable for correlating different bearing capacity parameters, some of them were used to verify the possible correlation of results for the soils analyzed in the present work.
First of all, relating dynamic modulus E_{vd} (recorded with LFWD) and static modulus M_d (calculated with static plate-bearing load test), an acceptable correspondence seemed to exist ($R^2 = 0,7$). A plot is presented in Figure 2.
Using the Baksay, New Baksay, Rafiroiu_1 and Rafiroiu_2 equations (Figure 3), reliability of different formulations for E_{vd} versus M_d was verified. Baksay, "New Baksay" and Rafiroiu_1 formulas exhibited better confident relations ($R^2 = 0,58$) with respect to Rafiroiu_2 one, for which R^2 is equal to 0,43 (the lack of a stronger link can be probably ascribed to the low content of the fine fraction in soils). The equations used are the following: $E_{vd} = (0,52 \cdot M_d)+9,1$ for Baksay; $E_{vd} = 0,62 \cdot M_d$ for "New Baksay"; $E_{vd} = 1,1 \cdot M_d$ for Rafiroiu_1; $E_{vd} = (1,1+0,028 \cdot \alpha) \cdot M_d$ for Rafiroiu_2 (α is the percentage passing to 0,063 mm sieve). Using these equations to evaluate the real data, Figure 3 shows that "New Baksay" formula leads to an overestimation and Baksay formula to an underestimation of E_{vd}. Rafiriou_1 and Rafiroiu_2 formulas show an overestimation using low M_d values, and viceversa for high M_d values.

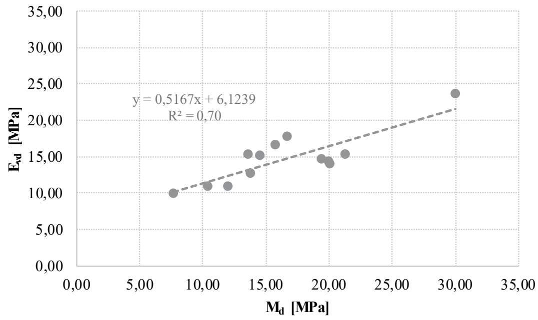

Fig. 2.
Relation between dynamic modulus Evd and static modulus Md

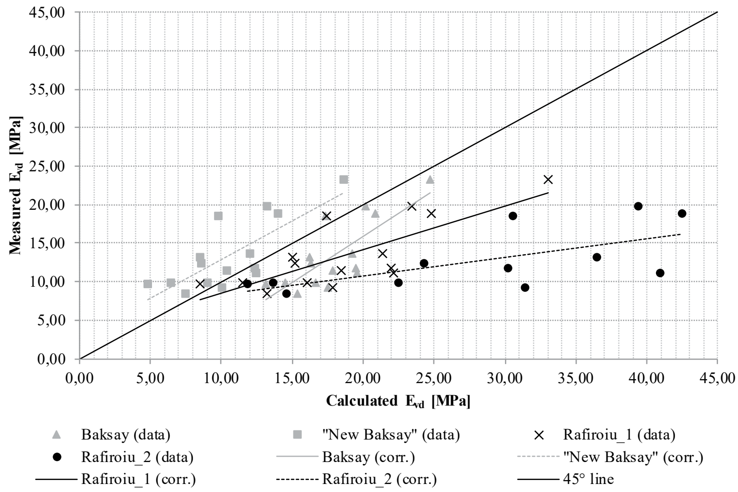

Fig. 3.
Relations between Evd (measured in situ) in the y-axis and different calculated Evd values in the x-axis

The relation between in-situ (DCP) and laboratory CBR index was also investigated. Figure 4 presents two relations: the first one (grey broken line) is the ASTM standard equation (between DCP in mm/blow and the CBR index in percentage) used to calculate the bearing capacity from DCP test; the second one (black dotted line) is the equation based on data from the field test (DCP) and laboratory test (CBR index). The Figure 4 shows that ASTM standard equation ($CBR = 292 \cdot DCP^{-1,12}$) underestimates the CBR values calculated in laboratory. The weak correlation between DCP and CBR index (measured CBR values are higher than those deriving from the ASTM standard equation) is caused probably by the better densification given by Proctor compaction in laboratory.

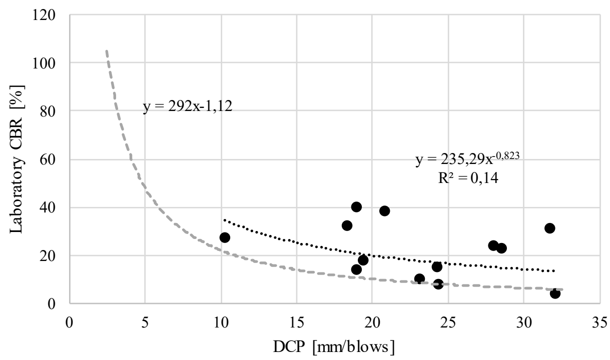

Fig. 4.
Relationship between laboratory CBR index and Dynamic Cone Penetrometer test (DCPT)

The correlations between static modulus E_{st} (in MPa) or deformation modulus M_d (in MPa) and laboratory CBR index (estimated from E_{st} or M_d) are presented in Figure 5. Jeuffroy formula ($E_{st} = 6{,}4 \cdot CBR^{0{,}65}$), Boussinesq equation ($E_{st} = 0{,}92 \cdot CBR$, with Poisson's coefficient equal to 0,4) and the equation $M_d = CBR/0{,}2$ (where deformation modulus M_d is measured in MPa – Ferrari et al., 1983) were used to estimate CBR indexes. Figure 5 represents: Jeuffroy formula, Boussinesq equation, the equation $M_d = CBR/0{,}2$ and the data distribution measured with in-field tests. Despite the quite low R^2 values, static modulus M_d is predicted with laboratory CBR indexes; Jeuffroy and $M_d = CBR/0{,}2$ formulas lead in this case to an underestimation of CBR values, but data show a fair fit with Boussinesq equation.

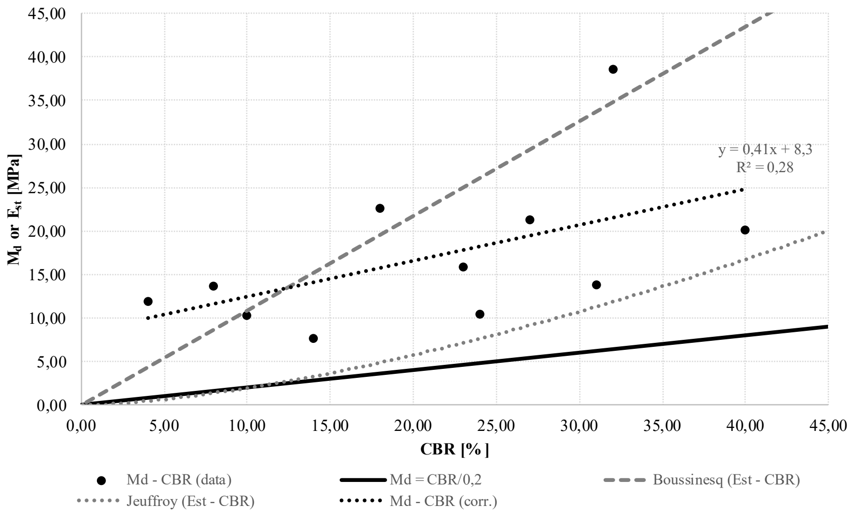

Fig. 5.
Relationship between CBR index and static modulus E_{st} or M_d

Figure 6 shows the correlation between static modulus (M_d) and reaction modulus (k); plotted data seemed to show no evident correlation between these two bearing capacity parameters.

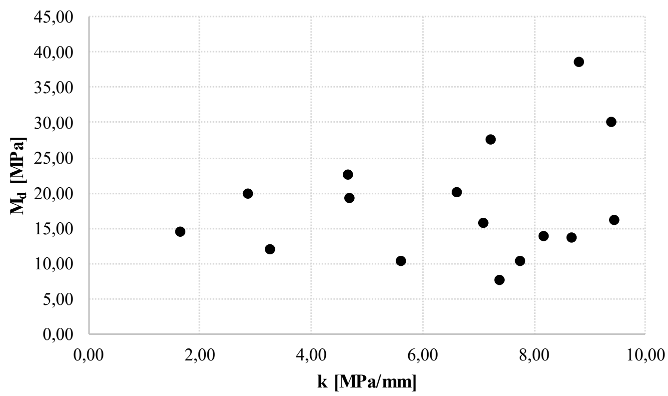

Fig. 6.
Relationship between measured static modulus M_d and measured reaction modulus k

4. Conclusions

An experimental study has been carried out on soils in order to determine the main mechanical parameters suitable for representing their bearing capacity. In field and laboratory tests have been performed involving the evaluation of static and dynamic moduli as well as current laboratory indexes in different operating conditions, with the purpose of defining possible correlations among the more common strength parameters. The first conclusion of the research was that tests carried out in laboratory, even if according to the standards in force, overestimate mechanical performances due to the different compaction conditions which guarantee a higher density of specimens: Proctor compaction procedures, CBR and IBI from laboratory tests lead to a less conservative classification of materials than in field trials. Generally, some correlation among the different parameters can be found, even if it is strictly related to materials' properties and test procedures. The dynamic modulus from LFWD is the most difficult parameter to be linked to other indexes due to the specific size of the tool, the loadings involved and the test protocol.
In any case, comparing the equations from in-field tests and literature, significant differences in form and coefficients were highlighted; soil characteristics (e.g. particle size distribution, etc.) play a crucial role. For these reason, more research is recommended in order to investigate better all the aspects which affect the typical parameters used to indicate the bearing capacity of soils.

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BIM REVERSE ENGINEERING: DIGITAL TRANSFORMATION OF EXISTING ROADS

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Abstract: The raising of the transport infrastructure sector through the digital transformation of roads is a factor for sustainable and intelligent development of the Country, in order to create safer, cheaper, better-used and fruited infrastructures generating data and services for a better travel experience for citizens, facilitating freight transport and helping to determine a technology-friendly ecosystem for businesses. A specific need for the digital transformation of roadways consists in acquiring the geometric features of existing roads. The process is known as reverse engineering, or Scan to BIM, and generates object models that can be implemented and usable on BIM platforms. BIM is the tool that best suits these operational needs in the various fields and in all the advancing stages of the life cycle of the work, from conception to disposal. The case study shows the solid parametric modeling of the rural road SP430 "Cilentana" (SS18VAR), one of the main route for the Southern areas of Campania Region. The BIM platform provides the ability to extract road alignment, profiles and cross sections from the 3D model at any time. Processes can be dynamically updated as a result of any modifications made to the model for extraordinary adjustments and/or maintenance of the road. Autodesk Software packages Civil 3D and Infraworks were used in a combined approach.

Keywords: I-BIM, reverse engineering, parametric modeling.

1. Introduction and Literature Review

Building Information Modeling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility (AGC, 2006). The specification for information management for the capital/delivery phase of construction projects using building information modelling (The British Standards Institution, 2013) defines Building Information Modeling (BIM) as "the process of designing, constructing or operating a building or infrastructure asset using electronic object orientated information". The National Building Information Model Standard Project Committee defines Building Information Modeling (BIM) as the digital representation of the physical and operative characteristics of a facility, providing a shared knowledge resource for the industry stakeholders during the whole facility life-cycle, from earliest conception to demolition. Another BIM definition is given by Penttilä (2006), as a set of interacting policies, processes and technologies, highlighting that BIM can be presented as a suitable management method to design and construction issues within the IT-oriented building projects and process environments. These definitions highlight some of the key concepts related to BIM, namely, technology, collaboration, knowledge, data and policy. BIM was first intended for applications in buildings, however, its introduction to infrastructure facilities has expanded over the last years, taking advantage of the knowledge base already established. Although infrastructure projects possess intrinsic characteristics that demand different modeling methodologies, the base of BIM application in terms of data management and exchange remains the same (Cheng *et al.*, 2016). Terms like "Civil information modeling", "Civil information management", "Construction information management", "Virtual design and construction", "Horizontal BIM" or "Heavy BIM" are often applied to define the deployment of model-based technologies and processes to non-building projects (McGraw, 2012). The origins of BIM are related to the development of Computer-aided Machining (CAM), and Computer Aided Design (CAD), that can be respectively dated to 1957 and 1961, developed by Dr. Patrick J. Hanratty. Another key historical point on the creation of BIM was the development of Sketchpad (Sutherland, 2003), a CAD software developed by Ivan Sutherland in 1963, at the Massachusetts Institute of Technology Lincoln Labs, that can be described as the forerunner of all CAD programs. Developed in a TX-2 computer, the system allowed the design and manipulation of drawing components, enabling the inclusion of symbols and making possible to establish relations between the parts of a drawing, defined as a computational representation of the geometry system. Eastman (1974) introduced the Building Description System (BDS), a graphical user interfaced software that served as a database for building projects, including editable design, construction and operational information. In the statement "In addition, building code checks on this database have the potential of being automated and violations could be checked for during design regularly.", Eastman establishes a very original consideration about clash-detection and the inherent cost reduction. With the project Graphical Language for Interactive Design (GLIDE), Eastman and Henrion (1977) present an efficient and detailed computer representation for physical systems (e.g. buildings, ships and machines) for the design and construction. The author distinguishes 3 levels of representation: image, shape and object, enabling a guaranty for the 2D projections consistency in 3D models. This project exhibits many characteristics of a BIM platform, namely, high level environment of CAD, representation of

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shape models with complete descriptions and definition of the relations between objects, set of data types and commands for interactively defining, arranging and inspecting a design. It is important to notice that developments in the Geographic Information Science (GIS) were also key on the environmental evaluation, resource arrangement and safety analysis that must complement the geometric and semantic information aggregated to a BIM model (Rafiee *et al.*, 2014). This achievements served as foundation-ground for the development of the current software applications for BIM-based projects. In fact, the importance of BIM in the Architectural, Engineering and Construction (AEC) resides on the integrated data environment where the facility is represented, which leads to benefits as, the effectiveness of processes, improved quality design, accurate cost-analysis and savings of the contract value (Azhar, 2011). Researchers described their behavior as regards their development and use (Taylor and Bernstein, 2009). This takes into account the four main elements of BIM: visualization, coordination, analysis, integration. The concept of integration reveals having two different aspects: the first one regards people and processes and the second one concerns the integration of interoperability systems. The integration of some stages and disciplines is extremely useful from an early stage of project. This allows the virtual construction of the work in its definitive configuration and the possibility to see the integration of more disciplines (Leone *et al.*, 2017). Still the BIM process seems to be too complicated for many and initially adopted in a limited manner (Howard and Björk, 2008). Nevertheless, literature is full of examples dealing with stage integration and the coexistence of various disciplines (Bonin *et al.*, 2009). Succar (2009) highlights the interconnections within different fields through BIM process, in particular identifying three interlocking BIM Fields of activity: Technology, Process and Policy (TPP) with two sub-fields each: players and deliverables. Particularly, a correct and clear implementation of all the information ensures a successful development of the project and a reduction of modification and reissues, which results in efficiency maximization and time saving. In this way BIM can be defined a model checker, since the first phases of project implementation up to the operational phase, and more, as for example manufactured product information, can be uploaded into the BIM database too, and this allow even to budget and schedule maintenance. Essentially the BIM is not simple software but a complex management system in planning steps of a building or infrastructure. The 3D modelling, in fact, includes dimensional, quality, timing and coordination data, and along with outputs provided, such as work order flows, costs, accounts, and financial elements, it supports the decision-making processes. (Ingletti *et al.*, 2017). The spread of BIM in Europe started in 2014 with the European Directive 2014/24 / EU on Public Procurement (European Parliament and of the Council, 2014) that clearly expresses the indication to introduce BIM within the Member States of procurement procedures. In particular, the Article. 22 "Rules applicable to communication", c.4, specified that for public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar. In Italy the first indications of BIM is indicated in the new Public Procurement Code (Presidente della Repubblica, 2016). In particular, Article 23, paragraph 1, point H expresses the desire for a progressive rationalization of design activities through the incorporation of IT tools and technologies for modeling buildings and infrastructures. In the MIT Decree n. 560 (Ministero delle Infrastrutture e dei Trasporti, 2018) are defined the modalities and the times for the progressive introduction, by the general contractors, of the obligation of specific methods and electronic instruments, to rationalize design activities and related specifications, in according to the European Directive. In particular from 1st January 2019 is a mandatory for relevant works with amounts exceeding € 100000000; from 1st January 2020 for works with amounts between € 50000000 and € 100000000; from 1st January 2025 for minor works with amounts less than € 1000000. The case study is a reverse engineering process, which consists of extracting knowledge or design information from anything man-made and reproducing it or reproducing anything. The case study focuses on the rural road S.P. 430 "Cilentana Road" (SS18VAR) localized in in Southern Italy. The roadway has been developed in BIM mode with the aim of highlighting the main potential of this innovative process including some improvements in order to promote the full implementation of the BIM technology for road infrastructure.

2. Case Study

The study focus on two-lane rural road S.P. 430 in Salerno Province (Southern Italy) network, connecting the National Park of Cilento and Vallo of Diano, for a total length equal to 72.65 Km. S.P. 430 (see Figure 1) is a single carriageway without traffic island, with a width equal to 10.50 m, lanes width equal to 3.75 m and shoulder width equal to 1.50 m.

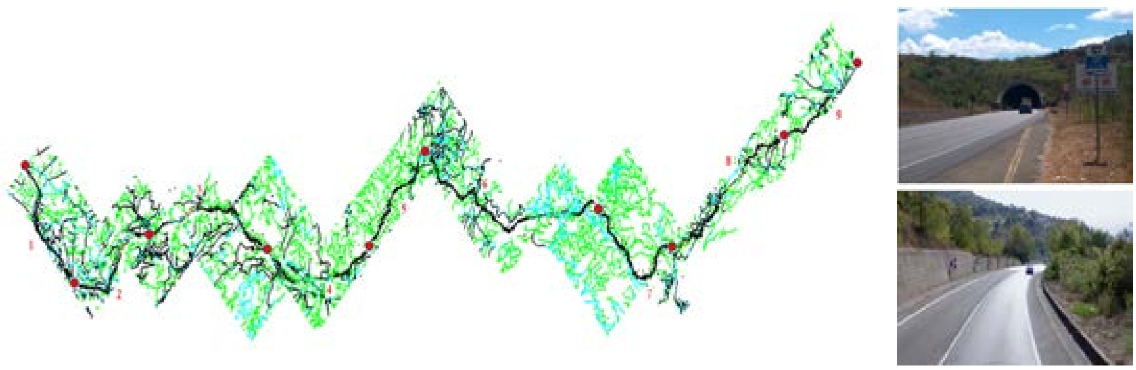


Fig. 1.
Output of the S.P. 430 geometric layout and cross sections

The SP430 is composed by 91 circular curves elements, 121 tangent elements, and 186 spiral transition curves which of 154 tangent to circular curve spiral transition curves (TC), 28 circular curve to circular curve spiral transition in the opposite travel direction (CCOTD), 4 circular curve to circular curve spiral transition in the same travel direction (CCSTD). Table 1 shows the overview of the main geometric features of S.P. 430: minimum value, mean value, maximum value, standard deviation St. Dev. and coefficient of variation C.V. (standard deviation divided by mean value).

Table 1
Road homogenous elements of S.P.430

	Tangent Length (m)	**Curve Length (m)**	**Circular Radius (m)**	**TC (m)**	**CC_{OTD} (m)**	**CC_{STD} (m)**	**Grade (%)**
Min Value	11.32	1.21	118	53.67	84.52	54.25	0.10
Med Value	281.38	202	496.08	271.74	150.69	69.56	2.97
Max Value	1626.33	800	900	511.36	323.73	94.70	6.00
St. Dev.	272.58	157.30	644.11	79.60	109.60	64.30	2.03
C.V.	0.97	0.78	0.93	0.53	0.63	0.86	0.68

This reverse engineer project has been developed and elaborated in the following steps using Autodesk CIVIL 3D and InfraWorks software: a) Modeling surface, b) Modeling horizontal road alignment design, c) Modeling elevation profile, d) Setting-out cross section and Modeling the corridor, e) Rendering

2.1. Surface

The starting point is the Regional Technical Cartography (CTR). The goal is to create a 3D model of the existing surface. The digital model was obtained in two steps: a) select the points and modify the elevation information in order to be displayed in a 3D space rather than in a 2D space; b) add level curves data in order to obtain a very detailed surface. Triangular irregular network (TIN) has been used as digital means to represent surface morphology. TIN is a form of vector-based digital geographic data and is constructed by triangulating a set of vertices (points). The vertices are connected with a series of edges to form a network of triangles. The output of TIN 3D surface using Autodesk CIVIL3D software is shown in Figure 2.

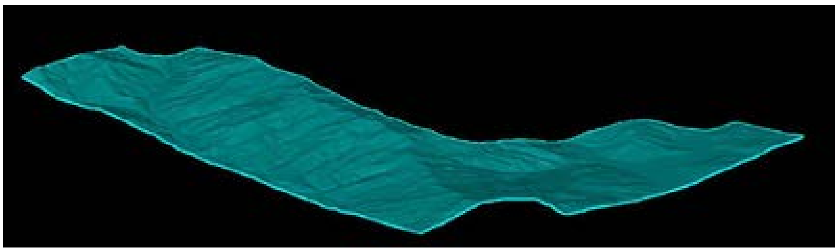


Fig. 2.
Output of the TIN 3D surface

2.2. Horizontal Road Alignment Design

The next step is to create the existing road alignment (see Figure 3), starting from all the available data on the tangent, curves and spiral transitions elements. Nine homogenous road elements, considering the distance between two following interchange, were identified. Table 1 shows the Average Annual Daily Traffic (AADT) associated to the nine homogenous road elements. The AADT is defined as the ratio between the number of vehicles transiting in a year and the number of days of the same and is measured in veh/day. Also, Table 2 shows the medium curvature change rate (CCRm) of the nine homogenous road elements. The CCRm, measured in gon/km is defined as the sum of the absolute values of angular changes in the horizontal alignment divided by the total length of the road section.

Table 2
Road homogenous elements of S.P.430

	Km 98.00 107.90	**Km 107.90 113.15**	**Km 113.15 119.81**	**Km 119.81 126.61**	**Km 126.61 132.93**	**Km 132.93 144.17**	**Km 144.17 155.27**	**Km 155.27 160.68**	**Km 160.68 166.96**
Lenght (Km)	9.9	5.25	6.66	6.8	6.32	11.24	11.1	5.41	6.28
AADT (veh/day)	9560	7405	5973	5907	5291	4288	3745	2032	2029
CCRm (gon/km)	32	9	50	12	60	100	120	110	115

Fig. 3.
Output of the road alignment

2.3. Elevation Profile

The next step is to create the design profile (see Figure 4) showing the elevation of the surface along the axis of the road alignment in order to identify viaducts and tunnels.

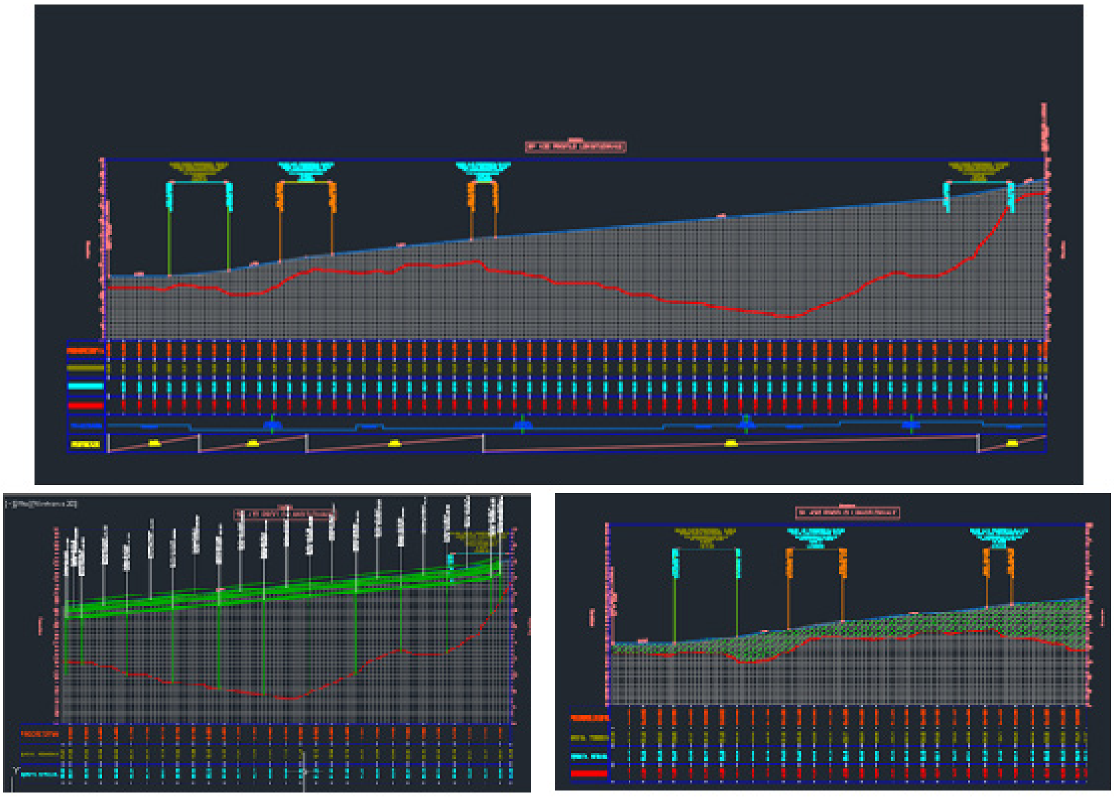


Fig. 4.
Output of the design profile

2.4 Cross Section and Corridor

One of the main step is creating and modelling of the corridor based on various 3D objects and data, in particular sub-assemblies, cross section type, surfaces, feature lines, alignment and profiles.
BIM for Infrastructure is not yet developed as for Buildings. For this reason, several elements are not present in the Library such as canals and gutters of different sizes. All the elements missing were created using polylines with the definition of each parametric point. Figure 5 shows an example of graduate trapezoidal gutter.

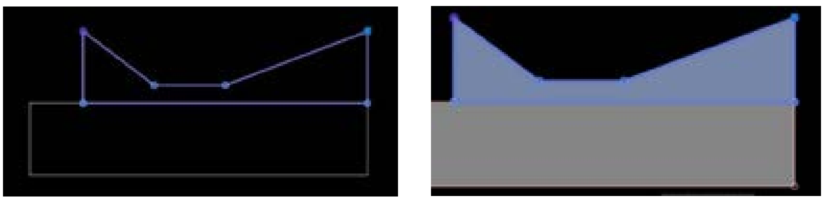
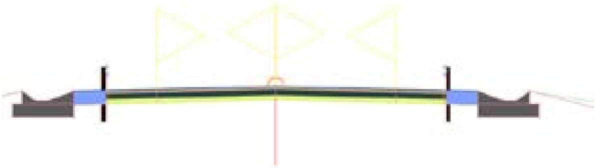
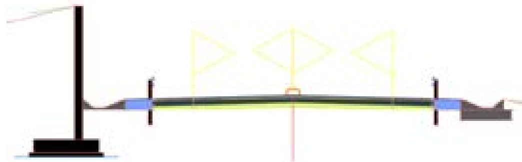


Fig. 5.
Example of graduate trapezoidal gutter

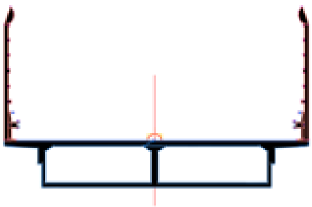
Figure 6 and Figure 7 show respectively the main cross sections type used in the study and the output of the corridor.



a) *cut cross section*



b) cut cross section with retaining wall



c) *viaduct cross section*

d) tunnel cross section

Fig. 6.
Example of cross section type

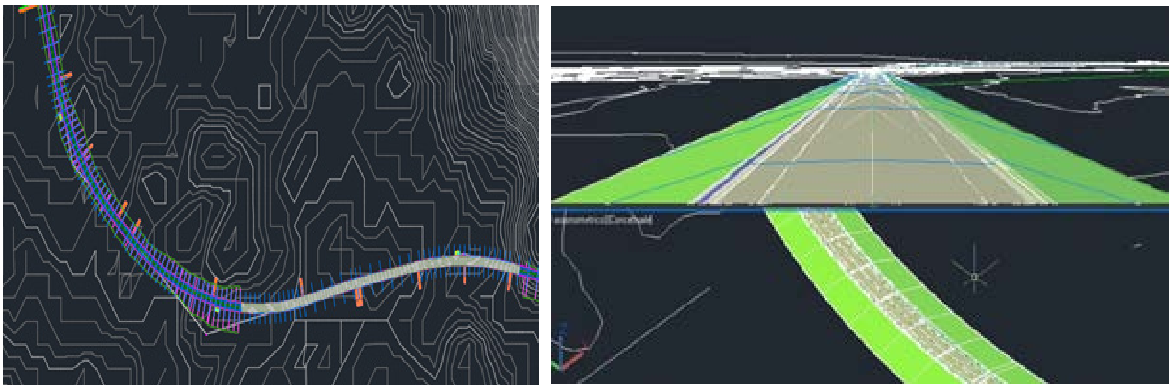


Fig. 7.
Output of the corridor

2.5. Rendering

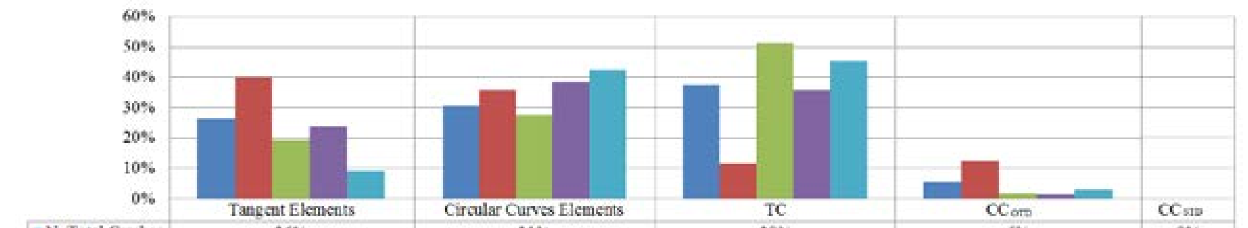
InfraWorks software supports connected BIM (Building Information Modeling) processes, letting designers and civil engineers plan and design infrastructure projects in the context of the real world. InfraWorks preliminary design software helps improve project outcomes. Combine and connect data to better create, view, analyze, share, and manage information to make decisions in context. Figure 8 shows some of the rendering generated with the tool.

Fig. 8.
Rendering of S.P. 430

3. Results

In this case study a reverse engineering process has been carried out, which consists of extracting knowledge or design information from anything man-made and reproducing it or reproducing anything. The model of an existing road in

BIM is very helpful for safety considerations analyzed in several studies during the past years (Abbondati *et al.*, 2017; Biancardo *et al.,* 2016, Dell'Acqua, 2015; Dell'Acqua *et al.*, 2017; Russo and Biancardo, 2017; Russo *et al.,* 2013, 2014, 2015, 2016). In particular is possible to create hyperlink in a specific section and associate additional information such as crash data. Crash reports and geometric and traffic data were made available by the Administration of the Province of Salerno. The main features available were as follows: the location of the intersection where the crashes happened, the number of crashes, injuries and deaths, crash type, the type and number of vehicles involved, road surface conditions, lighting conditions. A total of 344 crashes were recorded from 2003 to 2010, which of 167 property damage only (PDO), and 177 that have registered at least one injured or fatality. Figure 9 shows the Crash Severity percentage for the different road element type. In particular, the highest percentage of injury crashes was observed on TS elements, the highest percentage of injuries was observed on circular curves elements, and the highest percentage of fatalities was observed on TS elements. No crashes were observed on CCSTD elements.



	Tangent Elements	Circular Curves Elements	TC	CC_{OTD}	CC_{STD}
N. Total Crashes	26%	31%	38%	6%	0%
N. PDO crashes	40%	36%	12%	13%	0%
N. Injury crashes	19%	28%	51%	2%	0%
N. Injuries	24%	39%	36%	2%	0%
N. fatalities	9%	42%	45%	3%	0%

Fig. 9.
Crash Severity for the different road element type

It was checked a possible correspondence between the observed road crashes detected on the road and design problems. In particular the visibility distance (see Figure 10.a) was evaluated showing the allowed (green lines) and obstructed (red lines) visibility. Two critical intervals with problems of visibility distances for stopping and overtaking were identified with a high percentage of injuries associated. The first one (see Figure 10.b) is due to the presence of the tunnel, which, combined with the elevation of the road alignment and the following curve element, generates an obstacle to the driver's vision, particularly leaving the tunnel. The second critical interval (see Figure 10.c) is due to the low curve radius value and the obstacles on the roadside.

a) *allowed and obstructed visibility*
b) *critical interval in presence of tunnel*
c) *critical interval in presence of low curve radius*

Fig. 10.
Visibility distance check

4. Conclusion

The BIM method represents a remarkable innovation compared to traditional design practice as it allows to digitally programming every aspect of the life cycle of a work from planning to design, implementation and management, minimizing errors and optimizing time and cost. In addition, a focal point for the steady introduction of the BIM methodology in the design practice is to facilitate the maintenance operations. In fact, it should be taken into account that in Italy, while in other fields, such as the mechanical one, BIM-style IT tools have advanced technological and regulatory progress, in the field of construction and, in particular, infrastructure, of the legislation and the structuring of the methodology, unlike other countries such as Germany or Japan where BIM for civil engineering and civil infrastructure is now a common practice for a long time. The progressive introduction of the BIM methodology in design practice could thus give a fundamental impetus to the entire national landscape, both in terms of ex-new construction, but above all as regards the management, maintenance and enhancement of the currently existing building-infrastructure heritage. The case study provided interesting elements to evaluate the advantages and disadvantages of design practice through BIM style tools, as well as the current state of the methodology itself. First of all, despite the fact that the starting cartography has limited information due to its scale, it was possible to reconstruct the existing road with discrete precision and remarkable level of detail, through consequential, parametric operations, which could favor the transition from graphic objects To "intelligent" objects, thus facilitating the process, thus slimming the time for modification and, consequently, for the elaboration of the process. It is clear, however, that having more detailed detail data and surveys, such as stratification of the road superstructure or the joining lengths of the planes, can yield a better final result and with even less approximations. It is necessary to take into account some of the improved aspects of the computing code used: Firstly, it requires elaborate processing capabilities and significant graphics, which are not always supported, thus making the operations slow, especially after the modeling. It is therefore advisable to break the path into multiple worksheets to minimize the slowdowns due to the parameters load in the model. In addition, the worksheets generated by Civil 3D have a considerable amount of data inside them and for this reason their size is about ten times higher than the files generated by traditional CAD calculation codes. From a graphical point of view, Civil 3D has a display capacity of elements, especially 3D solid objects, acceptable, but of course certainly inferior to other computing codes for the function. Finally, a possible future development is to deepen the characteristics of the solid objects extracted by allowing them to be parameterized in accordance with current regulations. In fact, as seen above, inserting materials from the tool library does not provide a description of the intrinsic property of the object, but only increases its graphic yield. Instead, by parameterizing the specific characteristics of each material, it would be possible to implement object properties including the results obtained in the previous research works (Abbondati *et al.*, 2016; De Luca *et al.* 2016, 2017; Dell'Acqua *et al.*, 2012, 2018; Russo *et al.* 2018; Veropalumbo *et al.*, 2018) by significantly increasing the level of detail in full compliance with the BIM modeling principles.

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ENHANCING THE FINANCIAL FEASIBILITY OF PPP PROJECTS WITH HYBRID FUNDING

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Abstract: In transport infrastructure concessions, the sources of revenue to the private partner (or concessionaire) may include (i) the infrastructure users (e.g., tolling, in the case of roads), (ii) the government (e.g. through availability payments), and (iii) both users and government, which might be called a hybrid concession. An example of the latter is a road concession where the concessionaire is allowed to charge tolls to the road users but, because of relatively low revenues, the government agency might have to complement the toll revenue. This paper summarizes the cases where it may be justified for the government to complement users' revenues and describes a model developed for the financial assessment of road concessions involving both tolling and government payments. The methodology described for roads can also be applied to other forms of transport infrastructure. A practical application of the model is demonstrated in the paper. For example, given traffic volumes and maximum acceptable toll rates for a particular road project, the model can be used to estimate the minimum availability payment that would be required for the project to attract private sector interest, that is, potential bidders in a competitive bidding scenario. The model can also be used to carry out sensitivity analyses of the impact of key input parameters on outputs such as the investor's return on equity and annual debt service cover ratio.

Keywords: PPP, road concessions, tolling, availability payments, financial feasibility.

1. Introduction

Over the last couple of decades there has been an important contribution of the private sector to finance roads and other forms of infrastructure. In 2017, private investment commitments in energy, transport, ICT and water infrastructure in low- and middle-income countries totaled US$93.3 billion across 304 projects (World Bank, 2017). Private investment commitments in developed countries have also been substantial.

Driving policy makers' continued interest in attracting private financing to transportation projects is the need for greater investments to keep transport infrastructure in acceptable condition and carry out required expansions in a context of public budget constraints. When arrangements for private participation or, more generally, public-private partnerships (PPP) are designed well, they can lead to (Mladenovic and Queiroz, 2014):

(1) Greater financial efficiency, by leveraging public money through the mobilization of private capital, reducing the impact of investments in infrastructure on the fiscal budget, and creating fiscal space to expand public service delivery in other sectors;

(2) Better distribution of risks, by transferring design, construction, and performance risks to the private sector, which is best able to manage such risks; and

(3) Better governance, by increasing the accountability of the service provider through competitive bidding, disclosure policies, and public reporting.

Government support to potential PPP projects is justified when an economically feasible project does not offer, without such support, the financial benefits required to attract private concessionaires. The mixing of public and private funding to get projects completed is a way to leverage scarce public resources, not just replace them. Because transport infrastructure is so essential to a well-functioning, growing economy, it is vital that subsidy funding is well spent and helps to deliver infrastructure services people really need at the least possible cost (World Bank, 2012).

How a government contributes financial support to a concession project, and how much it contributes, are often limited to what is required to attract private financing and promote the success of the project (World Bank, 2012). Mechanisms that governments use to support private financing of roads include (Queiroz et al. 2013):

- Availability payment, which is paid to the concessionaire by the government on the basis of the availability and quality of the required capacity (e.g., number of lanes in acceptable condition), regardless of demand (e.g., traffic volume).
- Capital grants, or subsidies, to cover part of the construction cost. Where user charges (e.g., toll revenue) would not be enough to recover the full construction cost of a project, reducing the privately financed construction cost may make the project financially attractive to the private sector.
- A per-vehicle subsidy (a toll subsidy) which is paid to the concessionaire based on traffic volume.
- Minimum revenue guarantees, in which the government pays the concessionaire compensation if revenue falls below a specified minimum (for example, 90 percent of the expected amount).

Recent practice in transport projects has seen the use of a mixed payment mechanism consisting of an availability payment and a direct user charge, or toll (Yescombe, 2007). Such an arrangement is designed to cover operating expenses, debt service and equity return.

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There are several toolkits available for the analysis and ex-ante assessment of highway PPP projects. These toolkits provide a wide range of tools and manuals that may assist stakeholders involved in PPP projects from early phases of project development to financial closure and implementation, as summarized below.

The Government of India (2010) released a web-based toolkit for the improvement of the decision-making process in PPP arrangements for the delivery of infrastructure projects. The toolkit can be used for the assessment of highway projects, which is one of five sectors covered. It is suitable for detailed analysis of greenfield and brownfield projects. The primary resources of revenues considered are user charges, shadow tolls, or annuities. Results consist of a set of accounting ratios such as debt service coverage ratio, loan life cover ratio, return on assets, net profit margin, and return on equity. Also, results cover a set of output parameters related to the project such as the project's internal rate of return and net present value, and shareholder accounts, such as the equity internal rate of return and the equity net present value.

Beaty and Lieu (2012) developed an Early-Stage Toll Revenue Estimation Model. The model is standalone, spreadsheet-based, and prepares early stage traffic and toll revenue estimates, and allows a user to simultaneously examine the interaction of multiple tolling variables and traffic scenarios, so the agencies can make an informed decision about future toll road projects.

In 2013, the Federal Highway Administration's (FHWA) Office of Innovative Program Delivery launched a new toolkit, P3-Value, Public-Private Partnership Value-for-Money Analysis for Learning and Understanding Evaluation (FHWA, 2013). Although the main purpose of the toolkit is to help decision makers in the "value-for-money" analysis, it covers other important aspects of PPPs such as risk evaluation and financial feasibility. This toolkit consists of four tools, namely a risk analysis tool, a public sector comparator (PSC) tool, a shadow bid tool, and a financial assessment tool, all Microsoft Excel based and supported by associated manuals.

The World Bank (WB), supported by the Public-Private Infrastructure Advisory Facility (PPIAF), has developed a Toolkit for Public-Private Partnership in Roads and Highways (PPIAF, 2009) - the Toolkit - to assist policy makers in implementing procedures to promote private sector participation and financing in roads. The WB Toolkit includes financial models (in graphical and numerical formats) that can be used for the financial assessment of PPP toll roads. Based on the Toolkit toll road graphical financial model, a model was developed to assess the financial feasibility of road concessions involving availability payments (Mladenovic and Queiroz, 2014).

This paper focuses on availability payments (also called annuities, as in South Asia), as a complement to toll revenues, where such revenues are not enough for the project to attract private partners. This would occur, for example, because of relatively low traffic volumes and/or toll rates. The paper presents the development of a user-friendly tool for financial assessments of road concession projects that involve both tolling and availability payments based on the existing World Bank Toolkit (2009) and the model for availability payments (Mladenovic and Queiroz, 2014). In view of the brief summary provided above on existing financial models, as well as a comprehensive related literature review carried out by Vajdic (2016), it appears that the new model will fill an important gap in the set of tools available for the financial assessment of road PPPs or concessions.

Several practical applications of the model are demonstrated in the paper. For example, given traffic volumes and maximum acceptable toll rates for a particular road project, the model can be used to estimate the minimum availability payment that would be required for the project to attract private sector interest, that is, potential bidders in a competitive bidding scenario. The model can also be used to carry out sensitivity analyses of the impact of key input parameters (e.g. capital cost, concession life, loan terms) on outputs such as the investor's return on equity and annual debt service cover ratio.

While launching a concession project that involves availability payments (AP), a country should be aware that AP creates future liability for the government, and hence limits its future resources to invest in other needed projects. Nevertheless, when a "users pay" type of project is not feasible (due, for example, to user inability or unwillingness to pay the minimum required toll rate), AP may be used to complement the limited toll revenues.

2. Developing a Financial Model for Tolling and Availability Payment Concessions

Based on the WB Toolkit toll road graphical financial model, a model was developed to assess the financial feasibility of road concessions involving both tolling and availability payments.

As in the original model, the new financial model comprises five worksheets (Data Sheet, Cash Flow Graph, Debt Graph, Dividend Graph, and Summary of Assumptions and Results), the main functions and outputs of which are described in the next sections. Default values are provided for each parameter defining a hypothetical road concession project. The user can change the parameter values using the arrow keys (scroll bars) provided in the Data Sheet and Cash Flow Sheet (or any of the other graph sheets), to define the project to be financially assessed.

The **Data Sheet** (Figure 1) summarizes the main characteristics (assumptions) of the PPP project. A few assumptions, identified by arrow keys, can be changed using this sheet. The other key characteristics can be changed directly from any of the graph sheets.

Two types of loan repayment are incorporated in the model:

- P+I constant: A constant amount (including Reimbursement of Capital and Interest) is paid each year;
- Linear: The same amount of capital is reimbursed each year. The interest is calculated from the non-reimbursed capital.

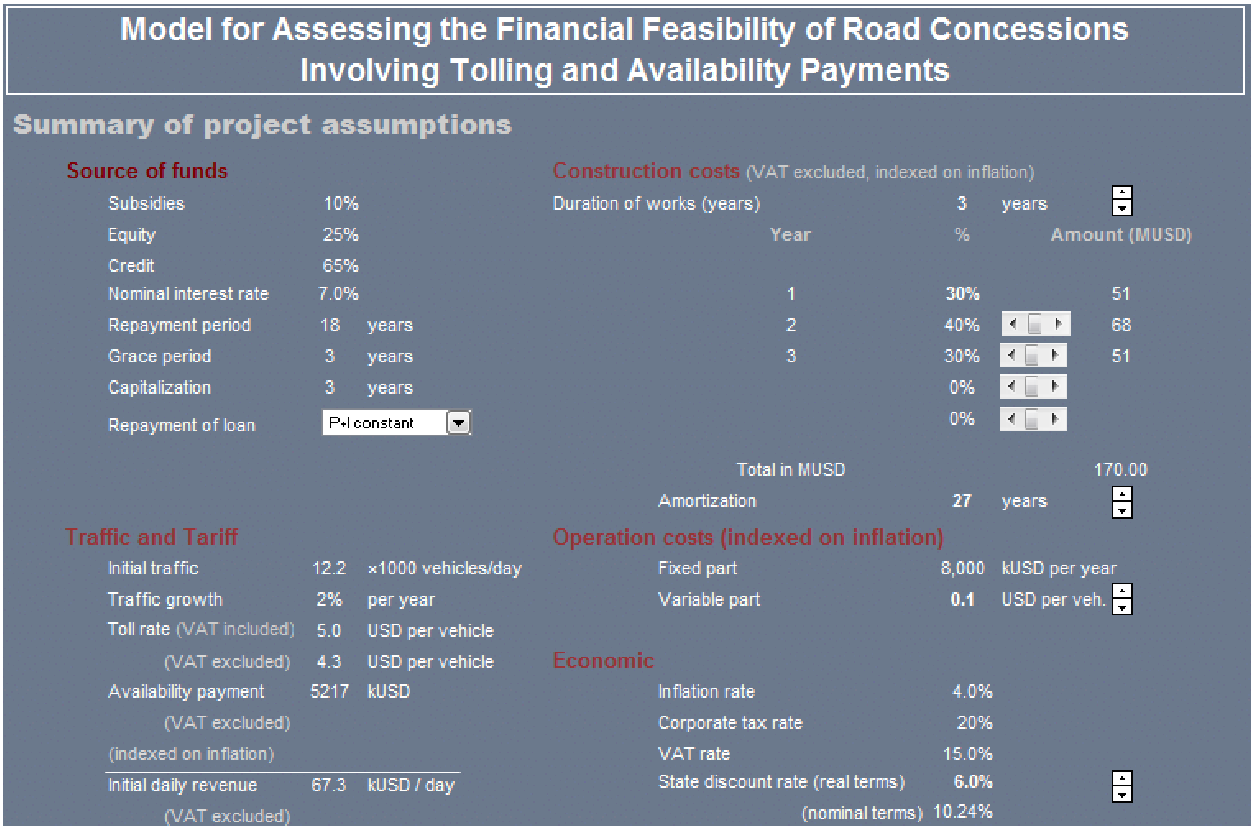

Fig. 1.
Data Sheet

The duration of works can vary from 1 to 5 years. The user enters the duration of works and default values for distribution of works are displayed. The user can modify the default values by using the scrolling bars. The percentage of the first year is calculated as: 100% - sum (% year 2 to % year 5).
The capitalized items are assumed to be depreciated on a straight-line basis throughout the amortization period. The amortization period is equal to, or less than, the difference between the concession life and the construction period.
The operation costs include all operating and maintenance costs that are incurred during the operation period (i.e., from completion of the construction period until the end of the concession period). The operation cost is expressed in terms of the annual equivalent amount of all operation, maintenance and rehabilitation costs during the operation period. The operation costs are adjusted for inflation every year.
State discount rate is the rate used to calculate the present value (PV) of government cash flows. The user should input the state discount rate in real terms (DR_r). The model then computes the state discount rate in nominal terms (DR_n) through the formula:

$$DR_n = DR_r + \text{Inflation} + DR_r \cdot \frac{\text{Inflation}}{100} \tag{1}$$

The **Cash Flow Graph** (Figure 2) represents the concession company cash flows during the concession period. They are classified by order of repayment priority: Operation costs > Taxes > Debt service > Dividends > Shareholders account.
The shareholder account represents a bank account controlled by the company shareholders (fiscal restrictions generally limit the authorized distribution of dividends to the project net income) to which the cash balance is transferred (or drawn from if negative) until it can be distributed as dividends.
When the shareholders' account is insufficient to service the debt, shareholders have to fill the gap and this appears in the graph in the form of negative dividends.
The **Debt Graph** (Figure 3) represents, for the first 30 years of the concession period, separately on the left and right vertical axes, respectively:

- Annual payment of principal and interest during the debt servicing period (grace period + repayment period);
- The two main bank ratios over the repayment period: Annual Debt Service Coverage Ratio (ADSCR) and Loan Life Coverage Ratio (LLCR).

The ADSCR represents, for any operating year, the ability of the project company to cover/repay the debt taking into account the assumptions made in the model. This ratio is determined as follows:

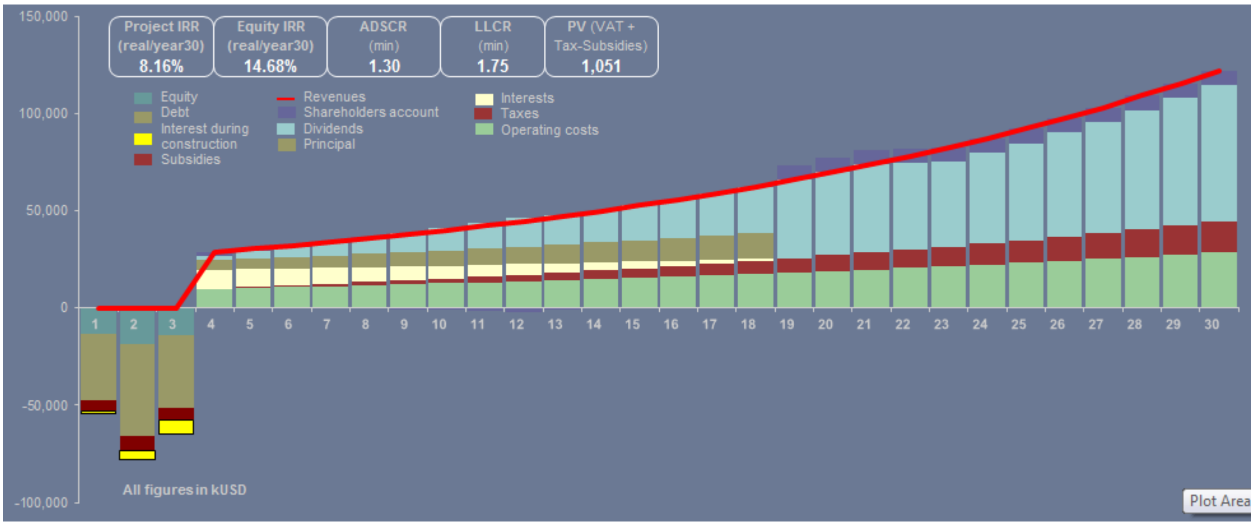

Fig. 2.
Cash Flow Graph

$$ADSCR_i = \frac{CBDS_i}{DS_i} \tag{2}$$

where:
CBDSi - the net cash flow before debt service in year i (i.e., the amount of cash remaining in the project company after operating costs and taxes have been paid), and
DSi - the debt service to be paid in year i (principal and interests).

The project is considered viable for the lenders when the ADSCR is greater than 1. If a margin of say 20% is deemed appropriate, then the ADSCR should be at least 1.20, for every year of the project life. This means that if, for whatever reason, the project revenue is 20% below what has been forecast in the financial model for a given year, the project company should still be able to repay the debt in that year. In high risk circumstances, a minimum ADSCR of 1.4 is sometimes used.
The LLCR indicates, for any operating year, the capacity for the project company to bear an occasional shortfall of cash while maintaining its debt service to the end of the debt. This ratio is calculated as follows:

$$LLCR_i = \frac{NPV(CBDS_i \rightarrow end)}{DS_i \rightarrow end} \tag{3}$$

where:
NPV (CBDSi→end) - the present value of the net cash flow before debt service from year i to the end of the debt repayment period, and
DSi→end - the total of debt service remaining at year i (principal and interests).

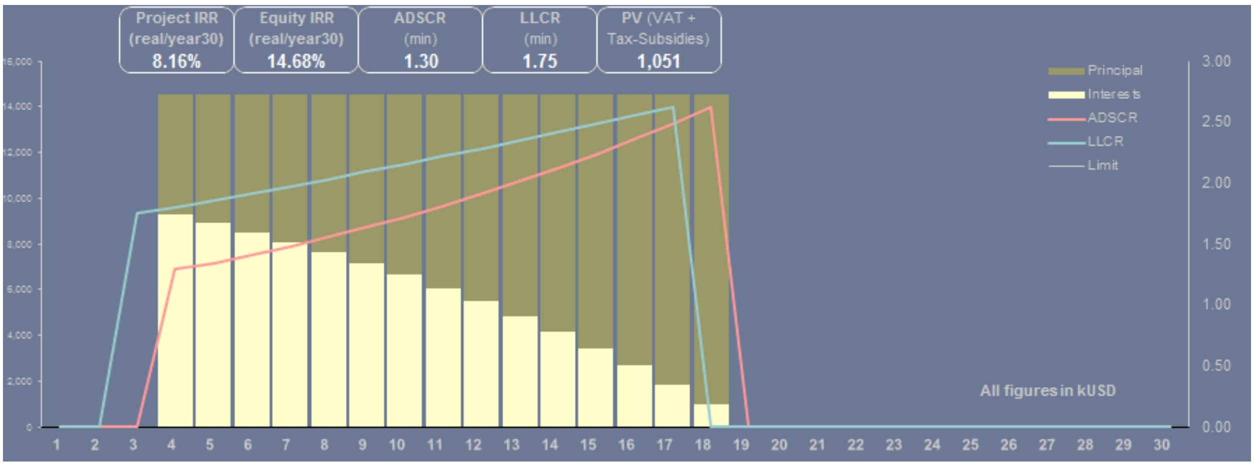

Fig. 3.
Debt Graph

The project is considered viable for the lenders when the LLCR is higher than 1 (in practice usually higher than 1.3) for every year of the project life. The ADSCR and LLCR are used by the lenders to check the project capacity to repay debt in adverse scenarios, including if revenues are below forecasted levels. Nominal interest rate is used to calculate the annual interest paid.

The **Dividend Graph** (Figure 4) displays, for the first 30 years of the concession period, respectively on the left and right vertical axes:

- The equity mobilized by company shareholders during the construction period and the dividends received by them during the operation period.
- The two main financial indicators over the concession: the financial Internal Rate of Return of the project (Project IRR) and the Equity IRR.

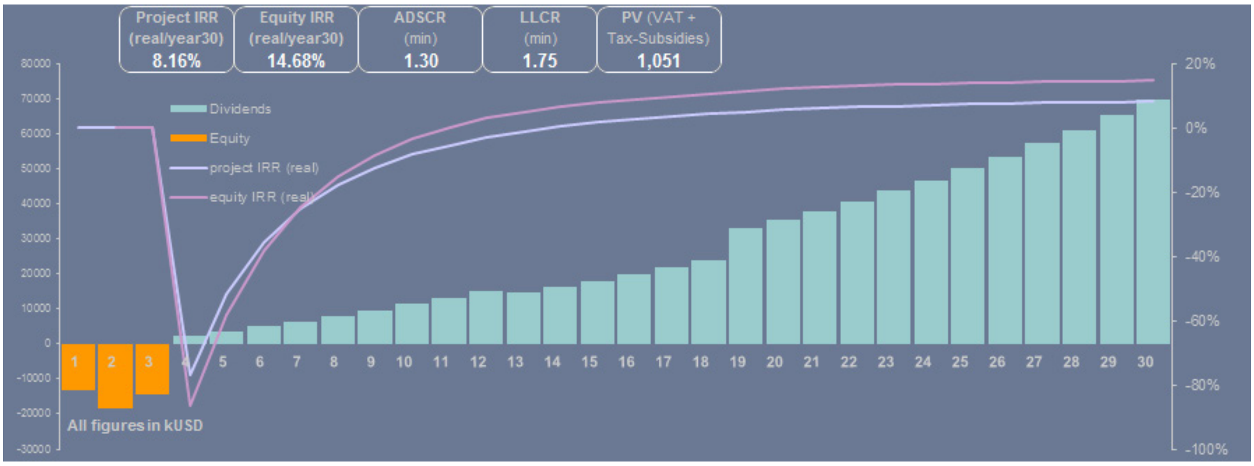

Fig. 4.
Dividend Graph

The model allows a rapid verification that Project IRR is independent from the project financial structure (i.e., the proportion of subsidies, equity, and loan) while Equity IRR is directly related to it.

The assumptions and results of the project financial assessment are summarized on the **Summary of Assumptions and Results** sheet, presented in Figure 5.

SUMMARY OF THE MAIN ASSUMPTIONS

GENERAL

Concession life	30	years
Construction Period	3	years
Construction costs	170,000	kUSD
Amortization	27	years

FINANCIAL STRUCTURE

Subsidy	10%	of the construction costs
Equity	25%	of the construction costs
Debt		
Maturity	18	years
Interest rate	7.0%	
Grace period	3	years
Repayment of loan	P+I constant	

TOLL AND TRAFFIC

Toll, VAT included	5	USD per vehicle
Initial traffic	12,200	vehicles / day
Traffic growth	2.0%	

AVAILABILITY PAYMENT

Availability payment in the first year (VAT included)	6,000	kUSD

OPERATING COSTS

Fixed part	8,000	kUSD per year
Variable part	0.1	USD per vehicle

OTHER KEY PARAMETERS

Inflation rate	4.0%
Corporate tax	20.0%
VAT rate	15.0%

SUMMARY OF THE RESULTS

FINANCING PLAN

Uses (in kUSD)	**196,776**
Construction costs (nominal terms)	183,957
Capitalised Interests	12,819

Sources (in kUSD)	**196,776**
Investment subsidy	18,396
Equity	45,989
Debt	132,391

FINANCIAL RATIOS

Minimum ADSCR (Annual Debt Service Coverage Ratio	1.30
Minimum LLCR (Loan Life Coverage Ratio)	1.75
Minimum PLCR (Project Life Coverage Ratio)	2.91

SHAREHOLDERS' RETURN

Project IRR after tax (real terms)	**8.16%**
Project IRR after tax (nominal terms)	12.49%
Equity IRR (real terms)	**14.68%**
Equity IRR (nominal terms)	19.27%
Equity return period (years)	11

PUBLIC AUTHORITIES' FINANCIAL FLOWS

PV on Subsidy (kUSD)	-15,145
PV on the VAT (kUSD)	48,063
PV on the Corporate Taxes (kUSD)	26,004
PV on Availability Payments (kUSD)	-57,870
PV on the State revenues (kUSD)	**1,051**

Fig. 5.
Summary of Assumptions and Results Sheet

Each one of the three graphs (Figures 2 to 4) displays five key project financial indicators:

- Project IRR – the project financial Internal Rate of Return for the concession period (in real terms);
- ROE – the Return on Equity for the concession period (in real terms);
- Minimum ADSCR - the minimum Annual Debt Service Coverage Ratio;
- Minimum LLCR - the minimum Loan Life Coverage Ratio;
- PV – present value of the net financial contribution from government. The government pays the required annual availability payment (or annuities) to the concessionaire and may also pay subsidies during the construction period, and recovers corporate taxes and VAT during the operation period. The indicator shows the present value the financial balance for the government throughout the concession period. When PV is zero, the project is fiscally neutral for the government. If PV is negative, it is shown in red in the graph sheets. The tax amounts (corporate tax and VAT) are considered positive (for this purpose), while government payments are considered negative.

Fifteen key project characteristics (Figure 6) can be modified in any of the three graphs. Following any change in parameters, all the worksheets are automatically updated. The ranges of variables included in the model reflect realistic conditions in most projects. When required, such ranges can be changed by model specialists.

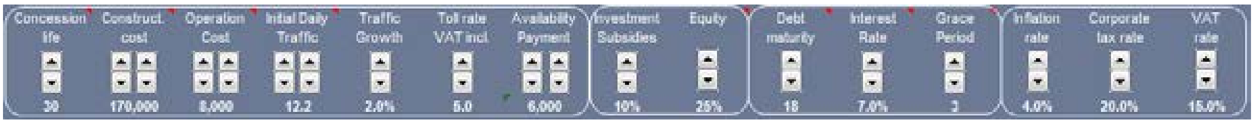

Fig. 6.
Key Project Characteristics

Comments are triggered by the model to inform of unrealistic or impossible data entries. For example, if the concession life is set at a value less than the debt maturity, a message is displayed to alert the user and the model automatically corrects the debt maturity to ensure consistency. Comments are also provided if results deemed unfeasible are obtained (e.g., ADSCR less than 1.2).

3. Numerical Example

Assuming that previous studies have shown that a proposed PPP project to build a road is economically justified, and socially and environmentally sound, the following numerical example shows how the financial model can be used to estimate the minimum Annual Availability Payment that a potential concessionaire will require from the government to undertake the project. Table 1 provides a summary of data for the proposed PPP project.

Table 1
Example of basic assumptions used to estimate the minimum availability payment for a PPP project to attract private investors

A. Project Parameters
Concession term: 30 years
Construction cost: $170 million
Capital structure: Equity, 25%; Subsidies, 10%; Loans, 65%
Three-year construction period, with progress rates of:
Year 1: 30%; Year 2: 40%; Year 3: 30%
Initial traffic: 12,200 vehicles per day
Traffic growth rate: 2%
Maximum acceptable toll rate (VAT included): $5.0 per vehicle per 100 km
Operating expenses: $8 million per year (at opening year) plus variable expenses of $0.1 per vehicle
Discount rate (real terms): 6%
Inflation=4% per year
Tax rates: (a) VAT: 15%; (b) Corporate tax: 20%
Amortization period: 27 years
B. Loan Terms
Nominal Interest rate=7% per year
Loan grace period: 3 years;
Loan repayment period=15 years

Let us also assume that the following targets (or constraints) will have to be met for the project to be able to attract private investors:

- Equity Internal Rate of Return (or Return on Equity): ROE $\geq$ 14%

- Annual Debt Service Cover Ratio: ADSCR ≥ 1.2.

The model can now be used to estimate the minimum Annual Availability Payment that a potential concessionaire will require from the government to undertake the project. As a first step, the user should enter the data provided using both the Data and the Cash Flow Graph worksheets.

The user can now go to the Cash Flow Graph and obtain the minimum Annual Availability Payment ($ million) by trial and error, by varying the Availability Payment so that the financial indicators calculated by the model are equal to or just above the minimum required threshold for ROE and ADSCR. By doing this, the user should find that an Availability Payment of $6 million (VAT included) is the minimum amount that would satisfy the two indicators.

In conclusion, an Annual Availability Payment of $6 million (in the first year of operation, in present value terms); payments in subsequent years would be adjusted according to inflation) should be able to attract private investors. The corresponding two financial indicators are ROE = 14.68%, and ADSCR = 1.3.

The financial model, as currently developed, does not directly address the uncertainty in model parameters, such as construction cost and traffic and revenue forecasts. Nevertheless, the model can be used to carry out sensitivity analyses. The user can change the value of an input parameter (e.g., construction cost) and obtain the resulting impact on the financial indicators. For example, if the construction cost increases to $200 million, ROE would reduce to 11.92% and ADSCR to 1.06, which would turn the project not financially feasible (according to the financial targets adopted above).

Similarly, the amount of availability payment can be adjusted to keep the project financial indicators at an acceptable level. Table 2 and Figure 7 present the needed availability payment if construction cost varies in the range from $140 million to $200 million.

Table 2
Needed availability payment as a function of construction cost

Construction cost (MUSD)	Availability payment (MUSD)	Project IRR (%)	Equity IRR (%)	ADSCR	LLCR
140	2	8.17	14.47	1.24	1.73
155	4	8.17	14.59	1.27	1.74
170	**6**	**8.16**	**14.68**	**1.3**	**1.75**
185	8	8.16	14.76	1.32	1.76
200	10	8.15	14.83	1.34	1.76

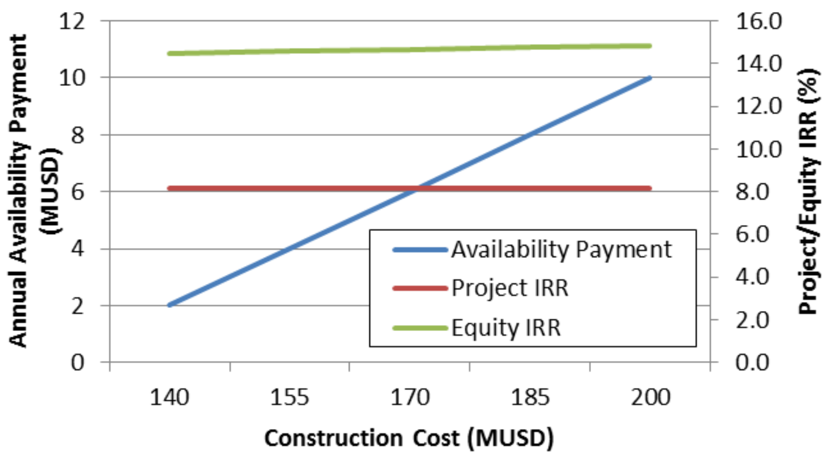

Fig. 7.
Variation of needed Availability payment with change of construction cost

Such a simplified model is particularly useful when only preliminary project data is available.

4. Summary and Conclusion

This paper focused on availability payments (also called annuities, as in South Asia), as a complement to toll revenues, where such revenues are not enough for the project to attract private partners. This would occur, for example, because of relatively low traffic volumes and/or toll rates. The paper presented the development of a user-friendly model to assess the financial feasibility of road concessions that include tolling and availability payments. The tool is based on the graphical financial model of the Toolkit for Public Private Partnership in Roads and Highways, which was developed by the World Bank.

Based on a comprehensive related literature review, it appears that the new model will fill an important gap in the set of tools available for the financial assessment of road PPPs or concessions.
A practical application of the model was demonstrated in the paper. For a set of road project parameters, traffic volume and maximum acceptable toll rate, the model was used to estimate the minimum availability payment that would be required for the project to attract private sector interest, that is, potential bidders in a competitive bidding scenario. The model can also be used to carry out sensitivity analyses. The user can change the value of an input parameter (e.g., construction cost) and obtain the resulting impact, for example, on the investor's return on equity and annual debt service cover ratio. Such a simplified model is particularly useful when only preliminary project data is available.

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PROPOSAL FOR SUITABLE METHOD TO EVALUATE THE PUBLIC PASSENGER TRANSPORT ENTERPRISES' ECONOMIC SITUATION

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Abstract: The paper deals with the fundamental parameters to evaluate the public passenger transport enterprises' economic and operational activities which may result in the entire management optimization of such enterprises. The essential data utilized to evaluate these activities involves the enterprises' balance sheets and the profit/loss reports. The most important part of the paper contains a description of the significant economic value added indicator and a proposal for modeling enterprise's prices per 1 km traveled for a certain period of time. The objective of this model is to settle up the enterprise in terms of economic requests and ensure the suitable system of public passenger transport. After the comprehensive transport enterprise's economic situation evaluation applying the procedure proposed within this research study, enterprise may identify the proper way how to eliminate the risk factors related to enterprise's poor economic situation or could positively affect its financial situation in next periods at least. The proposed method may be utilized as a pattern to be implemented within any financial analysis and the transport enterprise's economic situation assessment.

Keywords: public passenger transport, economic evaluation, economic value added method, transport enterprise, transport services.

1. Introduction

Aim of public passenger transport enterprise is to provide transportation services of a city area and regional territory according to the EU legislation, Czech Republic legislation and corresponding regulations and measures of local government and state entities complying with the quality standards of each transport mode, and transportation performances as well as public budget funds appropriate utilization (Gogola and Veterník, 2015), (Suleimanov *et al.,* 2017).
The most important objectives of such an enterprise can be achieved applying an extensive cooperation among carriers, customers and state administrations, and implementing the closer cooperation among regional transport offices (Wegelin and von Arx, 2016), transport experts, public as well as transport academicians and researchers. The fundamental function to accomplish the aforementioned aim is to ensure effective spending funds in terms of providing transportation services and related activities (Jurecki *et al.,* 2017).
In regard to public passenger transport enterprise, financial saving may be achieved mainly through (Fontes et al., 2016), (Košťálová, 2011), (Song *et al.,* 2018):

- streamlining transport line/connection routings within the urban area according to neighboring transport territories and increasing the number of transported passengers including journeys to first transfer,
- providing closer transport connections to private enterprises, shopping malls, stores, etc.
- streamlining the insufficiently used transport connections,
- using innovative and smart technologies and systems while transport operation,
- permanent affecting employees to optimize the operation and transportation, contract changes in terms of repair and purchase of spare parts including internal accounting and invoice issuing, etc.

In addition to cost saving, transport enterprise may continue to gain a profit, particularly through (Gong and Jin, 2014), (Hlatka *et al.,* 2017), (Poliaková, 2014):

- providing consulting services within public passenger transport (through processing research studies, performing traffic surveys, etc.),
- providing additional (value-added) services (advertisement, irregular transport services, rental of transport and handling equipment, service/repair activities, fuel station operation, offering parking spaces, etc.),
- participation within decision-making in terms of integrated transport system establishment,
- providing transport engineering solutions,
- scientific-research activities (scientific projects proposal, scientific manuscripts publication, etc.).

2. Data and Methods

In regard to dividing all the cost units related to accounting public budget funds per a calculation unit (CZK/traveled km), it may be stated that given public transport enterprise can establish the strategy specified within text below.

2.1. Costs Analysis Example

As an example, share of specific cost units' values of overall cost values per CZK/traveled km of particular public transport carrier in certain years are summarized, as follows (Table 1).

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Table 1
Example of a Share of Specific Cost Units' Values of Overall Cost Values per CZK/Traveled km

								Comparison with other carriers [%]
Specific cost units	2013 [CZK]	2014 [CZK]	2015 [CZK]	2016 [CZK]	2017 [CZK]	2018 [CZK]	Share of cost unit for particular carrier in 2017 [%]	Share of cost unit for other carriers in 2017 [%]
Fuel cost	10.45	11.25	12.65	12.13	13.17	13.41	24.00	22.01
Labor cost	11.4	11.03	10.17	11.35	11.59	13.23	21.12	22.00
Service cost	10.44	9.61	8.64	8.80	8.97	10.86	**16.35**	**4.87**
Overheads	7.08	7.37	8.41	8.17	7.87	6.83	**14.34**	**9.8**
Overall costs	**56.58**	**54.71**	**53.43**	**54.74**	**54.86**	**61.35**		

Source: authors

As already stated, aforementioned table presents an example of share (percentage) of specific cost units' values of overall cost values per CZK/traveled km ordered within the profit and loss account related to transport activities of particular public transport enterprise compared to other similar public transport carriers in the Czech Republic. Moreover, these specific factors provide a clear and sophisticated comparative (benchmarking) statistical report of cost units' values structure.

Whilst cost units, such as labor cost, travel expenses, fuel cost, tire casing cost, etc., are comparable and do not differ by more than 2% compared to other carriers in terms of their share of overall costs, the service cost demonstrates an extreme difference in terms of its share of overall costs of the particular carrier where the share value of about 16% was achieved compared to 5% regarding other carriers. Similar deficiencies may be appeared in terms of overheads with a difference of about 4.5% between examined shares. Similar statements and outcomes are outlined by several research studies (Batarce and Galilea, 2018), (Bokor, 2013), (Burguillo *et al.,* 2017), (El-Geneidy *et al.,* 2016), (Li and Preston, 2015), (Takahashi, 2017), and thus they confirm or support our findings.

2.2. Economic Value Added Method

Economic Value Added method (EVA) may be utilized, among other purposes, also to evaluate the transport enterprise performance as well as its economic situation. This method (indicator) was designed in 1993 by the American enterprise Stern Stewart Management Services (Holian and Reza, 2011). Determining this indicator value consists in specifying the difference between the operating profit/loss net compared to the overall corporate income tax.

Average capital cost can be defined as the utilization of foreign and private capital (equity) by the enterprise associated with the equity and foreign capital cost. Each corporate unit (function) can have separate overall capital structure.

Nowadays, it is usual to procure the foreign capital through loans (mortgage), since it is basically cheaper for lots of enterprises compared to equity to a certain value if tax shield functions and shareholders risk chance is not so large. Generally, the larger foreign capital value is achieved, the bigger returned investments are required from shareholders. The reason consists in a risk of foreign capital non-payment through these loans or somehow else. EVA indicator value can be calculated (Arsenio and Ribeiro, 2015), (Jaroš and Švadlenka, 2015), (Le Pira *et al.,* 2017), (Lyamkin *et al.,* 2017), (Sochor *et al.,* 2015), as follows (Eq. 1):

$$EVA = NOPAT - WACC * C$$
$$NOPAT = (EBIT * (1 - t)) \quad (1)$$
$$WACC = r_d * (1 - t) * D/C + r_e * E/C$$

where:
NOPAT – *Net Operating Profit after Taxes;*
WACC – *Weighted Average Cost of Capital;*
C – *total payable capital/overall Costs;*
t – *corporate tax rate;*
EBIT – *Earnings before Interest and Taxes;*
r_d – *interest rate paid from payable foreign capital;*
D – *Debts/interest-bearing foreign capital;*
r_e – *required return on equity;*
E – *Equity/private capital.*

3. Results

Economic value added prerequisite is to achieve bigger profit from the total capital invested compared to the capital costs. Basically, it represents all obligations payment to shareholders, banks, etc. Three alternative option regarding EVA indicator may occur (Arsenio and Ribeiro, 2015), (Liu and Wang, 2017), (Salaga, 2016):

$EVA > 0$ enterprise generates a value for owners (over profit),
$EVA < 0$ enterprise value is diminished,
$EVA = 0$ capital investment returns without certain interest.

As an example, specified EVA values in given Czech public transport enterprises in 2017 are listed (based on its absolute value in ascending order) in following Table 2.

Table 2
Example of Specified EVA Values in Particular Public Transport Enterprises in 2017

Public transport enterprise	EVA indicator - absolute value [thousands of CZK]	EVA indicator - relative value [%]
ROPID - Prague	-4,086,689	-6.53
KODIS - Ostrava	-432,354	-9.46
KORDIS - Brno	-241,465	-4.72
Transport enterprise of Liberec and Jablonec nad Nisou	-98,437	-8.54
JIKORD - České Budějovice	-86,716	-10.67
KIDSOK - Olomouc	-78,733	-11.53
Transport enterprise of Most and Litvínov	-77,574	-14.71
Transport enterprise of Pardubice	-45,194	-9.87
DÚK - Děčín	-43,661	-13.05
OREDO - Hradec Králové	-34,165	-4.13
POVED - Pilsen	-26,889	-2.27
MHD Opava	-21,762	-9.48

Source: authors

In most cases, total technologies and ways overview in terms of service activities, provided transport services quality standards, transport line routings is necessary to indicate. If findings appear to be unfavorable, it is important to modify the current contract in these matters and continue to streamline the relevant operations, given the fact that all these evaluation factors are mostly considered the main reason to strengthen an interest in public passenger transport by passengers (Fadaei and Cats, 2016), (Šťastná and Vaishar, 2017).
The major assignment of transport enterprises is to provide and improve the transport connectivity among given transport territories (to enhance the transport process quality and entire traveling culture, delays abatement, etc.) at an acceptable (adequate/optimal) costs/prices for customers (Zitrický et al., 2016). Thus, one of the fundamental criteria in order to increase the demand for public passenger transport is to model the overall costs values to determine an optimal charge (price) per 1 km traveled (see Table 3) for a certain time period (2017-2023).
Modeling within this case study is performed in 3 levels, of 1, 3 and 5% of possible inflation level. Table 3 does not take into consideration possible saving to abate the overheads (including service cost) of the particular transport enterprise.

Table 3
Model of the Overall Costs Values to Determine an Optimal Charge per 1 km Traveled for Years 2017-2023

Inflation level	Overall costs value in particular year						
	2017	2018	2019	2020	2021	2022	2023
1 % increase	54.86	55.51	56.07	56.68	57.17	57.70	58.38
3 % increase	54.86	56.63	58.39	60.04	61.80	62.44	63.06
5 % increase	54.86	57.74	60.62	63.68	66.79	67.43	68.11

Source: authors

In regard to public passenger transport performance, no significant increase regarding the volume of km traveled is anticipated. The main objective is to streamline the enterprise in terms of financial demands and provide adequate public passenger transport system.
This may be ensured by gradual abatement of service cost values. Tables 4 and 5 below present the model of overall operational costs values per 1 km traveled depending on the development trend of service cost values abatement while increasing the inflation level. 2017 is considered the benchmark year.

Table 4
Gradual Abatement of Service Cost Values According to the Development Trend for Years 2017-2020

Year / Trend	2017	2018	2019	2020

Development trend, i.e. annual abatement of service cost values by 0.78 CZK	8.97	8.19	7.41	6.63
Difference in abatement		-0.78	-0.78	-0.78

Source: authors

Table 5
Model of the Enterprise's Saving Related to Service Cost Values Abatement While Increasing the Inflation Level Compared to Original Model

Inflation level	Model of the enterprise's overall costs values per 1 km traveled for a given year			
	2017	2018	2019	2020
1 % increase	54.86	54.73	54.51	54.34
3 % increase	54.86	55.85	56.83	57.70
5 % increase	54.86	56.96	59.06	61.34

Source: authors

As can be seen, relatively significant enterprise's saving (compared to original model outlined in Table 3) may be achieved until 2020 when taken into consideration above principles.
All the data in previous tables demonstrates the expected abatement of the overall costs per 1 km traveled in connection with the service cost values abatement (Sierpinski, 2017). This model represents the crucial stage for the particular transport enterprise economic situation future development (Černá and Mašek, 2015), (Jurkovic and Sosedova, 2013), (Tuero et al., 2017).

4. Conclusion

This research case study takes into consideration an option to evaluate an economic situation of the particular public passenger transport enterprise. A specific evaluation model was performed on the basis of publicly available data from certain reports related to economic data. In regard to this enterprise's economic health assessment, suitable method (model) to minimize economic risk factors resulting in the enterprise's poor economic situation as well as possibly favorably influence its economic situation in next time periods was designed. This method may be utilized as an example to be implemented within processing a general financial analysis and transport enterprise's economic health assessment as well.
Due to permanent need to monitor a current transport enterprise's economic situation, primarily considering its engagement within the complex of transport-logistics services, this evaluation may also be utilized as a reference document for potential customers in order to choose an appropriate transport service provider.
Transport enterprise's economic situation assessment and view to enterprise's management within 5-year time period, processed within this research study, require to elaborate transport services plan for their transport territories from individual concerned entities.
When evaluating several enterprises economic situation at the same time, selected methods of the operations research may be applied to compare and classify them.

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THE ASSESSMENT OF THE QUALITY OF SELECTED PUBLIC SPACES IN THE CITY CENTER OF KRAKOW AND GDYNIA

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Abstract: Sustainable urban mobility planning focuses on satisfying people's travel needs and improving their quality of life. The quality of life is related, among others, to the quality of the space in which people live, rest and socialize. It is particularly important to properly shape and develop the space located in the city center, which can be achieved through the implementation of restrictions on car parking and car traffic. With these and other similar solutions in place, public space becomes more pedestrian- and cyclist-friendly, while its overall aesthetics is improved as a result of the revitalization activities that often accompany such restrictions. In spite of this, car restrictions often meet with social opposition, thus all evidence of their positive effects - also related to the improvement of public space quality - should be widely disseminated in order to build social awareness and acceptance of their implementation. This paper presents the results of a survey research study carried out in the city center of Krakow and Gdynia to assess the quality of selected city squares and streets in which car traffic and parking restrictions have been implemented. A brief description of the analyzed public spaces – six areas in Krakow and one in Gdynia – is provided, followed by a description and discussion of the results. The study results indicate that most users do not experience problems in accessing the analyzed public spaces and they positively assess their quality. In particular, respondents appreciate the rich offer of commercial and service facilities as well as the visual aesthetics and values of a given place.

Keywords: public space quality, car restrictions, sustainable mobility, transport accessibility, subjective assessment, smart city.

1. Introduction

Planning urban mobility based on the 'Sustainable Urban Mobility Plan' (SUMP) concept is the result of a strategic approach to defining issues related to urban development (Wołek, 2015). The goal is to provide city residents with unrestricted mobility, access, communication, trade and networking in a way that does not disturb social, environmental or economic welfare (World Business Council for Sustainable Development, 2004). The sources of such planning should be sought, among other things, in the need to respond to the challenges and problems of modern cities, related to: the growing urbanization rate, demographic changes, the expansion of city areas, or the excessive use of cars (including pollution and noise, urban degradation through road investments, traffic congestion and its effects, etc.) (Banister, 2005).

At the heart of the SUMP lies man and his needs, while the actions implemented in its scope are to contribute to the improvement of man's quality of life (Wefering, 2014). Additionally, El Din, Shalaby, Farouh and Elariane indicate that: '*Improving the quality of life in cities is no longer a simple matter of bricks and mortar, but the human satisfaction with different urban attributes such as transportation, quality of public spaces, recreational opportunities, land use patterns, population and building densities, and ease of access for all to basic goods, services and public amenities' (El Din et al., 2013).* According to this statement, the quality of life in cities is determined, among others, by the accessibility of public spaces and their quality. This is also confirmed by Adams (2013) and Markowski (2007). Public space is a space to which everyone has easy access, and in which interpersonal interactions take place or can take place (Bierwiaczonek, 2016), a space open to people's freely chosen and spontaneous activities (Lynch, 1960). Public space is a place of meetings and establishing social ties that make up the cultural backbone of the city, enabling residents to identify with it (Wojnarowska, 2016). Depending on the shape and functions, the following types of public spaces can be distinguished: squares, streets, roads, public property buildings, as well as parks, greeneries, boulevards (Budner, 2016). Lansing and Marans (1969) argue that a high-quality public space conveys a sense of wellbeing and satisfaction to its population through physical, social or symbolic related characteristics. Other studies on public spaces also indicate that their quality is determined by a number of factors (Adams, 2013, Jurkovič, 2014, Budner, 2016), both physical and social, objective and subjective, and only a combination of these elements translates into a high level quality (Wojnarowska, 2016).

First and foremost, a high-quality public space should be easily accessible and well-connected (Gdansk Development Office), so as to ensure ease of moving around, and therefore, the possibility of using various parts of the space. In addition, its high transport accessibility should be ensured by various means of transportation, in particular by public transit, by bicycle and on foot. Accessibility can be also facilitated by the appropriate design and ease of perception of information signs (Budner, 2016). A public space should be appealing, and its appeal is conditioned by factors such as: diversity of services and aesthetic impressions; appropriate compositional, urban and architectural activities; high standard, lack of barriers, variety of equipment (including street furniture, elements of art, elements of small architecture, etc.), as well as a multitude of events that take place within its boundaries: street theaters, visual art performances, concerts, fairs, etc. (Gdańsk Development Office). The high quality of a public space should guarantee a high level of personal security, including through appropriate lighting, monitoring and keeping the area clean (Wojnarowska, 2016), as well as transport-related safety, through eliminating potential hazards (e.g. removing barriers

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for disabled people, as well as points of collisions of different traffic users) (Budner, 2016). In addition, a public space should offer a harmonious distribution of architectural elements, greenery and leisure spots, and it should be clearly marked and easily identifiable (Gdańsk Development Office). It is also important to properly arrange the entrance zone in the peripheries of this space (in the form of shops, bars, cafés with terraces, etc.), which promotes a greater attendance of users (Gehl, 2014) and presence of people in public spaces, consequently attracting other people (Gehl, 2011).

Urban space management is an important aspect in the increasingly popular concept of smart cities. Land use demonstrates a significant correlation with the assessment of such cities. According to this concept, city centers should be arranged so that 'public spaces are organized and accessible, public transport and car traffic are limited' (Stawasz, Sikora-Fernandez, 2015). A key element in a smart city is smart living, whose priority in terms of development is public space, perceived as: the quality of residence, social cohesion, public safety, and social infrastructure. Another smart dimension related to public spaces is smart environment, where the share of 'green' mobility (non-motorized individual transportation) and the development of green areas as multifunctional city spaces are considered. The Smart City Council also points to the correlation between public space and smart cities by presenting ISO 37120 Sustainable Development of Communities: Indicators for City Services and Quality of Life as a new standard for smart cities (Smart City Council). The standard in question covers several indicators compiled in 17 categories, such as the environment, health, leisure, transportation, and urban planning. Some of these indicators refer directly to public spaces, e.g. green areas (in hectares) per 100,000 inhabitants or the number of kilometers of bicycle lanes per 100,000 residents (World Council on City Data).

Studies confirm the importance of high-quality public spaces for societies and individuals, and their relation to environmental quality and economic growth. These benefits concern the improvement of health of residents (Halpern, 1995; Regional Public Health, 2010), their security (Gehl, 2011), reducing harmful emissions (David Suzuki Foundation, 2015), as well as reviving local economics (Sandahl and Lindh, 1995; Antosiewicz, 2008) and increasing property values (Diao and Ferreira, 2010). Importantly, the high quality of a public space also translates into more social contacts (Gehl, 2014).

A special type of public space is a space located in the city center (Nosal et al., 2017), serving not only its residents, but also people coming from neighboring towns and tourists. This space performs a number of functions, including economic, social and cultural, and it is a showpiece of the city that creates its image and determines its attractiveness and competitiveness (Wojnarowska, 2016). It is, therefore, extremely important to ensure the high quality of public spaces in the city center. Originally, spaces in city centers were designed for pedestrians, but as the automotive industry developed, many were handed over to vehicles, having been transformed into transport routes, transit sections and car parks (Montgomery, 2013). This led to a significant reduction in the quality of space, and in many cases - even their degradation. Currently, the local authorities of many cities around the world are taking corrective actions aimed at restoring public spaces to their original functions and improving their quality (Montgomery, 2013). A frequent component of such activities is the introduction of restrictions on car traffic and car parking (Sadik-Khan and Solomonow, 2017). These activities are usually accompanied by the implementation of solutions to improve the conditions of travel on foot and by bicycle, as well as giving priority to public transport (Antosiewicz, 2008).

In many cases, the quality of a public space is improved by its renovation, comprehensive and cohesive design of new space development with the use of high quality elements of landscape architecture (Budner, 2016). Traffic and parking restrictions for cars, although considered an effective means of improving the urban environment (Gehl, 2014; Sadik-Khan and Solomonow, 2017), still meet with social opposition and remain one of the most sensitive and controversial aspects of urban transport policy (Garling and Loukopoulos, 2007). The objections on the side of both residents and other interested parties (including owners of commercial and service facilities) as to the introduction of restrictions most often spring from a negative perception of the future effects of such actions (Hall and Hass-Klau, 1985). Thus, all evidence of the positive results of these solutions - also related to the improvement of public space quality - should be widely disseminated in order to build social awareness and acceptance of their implementation.

This paper addresses the issue of improving the quality of public spaces by applying restrictions on car traffic and car parking. It presents the results of survey studies carried out among users of public spaces located in the city center of Krakow and Gdynia (Poland), in which these solutions have been introduced over the past years or past decades. The study considers the means of transportation used to access these spaces and the subjective feelings of respondents related to problems occurring during travel and selected aspects of the quality of space.

2. Survey Studies on the Assessment of the Quality of Selected Public Spaces in the City Center of Krakow

Krakow is the second city in Poland by number of residents and area, located in the southern part of the country. It is the main administrative center of Malopolska Province, one of the major academic and cultural centers in Poland and an important transport node in Europe. The city center of Krakow is a unique treasury of works of art, historical mementos and monuments. It also brings together a large number of cultural institutions, luxury stores and various types of service and catering facilities. Its area is successively implemented with solutions aimed at improving the quality of public spaces and giving them back to pedestrians. Six locations were selected to study the quality of public spaces in the city center of Krakow, including five that have recently seen rather radical changes in traffic organization, aimed at total or partial limitation of car traffic. These sites are:

- Mały Rynek [Little Market Square] (1) and Plac Szczepański [Szczepanski Square] (2) – urban squares, currently performing a cultural and recreational function; trade fair functions were withdrawn from both in the 1950s and the free space was arranged for urban car parks; in 2008, as part of the CiViTAS CARAVEL project, the two squares were included in the program 'Integrated Access Control Strategy in Krakow', which resulted in the liquidation of car parks, revitalization of their space and incorporating them into Zone B (there are 3 zones of restricted traffic and parking for vehicles in Krakow: Zone A - with access for pedestrians and cyclists, zone B - accessible only for residents of the properties located in the area and zone C - with parking fees for parking vehicles) (Rudnicki et al., 2010);
- Grodzka Street (3), one of the most popular and most frequently visited street in Krakow, being also one of its oldest; forms part of the Royal Road leading from the Main Square to the Royal Castle in Wawel; until 2013, the street was included in Zone B, with only residents and authorized vehicles having the right to access it; in 2013, it was incorporated into Zone A, with access allowed only for pedestrians, cyclists and horse-drawn carriages;
- Dunajewskiego Street (4), part of Krakow's first ring road; in 2008, as part of the CiViTAS CARAVEL project, it was included in the program 'Integrated Access Control Strategy in Krakow' program, and consequently incorporated into Zone B (Rudnicki et al., 2010); in 2015, the street was reconstructed – one of the car lanes was liquidated and one-way car traffic was introduced, while the recovered space was handed over to cyclists and pedestrians (a new bike lane and wider sidewalks); at the same time the traffic of public transport vehicles has been improved;
- Karmelicka Street – the study covered two sections of this street, namely: the section running from Garbarska Street to Dunajewskiego Street (5), marked Zone B for restricted car traffic since 2009, and for comparison purposes, the section running from Garbarska Street to Trzech Wieszczów Avenue (6), located outside Zone B, in Zone C, where parking charges are applied for cars.

The study was conducted on weekdays, in the afternoon, in the second half of June 2016. In all five locations, a total of 1848 questionnaire survey interviews were carried out (Table 1 lists the number of surveys carried out in individual locations). 57% of respondents were women, and 43% were men. Respondents were mostly people aged 18 to 25 and 26 to 40 (47% and 32%, respectively). People aged 41 to 50 accounted for 13% of the sample, while those aged 51 to 65 for 5%. People aged above 65 made up 3%. 1% of respondents were people with disabilities.
Table 1 presents the results of research on the means of transportation used in traveling to the examined spaces. Analyzing these results, it can be observed that most respondents reach these place either on foot or by public transit. On average, only 10% of journeys were made by car, and the largest number of their users were reported among those polled on Karmelicka Street. Bicycle trips accounted for between 4% and 9% of all journeys, which is a relatively good result for Krakow (according to the 2013 Comprehensive Traffic Study, the share of travels by bike to the city center is 1.9%).

Table 1
Modal split in trips to the analyzed areas of Krakow

	Grodzka	Mały Rynek	Plac Szczepański	Dunajewskiego	Karmelicka (Zone B)	Karmelicka (outside Zone B)
Number of respondents	498	300	300	197	264	289
Modal split in trips to the analyzed public spaces [%]						
On foot	58	32	50	44	23	45
By bicycle	4	7	9	6	6	4
Public transport	25	48	36	45	47	33
Car	10	4	3	5	22	16
Other	3	9	2	0	2	2

Source: Own study.

Respondents were also asked if they had any problems in accessing the analyzed areas. The vast majority had no problem getting to these spaces (94% for Grodzka Street, 96% for Mały Rynek, 96% for Plac Szczepański, 91% for Dunajewskiego Street, 92% for Karmelicka Street in Zone B, and 93% for Karmelicka Street outside zone B). On the other hand, people for whom access to these spaces was problematic most often indicated issues with traffic congestion. Other issues that were experienced concerned car access and car parking, lack of air conditioning in public transit vehicles, necessity of transfer, and long waiting time at a stop for a public transport vehicle. Interestingly, respondents who were users of Grodzka Street complained about too much pedestrian traffic.
Analyzing the results on the perceived quality of the examined spaces (Table 2), it can be concluded that for areas located inside or along the city's first ring road (all areas outside Karmelicka Street), the level of satisfaction is very high, with an average of 83.5%. For Karmelicka Street, located outside the first ring road, a much lower percentage of users are shown to be satisfied with the quality of the street – only about 50% said they were happy with it.
Two reasons for satisfaction in each of the examined spaces are their visual aesthetics and a wide range of commercial and service facilities (the latter is particularly important in the case of two sections of Karmelicka Street). As far as

Grodzka Street and Mały Rynek, user satisfaction is also guaranteed by the architecture and unique atmosphere of these areas, while Plac Szczepański scores high for the peace and quiet and the presence of a fountain. Respondents who were users of Dunajewskiego Street also pointed to peace and quiet, as well as the presence of greenery and good access to public transport. Interestingly, some respondents in spaces with limited car traffic (Dunajewskiego Street and Zone-B section of Karmelicka Street) associate the quality of these spaces also with small car traffic.

Table 2
Reasons for satisfaction with the quality of the analyzed spaces in Krakow.

	Grodzka	**Mały Rynek**	**Plac Szczepański**	**Dunajewskiego**	**Karmelicka (zone B)**	**Karmelicka (outside zone B)**
Percentage of users satisfied with the quality of space [%]						
Yes	87	81	81	85	53	49
No	13	19	19	15	47	51
Reasons for satisfaction with the quality of space [%]						
A wide range of commercial and service facilities	8	2	6	9	44	67
Easy access by car	-	-	-	-	10	7
Small car traffic	-	1	4	17	12	-
Convenience to travel on foot	7	-	-	11	7	6
Aesthetics	37	55	30	13	24	9
Architecture	24	9	-	-	-	-
Vibrant space, conducive to social gatherings	6	-	2	-	-	3
Good access by public transport (bike)	-	-	-	11 (6)	3	-
Peace and quiet	-	7	15	17	-	-
Greenery	-	-	4	10	-	-
Overall atmosphere	16	17	2	-	-	-
Fountain	-	-	30	-	-	-
Other	2	9	7	6	-	8

Source: Own study.

Among the most commonly cited reasons for dissatisfaction with the quality of all the considered spaces (Table 3), respondents mentioned little greenery, particularly for Plac Szczepański (where there is, indeed, not much greenery). An important reason for dissatisfaction with Dunajewskiego and Karmelicka Street was also their unappealing visual aesthetics, associated with advertisements and damaged facades of buildings, while in relation to Mały Rynek – the fountain, which, in the opinion of respondents, does not match the surrounding environment Additionally, the negative perception of the quality of Grodzka Street is also influenced by high pedestrian traffic and what respondents saw as an improperly designed infrastructure for cyclists (which prompts collisions with the traffic of pedestrians) and restrictions for motorized traffic. Respondents for Mały Rynek pointed to unreasonable development of the square and its poor infrastructure, whereas respondents for Dunajewskiego Street cited bad conditions for traveling on foot (low comfort and safety level) and pollution. It should be noted that a fairly high percentage of users complaining about the low quality of the considered spaces (from 30% to 41%) is not satisfied with the disruptive traffic of cars and their parking on streets where car traffic and parking is not prohibited, only limited (Dunajewskiego and Karmelicka Streets).

Table 3
Reasons for dissatisfaction with the quality of the analyzed spaces in Krakow.

	Grodzka	**Mały Rynek**	**Plac Szczepański**	**Dunajewskiego**	**Karmelicka (zone B)**	**Karmelicka (outside zone B)**
Reasons for dissatisfaction with the quality of space [%]						
Disruptive traffic and parking of cars			4	30	41	34
Too little greenery	12	28	73	13	24	26
Too few places to sit	7	7	4	3		
Visually unattractive space		24	7	16	13	24
Restrictions in the traffic and parking of cars	10	4	-	6	8	4
Improperly designed or lack	11	-	4	-	7	7

	Grodzka	Mały Rynek	Plac Szczepański	Dunajewskiego	Karmelicka (zone B)	Karmelicka (outside zone B)
Reasons for dissatisfaction with the quality of space [%]						
of infrastructure for bicycles						
Bad conditions for traveling on foot	-	-	-	12	3	2
Dirtiness	-	-	-	10	-	-
Too many people (horse-drawn carriages and electric carts)	45 (6)	6	8	-	-	-
Unreasonable development	-	18	-	-	-	-
Other	9	13	-	10	4	3

Source: Own study.

3. Survey Studies on the Assessment of the Quality of Selected Public Spaces in the City Center of Gdynia

Gdynia is a relatively young but fast-growing port city, located in the northern part of Poland. Gdynia, together with the historic city of Gdańsk and the seaside resort Sopot, make up Tricity (Polish: *Trójmiasto*), with a total of nearly 750,000 residents. Gdynia is perceived as a modern city, implementing new solutions in various spheres of life. In 2017, Gdynia was the first Polish city to receive the ISO 37120 certificate, also known as Smart City Standard (World Council on City Data). Gdynia promotes sustainable transportation and mobility by means of trolleybus and bicycles. Along with the entire metropolitan area, Gdynia is currently setting up the largest electric bike system in the world (Roads and Greenery Management Board in Gdynia). To enable the authorities to establish dialogue with the residents, the website *mobilnagdynia.pl* was launched, providing information on changes in the area of public spaces and transportation in the city. The website also allows residents to express their opinions and participate in surveys. Thanks to this website, the city could inform the residents about the introduction of restrictions for cars to improve pedestrian and bicycle traffic. To assess the quality of public spaces in Gdynia, Armii Krajowej Street, located in the very center of the city, was chosen. Over the last few years, the following changes in traffic organization have been made on this street:

- the number of parking spaces for cars was reduced to improve pedestrian traffic,
- the width of pavements was increased – parking spaces perpendicular to the street were transformed into parallel spots to give pedestrians more freedom in moving around,
- a paid car parking zone was introduced,
- a 30 km/h speed limit zone was introduced,
- bicycle counterlanes were designated in the vicinity (Antoniego Abrahama, Stefana Batorego and Jana Kilińskiego Streets).

The research was conducted on Wednesday, November 8, 2017, between 11 a.m. and 3 p.m.. A total of 135 survey questionnaires were obtained. 53% of respondents were women, and 47% were men. They were mainly young people aged 18 to 25 and 26 to 40 (34% and 20%, respectively). People aged 41 to 50 accounted for 17%, while those aged 51 to 65 - 13%. People aged above 65 accounted for 16%. 2% of respondents were people with disabilities.

The research shows that respondents most often traveled to the study site by public transport (41.5% of respondents). The next group (34%) was represented by people reaching the site on foot. As for individual means of transportation, a significant part of respondents used the car – 22%, while people traveling by bicycle accounted for only 1.5% of the sample. Among other methods of travel, taxi was mentioned, accounting for 1% of the journeys. Comparing the results with the city's modal split (Wołek, 2016), it can be observed that the share of pedestrians is three times higher in the center than for the city as a whole, whereas the share of cars is two times lower, the share of public transportat is higher by a few percentage points, and the share of using bicycles remains equally low.

In the study, respondents were asked about problems related to reaching Armii Krajowej Street. Most (84%) did not indicate any such problems, while others complained about the lack of car parking spaces, traffic congestion, a large distance to cover from the car parking place to the destination, and significant car parking charges. Those who voiced these concerns were mainly car drivers, who parked at a distance of 100-1,500 meters from the study site at paid parking places.

The key issue of the study was to get to know the respondents' opinions about satisfaction or dissatisfaction with the quality of the public space at Armii Krajowej Street. 83% of respondents expressed satisfaction with the quality of that space, and only 17% – lack of satisfaction. Respondents were particularly satisfied with the rich offer of commercial and service facilities (31% of reasons), and the proximity of travel sources and destinations – 24% (Table 4). Respondents also assessed positively the transport accessibility, pointing to effective public transport and the proximity of bus stops. A pleasant atmosphere and visual aesthetics in the city center of Gdynia were also considered important. In addition, respondents indicated satisfaction with coastal values, such as the boulevard or the city beach.

Table 4

Reasons for satisfaction and dissatisfaction with the quality of Armii Krajowej Street in Gdynia.

Reasons for satisfaction with the quality of space	[%]		Reasons for dissatisfaction with the quality of space	[%]
A wide range of commercial and service facilities	31		A small number of car parking spaces	24
Proximity of travel sources and destinations	24		Too many people	24
High public transport accessibility	11		Significant car traffic	22
Pleasant atmosphere	9		Too few cafes	8
Aesthetics	6		Too few benches	8
Seaside boulevard	6		Other	8
Other	6		No proper marking of pedestrian crossings	6
City beach	4			
Architecture	3			

Source: Own study.

On the other hand, the most commonly cited reasons for dissatisfaction with the quality of Armii Krajowej Street concerned a small number of car parking spaces, too many people on sidewalks and premises, and high car traffic (24%, 24% and 22%, respectively) (Table 4). The remaining respondents complained about too few cafes and benches to have a rest. Some respondents also indicated improperly marked pedestrian crossings.
Comparing the problems in reaching Armii Krajowej Street and the reasons for the satisfaction and dissatisfaction of respondents with the its quality, two opposing groups can be distinguished: 1) drivers, who mention problematic parking and the long distance to cover on foot after parking their car, and 2) people traveling on foot and by public transport, who are satisfied with the public transport offer, but not satisfied with large car traffic.

4. Discussion and Conclusions

Krakow and Gdynia are cities with a very different population, space, spatial layout and transportation network. However, deterioration of the quality of life caused by the increase of congestion, air pollution and excessive occupying of public space by cars have propelled the search for new transport solutions in both cities. In Krakow and Gdynia, initiatives are taken to promote public transport, cycling and walking, combined with the introduction of restrictions on car traffic and car parking.
This study finds that, despite the existence of car restrictions in both cities, a very high percentage of respondents indicate having no problems in accessing the analyzed areas. They reach the city center mostly using sustainable forms of transportation, i.e. they travel on foot, by public transport, or by bicycle. People for whom access to the city center is problematic point to troublesome traffic congestion, with drivers mentioning the insufficient number of car parking spaces the large distance to cover on foot from the car parking space to the destination.
Also noteworthy is the fact that the vast majority of users of public spaces positively assess their quality. The main reasons for satisfaction are the rich offer of commercial and service facilities as well as the visual aesthetics and values of a given place. It should be added that, in Krakow, the most common reasons for dissatisfaction with the quality of all considered spaces included little greenery, which should be an indication for the City Authority in terms of future activities. Furthermore, it should be noted that quite a high percentage of Krakow respondents complaining about the low quality of space (from 30% to 41%) is not satisfied with the disruptive traffic of cars and their parking on streets where car traffic and parking are not prohibited, only limited.
Analyzing the results of this study, the effects of the introduced car restrictions to improve the quality of public spaces in the city centers of Krakow and Gdynia should be assessed positively. A very high percentage of users who do not experience issues with accessing the analyzed areas and who are satisfied with their quality should encourage other cities to implement similar solutions.

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DEALING WITH VANDALISM IN URBAN TRANSIT NETWORKS – A PRESENT-DAY PROBLEM FOR INFRASTRUCTURE AND OPERATION

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Abstract: Initially a negligible phenomenon of the past century, vandalism has become a not negligible problem in Vienna's urban transit network after the millennium. This paper provides scientific background information on the topic and displays the hazard potential of vandalism. A scientific study conducted in 2014 evaluates the steadily increasing cases of graffiti-vandalism on trains of the Vienna underground network. However, acts of vandalism do not only affect trains but also stations of the urban transit network. That is why a follow-up study from 2017 investigated causes, impacts and handling of vandalism in stations of Vienna's urban transit network. Since there was no comprehensive data of vandalism-cases available, a data collection for all Viennese Underground stations was initiated and a database differing type, place, size and surface-material was generated. Further types of vandalism beside Graffiti-Vandalism were assessed: smearing, etching, scratching, breaking and destroying infrastructure's surfaces. Connections between the cases of vandalism, the passenger frequency, the geographical location of the station and the type of station surveillance were evaluated. Wiener Linien's strategy of not putting vandalised trains into service is justified from an economic and safety-focused point of view. This strategy is not applicable for stations because infrastructure cannot be easily closed. Damaged surfaces can be cleaned, repaired, painted or must be replaced. As opposed to now, it is highly recommended that all actual costs related to the 'trains and stations' repairs have to be taken into account when talking about vandalism-based damages.

Keywords: graffiti, vandalism, urban transport operation, safety management.

1. Introduction

"Vandalism is an intended, damaging and a norm violating behaviour against objects" (Rölle, 2009).
Following this definition vandalism is marked by the intent to destroy. From a legal point of view any form of vandalism is handled as a criminal offence (damage to property). Most common targets for vandalism are public institutions, most likely the public transportation systems.
The Technical University of Vienna in cooperation with Vienna's public transport operator *Wiener Linien* investigated this topic scientifically and gave recommendations on *Wiener Linien*'s general approach and internal process flows concerning vandalism.

2. Intent to Destroy

Initially vandalism was politically motivated starting in the late 18th century and changed to senseless destruction of public goods in the 20th century (Buhr, 2012). Depending on the offender's motivation it's possible to distinguish several forms of vandalism: *malicious vandalism, demonstrative vandalism, retaliation vandalism, playful vandalism, cumulative vandalism, erosive vandalism* and *vandalism of procurement* (Rölle, 2009). Damages due to vandalism have different forms of appearance which are following this variety of motivations and set a particularly significant challenge of preventing vandalism. The most frequent forms of vandalism in the urban public transport are malicious and demonstrative vandalism. Offenders of the last-mentioned form of vandalism want to attract attention of the public on personal messages or concerns. Graffiti is a prime example.
Cases of graffiti-vandalism have significantly increased after the millennium. Since this form of vandalism is a rather recent phenomenon, general strategies for tackling such problems are scarce.
Destructive treatments caused fully on purpose without any benefit (breaking windows and slitting seat cushions) are part of the so called malicious vandalism.

3. Impact of Vandalism

The perception of personal security is strongly affected by the awareness of crime caused by vandalism damages in the public. The presence of vandalism gives the impression that an environment or area is uncontrolled and unmanaged. (Stafford and Pettersson, 2003) explain the subjective feeling of insecurity in environments with vandalism damage with the obvious line of reasoning "if something like this can be done unnoticed, what else can happen to me in this system?" (Stafford and Petterson, 2003) According to criminologists, graffiti and vandalism not only affect the fear of crime, but also the density of criminal occurrences. In accordance with the widely used Broken Windows theory (where broken windows are visible, more glass panels are destroyed in the area) (Kelling and Wilson, 1982) the apparent presence of vandalism damage is perceived as a subjective tolerance of vandalism. Awareness of wrongdoing decreases among perpetrators and leads to a lower inhibition threshold as well as a reduced assessment of exposure to risk.
If vandalism damage in public transport systems - on infrastructure or vehicles - is visible, this leads to an increasing sense of insecurity among the passengers and subsequently to a loss of image of the operators. The sense of insecurity can therefore be reflected in declining numbers of passengers and thus in reduced revenue (Forsblom, 2005).
Overall, the following negative effects on operators and passengers of public transport are apparent:

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- Subjective uncertainty in the use of public transport;
- Reduced revenues due to lower usage;
- Cleaning, repair and replacement work to eliminate vandalism damage;
- Security and design measures to prevent vandalism.

4. Handling of Vandalism on Subway Trains of *Wiener Linien*

Since 1991, *Wiener Linien* has systematically collected data on graffiti damage to vehicles, but data for damage caused by vandalism to infrastructure structures are not available on a comprehensive basis. For example, damage under the title "Smearing action Vehicle Interior or Buildings" has been recorded centrally for some years, a distinction between damage to vehicles or infrastructure is not possible in this category. Other forms of vandalism damage (eg: destruction of components) are not available in this database. Therefore, a statistical analysis of the development of vandalism damage at stations of the Vienna Underground is currently not possible.
However, a look at the data on graffiti incidents on vehicles shows that they have increased significantly since the turn of the millennium.
Due to the implementation of effective technical and organizational measures of property protection and the legal assertion of the total costs determined has been recorded a decline since 2014.

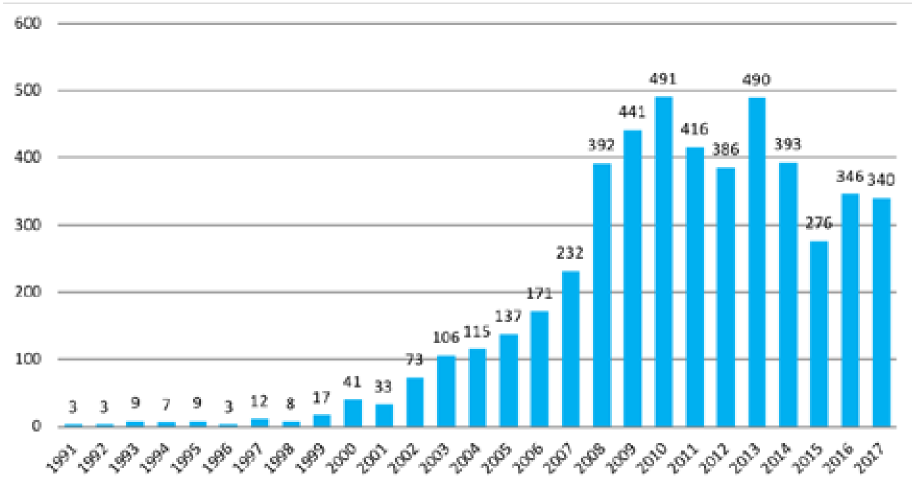

Fig. 1.
Cases of graffiti-vandalism per year on trains in Vienna's public transport network

In contrast to other major cities such as New York, where graffiti vandalism was already a serious problem in the 1980s and had a significant impact on passenger acceptance as well as falling passenger numbers, hardly any such incidents were recorded in Vienna during the first survey years. Generally, vandalism damages, both to vehicles and to the infrastructure, must be regarded as a current problem. *Wiener Linien* follows the principle of not putting trains covered with graffiti into service but transferring them to restauration and cleaning as quickly as possible instead. Until the mid 90ies that ground rule posed no major challenge for vehicle disposition. The number of trains taken out of service due to graffiti-vandalism was negligible in comparison to those taken out of service due to technical failures.
That's why until 2015, only the costs for cleaning the trains' liveries had been taken into account when assessing the damage of graffiti-vandalism. However, the process of restoring trains covered with graffiti has become more important after the number of incidents has increased steadily over the years. Goal of the joint scientific project was to investigate the process flow of graffiti-removal on the one hand and assess and quantify all cost-components caused by graffiti-vandalism on the other hand.

4.1. Restoring Trains after Graffiti-Incidents

Wiener Linien has a predefined process flow for restoring trains damaged by graffiti. Only the most severe cases, if the train's livery has to be newly painted instead of just being cleaned, do not follow this pattern.
The discovery (usually by the train driver) of the graffiti-damage is the first step in the process. After a report to operations control, the control centre puts a replacement train (if available) into service while the damaged train is taken out of service and transferred to the cleaning facility. Usually transfers of both replacement and damaged trains have to be done during regular operating hours. After the train arrives at the cleaning facility, a contractor has a time window of 6 hours by contract to commence the cleaning. The cleaning of a train takes – depending on the train's type and the size of the graffiti and the used paint – at least one to two hours. The contractor uses state of the art detergents that are effective at removing the graffiti-paint after one to three cycles.

Fig. 2.
Cleaning cycle of a metro-train's livery by a contractor
Source: Wiener Linien, 2014

Depending on its type, a freshly cleaned train then has to be labelled with security-related and corporate-design stickers. Since labels only stick to utterly dry surfaces, there has to be a time gap of at least six hours between cleaning and relabelling a train's livery.
All these time spans added up, a train can put into passenger service the day after the detection of graffiti-damage at the earliest, usually two days after the detection. If the train's livery is severely damaged by the graffiti-paint and it needs a new coating, it has to be transferred to the main workshop. That means a dropout of several weeks.
The effectiveness of the trains' cleaning depends on multiple factors: Not only the paint used by graffiti-vandals but also the number of layers they sprayed onto the livery, the time gap between the spraying and its detection and the exposition to the sun have an impact on the number of cleaning cycles it takes to remove the graffiti-damage.
So far *Wiener Linien* has just recorded costs for cleaning and relabelling a train's livery after a graffiti-damage both for internal documentation and claims for compensation in court whereas costs for transferring the train and the additional reserve train have been ignored.

5. Handling of Vandalism on Subway Structures of *Wiener Linien*

Wiener Linien's strategy of taking out of service the damaged train and replacing it, is not fully applicable in the case of damaged station structures. Since stations are part of the infrastructure and cannot be replaced by other equipment, the closure of an entire station cannot be justified due to punctual damage caused by vandalism. Due to the large number of damage caused by vandalism of varying severity, it is not always possible to repair all damage the following night (next period off). If any graffiti or other motive is sexist, racist or otherwise inhuman, it will be removed as soon as possible. If damage is also safety-relevant, the respective station area is immediately shut off and the damage is also repaired as quickly as possible.
Following the 2014 project on Train-vehicles of Vienna's Underground lines (Kehrer and Steckler, 2014) the Vienna University of Technology was commissioned in 2016 to carry out a study on damage caused by vandalism in station structures of the Viennese Metro-Network.

5.1. Creation of a Database

Since at the beginning of the project there was no uniform database for further evaluation of damage caused by vandalism at *Wiener Linien*'s underground stations, all damages caused by vandalism at each underground station at the time of the survey were recorded and documented. The database created in this way forms the basis for further evaluations and conclusions.
The survey was carried out on randomly chosen days, whereby each station was recorded in one day. The database represents a sample of the total damages on a certain day. The survey includes a list of the damages found, including the extent of the damage, their location within the station and photos of each damage (see Figure 3).

Fig. 3.
Damage pictures of different categories
Source: (Daniel Schlager, 2016)

The damages were also divided into the following categories, depending on how they occurred and how they were repaired:

- Smearing with pins;
- Graffiti and Smearing with paint spray;
- Etching and scratching of surfaces;
- smashing and destroying components.

While graffiti with conventional pencils often affects small areas, graffiti and smearing with paint spray usually take on larger dimensions. Etching and scratching are damages caused by vandalism - mainly on glass surfaces - where surfaces are either scratched or permanently clouded by acid. These damages can only be repaired by replacing the component.

5.2. Data Analysis

Afterwards, the data were evaluated and statistics relating to individual lines, stations, etc. were compiled.
Looking at the 15 stations with the most vandalism damage, it can be seen that there are stations of all underground lines, including transfer stations and stations without transfer possibilities. A comparison of the number of damages with the passenger frequency of these 15 stations is shown in Figure 4.
Karlsplatz station has by far the highest number of vandalism damage. This station is the only one in the Vienna subway network that is connecting three subway lines. Both the passenger frequency and the spatial extent of the station structure are correspondingly high. It is remarkable that the Stephansplatz station in the city centre, a station with the highest transfer frequency in the entire network, does not show the most damage.
In addition to the number of vandalism damages, the damage category and its location, the evaluations also took into account features such as design, platform forms and type of surveillance (ward supervision or video surveillance). Although the correlation between the individual station characteristics and the occurrence of damage is low, the following statements can be made:

- The majority of the most affected stations originate from the early construction phases of the Vienna subway (late 1970s) and are located underground.
- The number is not directly related to the size of damage types. A large number of small damaged areas are often offset by a smaller number of large damaged areas.
- There is no direct correlation between the frequency of cases of different damage categories. The increased occurrence of a damage category in a station does not necessarily mean that the same station is also heavily burdened by other damage categories. However, the station design can have an influence on the forms of damage (e.g. large glass surfaces lead to increased breaking of panes).

- No influence on the frequency of damage can be determined by the presence and regular control visits by ward supervision. However, stations with station control rooms have smaller areas of damage than unmanned stations for the same frequency of damage.

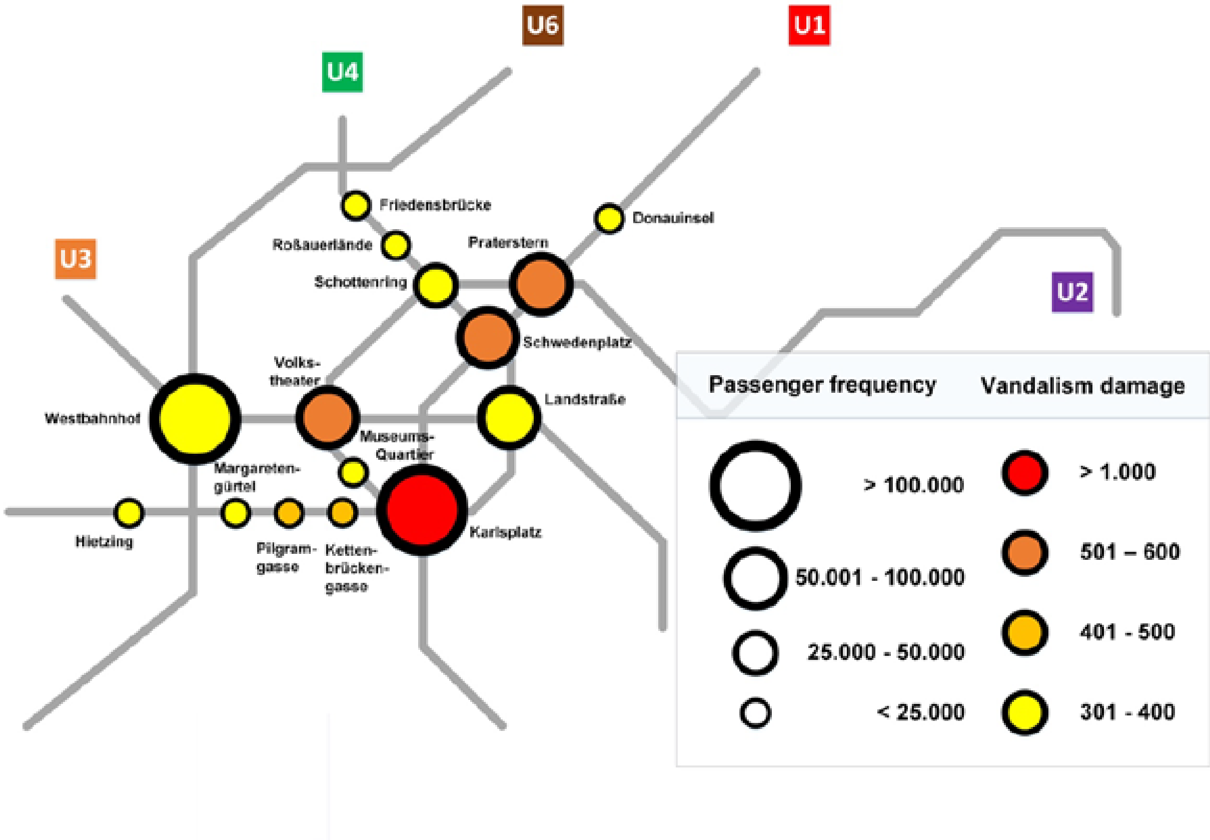

Fig. 4.
Stations with the most vandalism damage and their passenger frequency

5.3 Process and Analysis of Damage Repair

The removal of vandalism damage in the station buildings of *Wiener Linien*, which is neither security-relevant nor inhuman content, depends on the type of repair and the effort involved. If some of the paints and varnishes applied can be removed as part of daily standard cleaning, other components (such as etched and scratched glass panes) would have to be replaced completely. Only a fraction of the costs incurred in repairing the damage can be reclaimed because only a small number of perpetrators can be identified.
At the beginning of the process, the damage is detected by the ward supervision or by the cleaning personnel as part of daily station cleaning. These damages are reported to the control center. Depending on the degree of damage, video evaluations can be requested from the control centre. Graffiti damage is always documented photographically in order to be able to assign it to certain perpetrator profiles. Subsequently, a complaint will be filed. In the event of serious damage to property or if a perpetrator is known, the costs are determined internally and reclaimed by legal action.
At the same time, the control centre creates an entry in the central claims management system of *Wiener Linien* with the respective claim, which is automatically assigned to the respective specialist department responsible for rectification.
Depending on the damage category and damaged surface, the following options for repairing damage caused by vandalism are available:

- Cleaning of smearing;
- Overpainting of smearing;
- Removal of smearing by vacuum blasting process;
- Exchange of components due to etching, scratching or smashing.

The cleaning and overpainting of smearing can usually be carried out in the following night (off time). Removal by vacuum blasting (on natural stone surfaces) can take longer as it sometimes has to be put out to tender and awarded separately due to the high financial outlay involved. The replacement of components, especially glass surfaces, is usually only carried out in critical cases due to the high costs involved.
If vandalism damage is dangerous for the environment or its motives racist, sexist or inhuman, it is considered critical and will be repaired as quickly as possible.

5.4. Evaluation of Damage Caused by Vandalism

All damage was documented in the survey for creating the database. The damage was evaluated with regard to the costs for cleaning or repair on the basis of the cost rates determined in the project.
In this way an overview of the random samples of vandalism damage (despite ongoing cleaning and damage repair) was created. To calculate the value of costs for cleaning and repair, the sums of all damages in the network are first broken down by type of damage, their total area affected and then an average area value per damage event was determined.
Depending on the type of damaged surface, the most cost-effective way of repairing the damage is assumed as a conservative estimate. From this, a ratio of cleaning to overpainting for the damage forms graffiti and smearing with paint spray, smearing with pins and scratching of surfaces other than glass is determined. With the help of the cost rates determined in the project, the costs for the repair of all documented damages were calculated. In total, this results in a value of around 3.7 million EUR, which represents the lower limit value of the damage sum on the basis of conservative estimates of the input parameters. Figure 5 shows the cost shares per damage category and damaged surface. The large share for the replacement of small and large glass panes can be explained by the fact that these damages are usually not repaired and are also very cost-intensive. In addition, most of the glass panes are made to order; there is no standard size that allows the elements to be kept in reserve for several stations.

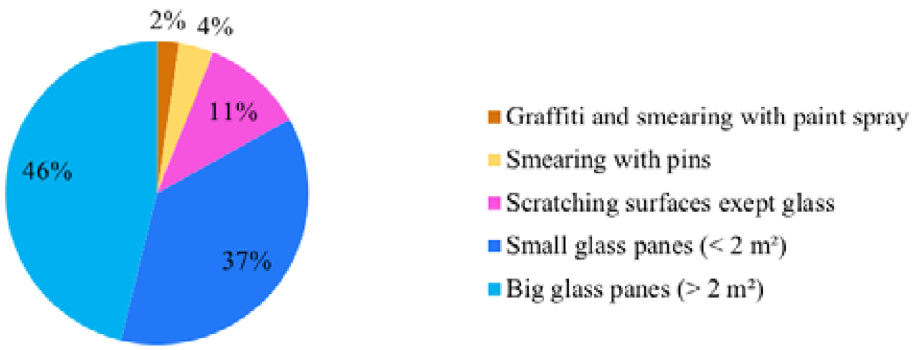

Fig. 5.
Cost shares for the repair of the raised damages

6. Hazards for Riders, Employees and Vandals

Vandalism poses a threat for riders and employees of *Wiener Linien* as well as for the sprayers themselves. Direct physical contact to fresh paint – either on the train's livery or on the interior – contains a direct risk for riders. It is not possible to assess the chemical composition of the used paint and its effects on the human body when inhaled or touched. If the trains' windows are covered with paint, rescue works can be hindered in case of an accident. The same threats apply for employees of *Wiener Linien*. Additionally, an employee might catch vandals in the very act. In this case, a vandal's reaction is unpredictable not unlikely to result in physical violence (as documented for several cases in Vienna). From this point of view, an as restrictive approach towards graffiti as possible is favoured.
Sprayers themselves are also threatened when trespassing onto train tracks in order to commit acts of graffiti-vandalism. During operation hours approaching trains pose a major threat while outside operating hours the power rail and the rough terrain without lighting pose major threats to trespassing people. Especially in stressful situations, when caught in the act for example, the risk of having an accident increases.

7. Image Loss for the Transport Company

Apart from the direct threats as mentioned above, the presence of vandalism in a public transport network creates a subjective feeling of insecurity for riders, especially during off-peak hours. People tend to think "if that [graffiti] can happen undetected, there is so much that could happen to me undetected as well" (Stafford and Petterson, 2003). The visible presence of graffiti and its perception by riders lead to a significant decrease in ridership (Weisel, 2004). Additionally, cancelling trains result in longer waiting times for riders. If the very first trains in the morning are affected that means a later commence of operations which severely harms the security of supply for riders. In order to convert these damages to money the number of passengers and their individual delay is multiplied with an average cost per time. This quantifies the damage to society but does not include the image loss of *Wiener Linien*. Delays are specifically harmful to the company's image since they can result in further complications for riders, such as private or professional troubles. When *Wiener Linien* asked their riders about barriers to public transport usage in a study in 2014, delays turned out to be the biggest one, cited more often than too long intervals or too little connections. During daytime, at intervals of 5 minutes, the cancellation of a single train does not weigh as heavily as in off-peak hours. However, a cancelled train leads to overcrowded following trains which turned out to be the second biggest barrier in the very same study.

8. Conclusion

8.1. Vandalism on Trains

The analysis shows that graffiti-vandalism on trains has direct negative effects on ridership and the passengers' subjective feeling of safety. Furthermore graffiti-vandalism poses direct threats to riders, employees and the sprayers themselves. *Wiener Linien*'s principle of not putting trains covered with graffiti into service is justified both from a safety-related point of view and a public-economic point of view. Since the presence of graffiti-vandalism leads to an increase of copycats and to decreased ridership, this policy is also reasonable from a business-economic point of view.
The costs for transferring trains and keeping reserve trains have to be assessed in order to demand for their compensation in court. In the present study the costs caused by graffiti-vandalism were reassessed for the year of 2013. The inclusion of the cost components mentioned above meant a multiplication of the costs by the factor ten compared to the old model where only the costs for cleaning the trains' liveries had been taken into account. The old calculations lead to costs of 339.000 EUR for 2013 whereas the real costs are 3.261.000 EUR. Now that the real costs are displayed, prevention of graffiti-vandalism gets more attention within the company. Furthermore, graffiti-vandalism and its consequences are taken into account when planning operations and vehicle disposition.

8.2. Vandalism on Station Structures

Based on the data evaluation and the process analysis damage-reparation caused by vandalism on station structures of the Vienna Underground, the following conclusions can be drawn, which should be taken into account in order to prevent and minimise damage in the future:

- The more vandalism damage is present in an environment, the greater the subjective feeling of insecurity among people moving in that environment. Damage to infrastructure suggests that violence and other crimes could also be committed unnoticed. Environments with obvious vandalism damage also reduce the inhibition threshold for further damage.
- The strategy of repairing damage caused by vandalism as quickly as possible is justified not only by avoiding additional acts of vandalism, but also by the effects on passengers' subjective perception of safety and by the overall lower number of cases of damage to be expected.
- The costs calculated by *Wiener Linien* for the individual cases of damage are shown according to expenditure. No hidden cost components have been identified that are not taken into account in the case of further allocation.
- The systematic documentation and categorization of vandalism damage that occurs is important in order to have a meaningful database available. Complete data collection could in future enable ongoing statements to be made on the development of claims and the effectiveness of preventive measures to be checked.
- When designing architectural guidelines for station structures, standard elements for the individual surfaces should be provided wherever possible. By keeping standard elements in stock, damage can be repaired more quickly and costs can be saved. Large glass surfaces should also be avoided, as repairing damage to glass surfaces is by far the most cost-intensive.

In summary, the study shows that damage caused by vandalism at public transport stations has a negative impact on passenger acceptance and safety. The basic approach of *Wiener Linien* to repair these damages (to vehicles and infrastructure) as quickly as possible makes economic sense due to the negative model effect of visible damages. Prevention approaches include not only rapid damage repair and the clear design of stations, but also raising public awareness that vandalism in public transport is an attack on the general public. To reduce the costs of damage repair, it is desirable to have an architecture of the station that enables cost-effective damage repair and relies as far as possible on standard elements. Finally, it is recommended to raise public awareness: Vandalism is an attack on the public!

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PROPOSED SOLUTION FOR CAPACITY INCREASING ON THE INTERNATIONAL RAILWAY LINE ZAGREB – SISAK – NOVSKA

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Abstract: This paper analyses the bottlenecks on the international railway line M502, a bypass track of the Corridor RH1. This is a bypass line of the former X Pan-European traffic corridor that connects Bosnia and Herzegovina and Serbia with Central Europe and with the RFC 6 – Mediterranean Corridor. Upon the detailed analysis of the bottlenecks, technological solutions are proposed for the maximum utilisation of the available line capacity. The result of applying technical and technological solutions shall be quantified through indicators of timetable quality, and especially several other parameters, such as journey time or the way how trains are dispatched in certain directions with the maximum utilisation of the available capacity. Potential solutions will be quantified together with indicators of railway infrastructure charges by the infrastructure manager in Croatia. Simulation tool OpenTrack is going to be used to develop a model and run a simulation of the proposed solutions.

Keywords: utilisation of railway track capacity, technological timetable parameters, UIC 406 capacity method, simulation of technological process, simulation analysis, OpenTrack.

1. Introduction

The M502 railway line, which is the focus of this paper, is a bypass route of the Corridor RH1, which ensures a direct access to the Mediterranean Corridor. This line is, therefore, of great regional importance to the neighbouring Bosnia and Hercegovina, with a potential of joining the International Rhine-Danube Corridor, due to the maintenance and closing down of the international single-track railway line M103 Dugo Selo – Novska. Since M502 is in a relatively good exploitative condition all the way to the station Sisak Caprag, this paper shall analyse the section from Sisak Caprag to Novska. Owing to the war, this entire section is a bottleneck, so the train stations along the section are not being fully utilised. This paper shall analyse the current state of the section, and with the help of OpenTrack Simulation tool provide and simulate certain technical and technological solutions. The latter shall be presented by means of improvements in train traffic regulation, as well as in railway infrastructure fees.

2. Description of the Observed Section of the Railway Network

The M502 officially named Zagreb – Sisak – Novska (as shown in Figure 1), is a single-track railway line electrified with 25 kV AC. Based on the maximum axle load permitted, it is a D4 category line, which means the maximum axle weight amounts to 22.5 tons/axle, and 8 tons/m. The entire construction length of the railway line is 118 km. The movement of trains on Zagreb – Sisak Caprag is controlled by automatic block signals (ABS), whereas between Sisak Caprag – Novska the headway of trains is controlled by station distance (HŽ Infrastruktura d.o.o., 2018).
Based on its exploitative potential, the railway line can be divided into sections:

- Section Zagreb – Sisak Caprag,
- Section Sisak Caprag – Sunja, and
- Section Sunja – Novska.

The division of the railway line into the aforementioned sections also follows the passenger train cycle. The railway track beyond Sisak Caprag has been in a rather poor condition ever since the war.

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Fig. 1.
Location of the Railway Track M502
Source: (HŽ Infrastruktura d.o.o., 2018), Authors edit

The analysis of the timetable for the railway line shows that passenger and cargo transport is much more intense on the section Zagreb GK – Sunja, as most residents use the railway to commute, since the distance between Zagreb and Sisak Caprag is 55 kilometres and the passenger train journey time is 65 minutes on average. The number of passenger and cargo trains on the sections is listed in Table 1 (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2017).

The section Sisak Caprag – Sunja is 15 kilometres in length, which means the average passenger train journey time is 38 minutes. The track along this section had been significantly destroyed during the war, and due to the lack of safety and signalling systems, and the general condition of the railway, higher train speeds are not possible. After Sunja station, the line is divided, with one line heading to Volinja and continuing towards Bosnia and Hercegovina and the other line towards train station Novska. The number of passenger and cargo trains on the sections is listed in Table 1 (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2017).

There are fewer trains operating between Sunja and Novska because of the lack of exploitative potential due to the poor technical condition of the railway, and safety and signalling systems. This section of the railway line is mostly used for local passenger transport towards the administrative centres, so the number of trains is clearly lower. The number of passenger and cargo trains on the sections is listed in Table 1, and the analysis of the most important stations follows below (HŽ Infrastruktura d.o.o., 2017).

Table 1
Number of Trains per Sections on M502 Track

Train number	**Zagreb GK – Sisak Caprag**	**Sisak Caprag – Zagreb GK**	**Sisak Caprag – Sunja**	**Sunja – Sisak Caprag**	**Sunja – Novska**	**Novska – Sunja**
Passenger [number of trains]	16	15	9	10	4	5
Cargo [number of trains]	11	10	7	7	1	2

Source: (HŽ Infrastruktura d.o.o., 2017)

Zagreb Main Station (Zagreb GK) is a marshalling yard which issues all the changes in train traffic in marshalling sections. Two important railway lines come out of the station – the M102 and M202. Apart from the basic passenger acceptance and discharge, the station also performs shipment transport to and from industrial tracks, wagon shipments for HŽ Cargo d.o.o and postal shipments. It consists of several track groups: reception and dispatch of passenger train group, reception and dispatch of cargo train group, washing and cleaning of passenger wagons group, turn-round group, and other tracks. The longest permitted track length for cargo trains is 379 m, i.e. 376 metres in the opposite direction, and 574/561 m for passenger trains. The train station is fitted with electronic signalling and safety interlocking Simis W Siemens (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Zagreb Klara is an interstation, marshalling, and rail yard open for acceptance and discharge of passengers and wagon shipments with the exception of explosive goods, and live animals (HŽ Infrastruktura, 2010). The station has a total of 14 tracks, 5 of which are used only for reception and dispatch of passenger and cargo trains. The usable track length of the longest tracks intended for reception and dispatch of trains is 534, i.e. 517 m. The station is equipped with electrical signalling and safety interlocking Sp Dr L 30 Lorenz. All the tracks intended for reception and dispatch of trains, as well as all the elements, are a part of the signalling and safety system (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura, 2010).

Station Velika Gorica is an interstation along the M502 railway line and a rail yard on the track Sesvete – Velika Gorica. It is open for acceptance and discharge of passengers, wagon shipments, and live animals. There are 6 tracks, 3 of which are used for train reception and dispatch. The longest usable track length is 603/616 m. It is fitted with the electrical signalling and safety interlocking Sp Dr L 30 Lorenz and located on the part of the track equipped with the APB (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Turopolje is an interstation on the M502 used for acceptance and discharge of passengers trains and wagon shipments. Out of its 7 tracks, 4 are used for train reception and dispatch. The longest usable track length is 573/570 m. The station is equipped with electrical relay interlocking Siemens, and located on the part of the railway track that has APB (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Lekenik is an interstation on the main railway line M502 used for acceptance and discharge of passengers and wagon shipments. An official location subordinate to station Lekenik is the unallocated stop Pešćenica. The station is equipped with three reception-dispatch tracks, two dead-end tracks, and one industrial track. The longest usable track length is 614/608. The station is equipped with electrical signalling and safety relay interlocking SIEMENS EL (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Greda is an interstation on the M502 with the basic function of passenger acceptance and discharge. In the organisational sense, the station is subordinate to official location Sisak. It has 3 tracks, the second of which is continuous. The longest usable track length is 511/528 m. Station is located on the part of the network that is equipped with APB. It has been fitted with electrical relay interlocking INTEGRA (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Sisak is an interstation on the M502. It consists of a passenger and cargo section. The passenger section has 4 main tracks for reception and dispatch of passenger trains, the fourth of which is also the main transient track. The cargo section has at disposal 7 main tracks, the fourth of which is the main transient track. The longest usable track length for cargo trains is 671/686 m, and for passenger trains 208/233 m. The station is equipped with electrical signalling and safety relay interlocking INTEGRA (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Sisak Caprag is a station for acceptance and discharge of passengers and wagon shipments. As far as the regulation of train traffic is concerned, the role of the station is that of a rail yard. The station has 8 tracks, and each of them is used for a different purpose. The longest usable track length is 583/575 m. The station is fitted with an electrical relay interlocking SS INTEGRA (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Sunja is an interstation along the M502 and a marshalling and rail yard for the R102 railway line. Its main task is traffic regulation, and the acceptance and discharge of passengers and wagons shipments. The station has 7 tracks, 6 of which are used for passenger and cargo train reception and dispatch. The longest usable track length is 661 m. Based on the safety, the station is equipped with a mechanical safety, there are either no entry signals, or they are invalid (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Hrvatska Dubica is an interstation along the M502 with the main purpose of acceptance and discharge of passengers. An unoccupied station Višnjica is under the authority of the station. There are 4 tracks, the third of which is main transient. The longest usable track length is 617 m. The station's safety is mechanical (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

Novska station is a marshalling and rail yard. It is also a station at which a single-track becomes a double-track line. It is open for acceptance and discharge of passengers, wagons shipments, and live animals. In the passenger track group, there are 5 tracks for reception and dispatch of passenger trains, the third and fourth of which are the main transient. There are 6 tracks used for cargo trains, and the other tracks are either dead-end tracks or used for train manipulation. The longest usable track length is 685/632 m. The station is fitted with an electrical safety relay LORENZ (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2010).

3. Modelling the Potential Improvement in Stations

3.1. Improvements in the Stations on the Sisak Caprag – Novska Section

This part of the paper shall examine the railway section Sisak Caprag – Novska. The track along this section is in poorest condition of all, since it was in a war zone. As mentioned earlier, Sunja station and Hrvatska Dubica are not secured (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018).

The other stations on the section are unoccupied, i.e. declared as stops equipped only for passenger acceptance and discharge. There is a total of 5 such stops: Blinjski Kut, Staza, Šaš, Živaja, and Jasenovac. Prior to the war, these official locations used to be secured with the most modern signalling and safety systems and devices, they were in operation and used for train traffic regulation (HŽ Infrastruktura d.o.o., 2007). This points to a need to analyse and assess the operational state of the infrastructure and the building at the official locations, all of which are under the supervision of the infrastructure manager. After the analysis, the OpenTrack simulation tool was used to illustrate the condition of the official locations, as shown in Figures 2 and 3 (HŽ Infrastruktura d.o.o., 2007).

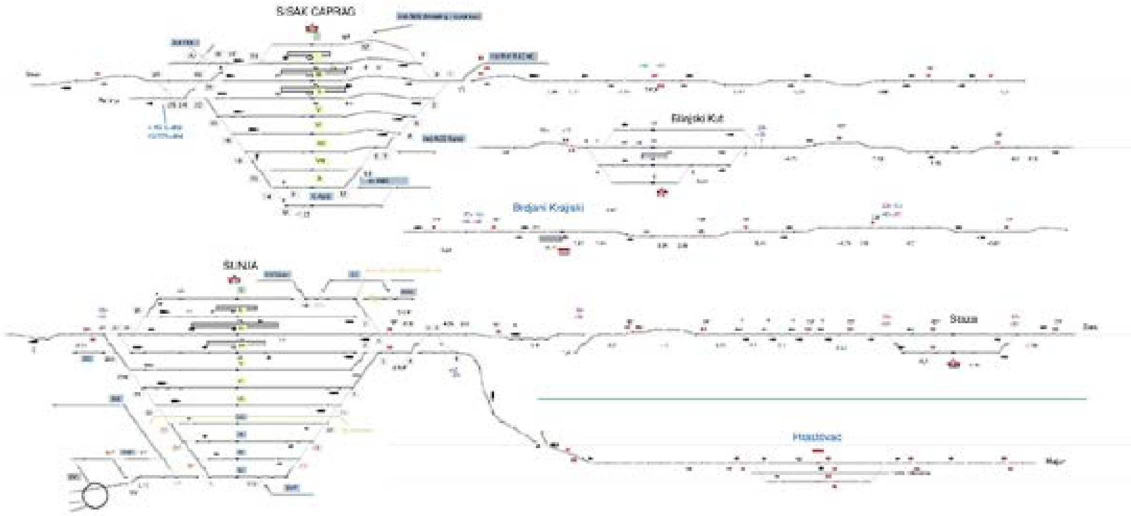

Fig. 2.
Official Locations on the Section Sisak Caprag – Staza
Source: Computer model

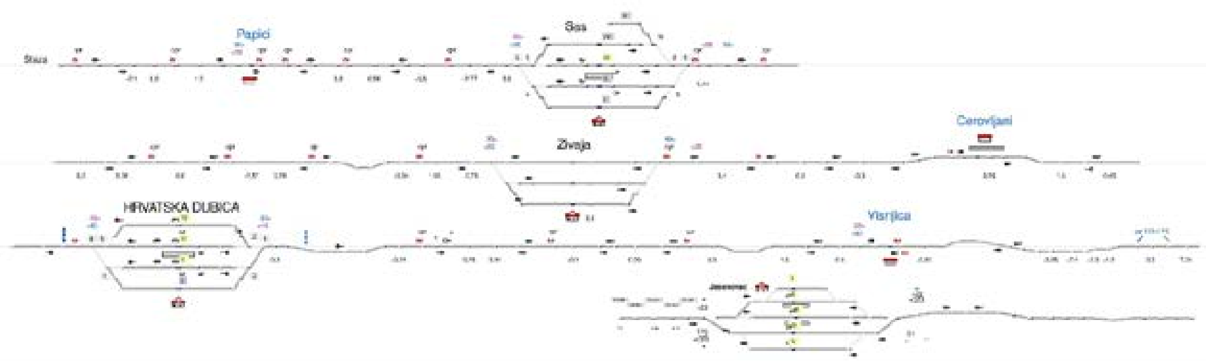

Fig. 3.
Official Locations on the Section Staza – Jasenovac
Source: Computer model

After the construction of the model and running of the simulation, the model was additionally corrected and modified so as to obtain a faithful representation of the actual state. The journey times obtained through the simulation were compared to the actual journey times in the valid timetable. Upon calibration and verification of the model, the above-mentioned official locations were equipped with signalling and safety systems as well as an electrical relay interlocking. Next, we are going to briefly describe all of the official locations. Train speeds and the entire existing infrastructure at a station will not be altered. All the official locations are modelled and shown based on the available documentation, such as the longitudinal profile of the railway track (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2017).

Official location Blinjski Kut was modelled based on the available documentation. It contains 4 tracks, 3 of which can be used for train reception and dispatch. The tracks are 700 m in total length. The station has 4 switches. The speed has not been changed at the station and is 20 km/h. The calculation determined that the station interval of non-simultaneous train arrivals is 2 minutes, and station crossing interval is 50 seconds (Badanjak, et al., 2006), (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018).

Train station Sunja, which currently does not regulate train traffic, is also non–secured, which is why traffic regulation is conducted manually, which, in turn, is time-consuming. The station interval of non-simultaneous train arrivals is 8 minutes, and station intersection interval is 9. It has already been mentioned which means the station has. The station was upgraded with signalling and safety equipment and a modern electrical relay. The speed has remained the same as in real-time. Based on the calculation, the station interval of non-simultaneous train arrivals amounts to 2,2 mins, and station crossing interval to 1 minute (Badanjak, et al., 2006), (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2017).

The next official location is Staza, which had previously been used as crossing point with 2 switches and 2 tracks with usable length higher than 1000 m. In the model, the official location was fitted with entry and exit signals as well as with an electrical relay which enables a central train path setting and train intersection. Based on the calculation, the station interval of non-simultaneous train arrivals is 2,5 mins, and station crossing interval is 1 minute (Badanjak, et al., 2006), (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018).

Official location Šaš has been modelled as a station with 4 tracks, 3 of which are intended for train intersection, and 5 switches. The usable track lengths are higher than 500 m, respectively. The station is equipped with entry and exit signals and a modern electrical relay. Based on the calculation, the station interval of non-simultaneous train arrivals amounts to 2 minutes, while station crossing interval is 1 minute (Badanjak, et al., 2006), (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018).

Živaja is also modelled as a station with 3 tracks for train reception and dispatch. It has 4 switches and usable track length of 600 m. The station is also equipped with entry and exit signals and an up-to-date electrical relay. Based on the calculation, the station interval of non-simultaneous train arrivals is 2,08, while the station crossing interval is 1 minute (Badanjak, et al., 2006), (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018).

Hrvatska Dubica, currently not regulating train traffic, is also a non-secured station, which means train regulation is carried out manually, which requires a lot of time. The station interval of non-simultaneous train arrivals is 8 minutes, and the station crossing interval is 8 minutes. As mentioned earlier, due to the lack of financial means, the station has only been equipped with signals and a modern electrical relay. The speed has remained the same as in real-time. The calculation reveals a station interval of non-simultaneous train arrivals of 3 minutes, and station crossing interval of a minute (Badanjak, et al., 2006), (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018), (HŽ Infrastruktura d.o.o., 2017).

Official location Jasenovac was modelled as a station with 5 tracks, 3 of which are used for train reception and dispatch. The station has 10 switches and a usable track length for train reception and dispatch higher than 500 m. There are also entry and exit signals and a modern electrical relay. Based on the calculation, the station interval of non-simultaneous train arrivals is 3,26 minutes and the station crossing interval is 1 minute (Badanjak, et al., 2006), (HŽ Infrastruktura d.o.o., 2007), (HŽ Infrastruktura d.o.o., 2018).

After the model was designed and all the elements that ensure train intersections were added, a calculation of the capacity of a certain station distance was performed by means of the designated UIC method. The UIC 406 method is used for calculating the maximum transport capacity of a railway track, i.e. a section of the railway track. The simulation also established journey times between certain official locations by simulating the real-time conditions with the actual maximum train speeds as listed in the timetable (HŽ Infrastruktura d.o.o., 2014).

3.2. Method for Calculating Capacity Utilization - UIC 406

Back in 2014, the UIC recommended a new method of calculating the utilisation of the capacity of a track by compressing timetable. It is unique in the way that it is applicable to real-time timetables. Apart from capacity calculation, it also makes it possible to determine the capacity of intersections based on the same principles. To determine the maximum track transport capacity, the track first needs to be divided into sections, which consist of several interstation spacings. For each section, a maximum railway transport capacity needs to be calculated for the limited interstation spacing. The limited spacing is the space between two neighbouring stations, in which the median interval of train headway is the longest, i.e. the one with the lowest transport capacity (HŽ Infrastruktura d.o.o., 2014).
There are five steps to be taken when determining capacity by means of compressing:

1. Defining the infrastructure and limiting the timetable,
2. Defining the section for estimation,
3. Calculating the utilisation of capacity,
4. Estimating the utilisation of capacity,
5. Estimating the existing capacities – this part uses the calculations from the previous steps on the representational sections of the railway which is then completed with additional train routes until a desired (defined) capacity utilisation is achieved.

Capacity utilisation may be calculated using the following formula:

$$capacity\ utilisation = \frac{occupancy\ time + additional\ times}{defined\ time\ interval} * 100\ [\%] \quad (1)$$

whereby additional times refer to any time added with the aim of ensuring transport quality (HŽ Infrastruktura d.o.o., 2014).

Upon the calculation of capacity utilisation, an estimation needs to be made (step 4). If the capacity utilisation value is under 100 per cent, a part of the capacity has remained unutilised. In that case, additional routes are needed until the utilisation on the analysed section reaches 100 per cent or until it is no longer feasible to add a route.

4. Case Study – Simulation of the Potential Solutions

This part of the paper briefly outlines all the improvement suggestions obtained in modelling and a new way of securing stations. Moreover, the calculation has shown that the maximum capacity of the line Zagreb GK – Sisak is 110 trains, that is, capacity utilisation based on the actual timetable is around 55 per cent. The section Sisak – Sunja has 29 trains, i.e. 58 per cent of capacity utilised, and Sunja – Hrvatska Dubica section 19 trains which means 58 per cent. A reason

for this relatively low number of trains on Sunja – Hrvatska Dubica is the headway interval of 40 minutes (Fakultet prometnih znanosti & DB Engineering & Consulting GmbH Zagreb, 2016), (HŽ Infrastruktura d.o.o., 2017).
Since all the stations in the model were equipped with signalling and safety systems, capacity was calculated on certain station distances up to capacity occupancy of 100 per cent.

Table 2
Capacities at Certain Station Distances

SK Caparag – Blinjski Kut	B. Kut – Sunja	Sunja – Staza	Staza – Šaš	Šaš – Živaja	Živaja – H.Dubica	H. Dubica – Jasenovac	Jasenovac – Novska
46 trains	41 train	65 trains	60 trains	70 trains	78 trains	43 trains	49 trains

Source: (HŽ Infrastruktura d.o.o., 2017)

The comparison between previous and new results reveals that the most unfavourable station distance is no longer Sunja – Hrvatska Dubica, but the newly secured Blinjski Kut – Sunja (Figure 4). The headway interval on this section is 17 minutes. 46 trains can pass through Sunja – Novska section which is 17 trains more than in the existing conditions in which all the stations along the section are non-secured (HŽ Infrastruktura d.o.o., 2014).

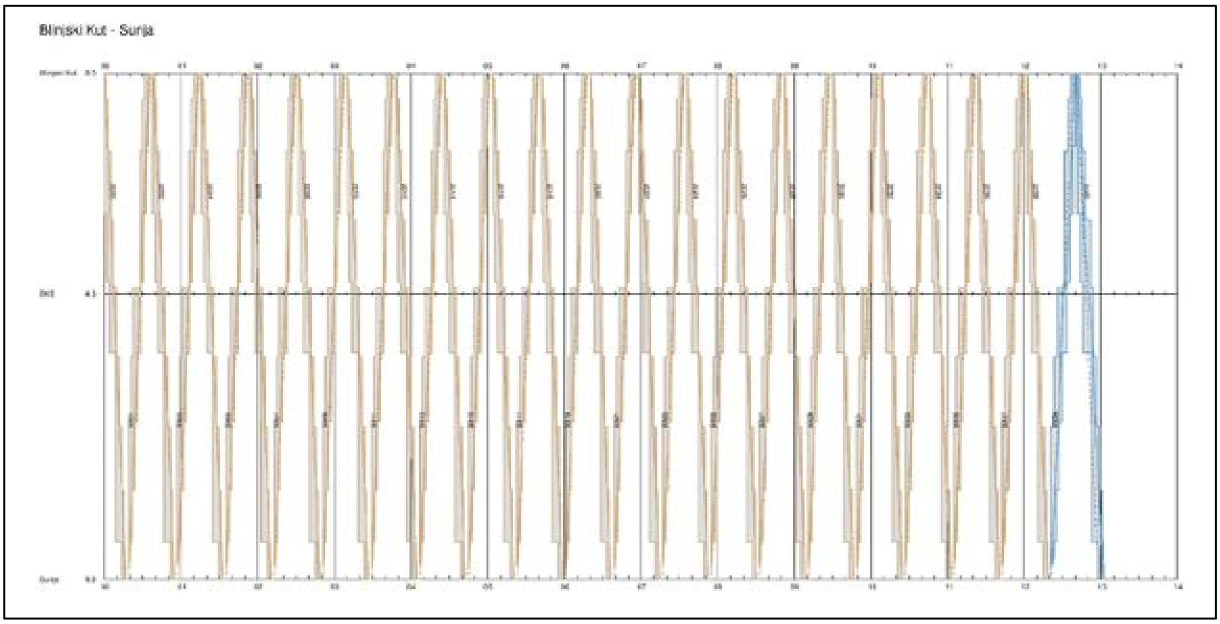

Fig. 4.
An Overview of the Limiting Station Distance Blinjski Kut – Sunja
Source: Computer model

A calculation was made for the minimum access package charge on the Sisak Caprag – Novska route. The charges are determined separately for passenger and cargo trains, as listed in Table 3 and 4.
According to the Network Statement (HŽ Infrastruktura d.o.o., 2018), the charge for the minimum access package is calculated using the following formula:

$$C = [(T + d_m + d_n) * \Sigma(L * l) * C_{vlkm} + (l_{el} * C_{el})] * S \quad \textbf{(2)}$$

whereby,

C – minimum access package charge
T – train path equivalent
d_m – additional charge for train mass
d_n – additional charge for the use of tilting technique
L – line parameter
l – train path length (km)
C_{vlkm} – basic price (HRK/trainkm)
l_{el} – length of train path with electric traction (km)
C_{el} – additional charge on trainkm price for the train path with electric traction

(HRK/trainkm)
S – coefficient for the single wagon load train

Table 3
Minimum Access Package Charge Calculation for a Passenger Train

C	43,56 EUR + VAT
T	0,87
d_m	0
d_n	0
L	1,90
l	62 km
C_{vlkm}	0,39 EUR/vlkm + VAT
l_{el}	62 km
C_{el}	0,06 EUR/vlkm + VAT

Source: (HŽ Infrastruktura d.o.o., 2018)

Table 4
Minimum Access Package Charge Calculation for a Cargo Train

C	90,98 EUR + VAT
T	0,98
d_m	0
d_n	0
L	1,90
l	62 km
C_{vlkm}	0,75 EUR/vlkm + VAT
l_{el}	62 km
C_{el}	0,06 EUR/vlkm + VAT

Source: (HŽ Infrastruktura d.o.o., 2018)

5. Conclusion

This paper analysed the bottlenecks along the M502 railway line, particularly the section Sisak Caprag – Novska which had been devastated in the war and represents the bottleneck of the entire railway line. The analysis has revealed that stations Hrvatska Dubica and Sunja, both of which are non-secured, are the only stations that regulate train traffic. Using OpenTrack, a specialised software package for modelling and simulating railway systems, a simulation of the proposed solutions was performed. The solutions proposed in the paper include securing the aforementioned train stations by means of modern signalling and safety interlocking systems, as well as securing other stations which are now registered as official locations, although they used to regulate train traffic prior to the war. With these solutions, additional infrastructure capacities were obtained on the section, namely, 17 additional routes that could operate along the section. For the railway infrastructure fee, charged by the infrastructure manager, this would secure an additional 742,29 EUR per day for passenger trains, i.e. 1550,13 EUR per day for cargo trains. The benefits that a railway operator would have from such a traffic organisation are the possibility of adjusting the timetable to its users, as well as a better utilisation of passenger train fleet by means of a more efficient turn-round.
In the future, this railway line might become a substantially important electrified line for the Adriatic ports, as well as for linking Bosnia and Herzegovina to the TEN-T Trans-European Transport Network.

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DEVELOPMENT OF RAIL PASSENGER TRANSPORT BY OPTIMIZING THE OPERATIONAL AND ORGANIZATIONAL MEASURES

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Abstract: The characteristic feature of rail passenger transport is its high transport capacity. It predestines the railway to form a key transport mode. The goal of EU transport policy in passenger transportation is to complete a single rail market and to increase the share of transport performance by rail transport. The fourth railway package is a tool that can help to strengthen the efficiency as well the share of rail transport in the European transport market. It can help to open up the sector to greater competition with better and higher quality of cross-border services at the same time. However, the transport infrastructure is the bottleneck. There are no high-speed rail links in many new EU Member States and highway networks are on average much less developed than in the old EU Member States. The aim of the paper is to analyse the basic problems of the operation and organization of rail passenger transport and to propose measures for increasing its efficiency, attractiveness, better image in the eyes of the public, but especially the increase of transport performance. By setting the appropriate operational, organizational and infrastructure parameters, the competitiveness of rail transport will be enhanced. The Systematic measures will lead to an effective integrated multimodal transport system supporting the economic and social needs of the EU population.

Keywords: railway passenger transport, organizational measures, operational measures, public passenger transport.

1. Introduction

Public transport services in passenger transport must be provided on a non-discriminatory and continuous basis. Passengers as a customers expect that public passenger transport meet their major mobility and availability needs. It is more important to well-defined the groups of passengers, which take part on the transportation process. There must best be defined their specific requirements, the transportation time requests of these groups, the need for special vehicles. The main advantages of rail transport system is its high transport capacity and environmental friendliness. So could the rail transport system play structural part in the public passenger transport. However, the problems specified in this paper are often a limiting factor to fulfil this vision. On most rail lines it is not possible to provide attractive and efficient transportation with the short time intervals. The problem is the lack of rail vehicles, as well as the slow and poor quality railway infrastructure with lack of capacity. This factors increases essentially the probability of the passenger waiting time in the transport system. However, as passengers currently prefer the shortest waiting times, this current situation leads to the preference of other modes of transport. Existing demand is thus discouraged by the insufficient frequency of connections. The basis current problem of passenger rail transport management is the planning with existing demand only.

2. Global Problems of Public Passenger Transport

In the EU conditions has been noticed significant decline of public passenger transport in the last years. Since 2010, the situation is stabilized and public passenger transport services are stagnating. While in 1995 the proportion of public passenger transport and individual car transportation was almost the same in the most of European countries, at present, this ratio is unfavorable for public passenger transport. In 2015 the ratio of public passenger transport accounts for 25% only of total transport performance. A comparison of individual transport performances across the EU is shown in Figure 1.

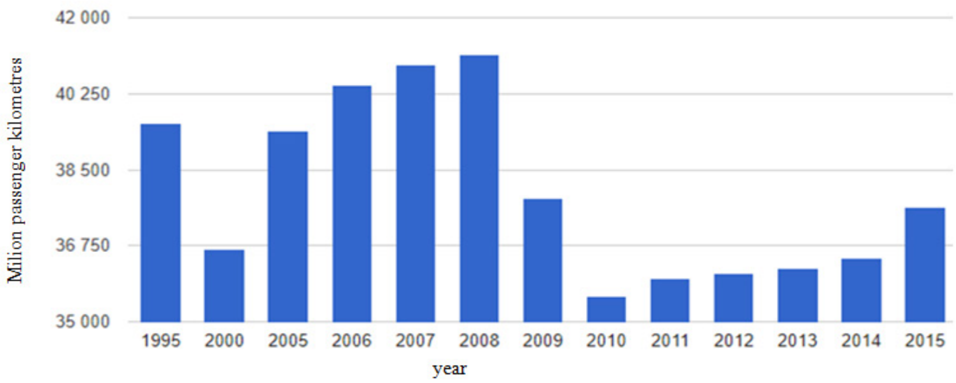

Fig. 1.
Development of transport performance in the EU
Source: (European Commission. 2018. Eurostat – Your key to European statistics. Available from Internet: http://ec.europa.eu/eurostat/web/sdi/indicators)

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One of the fundamental problems of the transport sector is the long-term unfavorable division of transport work (modal split) for the benefit of road transport, particularly individual (non-public) transport. As an example we can mention the situation in Slovakia. The share of non-public transport at all transport is around 75% (see Figure 2). The preference of individual motorism is developing close in dependence on rising living standards. This also results in a massive growth of number of passenger cars. This is documented by degree of motorization, that means number of passenger cars per one person. In the early 1990s, this indictor was one motor vehicle per more than 5 people. Currently it is less than 3 inhabitants (depending on the EU state) (White paper, 2016).
Also the demand of the traveling public on transport is constantly increasing. The passengers no longer request to be only transported between two selected places, but they are interested in transportation on the appropriate qualitative level. Following the fact that public passenger transport is unable to progress in meeting these requirements, the customers solve their transport needs by easier and more efficient way also by individual transport. The public passenger transport currently deal with a number of different issues how to improve the quality and stop the passenger number decrease, i.e. financing issues, organizational problems, infrastructure quality, vehicle park, maintenance, low vehicle capacity, as well negative public passenger transport images. The figure 2 shows the ratio of public and non-public transport performance development in period 1995 - 2014 in the Slovak Republic (IRG-Rail, 2017).

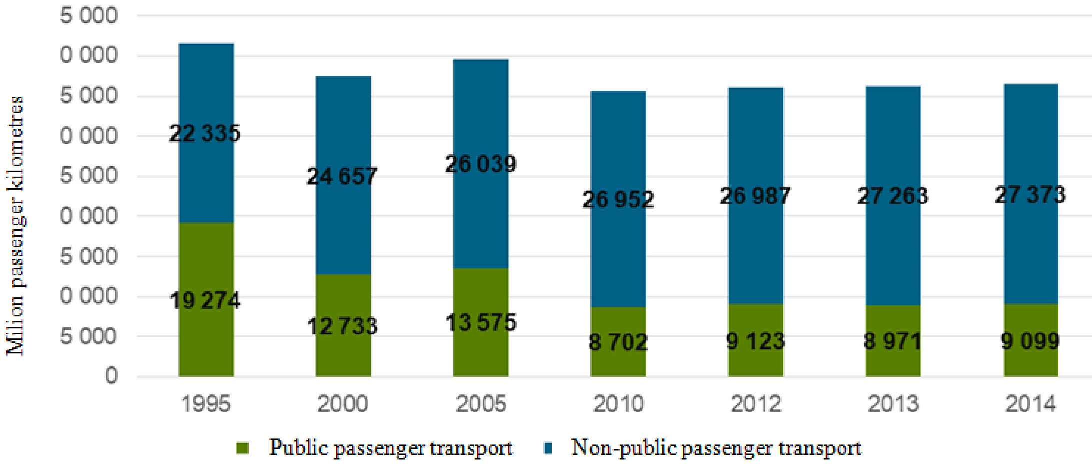

Fig. 2.
Comparison of public and non-public passenger transport performance in years 1995 – 2014 in the Slovak Republic
Source: (European Commission. 2018. Eurostat – Your key to European statistics. Available from Internet: *<http://ec.europa.eu/eurostat/web/sdi/indicators>*)

3. Methodology and Objectives

Bearing these targets in mind, an insight into the transport sector is need, especially for rail, and the research attempt to identify current trends, quantify future demand, identify customer requirements and suggest ways to meet them. Three critical questions for the rail transportation are:

- How can rail offer the quality of service that will attract customers and fulfil the targets?
- How can rail offer an appropriate time table and connections?
- How can rail offer the capacity to meet the increased demand from modal shift?

The current research attempts to determine, from a technical and operational point of view, how to develop the rail passenger system to fulfil the targets, from the state-of-the-art.
The current research evaluates the major trends in the European passenger system, identifies customer needs and suggest a technological as well operational measures.
The main objectives of this research are to:

- Elaborate the state-of-the-art of the European rail passenger system;
- Identify measures that will make rail more effective from the technological point of view;
- Provide an insight into a less developed passenger transport system.

The current research applies a methodology to elaborate a most attractive time table for passenger system and to suggest some steps to meet those needs. Literature surveys are conducted, reviewing the current body of knowledge in the field, such as relevant scientific conference and journal papers, publicly available reports from both EC and national Government funded projects, and working documents that have already been published, are in the process of publication, or whose results are available to the researchers due to their involvement in other research (Skrúcaný, Kendra, Škorupa, 2017).

4. Current Problems of Railway Passenger Transport

In a number of post-socialist countries, especially in eastern, south-eastern and central Europe, public passenger transport problems appear to be much more intense than in more developed Western countries. The current negative situation of public passenger transport is particularly appear in the area of rail passenger transport. The basic advantages of this transport mode is greatly underestimated and is often bow down by the advantages of individual motorism. In many of these countries, after 1989the individual motorism has become highly preferred as modern democratic right for free transport mode The rail transport started to be ignored as a remnant of the old regime and gradually created various problems related to the organization, operation, problems with rail infrastructure and rolling stock. The individual problems are summarized in the following text.

4.1. The Main Problems of the Organization and Operation of Rail Passenger Transport

The most significant deficiencies in the organization of rail passenger transport are related in particular to the construction of railway time table. It is most constructed with a priority for long-distance transport. This results in insufficient satisfaction of regional train needs. The self-governing regions order bus connections mostly at the same time and almost on the same routes as operated regional trains. This creates the parallel connections of trains and buses. Eliminating this parallel connections would mean a significant decrease of bus transport performance ordering. Also, the terms "acceptable parallel connections" and "unacceptable parallel connections" are not exactly defined.

Other organizational problems of rail passenger transport as well all public transport can include the absence of functional tariff integration at national level. This also includes the absence of insufficient interconnection of transport management across all transport modes. This causes the impossibility of information sharing regarding the operating deviations and links between transport modes or transport operators. There are also significant deficiencies in the area of transport planning. These often do not take into account the results of various transport analyzes, transport research or ticket sales. To the reduction of attractiveness of rail transport can be also count an insufficient train connection frequency, weaker time and space availability, i.e. long distance of railway stations (stops) from the centers of villages (towns). A small accessibility of long-distance rail transport as well not sufficient intervals in regional rail transport (2 hours interval) does not correspond to the basic tasks of rail transport system. (Blašković, Abramovic and Šipuš, 2017)

4.2. Other Problems of Rail Passenger Transport

The other problems of rail passenger transport are caused by infrastructure quality. In many EU countries is this infrastructure, inadequate with low line speeds, old security devices or level This situation markedly reduce the line capacity, which causes the lengthening of travel time. The line capacity is also limited on single-track lines, which are very numerous in each country and connect the important centeres and agglomerations. The most of stops and stations on non-corridor lines are also not modernized, there are no underpass or upper bridges to the platforms, which is not safe for passengers and, in addition, an outdated and unclean environment reduces the culture and quality of transport. The stops and stations are mostly not equipped with modern information systems.

Railway passenger transport rolling stock is often unkept and not renewed. The situation is improved slightly by the purchase of new vehicles or reconstruction of locomotives and train units, at all for regional transport. However, in a complex assessment, the situation about the carriages and locomotives is still unsatisfactory while the new vehicles cover only part of the traffic. The problematic is the maintenance and repair process too. Also, there is no guarantee of transportation by modern low-floor train units with barrier-free access on the most lines.

In recent years, railway transport and all public transport have lost their modern status and in many areas have begun to be significantly underrated. At present, in the eyes of the traveling public, it is a bad image and is often considered to be an outdated mode of transport, as something unpleasant and enforced since the 1990s, because it was unable to respond adequately to increase in individual motorism. The rail passenger transport system is often solved non-conceptually and unsystematically and it can reduce the interest in public passenger transport too (Blašković, Abramovic and Šipuš, 2017).

5. Proposal of the Operational and Organizational Measures for Development of Rail Passenger Transport

The basic task of implementation of the individual proposals is to revitalize rail passenger transport as a whole on the basis of generally applicable measures, especially in less developed countries. First of all, it is necessary to consider the operational and organizational measures concerning certain changes, particularly in the area of the rail passenger transport system operation and organization. These measures are not very financially demanding. If these measures are not sufficient, it will be important to implement more investment-intensive building and reconstruction measures.

Several measures have been identified in the various researches (see i.e. Bartuška, Černá and Daniš, 2016 or Ponicky, Čamaj and Kendra, 2017) to increase the capacity of railways and to make rail passenger transport more attractive, but the focus on the most important ones was absent. Therefore the aim of the contribution is to focus on the operational-organizational measures at all, which are considered to be the most important. In view of previous research and scientific outputs, the assumption is that their efficient implementation will improve passenger rail transport and increase transport performance. The main priorities are following:

- Exact detection and modeling of the transport demand;
- Railway network optimization;
- Time-table appropriate adjustment;
- The unit (train/crew) turnaround optimization.

An important goal in ensuring organization and operation quality of passenger rail transport is to ensure maximum efficiency and to plan the most efficient rail passenger transport system. The main feature is the quality of the timetable construction. The proposed measures should be an important tool to achieve this goal. They can also be determined by a brief methodology, shown in the figure 3. Its essence consists in solving the basic technological issues of the operation of rail passenger transport.

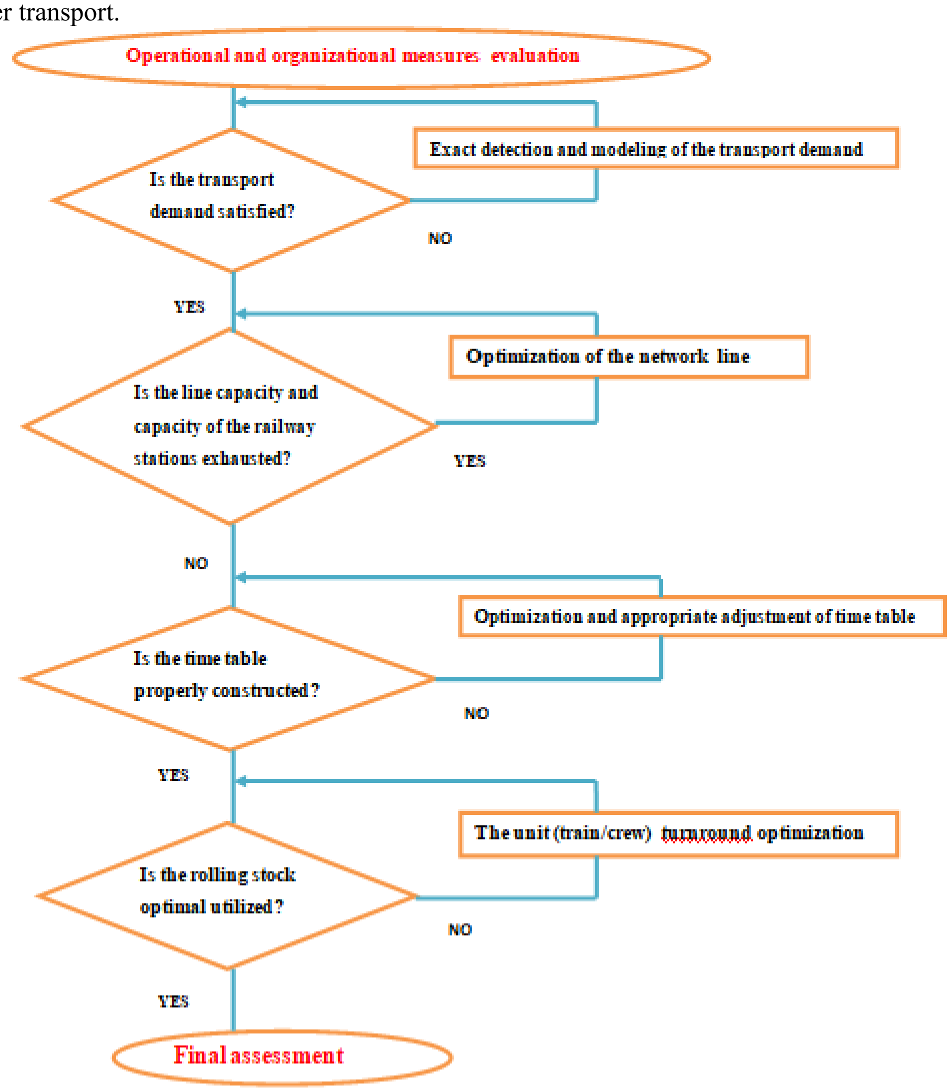

Fig. 3.
Framework methodology for identifying the most important measures for improving rail passenger transport
Source: (Authors)

5.1. Exact Detection and Modeling of the Transport Demand

This step involves an analysis of the current state of the traffic flows, which subsequently implements the next transport demand forecast. The most important is to get answers to questions WHO, WHEN, WHENCE and WHERE needs to be transferred. The basis of the passenger flows quantification may be for example models of transport relationships in the area that model traffic flows in the area over a period of time.
For transport demand modeling and determining the approximate value of the optimal number of journeys between two inhabitant units of account can be used the Lill´s gravity model. Its more efficient use or small mathematical changes would certainly improve the identification and modeling of the transport demand. The basic relationship of this model is: (Gašparík, Ľupták and Meško, 2016)

$$j_{1,2} = \frac{A_1 * A_2}{d^n} * K \tag{1}$$

where:

j1,2 The number of journeys between two cities for a specified period of time,

A1,2 Number of inhabitants (in thousands) of specific cities,
d distance of cities (places),
K coefficient (its size depends on the characters and boundings of places 1 and 2,
n the magnitude approaching 2.

5.2. Optimization of the Network Line

Design of the line network concept is based by the first step, where a model of transport relations is available and it is possible to create a network of lines which describes the maximum coverage of transport links according to importance using the network optimization criteria from the passenger's point of view and from the point of view of the operator.
The criteria for optimizing the line network from a passenger perspective are:

- the opportunity to use "the shortest time" between all places;
- attractive interval;
- minimum number of transfers.

The criteria for optimizing the network from an operator perspective are:

- the choice of the rolling stock type on the basis of infrastructure;
- the choice of the rolling stock type on the basis of their capacity;
- setting an attractive interval on the lines;
- use of railway stations and stops;
- concurrent line guidance (reinforcement, translation).

To accomplish this step, it is very important to rely on these criteria, and it is necessary to find an optimal penetration between the requirements of passengers for which it would be best to have secure connections on all routes at the widest intervals and operators with limited funds, which they must to spend efficiently.
Consequently, it is very important to be able to apply the plan of the proposed network of lines to the existing transport network. It is a rather complex process that will inevitably lead to constraints in which it is finally necessary to adapt the plan of lines to the current infrastructure. It also depends on the type of time table that operates on the network, because some types of time tables require specific network requirements.
The basic scheme of efficient line guidance is shown in figure 4 and the lineage typology can be (Ľupták and Chovancová, 2017): radial; tangential; diametral; power; circular; and auxiliary.

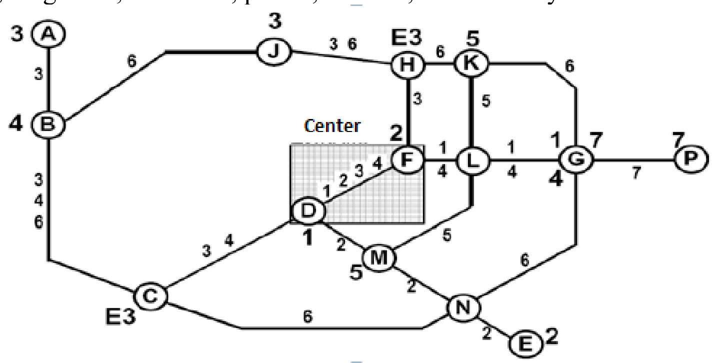

Fig. 4.
Basic types of lines
Source: (Authors)

5.3. Optimization and Appropriate Adjustment of Time Table

Within the operational and organizational criteria, the creation of a quality and optimal timetable can be considered as the most important. If a working line plan is already prepared, which takes the current railway infrastructure into account and meets all transport needs, it is possible to create the final timetable and schedule.
During its creation, to the individual lines are assigned the times of departures and arrivals, with respect to station and line operational intervals, as well other normative technological times, including turn-around of train sets in the end station, waiting times for connections, etc. In the time-table are incorporated the other technological linking for operational and technical reasons (train crossing, passing) and transport reasons (connections, uniform service interval on the line).
When designing timetable for individual lines and individual train types, it is important to take into account the fact that rail transport as the transport system should offer several layers of traffic. In general, the following are known:

- "long distance" / "fast" layer – a train type layer connecting the most important (mostly regional) cities of the country / territory, normally provided by express train types of SC, EC, IC, Ex;
- fast regional / spine / "middle" layer – a train type layer stopping at major centers of regions and important changing nodes, generally provided by fast train types R, REX;

- regional service / "slow" layer – trains connects stop at most or at all stations and stops, generally provided by regional and suburban trains.

Each train type layer has its own task in timetable and in operational concept. At the same time, however, it is very important to ensure maximum synergy effect and interconnection of these layers for optimum traffic model, also for optimum time-table. The main railway lines connecting the most important centers are dominated by all mentioned three layers using all categories of trains. On the other lines, there is the possibility to use "two-layer" or "single-layer" traffic model. The possibilities how to create the traffic model depends on the character and location of individual lines as well as on other circumstances.

The basic aim is to use also the combinations of the individual layers of transport operators in order to exploit the potential of individual railway lines with the maximum satisfaction of the customers. However, the current concept of rail passenger transport depends, in particular, on planned train kilometers. Therefore, it is not always possible to satisfy all the local needs, while there is priority on connections to long distance train layer.

Modern transport systems used in the developed countries usually include backbone lines originating from catchment areas in all directions and interconnecting these cities. Systematic periodic timetable is used within this system. Its basic substance lies in the coordination of tactical (periodic) travel timetables on long distance, fast and regional service lines to transport chains. Through this link, all areas are processed in fixed and easy-to-remember ways (intervals) with optimal connections in so-called "nodes" (transfer stations). This is achieved through time-almost identical arrivals and departures of all connections in the transfer nodes. All integrated clock cycle timetables trains run on the lines. All lines have the same service interval (clock time) that is equal to 2 times the basic clock time (typically 60 minutes) where 2k is an integer. Trains of all lines cross at the same time (symmetry time). The integrated clock cycle timetable principle implies that trains leave the clock node shortly after the symmetry time, and must return to the next clock bite shortly before the symmetry time to avoid unnecessary downtime (Gašparík and Šulko,2016).

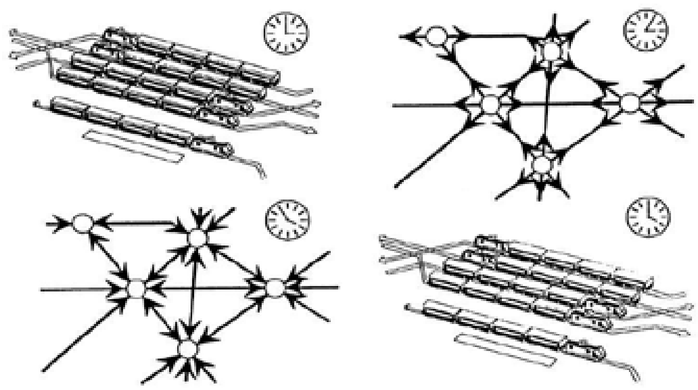

Fig. 5.
The Integrated clock cycle timetable principle represented by the symmetry time phase in the node
*Source:(*Kuník, 2012)

It is important to start from the fact that the symmetry time is repeated every half of the cycle time. Then, the edge equation can be defined (Drábek, Jánoš and Michl, 2016):

$$t_{J,A\leftrightarrow B} = \frac{n}{2} \cdot t_T \qquad (2)$$

$t_{J,A\leftrightarrow B}$ is the system drive time between the clock nodes A and B
n is the natural number
t_T is the clock time (interval between links).

5.4. Preparation of Vehicle Circulation and Crew Turnaround

After construction of the time table, it is necessary to ensure the optimization of the turnaround of the rolling stock and train crew. It is very important to plan the turnaround so that turn times at the destination station are optimal (enough time for service processes and for delay elimination, and not too short).

In the case of locodrivers and conductors staff, it is necessary to follow all the issues arising from the current legislation in the labour law area (Mašek, Kendra and Čamaj, 2016).

6. Conclusion

The problem of the current state of public passenger transport in less developed EU countries is the obsolescence of the individual subsystems involved in its further development and the overall increase in the attractiveness of public passenger transport. Very important activity of the engagement subjects on the transport market is to create of strategic

documents whose global objective is to promote sustainable mobility, economic growth, job creation and improved business environment. These aspects will be achieved through the development of transport infrastructure and the development of an information society, including the provision of environmentally friendly and cost-effective public transport.
At the same time, it is very important to place great emphasis on the transparent interconnection of the different levels of the strategy, clear linking of the analytical and the design part, and, last but not least, the clear definition of the barrier. By achieving these goals, several operational-organizational or building-reconstruction measures need to be carried out.
The aim of the paper was to analyze the current state of public passenger transport with emphasis on passenger rail transport and subsequently to focus on optimization of selected operational and organizational measures resulting in particular from accurate tracking and modeling of transport demand and appropriate adjustment of timetable or optimization of time table.
Appropriate implementation of these measures and an optimal setting of synergies between them will create a prerequisite for streamlining rail passenger transport, increasing traffic flows in rail passenger transport, making it attractive and consequently improve public passenger transport, in general.

Acknowledgements

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POTENTIAL FOR IMPLEMENTING THE “HUB&SPOKE” CONCEPT IN SUBURBAN BUS LINE NETWORK – CASE STUDY OF AVALA CORRIDOR

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Abstract: Public transport system forms an indispensable part of urban transport because of its major share in the social and economic growth of the area. Therefore, it should be tackled by implementing modern concepts of urban transport planning in order to increase its quality and passenger satisfaction, as well as catering to the interests of service providers. Implementing these concepts will result in a decrease in overall expenses, including operational costs and travel time costs. This paper introduces the Hub and Spoke concept as a pioneer concept in public transport route network design, as well as highlighting its main advantages. A case study of suburban bus routes of the „Avala corridor“ in Belgrade was conducted to analyze all important elements of mentioned bus routes, and additionally to identify all important problems that influence efficient functioning of „Avala corridor“ bus routes. As a result of the analysis, a new route network variant was proposed, as well as a new set of corresponding bus timetables. In essence, the proposed variant introduces a new hub (“Jaričište”), located on a junction of two major roads, which is now the starting point of all suburban lines with routes contracted to the hub. Hub location was not determined as a result of implementing corresponding models, but a result of implementing a set of criteria that includes location suitability, area size and also a presumption of minimal investments. Furthermore, a comparative analysis of the proposed variant was conducted using a set of criteria including overall costs, mileage, demanded number of vehicles and number of departures and then compared to corresponding parameters of the current network. The results suggest noticeable savings in operator costs and overall costs, as well as reductions in mileage and necessary number of vehicles.

Keywords: Hub and Spoke; Bus line network; suburban lines; public transport planning.

1. Introduction

The essence of future development of world cities is based on achieving optimal modal split between passenger cars and public transport (PT). In order to motivate users to use PT instead of private cars it is necessary to provide users of PT with quality transport service competitive to the comfort of passenger cars. In addition, PT is always cheaper than individual transport, users are released from driving stress and also from the stress necessary for finding an empty parking spot in urban centres. Urban public transport network or line network of urban public transport (PTN) is a sub-system of city transport network and it comprises lines network of all sub-systems (modes) of PT. The structure of the PT line network comprises static and dynamic elements. Static elements are the infrastructure of urban public transport network: routes, stops, terminal stops, stop distances and line lengths (network structure). Dynamic elements of PTN are the operation elements: times, speeds, number of vehicles, headways, frequency, capacity (scheduling) etc (Tica et al., 2016b).

Public transport aims to provide transport service to users with different trip origins and destinations, which are constantly growing due to rise in city population and massive urbanization of city suburbs. Therefore, public transport systems struggle to provide a wide variety of destinations in order to fulfil users’ transport demands on a satisfactory level. However, some authors such as Mees (2000) object to the principle of *demand-oriented PT planning* as it can lead to serious misconceptions and, furthermore, connects this model with the idea of a liberal, deregulated market.

This have raised a question on whether the PT system should be planned as a widely distributed integrated transport network to support seamless multi-destination travel rather than as dedicated routes to meet specific passenger demands (Dodson et al. 2011). Even though local governments encourage using PT systems as integrated networks that can support users’ trip making behaviour which is not completely predictable by PT planners (called the “network effect”), Mees et al. (2010) suggest the new, *supply-oriented approach* according to the one applied in the Zurich region.

Few authors have presented guidelines, strategies and principles in order to achieve the “network effect”. Providing a stable interconnected network with user friendly lines, routes and timetables on one hand, and to accept and support the fact that many of travellers will need to transfer between lines to access their selected destination, on the other hand are the two main principles that pander to the mentioned effect (Neilsen et al., 2005; Dodson et al., 2011).

A critical task for planners, according to Dodson et al. (2011), suggests planning PT systems as seamless integrated networks, rather than as a series of individual routes serving a specified set of origin-destination pairs. Although benefits of the supply-oriented planning model are undeniable, this approach can be economically unfeasible due to implications such as additional vehicle fleet, more driver working hours etc. Therefore, cities with limited financial resources must look for modified solutions - finding the right balance between demand and supply oriented planning, corresponding to the city masterplan objectives and goals (Tica et al., 2016b).

The aim of this paper is to analyse the possibility of organising the PT network according to the Hub & Spoke principles and its implementation in one part of Belgrade’s suburban line network (the “Avala corridor”) as a case study of a balanced network in a city with limited financial resources. The paper is not dealing with hub location models used

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to determine the optimal hub location, but based on a previously chosen hub location according to a set of criteria, such as location size and suitability, minimizing necessary investments and achieving operational savings.

2. Hub and spoke Concept – Literature Review

Hub & Spoke concept is defined as a system for transporting units of transport through the network in which transport units move through a point in the network called "the *hub*". Hub is generally a point in which activities concentration exists (for example commodity-distribution center, customs terminal, intermodal stop etc) and which serves other points in the network, called "the *Spokes*" (usually trip origins and destinations). Hub & Spoke concept is opposite to the *Point-to-point* concept where transport units always travel from starting points to their destinations using direct paths (Cook and Goodwin, 2008).

This concept has its roots in aviation and first emerged during the seventies (Babić, 2015). However, first research projects dealing with the topic of Hub and Spoke and Hub allocation problems were conducted only ten years after. O'Kelly (1987) was the first to introduce hub and spoke mathematical model based on a quadratic programming model of hub location allocation. Only after five years this model was improved and enriched with fixed costs factor necessary for establishing a Hub since practical research has shown that initial costs can discourage PT planners from opting for this concept (O'Kelly, 1992). After these papers, during the nineties, a few authors dealt with Hub & Spoke models and introduced multiple allocation models, the heuristic method and genetic algorithm for hub allocation in a set of multiple nodes (Hosapujari and Verma, 2013). Even though many hub allocation models were introduced during the nineties, majority of them primarily refer to airline networks where Spokes are usually directly connected to Hubs via air corridors. Nevertheless, in road transport many intermediate nodes exist between hub and the spokes, so these models are scarcely applicable. Until now very few studies dealing with Hub and Spoke concept in road transport were completed. A pioneer study was presented by Parti et al. (2002) which formed a Hub and Spoke bus line network using the genetic algorithm.

Many authors agree that hub location should be chosen and placed on a location where noticeable socio-economic activities exist and designed to cater the need of communities from the origin to the other end of journeys (Tony, 2006). However, according to Woxenius (2002) when identifying potential locations, a number of characteristics need to be considered. These characteristics include capability to host one or more modes of transit, enhancement of transit service, having inter-regional destination, market demand to attract high levels of mix use and land available for different types of development in and around the hub.

In his PhD thesis Gelareh (2008) agrees that Hub and Spoke concept and economy are closely linked as main advantages of this concept are based on *economies of scale* – reduction of costs per unit of flow or commodity or passenger caused consolidation of flows at larger connections (increase in service) and *economics of scope* – cost of performing multiple jobs simultaneously is more efficient than performing each job separately. Therefore, cost of service is reduced due to the increase in demand density and better vehicle occupancy. In addition, a multiplier effect occurs. Establishing a hub will stimulate establishing service industries in the vicinity of a hub. Furthermore Gelareh (2008) points out the main disadvantages of this concept: longer travel times and higher costs of some routes (usually where multiple transfers exist); capacity overload (higher vehicle occupancy is not well received by passengers); higher risk of accident (congestion phenomena); and risk of missing a departure (loss of connection) due to an unforeseen delay at some parts of the network.

Two Asian studies have managed to quantify effects of implementing this concept. In the first one, conducted in India, aimed on identifying optimal hub location and forming a line network which corresponds to interests of both operators and users and, moreover, aimed on reducing operating costs. In this example, study resulted in reduction of required number of buses by 13.64% with a slight increase in user travel time by 2.13%. On the other hand, reduction in required vehicles consequently leads to lower fuel consumption and alleviates emission of greenhouse gasses and, therefore, in this study, Hub & Spoke concept imposes as a sustainable concept (Hosapujari and Verma, 2013). In the second study, conducted in Penang region, Malaysia, hub location (Penang central station) was previously identified using a set of criteria: location suitability, space available for use, connectivity with other modes of transport, existence of nearby services (restaurants, shops, etc.). As a result of conducting correlation tests between hypotheses to determine the strength relationship between variables with a pre-chosen hub location, there is a moderate positive correlation suggesting that Penang central station is suitable for hub establishment (Ustadi and Shopi, 2015).

3. Implementation of the Hub and Spoke Concept – Case Study of Avala Corridor in Belgrade

Suburban public transport in Belgrade serves the settlements of peripheral urban municipalities Grocka, Obrenovac, Barajevo, Mladenovac, Lazarevac and Sopot and it is organized according to a principle similar to Hub & Spoke. It consists of more than 290 lines divided roughly into two groups: suburban transport (radial lines that run from urban terminals Belgrade Bus Station (BAS), Šumice and Banovo Brdo) and local transport (lines that run from bus stations in Obrenovac, Mladenovac, Lazarevac, Barajevo and Sopot). The first group of lines also includes the considered "Avala Corridor".

In the current state, there are 6 suburban lines (450, 451, 466, 470, 474 and 491) running on Avala Corridor, whereby 4 out of 6 lines (451A, 466A, 470A, 491A) have variations and connect the Main Bus Station in Belgrade with peripheral settlements of Mladenovac and Sopot municipalities, as well as the settlement of Vrčin belonging to Grocka municipality. In addition to the aforementioned lines on the corridor, there is also an urban line (408) whose route overlaps significantly with the routes of aforementioned lines. Table 1 and Figure 1 show the most important static and dynamic line elements, as well as the route map with the settlements served.

3.1. Identified Problems in Existing Line Network

In the current system of the suburban transport lines on Avala corridor, there have been identified several problems that contribute to the poor quality of service from user perspective and which are the basis for the line network reorganization. The problems, which will be discussed below, are the result of a detailed analysis of the static and dynamic elements of the considered lines, transportation demand research, the use of the mentioned lines and, finally, the results of the user surveys that are an integral part of the study on suburban and local lines in Belgrade (Tica et al., 2016a).

Table 1
The Most important static and dynamic line elements in existing line network

No.	Line number	Route	L (km)	Np (from BAS) (dep)	Np (to BAS) (dep)	Tp, sm (min)	Nr
1	408	VOŽDOVAC - RALJA /DRUMINE/	32.52	31	31	70	4
2	450	BAS - RALJA - SOPOT	49.31	8	8	80	2
3	451	BAS - BABE - DUCINA MONUMENT - STOJNIK	61.76	4	1	115	2
4	451A	STOJNIK - BAS (does not go to Babe & Duc. Mon.)	52.75	0	3	90	2
5	466	BAS - JARIČIŠTE - VRČIN CENTER	28.20	4	5	50	2
6	466A	BAS (via E-75 Highway)-JARIČIŠTE-VRČIN CENTER	32.90	1	0	50	1
7	470	BAS - RALJA - MALA IVANČA	46.49	6	9	80	2
8	470A	BAS - RALJA - PARCANI - RALJA - MALA IVANČA	55.11	2	0	100	2
9	474	BAS - RALJA - PARCANI	41.31	3	3	70	1
10	491	BAS - RALJA - MLADENOVAC	57.59	21	23	90	6
11	491A	BAS - RALJA - SOPOT - MLADENOVAC (night line)	66.53	1	0	115	1

Abbreviations and tags used in the table above have the following meaning:

- *L* – line length;
- *Np* – number of departures (from and to BAS – Belgrade central bus station);
- *Tp* – planned travel time;
- *Nr* – number of working vehicles.

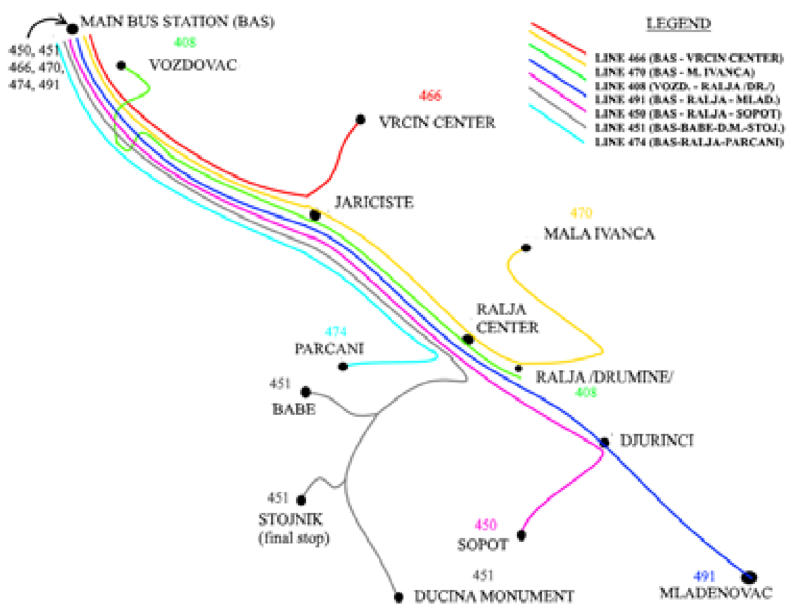

Fig.1.
Existing line network route map

Some of the problems are specific only for one specific route section, while some of them, in the same or modified form, may refer to suburban and local transport as a whole. Here are shown those that, by authors' opinion, contribute to poor quality of transport service, leaving the space and the possibility for new problems to emerge, outside the list below. The most important problems in the current situation are:

- *Competition with urban public transport* - On certain road sections, suburban transport is an alternative to urban transport that offers the transport "by shorter route" and shorter travel time between two points connected by regular urban public transport line routes. For example, on the considered network, using the suburban lines that are the subject of this paper, one can travel from BAS station to Voždovac up to several times faster than urban bus, tramway or trolleybus subsystem. The "mitigating" circumstance is the fact that a large number of users are not informed about the possibility of using suburban transport within the zones for which they have individual ticket or monthly pass; however, by informing the users a large user redistribution from the tramway and trolleybus subsystem to suburban transport can occur, but this is not the goal, since it is necessary to force tramway and trolleybus subsystems, in particular tramway subsystem that is underutilized while offering a relatively high capacity. On the other hand, the suburban lines that are subjects of this paper have routes that are almost completely overlapping with the route of urban line 408.
- *Timetable overlapping* – timetable overlapping occurs when vehicles of several different lines with a common part of the route have departures in a short time interval or have simultaneous departures. Sometimes departure overlapping presents a form of unburdening certain lines (specific for urban transport); however, in suburban transport, where time intervals are longer than an hour (i.e., there are only a few departures during the day), the overlapping of the departures affects the transport service frequency by the fact that there will be more vehicles with a common route in a short time interval, and then, after these vehicles pass, there are no vehicles in the longer time period. By analysing timetables in the current state, it has been determined that the lines 408 and 491 have even 13 departures in one direction with the time span of just a few minutes. In addition, if the departures from BAS are considered, the suburban lines often overlap (Table 2)

Table 2
Overlap of departures

DEPARTURES FROM MAIN BUS STATION (BAS)				
LINE 450	**LINE 451**	**LINE 470**	**LINE 474**	**LINE 491**
	07:10			07:15
07:50		08:00		07:50
10:50			10:45	10:40
	15:30	15:15		15:30
	17:30	17:15		17:30

3.2. Proposed Variant

Having in mind the arguments presented above and in particular those concerning the problem of alternatives to the bus, tramway and trolleybus subsystem of urban public transport, as well as the optimization of the lines that are the subject of this paper, bellow will be presented a proposal in accordance with the principles of Hub & Spoke. It should be kept in mind that this is a solution at the level of the proposal (possible organization) and it will be subject to evaluation later in order to assess the quality of this solution, i.e. to determine the extent to which the identified problems can be solved, that is, to achieve certain cost savings. The essence of the proposed solution is reflected in the reorganization of existing lines by establishing a new terminal "Jaričište", which presents the local Hub for the suburban lines of the Avala Corridor. The choice of location "Jaričište" in the future state is based on the application of the following criteria:

1. Location suitability,
2. Enough space to organize 3+1 platforms (stop areas),
3. Proximity of location with significant passenger interchange,
4. Terminus position on intersection of important road directions,
5. Minimization of investments needed for variant realization with achievement of savings and benefits in the future,
6. Comfortable conditions for passenger stay at terminus due to the natural ambient.

However, it should be noted that Hub "Jaričište" does not meet a preconditions that every hub needs to fulfil – to be a centre of activity and a place with significant passenger interchange. Figure 2 shows the location of the site itself and the proposal of a possible organization.

Kragujevacki put and Jaričište-Vrčin road (link road to motorway E-75) are shown by numbers 1 and 2, respectively, on Figure 2. A yellow dotted line shows the surface that is used as a terminus in the current state, so there are no real administrative obstacles, such as the cost of land expropriation, to adapt this area into a new terminus. Within this area, it is planned to organize three platforms, designated by grey lines, at an angle of 45 degrees in relation to the Kragujevac road. The space planned for the terminus is designated by number 4 on the Figure 2. Number 3 designates a shop, which is important for the proper functioning of the terminus, since passenger accumulation and staying are expected on this place. On the other hand, it is necessary to build toilets. If there is a real need, for the line 466 (and the local lines 462 and 463 using this terminus), it is possible to establish an additional departure platform, designated by number 5 and the green rectangle on Figure 2. The proposed way of platform use is shown by red arrows.

Fig. 2.
Possible organization of the proposed Hub location

The new line organization implies the shortening of existing (suburban) lines to the new terminus "Jaričište", with the emphasis on better utilization of the urban line 408, which is underutilized in the current state, since users choose between the line 408 and the suburban lines whose routes overlap with its route. Compared to the current state, the part of the route between the BAS station in Belgrade and Jaričište is abolished for suburban lines, while the routes on the section Jaričište - peripheral terminuses are unchanged. In addition, the urban-suburban line 408 is shortened to the terminus "Prnjavor/School/" based on the analysis of passenger flow data on the considered lines (Tica et al., 2016a). In addition to the modified routes, new routes have been proposed. Figure 3 shows the route line map by proposed variant and Table 2 shows the most important static and dynamic elements.

Table 3
Basic static and dynamic elements of the proposed line network

No.	Line number	Route	L (km)	Np (from BAS) (dep)	Np (to BAS) (dep)	Tp, sm (min)	Nr
1	408	VOŽDOVAC - PRNJAVOR /SCHOOL/	32.52	20.99	48	48	5
2	450	JAR - RALJA - SOPOT	49.31	24.10	6	41	2
3	451	JAR - BABE - DUCINA MONUMENT - STOJNIK	61.76	36.55	1	76	1*
4	451A	STOJNIK - JAR (does not go to Babe & Duc. Mon.)	52.75	27.54	5	53	1*
5	466	JAR - VRČIN CENTER	28.20	2.99	8	11	1*
6	466A	LINE DISMISSED					
7	470	JAR - RALJA - MALA IVANČA	46.49	21.28	9	42	1*
8	470A	JAR - RALJA - PARCANI - RALJA - MALA IVANČA	55.11	29.90	2	58	1*
9	474	JAR - RALJA - PARCANI	41.31	16.10	3	27	1*
10	491	JAR - RALJA - MLADENOVAC	57.59	32.38	23	51	3
11	450N	BAS - RALJA - SOPOT (night line)	66.53	49.31	0	90	1**

Abbreviations and tags used in Table 3 have the same meaning as those used in Table 1, with two exceptions, marked with symbols * and **. Symbol * means that six lines marked with this symbol are served by 4 vehicles changing lines during the operation period, whereas, ** means that this line is served by the vehicle coming from another line.

3.3. Developed Model for Evaluation of the Proposed Variant

In order to evaluate a new variant, a comparative analysis was carried out, i.e. a comparison based on the criterion of *the total cost of the variant,* which includes *operational costs* and *user costs*.

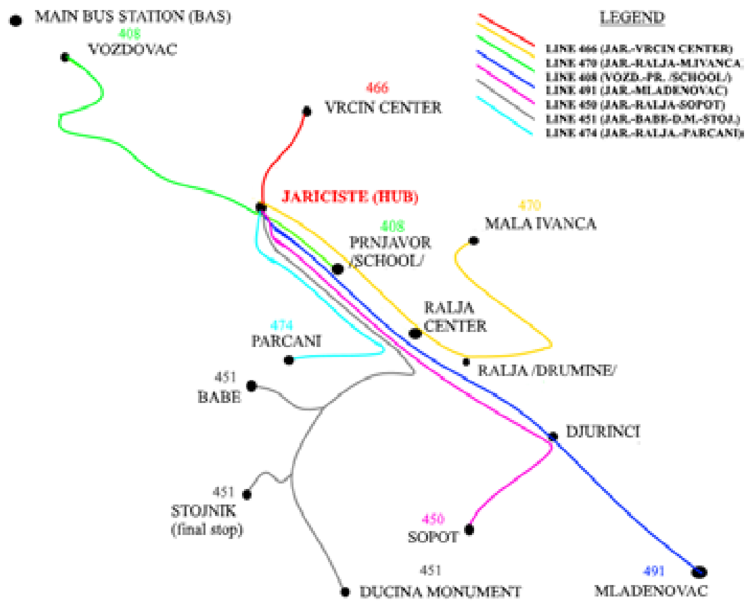

Fig. 3.
Route map for proposed line network

Operational costs are quantified based on the number of vehicle departures, the average line length and the fixed price paid by the city to operators, which depends on vehicle type.

$$T_{op} = \sum_{i=1}^{k} (n_{pi,solo} \times c_{solo} \times l_{sr,i} + n_{pi,zglob} \times c_{zglob} \times l_{sr,i}) \tag{1}$$

In the preceding formula (1) the following designations were used: k – total number of considered lines, T_{op} – operational costs, $n_{pi,solo}$ – number of departures by solo vehicle on line i, $n_{pi,zglob}$ – number of departures by articulated vehicle on line i, c_{solo} – determined price per kilometre for solo vehicle, c_{zglob} - determined price per kilometre for articulated vehicle, $l_{sr,i}$ – average length of line i.
In the cost calculation, price per kilometre for solo and articulated vehicles were taken based on determined prices from the decision on contract award (Secretariat for public transport, 2016). This document specifies the prices of 119.50 RSD/km for solo and tourist buses, i.e. 144.50 RSD/km for an articulated bus (whereby the prices are expressed without VAT).
User costs (T_K) present the costs that users bear due to the investment of a part of their time in travel. User costs can be divided into *waiting time costs* and *travel time costs*. Waiting time costs relate to costs arising from the fact that the passenger usually does not enter the vehicle immediately after arriving at the station, spending a part of their time on waiting for the vehicle. It can be assumed that these costs are equal in both variants and that can be neglected. Travel time costs can be determined on the basis of the total number of carried passengers, the average travel time, the travel time cost expressed in units of money per time unit (RSD/hour) and transfer costs.
In the first variant (current state), user costs are equal to travel time costs. These costs can be calculated according to the following formula:

$$T_{K\,(varijanta\ 1)} = \sum_{i=1}^{k} \sum_{sm=1}^{2} P_{u,i,sm} \times t_{sr,i,sm} \times c_{tv} \tag{2}$$

Unlike the current state, in the new variant (variant 2) it is necessary to include transfer costs into the calculation, so in the new variant, the user costs are calculated according to the following formula:

$$T_{K\,(varijanta\ 2)} = \sum_{i=1}^{k} \sum_{sm=1}^{2} P_{u,i,sm} \times t_{sr,i,sm} \times c_{tv} + P_{ut} \times t_t \times c_{tt} \tag{3}$$

Designations used in formulas (2) and (3) have following meaning:

- $P_{u,i,sm}$ – total number of carried passengers on the line i in direction sm; it is obtained based on passenger counting data,
- $t_{sr,i,sm}$ – average travel time on line i in direction sm; it is calculated as a ratio of average ride length to planned travel speed, which is a ratio of average line length and planned travel time,
- c_{tv} – the price of one hour of travel time, which, according to some research (VTPI, 2017), is about 30% of the price of one working hour,

- P_{ut} – total number of passengers waiting for a transfer/interchange; it is calculated as the sum of the flows on all lines at the interchange stop, reduced by the sum of entries at a specific stop across all lines,
- t_t – average waiting time for the connection; the average value of 7.5 minutes is adopted based on the planned times of departures and arrivals,
- c_{tt} – the cost of waiting time for a connection; according to some surveys (VTPI, 2017), the price of this time is 2.5 times higher than the price of travel time.

Travel time costs in both variants are the same, having in mind that the assumption of an unchanged number of passengers is adopted, as well as the assumption that the average ride length will not change in the future. In the future state, the costs arising as a result of waiting for a connection must be taken into account when calculating user costs. These costs are proportional to the number of passengers waiting for a connection (P_{ut}), which represents the difference between total passenger flow (on all lines and directions) at the "Jaričište" stop during the all day ($Q_{u,\ Jaričište}$) and the total number of entries in both directions on all lines at this stop ($U_{u,\ Jaričište}$), i.e. (4):

$$P_{ut} = Q_{u,Jaričište} - U_{u,Jaričište} = 5447 - 152 = 5295\ passengers \quad (4)$$

In formulas (2) and (3), the working hour price was calculated as 173th part of the average salary in Belgrade, which amounts to RSD 55,583 according to the data of the Statistical Office of the Republic of Serbia. The value of 173 was taken as the average monthly number of working hours, in accordance with the Labour law of the Republic of Serbia (Official gazette of the Republic of Serbia, Nos. 24/05, 61/05, 54/09, 32/13, 75/14, 13/17 (CC) and 113/17). Based on the previous considerations, the value of RSD 321.29 for one working hour was calculated.

4. Results

Table 4, given below, shows the comparison of the current state (variant 1) and the proposed solution (variant 2) according to the criterion of total cost of the variant, but, in addition to this criterion, other criteria were also selected for the comparison – these are the number of departures, total distance travelled and total number of engaged vehicles. Considering separately only daily costs of vehicles and organization, the savings of over RSD 290,000 are achieved, i.e. the savings of 31.08% of the present value. Values shown in Table 4 are expressed in Serbian Dinars (RSD). A conversion rate is approximately 1€ (EU Euro) ~ 120 RSD.

Table 1
Variant comparison

CRITERION	VARIANT 1 (EXISTING CONDITION)	VARIANT 2 (PROPOSED VARIANT)
Operating costs (RSD) per work day	938.277,5	646.669,2
Travel time costs (RSD) per work day	667.690,5	809.322,8
Overall variant costs (RSD) per work day	1.605.968,0	1.455.992,1
Overall number of departures (work day)	164	213
Overall mileage (work day) in kilometers	7.214,9	4.946,5
Necessary number of vehicles (work day)	19	14

Although the increase of travel time cost by 21.2% for users due to the transition on Jaričište terminus, the total costs of variant 2 are lower than the total cost of variant 1 by around 10 percent, which is certainly not a negligible reduction. On the other hand, in contrast to the higher user costs, users receive better transport quality and this is concluded based on the increase of number of departures by 29.9%, whereby the number of departures on some lines (451, 451A, 466, 470, 470A, 474) is almost double.
In addition, the carrier's interests are not neglected - in the new variant it hires even 5 vehicles less (a decrease of 26.3%) and drive 2,268.4 kilometres less (a decrease of 31.4%), which results in fuel consumption savings, while, on the other hand, the carrier has 5 unengaged vehicles that it can assign to other lines or even introduce some new lines. Since the operational costs relate exclusively to the distance travelled without taking into account the number of engaged vehicles, the proposed solution with 5 engaged vehicles less implies indirect savings, reflected in lower vehicle maintenance costs of vehicles, less engaged drivers etc.

5. Conclusion

This paper mainly deals with the issue of Hub & Spoke networks and the possibility of implementing such a system in suburban transport in Belgrade on “Avala corridor”. The Hub & Spoke concept emerged in the air transport during 1970s, and the first research was based on the air transport line network. However, a small number of authors dealt with the Hub & Spoke concept in road transport and generally few studies were done on this subject, so this work

simultaneously promotes this concept and belongs to pioneering research in these fields, since the concept has proved to be very effective in some cities in the world, bringing operational savings.
In response to the current state and problems observed, a variant solution with elements of the Hub & Spoke concept was presented, with one important difference - the Hub terminus location was not determined based on the allocation model or transport demand, but it was selected from the existing set of possible locations according to certain criteria. In addition to the proposed solution, a set of timetables was created with the aim of increasing the number of departures and quality of service in the future state and, on the other hand, to address certain problems from the current state.
Based on the proposed timetable, a complete picture of the dynamic elements in the future state is obtained, and this is one of the basis for evaluate the new variant in terms of economics and to compare it with the base case (current state). In addition to the total costs of the variant, chosen evaluation criteria were the total number of departures, the total distance travelled and the number of engaged vehicles.
Evaluation has shown that the new variant guarantees potential savings, which amounts more than RSD 290,000 per day when it comes to vehicle and organizational costs, while the saving in total costs of the variant is expected to be about 10%. However, passengers also have an interest in adopting a new variant since the number of departures has generally increased by 29.9%, with the number of departures on some lines being almost doubled. On the other hand, the carrier hires 26.3% less vehicles (5 vehicles less) that travel 31.4% less distance, and the new variant, although partially deviating from the original Hub & Spoke concept, provides significant savings.
In general, this paper covers all important aspects of the lines on Avala corridor and provides a solution that is the result of significant field research and observation, and collection of information from various sources and as such it can serve as a good basis for future research and projects, but also as the basis for a deeper analysis of the topic under consideration.

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TRANSPORT DEMAND ANALYSIS IN THE RURAL AREA: THE CASE STUDY OF SISAK – MOSLAVINA COUNTY

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Abstract: The demand for transport in a wide array of cities has so far been analysed mostly with regard to urban areas. Such areas seek to manage transport demand due to traffic congestions brought on by personal vehicle transport, whereas the rural areas place emphasis on defining the factors that affect the transport demand in order to achieve its increase. The lower transport demand in rural areas can be explained by the fact that their population density is far lower than in urban areas, leading to fewer options for public passenger transport. Operators are less interested in providing public transport services due to the low number of passengers, and therefore a lower potential profit. This paper outlines the factors that contribute to transport demand, determines the features of rural areas in Sisak-Moslavina county, and analyses the factors of the transport demand in the county. The aim of the study is to identify the transport demand of rural areas on the case study of Sisak-Moslavina county.

Keywords: transport demand, public passenger transport, rural area, Sisak-moslavina county.

1. Introduction

The population's need for mobility is what generates transport demand. A transport service is launched providing that all the vital prerequisites have been met, such as transport demand, users' capacity to pay for, and desire to use, the service. On the other hand, transport demand is also generated by relevant demographic, geographic, economic, and transport factors.
The lack of public transport service in rural areas, which are referred to as areas with low transport demand, present a challenge for passengers, operators, and transport planners alike. The low demand in rural areas does not guarantee the profitability of the routes in that area, nor does it encourage operators to provide a service in such a region. Such transport planning and route management lead to the emigration of the local population, transport marginalisation, and inhibition of the development of rural areas (Skrucany *et al.*, 2017; Zefreh *et al.*, 2017).
In their paper, the authors (Braičić and Lončar, 2011) stress the issue of unequal regional development, particularly from the standpoint of an aggregate model of determining unequal development. The emphasise the following factors of economic growth of a region as generators of transport demand: (1) the number of active companies, (2) employment rate, (3) unemployment rate, (4) GDP per capita, and (5) export rate per capita. In their conclusion, they confirm their hypothesis that there are substantial differences between administrative cities and municipalities in terms of the achieved socio-economic development.
Gašparović (Gašparović, 2016) claims that despite the fact that a car has become an essential part of everyday life, public transport has to be available to everyone. Transport marginalisation can, therefore, be defined as the impossibility of using public transport due to the lack of adequate access. In rural areas, from the viewpoint of the marginalisation, we identify the features of transport marginalisation of population and space. The features of space include the range of available transport services in that area and the range and location of activities that people wish to have access to. Population mobility can, that way, be affected by the lack of public transport in a certain area, the frequency of departures, the impossibility for the person to afford the high fares, the location of population residence compared to transport services and desired activities, and similar.
Transport demand in rural areas is also investigated by Petersen (Petersen, 2016) on the case study of the rural areas of Switzerland. He arrives at the conclusion that it is necessary to maintain and subvene public passenger transport routes in rural areas in order to maintain an adequate level of economic growth. He emphasises the need for a great number of subventions for public transport routes in rural areas but argues that adequate transport planning can achieve the best value-for-money.
A case study of transport demand analysis in rural areas was made in Sisak-Moslavina County due to the spatial and transport specificity of the area. The County is a predominantly rural area with a low population density. An adequate transport offer in public passenger transport is available mainly in urban parts of the County, whereas in the rural areas there is virtually none. There is a constant trend of emigration and a complete exodus from certain marginalised rural areas.

2. Transport Demand in Rural Areas

Transport demand is the fundamental transport parameter in creating a transport service. The existence of a demand for transport service directly correlates with the capacity to pay, which restricts a user when choosing the means of transport. The desire to use a transport service becomes higher if a user has the purchasing power to use the specific service. Generally, it can be defined as a totality of the demands for transport services which service users desire and can get for a certain price and in a certain time interval. The specificity of the transport service is seen in the fact that it

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is not an end in itself, but rather arises from the transport demand in order to achieve a certain benefit, or a demand arising from some other beneficial effects (Čavrak, 2002).
Since transport service is not an end in itself, we can state that it is in interdependence with socio-economic characteristics of the area in which users commute. With the increase in population, employment, income, adequate transport offer, there is a proportional increase in the demand for commuting, i.e. transport.
Transport service cost is one of the most important parameters in the formation of transport demand because even a slightly reduced fare may generate a substantially greater demand. Therefore, transport price management may generate additional demand (Abramović, 2010). Nevertheless, the following factors significantly affect the demand for passenger transport:

- Population and population structure,
- GDP and its structure,
- Income and consumption structure,
- Workers', pupils', and students' commutes,
- Development of tourism and agriculture, and
- Competitiveness and complementarity of transport modes.

The above-mentioned factors may globally be classified into four large categories: (1) demographic, (2) geographic, (3) economic, and (4) transport. The demographic factors impact transport demand because, with greater population, workforce, number of pupils and students there is greater transport demand. The development of a certain area, its geographic features, tourist activity, and agricultural growth also take part in generating transport demand from a geographic point of view. The GDP and its structure substantially affect the paying capacity which directly affects transport demand. The transport factor refers to the development of the transport infrastructure, transport offer, competitiveness and complementarity of transport modes. A well-developed transport system meets the needs of transport users, encourages journeys, and therefore, generates transport demand.
Economic processes, population ageing, and emigration of young people have led to a significant decrease in the population of the rural areas of Europe. Due to the unprofitability of public transport in rural areas, bus and railway route cancellations are more common, which brings about reduced population mobility. Young people often move to cities, while the older population remain excluded from transport and social mobility. Naturally, this affects the rural economy which encompasses agricultural companies and small enterprises, that is, irreversible damage is being made to the region and society as a whole (Humić, 2016). All these steps affect the transport demand in rural areas.

3. Case Study

This chapter presents an analysis of the factors that affect transport demand in rural areas. The case study was made for Sisak-Moslavina County.

3.1. Demographics

According to the last population census, carried out in 2011, Sisak-Moslavina County has 172,439 residents, 51.51 % of whom are women, and 48.48 % of men, which constitutes 4.02 % of Croatian population. Based on the number of the residents, the County is ranked 9th. Population density in the County is 38.59 residents per square kilometre, which is half of the median density of the Republic of Croatia (75.80).
Sisak-Moslavina County is characterised by an uneven distribution of population which is seen in high density in urban areas (Sisak, Petrinja, Kutina, Novska), with a considerably lower density in rural areas. The low density is particularly evident in municipalities Dvor, Jasenovac, Topusko, Gvozd, Hrvatska Dubica, and Donji Kukuruzari, where certain rural settlements are completely uninhabited. Such uneven distribution causes substantial differences in the levels of development of certain regions in the County. The demographic trends in Sisak-Moslavina County are negative, i.e. its population is constantly in decline. In fact, compared to the population census in 2001, the census of 2011 reveals a decrease of 6.98 %. This depopulation can be attributed to the emigration of young people in search of employment, but also to the previously significant process of deruralisation.
The median age of the population of the Republic of Croatia was 42 (40.2 men, 43.7 women), which makes it one of the oldest nations in Europe. In Sisak-Moslavina County, the median age is 43 (40.9 men, 44.9 women) which is above the Croatian average. Taking into consideration the figures, according to the population census of 2011, in Sisak-Moslavina County there were 45,227 residents older than 60, which makes up 26 % of the entire population. At the same time, according to the same census, only 20 % of the population is aged 20 or younger, which makes the County predominantly old. The share of the old population makes the County one of the most endangered counties in Croatia (SI - MO - RA d.o.o., 2014).

Table 1
Population and Population Density According to the Units of Local Self-Government of the Sisak-Moslavina County

Region	Area (km^2)	Number of settlements	Population			Population density 2011. (residents/km^2)
			(1991.)	(2001.)	(2011.)	
CROATIA	56,602.90	6,820	4,784,365	4,437,460	4,284,889	75.70
COUNTY	4,467.79	453	251,332	185,387	172,439	38.60
CITIES	2,012.16	208	166,660	127,173	120,756	60.01
GLINA	544.10	69	23,040	9,868	9,283	17.06
HRVATSKA KOSTAJNICA	52.60	7	4,996	2,746	2,756	52.40
KUTINA	295.44	23	24,829	24,597	22,760	77.04
NOVSKA	317.36	23	17,231	14,313	13,518	42.60
PETRINJA	380.60	55	35,151	23,413	24,671	64.82
SISAK	422.06	31	61,413	52,236	47,768	113.18
OPĆINE	2,455.63	245	84,672	58,214	51,683	21.05
DONJI KUKURUZARI	113.78	15	3,063	2,047	1,634	14.36
DVOR	504.76	64	14,555	5,742	5,570	11.03
GVOZD	214.27	19	8,082	3,779	2,970	13.86
HRVATSKA DUBICA	129.37	6	4,237	2,341	2,089	16.15
JASENOVAC	161.88	10	3,599	2,391	1,997	12.34
LEKENIK	228.57	18	6,248	6,170	6,032	26.40
LIPOVLJANI	108.70	4	3,866	4,101	3,455	31.78
MAJUR	66.72	11	2,555	1,490	1,185	17.44
MARTINSKA VES	125.05	17	4,643	4,026	3,488	27.89
POPOVAČA	216.75	13	11,822	12,701	11,905	54.93
SUNJA	288.41	40	12,309	7,376	5,748	19.93
TOPUSKO	195.92	16	6,824	3,219	2,985	15.24
VELIKA LUDINA	100.21	12	2,869	2,831	2,625	26.19

Source: (Državni zavod za statistiku, 2018)

3.2. Geography

Sisak-Moslavina County is situated in the southern region of Central Croatia. It covers an area of 4.467,76 km^2, which makes up 7.89 % of the entire continental part of the country. The land area is predominantly used for agriculture (52 %), followed by forests (44 %) and infertile land (4 %). Such a favourable land structure is a significant resource for the County. There are 455 settlements there, divided into 19 self-governing administrative units. The cultural, economic, and administrative centre of the County is Sisak, its largest town. There are 6 other towns in the County (Glina, Hrvatska Kostajnica, Kutina, Novska, Petrinja, and Popovača), and 12 municipalities (Donji Kukuruzari, Dvor, Gvozd, Hrvatska Dubica, Jasenovac, Lekenik, Lipovljani, Majur, Martinska Ves, Sunja, Topusko, and Velika Ludina) (Sisačko - moslavačka županija, 2017).

The criterium used for differentiating between rural and urban areas in Croatia is the one put forward by the Organisation for Economic Co-operation and Development (OECD), based on population density. The threshold separating rural from urban areas is 150 inhabitants per square kilometre. Based on the OECD criteria, the area of the County is largely an urban region with about 7 % of urban settlements in which there reside about 53 % of the inhabitants. The low density of most of the County's areas further impedes the adequate provision of social and healthcare service. Due to the size and geographic features, and population density, there are significant hindrances that obstruct development, particularly in terms of population mobility and connections to larger urban centres (Sisačko - moslavačka županija, 2015).

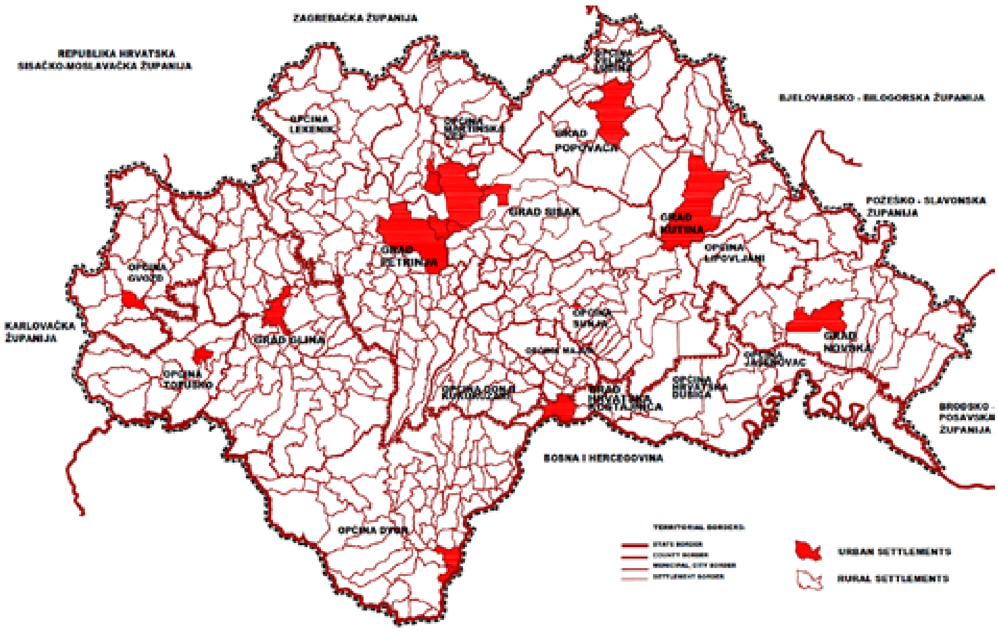

Fig. 1.
The Division of Sisak-Moslavina County into Urban and Rural Settlements
Source: Authors

3.3. Economy

The main branches of the economy in the County are industrial with special emphasis on energy, oil, petrochemical and chemical industry, metallurgical and metal industry, nutrition industry, agriculture, forestry, trade and service industry, civil engineering, and transport. Recently, there has been a rise in the development and utilisation of sophisticated technologies in the electronics industry, and there is a significant rise of the pharmaceutical industry, as well. Slightly behind are other branches of industry and economy and crafts.
The agricultural and nutritional complex is of vital importance and has a long tradition. Apart from agricultural products, outlined are the ones that the County is renowned for: the autochthonous breed of horse called the Posavac, the growing of fruit, mainly plums. What is so special about this County is the Lonjsko Polje Nature Park with elements of rural tourism. The entire County is abundant with economic and comparative advantages for the development of food production and processing, when taking into consideration all the relevant prerequisites and a completely enclosed reproductive supply chain (land, natural conditions, production of mineral fertilizers and crop protection sprays, facilities for growth, the tradition of production, and so on). Along with numerous preserved cultural and historic monuments, the tourist offer is complete with Lonjsko Polje Nature Park (506 sq. km), a thermal spa in Topusko, and the wine roads of Moslavina (Sisačko - moslavačka županija, 2017).
The gross domestic product of Sisak-Moslavina County in 2015 was €1,240,324,000 which makes up 2.8 % of the Croatian GDP. The average GDP per capita in the County in 2015 was €7,724, which is 37 % less than the average GDP per capita in the Republic of Croatia (Državni zavod za statistiku, 2018).
In 2015, the average nett monthly income per capita in the County amounted to about €677 (€925 pre-tax). The nett salaries are about 10 % lower compared to the Croatian median. The registered number of employed people was 37,550, with 19,676 unemployed, which makes up the 34.4 % unemployment rate, i.e. 15 % higher than average in Croatia (Državni zavod za statistiku, 2018).
The natural resources are the backbone of the tourist development of the County. According to the EU, Lonjsko Polje is one of the most important habitats of birds. Due to a large number of nests, the municipality Čigoč has been named the European stork village, and the village Mužilovčica is famous for being a habitat to swallows. The County is rich in rivers (Lonja, Una, Kupa, Sava, Odra, Glina, Sunja, Veliki Trug, and Trebež) which are abundant with fish and provide an opportunity for fishing tourism. The forest parts of the County are also a chance to develop hunting and outing tourism.

3.4. Competitiveness and Complementarity of Transport Modes

The County is situated at the intersection of two important road and railway traffic directions: Posavina corridor that connects Zagreb and Slavonski Brod, which means Western and Central Europe to South-Eastern Europe and the Middle East, and a traffic direction that connects Hungary and Podravina with Croatian coast and the Mediterranean.
Because of its favourable position and its key role in connecting the Croatian space, adequate infrastructure and a developed transport system are of vital importance for a balanced economic development and a stimulation of the County’s economy. In order to harness the benefits of its geographic location, it is essential to develop the transport

sector which is not only in accordance with its own but also international developmental potential. It is vital to integrate the transport infrastructure into the Trans-European transport network.
The geographic-transportation location is determined by the system of state roadways towards Zagreb, Karlovac, Slavonski Brod, and towards Bosnia and Hercegovina, as well as the system of roadways in the County, which are different within the County based on population density (the northern and central parts have a higher density of roads than the southern and eastern), and the motorway.
In Sisak-Moslavina County in 2015, there were a total of 1,767 kilometres of road infrastructure which comprise two motorways (74 km), 9 state roads (385 km), 68 County roads (668 km), and 160 kilometres of local roads. The density of the road network is 396 m/km^2 which, compared to the Republic of Croatia, is 19 % lower.

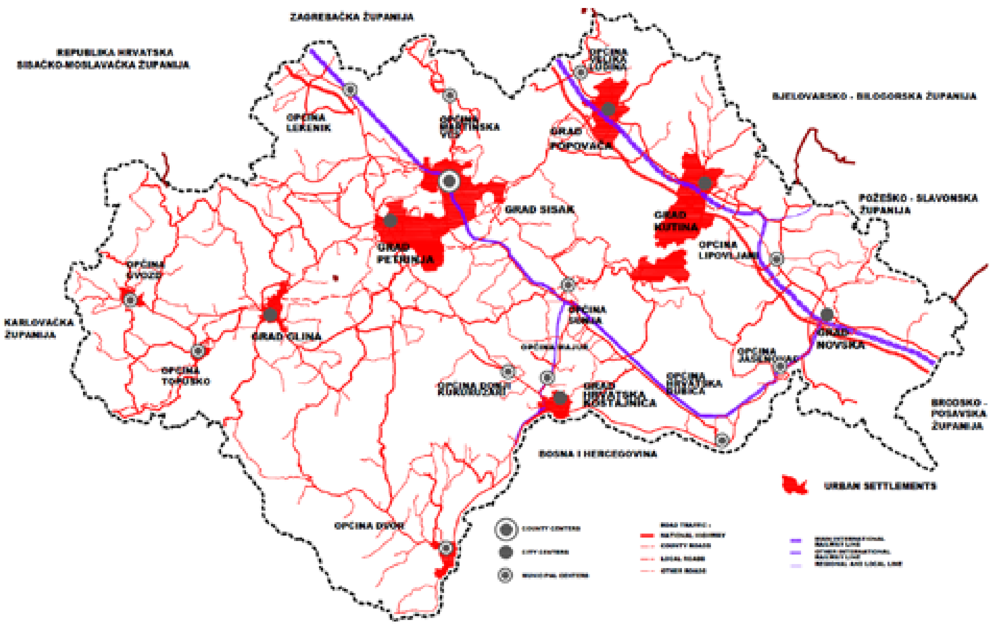

Fig. 2.
Road and Railway Infrastructure of Sisak-Moslavina County with Division into urban and Rural Settlements
Source: Authors

The number of registered road motor vehicles in the County is 68,535, where 50,812 of which are personal vehicles. Since there are only 62,487 households, each of them owns one registered personal vehicle on average. As for the cargo transport, in 2015 there were 1,627 tons transported which makes up about 2 % of the entire road cargo transport of the Republic of Croatia (Državni zavod za statistiku, 2018).
The impact of the railway transport as one of the most economically and ecologically friendly means of land transport is essential for the development of population, and thus indirectly the socio-economic transformation of urban and regional areas, the dynamics of urbanisation, and the development of the national and County economy (Ľupták, Gašparík and Chovancová, 2017; Stoilova, 2018). Owing to the poor infrastructure, the efficiency of the railway is reduced significantly, which is evident in low train speeds on certain sections and frequent cancellations and delays. The modernisation of the train fleet by means of improving the vehicles and introducing new services, along with the planned track reconstruction, will be crucial for increasing the degree of competitiveness with other transport modes. By diverting a part of the traffic from roads onto the railway, particularly cargo, the traffic on roads would reduce (Stopka, Chovancová and Kampf, 2017). This sector is relatively the most undeveloped one, but with substantial growth potential and stimulating a more balanced development of transport networks by increasing the share of investments in the railway sector, as well as a construction of new parts of the transport network, would increase the growth of the sector and the integration of Croatia and the County into the EU, thus triggering a growth of the economy and a sustainable transport sector as a whole.
An international railway line passes through Sisak-Moslavina County, namely, RH1, Salzburg - Solun, with the length of 317 in the Croatian territory, connection Central and Western Europe with South-East Europe and the Middle East. The strategic position of the County thus gains in additional importance. A part of the corridor RH1, SB - Savski Marof - Zagreb - Dugo Selo - Novska - Vinkovci - Tovarnik - SB is the railway line M 103 Dugo Selo - Novska with 50.9 km in length, and M 104 Novska - Tovarnik with 14.5 km in length. International transport railway line is M 502 Zagreb GK - Split - Novska with 91.3 km in length. Sisak-Moslavina County is essential for regional transport via municipality Sunj, with railway line R102 Sunja - Volinja - SB with 21.6 km in length, as well as a part of the Una corridor, which before the war used to provide a fast and safe connection between Central Croatia, Central Dalmatia, and Bosnia and Hercegovina. Its significance today has somewhat been played down, although there is a need for a reconstruction and revitalisation of the railway transport on that line. This would pave the way for a greater economic cooperation between Croatia and Bosnia, in which the County would play a key role, and securing the funding would improve the railway infrastructure and sustainable transport development in terms of safety, low fares compared to other transport modes,

eco-friendliness, and a rational use of energy. Important for local transport are the railway lines L204 Banova Jaruga - Pčelić with 6.7 km in length and L210 Sisak Caprag - Petrinja, 11 km. The entire length of the railway lines in the County in 2015 was 196 km (7 % of the country), 181 of which are single-track, with 15 km of double-track railway lines.
Cargo transport is found mainly at Sisak Caprag train station, where oil derivates are loaded and where cisterns are handled. In the winter period mazut is used, in harvest seasons corn, sugar, crops, etc. Loading spots are also the stations in Majur, Sunj, Lekenik, Hrvatska Dubica, Volinja, Jasenovac and Turopolje, where the most common cargo is wood.
The number of passengers that travelled using the railway in 2011 was 1,011 which is 4 % of the number of passengers on a national level. 627,120 passengers travelled from Sisak, which is 62 % of all the passengers departing from stations in the County. The cargo transport measured in the loading quantity in 2015 was 1,104 tons, i.e. 14 % of the Croatian cargo, whereas the unloading quantity is 602,000 tons or 13 %. The quantity of loading in the town of Sisak was 429,304 tons or 42 % of the County, with 201,386 tons being unloaded, i.e. 33 %.

4. Results

Apart from the analysed factors that affect transport demand, we need to take into consideration the entire road transport, the public transport offer, and the methods of transport that the population opts for, in order to establish a detailed picture of population mobility

4.1. Traffic Count

U This chapter outlines the data on the average daily traffic on state roads, motorways, County roads, local roads and all other roads. Traffic count on Croatian roads is performed regularly on an annual basis by Hrvatske ceste d.o.o. (Croatian Motorways, LLC). The counting methods include: (1) temporary automatic traffic count and (2) permanent automatic traffic count. The former is scheduled based on a count timetable of hour count in a day, day count in a week, whereas the latter uses stationary automatic counters installed on locations (Hrvatske ceste, 2016).
Figure 3. illustrates the average annual daily traffic (in blue) and the average summer daily traffic for the permanent traffic counting, where data represents an estimate based on an incomplete set of data, or the average daily traffic (in pink) for a part of an interval. The red colour denotes the incomplete count data from the permanent traffic count, with the bold lines indicating the intensity of the annual daily average.

Fig. 3.
Road Traffic Count of Sisak – Moslavina County
Source: (Hrvatske ceste, 2016)

4.2. Traffic Options in Public Passenger Transport

The town of Sisak is the town of a functional region with its own transport network (3 bus and 1 railway line). The vehicle fleet and services aim to adapt and meet to need and demands. Public passenger transport is provided by three operators (HŽ Passenger Transport, Auto promet Sisak, and Čazmatrans Promet Slavijatrans). Between the units of local self-government in the County, the transport has not been developed well enough due to the low number of passengers.
The analysis of the connectivity between rural areas in the County and the town of Sisak was made on the route Sisak - Volinja - Sisak. The railway public transport showed that the train departure frequency indicates a poor connectivity between the aforementioned areas.
There are 15 outbound trains to Volinja from Sisak to Sisak Caprag, 9 of which continue the journey to Sunj. From Sunj to border station Volinja there are only 4 passenger trains operating, with turning back in Volinja and destination in Sisak. From Volinja - Sisak there are 4 daily passenger trains from Volinja station. From Sunj to Sisak there are 9, and from Sisak Caprag to Sisak 16 passenger trains.
Public bus transport options on the route Sisak - Volinja - Sisak enables residents to commute to Sisak Caprag. In suburban and interurban transport between Sisak and Volinja there is only one bus line - Sisak - Blinjski kut - Sisak.

Departures in public bus transport on Sisak - Volinja - Sisak route illustrates the lack of connectivity of the large rural area of the County.
In urban public transport on the Sisak - Sisak Caprag route, the number of daily departures is 73, with 71 going the other way. The Sisak - Blinjski Kut - Sisak route is connected with the suburban line which provides 7 bus departures daily towards Blinjski Kut, with 6 buses going towards Sisak (Šipuš and Abramović, 2017).

4.3. Modal Split

One of the more significant parameters in the research of population mobility is the working age population, which is nowadays commonly referred to as contingent workers. This part of the population is aged 15-64 and able to work.
The working age population of the Sisak-Moslavina County is 113,750, which is 65 % of the entire population of the County (172,439). The labour mobility coefficient represents the relation between the working age population and the entire population of the region. In case of Sisak-Moslavina County, it amounts to 0.65.

$$labour\ mobility\ coefficient = \frac{working\ age\ population}{entire\ population} = \frac{113{,}750}{172{,}439} = 0.65 \qquad (1)$$

The comparison to the labour coefficient of the Republic of Croatia (0.67) reveals that the situation in Sisak-Moslavina County is approximately similar. The structure of journey frequencies in various means of transport on the regional level is illustrated by means of a modal split in the National Transport Model for the Republic of Croatia (MSTI, 2017).

Table 1
Structure of all Journey Frequencies by Various Means of Transport on the Regional Level

	RH [%]	Continental Croatia [%]	Adriatic Croatia [%]
Car	51.2	49.4	54.1
Public transport	12.5	15.1	8.1
Bike	5.1	7.1	1.9
Walk	30.0	27.2	34.6
Other	1.2	1.2	1.3

Source: Adjust by authors (MSTI, 2017)

Due to the similarities between Sisak-Moslavina County and continental Croatia, the modal split can be copied with a relatively small error possibility. In that case, Sisak-Moslavina County has the following journey frequency based on transport modes: (1) car - 49.4 %, (2) public transport - 15.1 %, (3) bicycle - 7.1 %, (4) walking - 27.2 %, and (5) other - 1.2 %.
The aim of all journeys in Croatia can also be copied on the Sisak-Moslavina County case. The modal split of journey aims includes (1) home-work trip, (2) home - school trip, (3) home - shopping trip, (4) home - leisure trip, and (5) home - other trips.

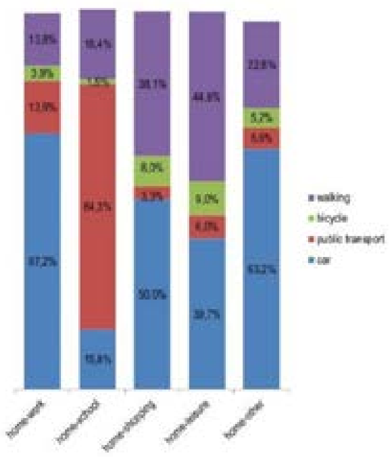

Fig. 1.
Aims of Journeys in the Sisak – Moslavina County (Continental Croatia)
Source: (MSTI, 2017)

5. Conclusions

When determining the transport demand in rural areas, the following factors need to identified: (1) demographic, (2) geographic, (3) economic, and (4) transport. Each of them is an integral part of the model of transport demand, so they need to be quantified. The most important results of the research of the demographic factors reveal that the population density of the Sisak-Moslavina County is half the Croatian average (38.59 compared to 75.80 inhabitants per sq. km). According to the criteria of the OECD, the County area is a predominantly rural area with about 7 per cent of urban settlements with 53 per cent of inhabitants. The economic factor indicates that the average GDP per capita in the County, which was €7,724 in 2015, is about 37 per cent lower than the average GDP per capita of the Republic of Croatia. The density of the road network is one of the transport factors that reveals a number of 396 m/km2 which compared to the country's average is about 19 per cent less. The number of registered motor vehicles in the County is 68,535, 50,812 of which are personal vehicles. Since the number of households in the County is 62,487, this leads to the conclusion that on average every household owns one registered motor vehicle. The entire length of the railway tracks in the County in 2015 was 196 km (7 per cent of the country's), 181 km of which are single-track, with 15 km of double-track lines.

The working-age mobility indicator is the labour mobility coefficient, which represents the ratio between working-age population and the entire population in an area. On the case study of Sisak-Moslavina County, the coefficient is 0.65, which, compared to the Croatian labour coefficient (0.67) is approximately the same.

The study reveals the need for stimulating public transport in rural areas from the standpoint of providing a quality service (number of lines, departure frequency, affordable fares). Naturally, because of the low demand, the level of transport service quality requires a high subvention. This is one of the ways to attract operators to stay or to improve the quality of their transport service.

The rural area of the Sisak-Moslavina County used to be appealing for its inhabitants and visitors. Its natural resources and features ensure a pleasant life, work and stay. The analysis of the transport demand in rural areas on the case study of Sisak-Moslavina County reveals that substantial changes are needed in order to develop the rural space. Working conditions and population mobility need to be improved. The vision of the growth of the rural area includes a continuous improvement of the living standard and a closing the gap between living standards in urban and rural areas. In order for the rural areas to be places both for work and residency, population mobility needs to increase by means of public passenger transport options which would connect villages, municipalities and urban areas. Stimulating the public transport by offering lower fares and increasing departure frequencies, rural areas would more quickly adapt to the economic, social, cultural, ecological, and technological challenges and completely integrate into the market economy. The development of the rural areas must be planned in a sustainable manner by balancing between economic growth, protection of the environment, and social stability of the rural communities.

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ANALYSIS OF BASIC FEATURES OF THE EXPECTED AND PERCEIVED QUALITY OF THE SERVICE IN THE TAXI TRANSPORT SYSTEM

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Abstract: Flexibility, dynamism and adaptability represent the basic characteristics of the modern urban space which constantly changes in time and space and adjusts itself to the intensive needs and demands of the modern society. Since there is a strong interrelation between transport and urban areas, one of the main objectives of urban transport systems is adapting themselves to the modern city functions. In order to optimize the operation of the system, it is requisite to establish the desired modal split among the subsystems. In other words, the travel distribution should be transferred to the subsystems which ensure the optimum balance in the realization of the inhabitants' mobility. Successful cities and liveable cities rely on an efficient mass passenger transport system which, in synergy with flexible transport systems (paratransit systems), provides users with the combined transportation services, i.e. supplies the inhabitants of urban agglomerations with the combined mobility service. The taxi transport subsystem, as part of the urban transport system, represents a significant factor in the development of the combined mobility concept. This concept has an extremely significant influence and benefits for the quality and efficient life of inhabitants. In order to obtain the optimum balance between the subsystems and the efficient management of the complete system, the centre of management is directed at users and the quality of service with the aim of reaching the maximum production and economic efficacy of the system. This paper contains the analysis of the results obtained in the research on the expected and perceived quality of service in the taxi transport system in the city of Kotor.

Keywords: public transport, taxi, expected and perceived quality of service.

1. Introduction

The vicious circle of the problems regarding the expansion of urban areas, overpopulation, insufficiency of quality living space, alongside the chronic lack of finances and permanent expansion of mobility needs, leads to the disturbance of the quality of life in cities.
Since there is a strong interrelation between transport and urban areas, one of the main objectives of urban transport systems should be directed at adapting the systems to the functions of modern urban areas. An inefficient urban transport system has a direct impact on the degradation of urban areas, particularly in the period of population growth and spatial expansion.
Therefore, the urban transport system is faced with the challenge of becoming a key factor in providing even more flexible and diverse services in order to accomplish the mobility of its users. Today, the strategies for the development of urban transport systems are implemented by leading the policy whose basic principle is the achievement of inhabitants' mobility with the restricted use of private passenger cars (Tica, 2016). Successful cities and liveable cities rely on efficient conventional mass transport systems which, in synergy with flexible public transport systems (paratransit systems), provide users with the combined transportation services, i.e. supply the inhabitants of urban agglomerations with combined mobility (UITP, 2011). Within the concept of combined mobility, different modal subsystems are coordinated to facilitate travelling of users through the combination of modes (subsystems), while each subsystem has the most suitable role in the physical and operational sense. The application and development of combined mobility provides numerous benefits for customers and, on the other hand, leads to the optimum quality of the production, technical and economic efficiency of the urban transport system.
In order to develop the concept of combined mobility, it is requisite to form strategic intermodal relationships which require partnership and integration of the available subsystems of public mass transport and the subsystems of flexible public transport, as well as the consistent application of the concept of sustainable urban mobility planning. Sustainable urban mobility planning implies abandoning the concept of modal focusing and orientation to the balanced planning and developing of all available public transport subsystems and placing the consumers into focus. This approach requires an efficient transportation policy which should supply the conditions for altering the public transport system from "a system on its own" into "the subsystem of the city".
The subsystem of flexible passenger transport (paratransit), often called the passenger transport available for hire, represents a passenger transport subsystem available for users in time and space as a public or semi-public service, provided by an operator in order to satisfy different individual transportation needs of consumers. In terms of the basic operational elements, the paratransit system most commonly does not have fixed line routes and fixed timetables.
One of the most famous and developed paratransit subsystems is the taxi transport subsystem. The taxi transport subsystem provides a specific transportation service, which is a public service fulfilling a commonly shared interest. This service is defined by the broader population and it is provided by a local transit authority (the owner of the transportation service market) responsible for expressing social demands through defined specifications and mobility standards.
Aarhaug (2016.) defined the taxi passenger transport as "...a vehicle with a driver available for hire". Tica (2016.) defines the taxi transport subsystem in a comprehensive manner as "...a flexible transport subsystem which provides the users with a whole-day public service in small-capacity vehicles (usually passenger car or van vehicles) at short

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distances according to the users' demands and the pre-defined tariff system". The operator provides the transportation service according to the defined requirement of the consumer (in terms of the journey start time, route, trip length...), which is paid by the consumer on the basis of the known tariff model.

One of the main characteristics of the taxi transport subsystem is its duality. The taxi system is a system on its own but at the same time it is a subsystem of a higher system (primarily the public passenger transport system). This duality is perceived in the hierarchically lowest elements of the system, where the effects of the whole system's operation can be measured.

This fact requires changing of the manner of organization and management of the complete urban public transport system. From the previously set objective that the system necessarily has to reach its maximum production efficiency, the focus is now shifted to the users and quality of service. The expectations of the system users continually change and thus the implemented transportation service should be constantly adjusted to the users' demands. According to the standards (ISO. 1994), service is defined as a result of activities between a provider (transport operator) and a user of service (passenger) and certain internal (prior) activities of the provider aimed at satisfying the customers' needs. In the same standards, the quality of service (QoS) is defined as overall features – service features, related to the ability of the provider to satisfy all demanded and supposed needs of customers (Filipovic et al., 2009.). These definitions are universal and applicable to all kinds of services, including the services of Public Transport (PT).

Monitoring, controlling and quality research of transportation services in PT systems should be continuous. The research subject should include all aspects of service quality, particularly the expected (desired) and perceived (subjective) service quality.

The expected quality represents the level of service quality which is explicitly or implicitly demanded by the users of the public transport system. It is the basis for planning, designing and improving the transportation quality of service. This quality level can be regarded as a set of a particular number of quality criteria which represent certain characteristics of the quality of service.

The perceived quality expresses the level of customers' satisfaction with the achieved system results. The customers' perception of the provided service quality depends on their personal experience related to the transportation service and on the information they obtain regarding the service – by the provider or other sources or their surroundings.

The research on the quality of service in the taxi transport system is not a prominent topic in the available literature. Most authors who have dealt with the taxi transport system scientifically or professionally primarily emphasize the problems related to the access to the transportation service market and the optimization of certain processes within transport systems (Nicholls, 2011; Noble, 2013; Cooper, 2007; Seymour, 2015). In addition to the market access, some authors have studied the development of the models for determining the optimal number of vehicles in the taxi transport system (Salanova Grau, 2013.), modelling the taxi service by modelling the transportation network with the focus on the demand function and density of traffic flow (Wong, 2002.), reconciling the supply and demand (Butkevicius and Juozapavicius, 2013), etc.

However, in the previous five years the taxi transport system has become a very popular topic in the broader scientific and professional community. According to the Final Report of UITP (International Association of Public Transport) from 2015, which includes the benchmarking of the operation of taxi systems in 23 cities, the taxi system has a specific role in the integrated urban public transport system. In other words, the taxi system does not represent a competition to the conventional public mass transport system but it supplements and strengthens the service quality of the whole urban public transport system. The most prominent topics are the regulation of the taxi service market, the role of taxis in the urban mobility and technological innovations in the taxi passenger transport, elements of the service quality, etc. Technological innovations were the most important topic at the latest global conference of UITP in Montreal in May 2017. The focus is on the advantages provided by modern technology, such as the increase of production and economic efficiency of the system, higher competitiveness of the taxi systems on the transportation service market, system management, improvement of the service quality, etc.

This paper presents the results of the research on the expected and perceived quality of service in the taxi transport system in the city of Kotor (the Republic of Montenegro), which was conducted using the direct interview method – surveying the system users in the sample of 291 users. The objectives of the research were to:

- Define QoS features and sub-features;
- Rank the importance of certain features and sub-features of the quality of service for users – expected quality;
- Define the level of users' satisfaction with the provided service – perceived quality.

2. Taxi System in the City of Kotor

Kotor is a town on the Adriatic coast in the Republic of Montenegro, with the area of 335 km^2. Due to its favourable and specific geographical position, its rich cultural and historical heritage (UNESCO's World Heritage Site) and the vicinity of the airport, Kotor is one of the most important regional and tourist centres of the South Adriatic region and thus an attractive transportation service market. The complex traffic situation of the stationary and dynamic traffic and the existing limited capacities of the traffic infrastructure represent significant limitations for the development of the public passenger transport system. The specific feature of the market is the uneven number of transportation demands made for the public transport system, particularly for the taxi passenger transport, depending on the season.

The system of the conventional public mass passenger transport in Kotor (the bus subsystem) operates in 8 urban-suburban lines which cover the entrance/exit direction into/out of the town centre, with the exception of the southern part in the direction of the town of Budva, which is served by the lines of the intercity bus passenger transport. The asymmetrical characteristics of the territory in relation to the central town part (Old town) and a large number of scattered settlements with a small number of inhabitants have an impact on the limited transportation offer of the public mass transport system. The consequence is the network of the lines of extremely low density. The total line length is 175.5 km, with the average stop distance of 2.105 km, which is not typical for the average stop distance at urban and suburban lines in the bus subsystem. This is primarily the consequence of the geographical and morphological town structure, the state of the existing traffic infrastructure and spatial distribution of the settlements and low population density. The planned departures according to the registered timetables requires 10 operating vehicles. The total number of all planned departures for all lines in both line directions on a workday amounts to 179 departures (Tica et al., 2016).

The taxi passenger transport in Kotor, in terms of structure, organization and functioning, has been humbly and insufficiently defined by the municipal Decision on taxi transportation. The Decision on taxi transportation includes only the manner of using basic static elements of the system – taxi stands. Operation, organization and management of this mode of public transport is practically completely deregulated and unofficially delegated to the operators, drivers themselves (entrepreneurs), associations and companies. The existing legislation and regulatory acts do not even define the basic criteria for the access to the taxi transport market.

The taxi transport system in Kotor operates 24/7. The activity is performed by 8 associations and companies and 34 independent entrepreneurs, which represents a positive share of professional taxi associations and companies on the transportation service market of this size. The temporal operation of the system is most frequently organized in two half-shifts in the periods of the day with the most intensive transportation demands. The request reception in the Kotor taxi system is organized over the radio, by users hailing the vehicle on the street and by drivers receiving the requests at the taxi stand.

The research conducted in the taxi transport system in Kotor by the University in Belgrade – Faculty of Transport and Traffic Engineering showed that on average taxi vehicles operated 7 hours and 59 minutes during a common working day, out of which 25.63% of the time was spent driving the passengers, 32.44% driving without passengers and 41.93% waiting for a drive. It can be clearly perceived that the vehicles spend only a quarter of the working day driving the passengers, which can be estimated as the low exploitation of the engaged transport capacities.

Within the taxi passenger transport, the average service time was approximately 8 minutes and the average realized driving of passengers was around 4.0 km. The average daily number of drives per vehicle accomplished in the system is relatively high, particularly during the summer season. According to the research results, the average number of passenger trips per vehicle amounted to 14.33, out of which the largest number (58.6% of all drives during a day) was realized in the prolonged morning peak hour from 8 a.m. to 1 p.m. The largest number of drives lasted from 2 to 6 minutes (63.0% of all drives), where the most prevalent drives were those lasting 4 minutes (25.6% of the drives). In terms of the operating technology, more than half of the drives (54.88%) were initiated over the radio, while other drives were initiated by users directly requesting the drives either at the taxi stand or on the street.

The taxi transport system in Kotor has a fleet of explicitly heterogeneous vehicle structure in terms of vehicle brands and types (123 vehicles in the system with 14 different brands and vehicle types) and a relatively favourable age structure in comparison to similar systems in the region. The average age of the fleet in the Kotor taxi transport system is 7.7 years.

There is no Decision on the economically lowest fare for taxi passenger transport in the Kotor taxi transport system. The system applies a unique tariff system based on the realized transport operation corresponding to the conditions on the taxi service market. The taxi service is charged on the basis of three tariff items: vehicle start, driving per travelled kilometre with passengers and per minute of waiting. According to the Decision on taxi transportation in Kotor, the pricelist of taxi services is determined by a taxi operator in accordance with the Law, and the operator is obliged to acquire the consent (verification) of the local authority – the Secretariat for entrepreneurship development, utilities and transportation in Kotor. The realization of suburban drives is charged differently in the system. Most taxi associations have their internal systems for monitoring and controlling vehicle operation and the system for reservation of drives and for recording the accomplished and not accomplished drives. However, monitoring of operation results on the level of the whole system is difficult (small number of indicators in the existing databases), so there is practically no recording of the operation results in the system.

3. Defining of the Features and Indicators of Quality

The system features according to standards can be defined as a set of quantitative and comparable system properties or characteristics which are user-centered, i.e. a set of features of the reliability of organizational and technological systems.

The indicators describing the quality of the system and the service can be assumed as characteristic parameters from the standards or as the parameters derived from the standard parameters, or they can be introduced and described as new parameters. It should be underlined that essentially all parameters in the actual time show the quality of the system's structure and operation, that they are measured (determined), that they have a clear physical meaning, that they belong to homogeneous sets of the parameters used in estimating and balancing the system operation (Tica, 2011).

Depending on the need, each property is used for planning, designing and estimating the quality of the system and the service. These properties can be described by a certain number of quantitative indicators, which can have an absolute,

relative, non-dimensional or probability aspect and which can be defined in a statistical, professional and theoretical manner.
Bearing in mind that the subject of the paper is studying the expected and perceived quality of service in the taxi transport system in the city of Kotor, the paper included the features and sub-features of the quality of service considering the objectives of the complete system and the practical applicability. These features generally reflect the quality of the optimization of key processes, sub-processes and activities of the taxi system operation.
Features and indicators of the quality of service (Table 1) used in this paper are defined on the basis of the recommendations given in standards (IEC, 1991), analysis of professional literature, and the authors' own research (Tica et al., 2017).

Table 1
Features and indicators of the quality of service

The feature of the quality of service	The sub-feature of the quality of service	Description of the sub-feature
Organizational support	Price of the service	The price corresponds to the quality of service
Organizational support	Journey time	Acceptable total trip time from the start to the end of the journey
Service stability	Reliability	No cancellation of the journey
Service availability	Accessibility of the service	The service is available in time and space
Easy of use	Comfortable journey	Sufficient space in the vehicle, air-conditioning and heating
Easy of use	Flexibility in journey planning	Possibility of planning and optimizing the journey according to the existing needs

4. Analysis of the Expected Quality of Service

The expected (desired or demanded) quality of service represents the level of service quality demanded by the users of the taxi transport system in Kotor. In the study, in order to determine the expected quality of service, the users were asked to respond to the question "*What do you consider to be the most important in the taxi transport system in Kotor*?" The method of studying the expected quality of service was the direct interview – within a specially designed questionnaire the consumers stated their opinions regarding the given features of the quality of service of the taxi transport system in Kotor.
The users were asked to select 3 features of the service quality out of the 7 offered responses. In addition to selecting the given features, the users also had the possibility to respond to open-ended questions and give suggestions regarding the improvements of the taxi transport system in Kotor. The results of the analyzed users' opinions are presented in the form of the frequency of occurring, i.e. the percentage of the users who selected certain features (Fig.1).

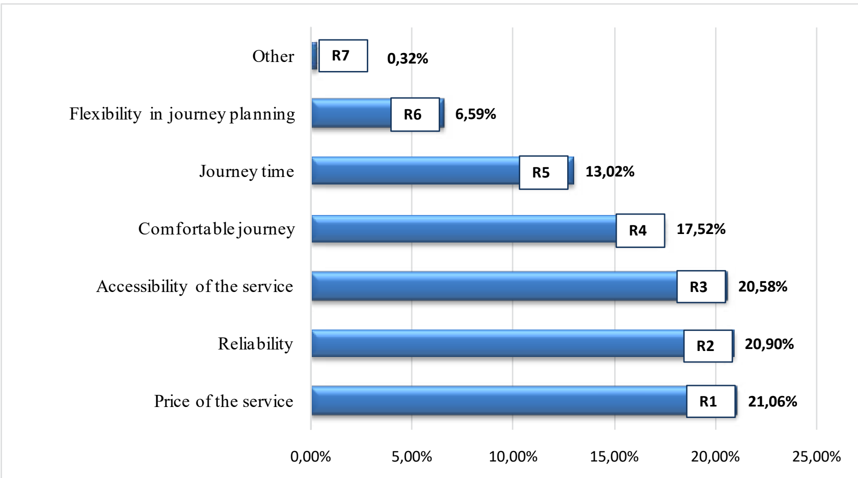

Fig.1.
Ranking of the significance of certain features of the expected quality of service in the taxi transport system in Kotor
Source: (Tica et al., 2017)

The largest number of the users of the taxi transport system in Kotor (21.06%) stated that the most important feature for them was the price they paid for the service. This opinion is the consequence of the accessible price of the taxi service which is defined "on the street" and not by regulatory acts determining the cost of the taxi transport. Also, only a few users suggested that the cost should be lower and that there should be an additional discount for regular users (1%), which indicates that the users were rather satisfied with the relationship between the price and the service quality

provided by the system. The reliability was the second most important feature for the system users (20.90% of responses). The parameter "service availability" had a similar share – 20.58%.
The feature of the service quality named "comfortable journey" was ranked fourth and had the share of 17.52%. It is interesting that the journey time was on the fifth place regarding its significance for the users (the response share of 13.02%). The city of Kotor is a witness of the everyday deterioration of the quality of the city transport system operation, which has a strong impact on the realization of the planned journey time. Therefore, the users obviously possess a high level of patience. These characteristics of the users are caused by the extremely complex conditions for using passenger cars, particularly in the town centre as the most attractive part for driving, constant disturbances in the operation of the bus subsystem and the limited capacity of the parking system on the territory of the town.
The users offered an extremely interesting attitude regarding the possibility of the direct participation in the journey optimization, expressed in the parameter "Flexibility in journey planning". This quality feature was the last in the list with the absolute ranking containing the share of 6.59% of the total number of respondents. It is noticeable that the users of the taxi transport did not perceive the benefits of the direct planning of their own journeys or that they believed that this feature should be understood.

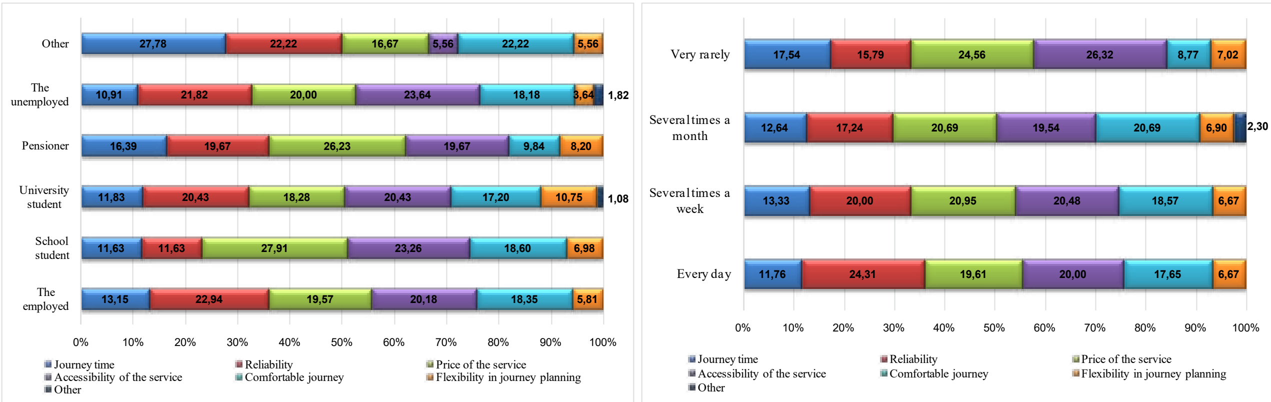

Fig.2.
The expected quality of service in the taxi transport system in Kotor according to the user structure per profession and frequency of using the service
Source: (Tica et al., 2017)

The characteristics of the system users were also analyzed within the conducted research, so it is possible to perform the analysis of the users' attitudes regarding the expected service quality according to particular categories of the users. The figure 2. show the attitudes of the users depending on their profession and frequency of using the taxi transport system in Kotor.
The analysis of the users' attitudes about the significance of certain features of the transport service quality depending on their profession showed specific attitudes of each group. The price of the service had the largest number of responses in terms of percentage. However, three categories of the users – the employed, the unemployed and university students – did not rank this parameter as the first in the list. In these three categories, this parameter was ranked third according to the number of responses, with the share of 18.28% in the category of students, 19.57% in the category of the employed and 20.00% in the category of the unemployed. The employed, as the most prevalent category of the users in the system, provided the responses where the largest share (22.94%) was related to the feature of the service quality "the reliability of the system operation".
The university students selected the two most important features of the service quality in the taxi transport system in Kotor: reliability and the accessibility of the service, with the same share of 20.43%. School students and pensioners considered the price of the service to be the most significant (27.91% and 26.23%, respectively), while the most important feature for the unemployed was the service accessibility – with the share of 23.64%.
Similarly to the users grouped by professions, the users grouped by the frequency of using the service also provided different responses about the most significant features of the quality of service. The obtained data showed that everyday users of this transport mode ranked the feature of reliability first (with the share of 24.31%), followed by the feature of the service accessibility (20.00%), while price of the service was ranked third with the share of 19.61%. These results show that the most important user categories would be prepared for a correction of the price of the service if the system operated in a more stable regime and with better accessibility in time and space.
Contrary to the everyday users, the consumers who used the taxi transport service several times a week ranked the price of the service as the most significant service feature (20.95%). Smaller shares were attributed to the accessibility of the service and reliability features with the shares of 20.48% and 20.00%, respectively. This is a typical attitude of periodical users of a taxi transport system.

5. Analysis of the Perceived Quality Of Service

The perceived (experienced or subjective) quality of service represents a subjective opinion of users regarding the quality of the complete system and the service of the taxi transport in Kotor. The users expressed their subjective

perception of the system and quality of service by selecting one of the five given grades on the scale from 1 to 5 (1 – unsatisfactory, 2 – satisfactory, 3 – good, 4 – very good and 5 – excellent).
The processed research results provided the integrated average grade for the quality of the taxi transport system service in Kotor given by direct users is 3.09 (Fig.3.).

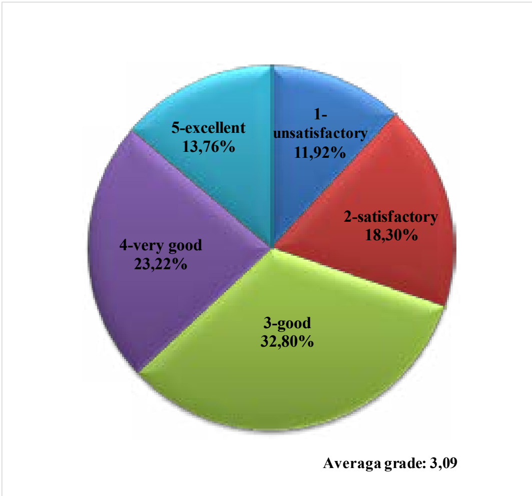

Fig.3.
The integrated grade of the quality of the taxi transport system service in Kotor
Source: (Tica et al., 2017)

The largest percentage of the users evaluated the system with the grade 3 (32.80%), while the smallest percentage (11.92%) used the lowest grade 1. The highest grade 5 was given by 13.76% of the users evaluated the system, while 23.22% of the users used the grade 4.
In addition to the total estimation of the quality of the taxi transport service formed on the basis of all users responses, subjective opinions of the users per categories were analyzed, depending on their professions and the frequency of using the service (Fig.4.).

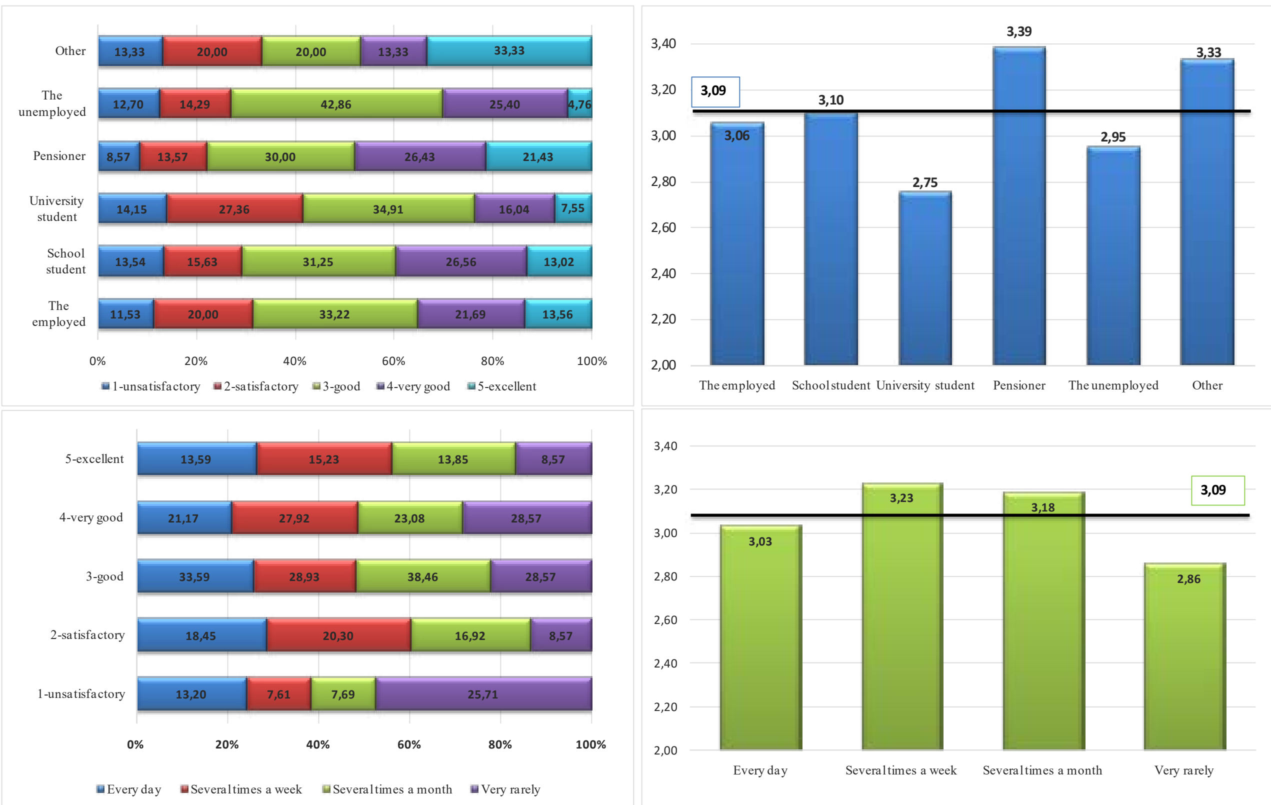

Fig.4.
Percieved quality of the taxi transport system in Kotor according to the user structure per profession and frequency of using the system
Source: (Tica et al., 2017)

The largest category of users per profession, the employed users, gave an average grade of 3.06 to the quality of the taxi transport service in Kotor. University students graded the quality of the service with the lowest grade 2.75. The highest grade was awarded by pensioners – they graded the quality of the taxi transport system with an average grade of 3.39.
The largest percentage of the employed gave the grade 3 to the quality level of the service (33.22%). Grade 4 was given by 21.69% of the employed users, while only 13.56% of the employed gave the highest grade to the service quality. The other categories also used grade 3 most frequently (30.00% of the pensioners and 42.86% of the unemployed).
Everyday users, the most prevalent category according to the frequency of using, evaluated the taxi transport service in Kotor with the grade 3.03. The grade higher than the average was given by the respondents who used the system service several times a week (3.23) and several times a month (3.18). The lowest grade was given by the respondents who rarely used the system (2.86). This attitude indicates that there are a number of users in the system who are absolutely dissatisfied with the level of the provided service by the taxi transport system. This represents a direct threat to the system but also an opportunity which the system can use in the process of reengineering.
Everyday users represent the most important category of users. The largest number of them evaluated the service quality in the taxi transport system in Kotor with the grade 3 – 33.59% of them. The opinion that the quality of service offered by the system is very good (grade 4) or good (grade 3) was also prevalent in other categories of users grouped by the frequency of using the system. These attitudes show that the captured market of the transport services in the taxi transport system in Kotor is rather stable.
It should be underlined that within all categories, except those using the system rarely, the share of the respondents who stated that the service of the taxi transport system was excellent (from 13.59% to 15.23%) was higher than the share of those who estimated the service as unsatisfactory (from 7.61% to 13.20%). Grade 1 was given by 25.71% of the users who rarely consumed the system, while 8.57% of them graded the system with the grade 5.

6. Conclusions

The target function of the taxi transport system is defined by the size and characteristics of the transport service market and the requirements of the key protagonists in the system and, on the other hand, by the characteristics of the structure, operational technology, organization and management of the complete system.
Efficient organization and management of the taxi transport system in specific conditions cannot be conducted without a representative estimation of the system from the point of view of the established objectives of the complete system. These objectives are directly represented by the indicators of the quality of the system and service. The difference between the elements of the expected quality and perceived quality of the system and service can be regarded as the level of the users' satisfaction. This underlines the importance of conducting continuous research on all quality aspects of these complex organizational and technological systems.
The city of Kotor is a regional and tourist centre with the expressed requirements for mobility, particularly during the summer season. The transport service provided by the taxi passenger transport system should contribute to the realization of a higher level of the service quality of the complete public transport system. The basic objectives should be directed at decreasing the travel time, improving the comfort, accessibility and easiness of use and reliability of the system operation.
The analysis of the operation of the taxi transport system in the city of Kotor and research on the characteristics of passengers and travel and the quality of the system and service in the actual exploitation conditions leads to the conclusion that the taxi transport system shows certain weaknesses at this point of time. Today, this system represents an alternative and/or competition to the bus subsystem of the public passenger transport, which degrades the efforts made for establishing the desired modal split among the existing subsystems of the public transport system. This also disrupts the principles of distribution and arrangement of travelling to those subsystems which lead to the balanced optimum in the accomplishment of passenger mobility. The consequence of this state is the inadequate distribution and use of the engaged capacity, which causes the complete public transport system to exist not focusing on the quality of the system and service, production and economic efficiency. This has an impact on the sustainability of each of the existing subsystems and the system as a whole.
In order to conduct reengineering and continuous improvement of the taxi transport system, it is requisite to conduct the research on all quality aspects, particularly the expected and perceived level of quality of the system and service. This would lead to the fulfilment of the actual needs and the users' requirements and harmonization with the real system possibilities, which would further improve the system structure and operation, increase the system efficiency and adapt the system to the actual market of transportation services.
The conducted research on the quality of service in the taxi transport system in Kotor provides a conclusion that at this point the most significant sub-features of the quality for the system users refer to the price of the service, the system reliability and accessibility (which is atypical for flexible transport subsystems). On the other hand, the sub-features such as comfort, journey travel and flexibility of planning the journey were not recognized as the quality elements which should have the priority of improvement in the future period.
The analysis of the perceived quality of service has shown that the users are relatively satisfied with the transportation service if the system is observed through the relationship between the quality level of the provided service and the price of the transportation service. The average grade of 3.09 indicates that in the future period a significant harmonization of the expected quality of service with the subjective (perceived) quality of service should be implemented. An efficient

tool for increasing the customer satisfaction index is continuous reengineering of the system in all its structure segments and periodical examination of all aspects of the quality of the system and service.
Thus, in the future, it can be expected that the taxi transport system would meet the requirements of the customers in the city of Kotor.

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ANALYTIC HIERARCHY PROCESS EVALUATION OF PUBLIC TRANSPORT SYSTEM IN BUDAPEST, HUNGARY

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Abstract: Public transportation improvement has always been a crucial issue to decision makers as well as to transportation researchers, especially in emerging and developed cities. However, in this study, the analytic hierarchy process approach (AHP) has been applied to rate public transportation supply quality criteria's in Budapest, Hungary. The analytic hierarchy process approach based on the dynamic analysis and sensitivity analysis gives the decision maker the confidence of the consistency and the robustness. Compared with the conventional transportation evaluation methods, the model has incorporated a wider range of long-term and short-term factors, which has been classified into main criteria and sub-criteria. Rating the criteria in the hierarchical structure is comprehensive and flexible and shows great potential for helping decision-makers and others concerned with the transportation decision-making process.

Keywords: multi criteria decision making (MCDM), analytic hierarchy process (AHP), Public transport, transport experts, supply quality.

1. Introduction

In recent decades, public bus transport system has been an important model of urban public transportation in the world, especially in advanced countries, due to inefficiencies in the operation of formal public transport services to meet the travel demand for their fast growing populations (Bhattacharyya *et al.,* 1995; Paulley *et al.,* 2006; Saharidis *et al.,* 2014). The acceptability of public transport for urban mobility in the developed cities particularly in Budapest city arose from the fact that public transport provides a more flexible services for urban passengers and make passengers feel safe and comfortable, save that it links different districts by shorter routes (Luke and Heyns, 2017). Hungary has a slowly diminishing population of 10 million, however, the capital: Budapest is the most densely populated area with its 1.7 million inhabitants, and the public transport in Budapest transports approximately 1.4 billion passengers a year. Recent studies have shown that mobility through public transportation provide better connectivity of people and location in order to decrease the congestion on roads (Yatskiv *et al.,* 2017; Földes and Csiszár*,* 2016).

There are many MCDM approaches support decision makers and transportation experts in their decisions in public transportation development issues (Celik *et al.,* 2013; Mulliner et al., 2017; Moslem and Duleba, 2018), however, the analytic hierarchy process is the most popular application of MCDM applications (Ho, 2008; Šimunović *et al.,* 2013; Govindan *et al.,* 2015), especially in transportation project developments and planning (Duleba *et al.,* 2012; Cascetta *et al.,* 2015; Tadić *et al.,* 2015; Kukadapwar and Parbat, 2016). AHP based on the dynamic analysis and sensitivity analysis gives the decision maker the confidence of the consistency and the robustness (Saaty, 1994). The only way to increase the use of public transportation is to raise the utilization level of the system by providing higher quality (Duleba et al. 2013), however, reaching higher satisfaction of the passengers, and encourage the non-passengers to start using public transportation (Cascetta, and Cartenì , 2014; Deb and Ahmed, 2018). This issue is relevant all development and emerging cities in the world, however, Budapest city has been selected as most important development city, where demand side is sometimes drastically neglected. In order to get an overall view on public bus transportation supply quality criteria's preferences of transport experts in Budapest, the AHP has been applied based on pairwise comparison (PC) questionnaire survey.

2. Methodology

The popular MCDM approach utilized by many analysts around the world (Arslan, 2009; Salavati et al., 2016; Ma et al., 2017). To improve supply quality of public bus transport in Budapest city, the AHP approach has been used by authors, because of its wide spread popularity in gathering stack holder's opinions over the last 30 years, especially in service quality improvements (Perez, 1995). The AHP approach is developed by Saaty to assist in solving complex decision problems by capturing both subjective and objective evaluation measures. It breaks a complex problem into hierarchy or levels (Saaty, 1994). AHP uses a pairwise comparison of the criteria importance with respect to the goal. This pairwise comparison allows finding the relative weight of the criteria with respect to the main goal. The AHP is a mathematically proven approach and it uses the eigenvector method ,however, its methodology is correct and there is the consistency in evaluation (Saaty, 1977).

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Table 1
Judgment scale of relative importance for pairwise comparison (Saaty's 1-9 scale)

Numerical values	Verbal scale	Explanation
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favor one element over another
5	Strong importance of one element over another	An element is strongly favored
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favored by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgments

Source: (Saaty, 1977)

Saaty provides the calculated RI value for matrices of different sizes as shown in Table 2.

Table 2
Consistency indices for a randomly generated matrix

n	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RI	0	0.58	0.9	1.12	1.24	1.32	1.41

Source: (Saaty, 1977)

Pairwise comparisons had to be made by the evaluators for all the elements of the model, regarding Saaty's 1-9 scale Table 1. and considering the hierarchy levels.
During the AHP process the consistency of answers has been examined by Saaty's Consistency Index (CI) and Consistency Ratio (CR) < 0.1, RI is the consistency indices for a randomly generated matrix Table 2, because the experiential matrices most of the time is not consistent:

$$\mathrm{CI} = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1} \tag{1}$$

where *CI* is the consistency index, $\lambda_{\max}$ is the maximum eigenvalue and *n* is the number of rows in the matrix. CR can be determined by:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{2}$$

where RI is the random consistency index If **A** is a consistency matrix, $\mathrm{A}\,.\,\mathrm{X} = \lambda_{\max}\,.\,\mathrm{W}$ .Then eigenvector **W** can be calculated as $(\mathrm{A} - \lambda_{\max}\,.\,\mathrm{I})\,\mathrm{W} = 0$, where $\lambda_{\max}$ is the maximum eigenvalue of the matrix **A**. $\lambda_{\max}$ is the principal eigenvalue of the matrix **A**. For determining the eigenvectors of the aggregate matrices the following method was applied:

$$\mathrm{w}_{\mathrm{A_i}} = \frac{\mathrm{w_j}}{\mathrm{w}} \frac{\mathrm{w_{ij}}}{\sum_{\mathrm{k}=1}^{\mathrm{n}} \mathrm{w_{ik}}} = \left(\frac{\mathrm{w_j}}{\mathrm{w}} \frac{1}{\sum_{\mathrm{k}=1}^{\mathrm{n}} \mathrm{w_{ik}}}\right) \mathrm{w_{ij}} \tag{3}$$

where $j = 1, \dots, m$ and $w_j > 0$ represents the related weight coordinate from the previous level($j = 1, \dots, m$); $w_{ij} > 0$ is the eigenvector computed from the matrix in the current level ($i = 1, \dots, n$), w_{A_i} is the calculated weight score of current level's elements ($i = 1, \dots, n$).
In the hierarchical structure of public bus transport fix cost has been expected, however, supply quality issues were investigated in order to improve public bus transportation system.

Table 3
The hierarchical structure of public bus transport

Level 1	Level 2	Level 3
Supply Quality	*Service Quality*	*Approachability*
Service Quality Transport Quality Tractability	Approachability Directness Time Availability Speed Reliability	Directness to Stop Safety of Stops Comfort in Stops
		Directness
	Transport Quality	Need of Transfer Fit Connection
	Physical Comfort Mental Comfort Safety of Travel	*Time availability*
		Frequency of Lines Limited Time of Use
	Tractability	*Speed*
	Perspicuity Information Before Travel Information During Travel	Journey Time Awaiting Time Reaching Time

Source: (Duleba, 2013)

Pairwise comparisons questionnaire had been created and evaluated by the expert evaluator groups for all the factors of the model, considering the hierarchy levels, where there are five (3×3) PC matrices and two (2×2) PC matrices and only one (5×5) PC matrix. For the 1st level the following questions were asked: "Compare the importance of improvement for the service quality and transport quality elements. Compare the importance of improvement for the service quality and tractability elements. Compare the importance of improvement for the transport quality and tractability elements". For the 2nd, and 3rd level the same comparisons had been constructed. The steps of applying AHP have been illustrated in figure 1.

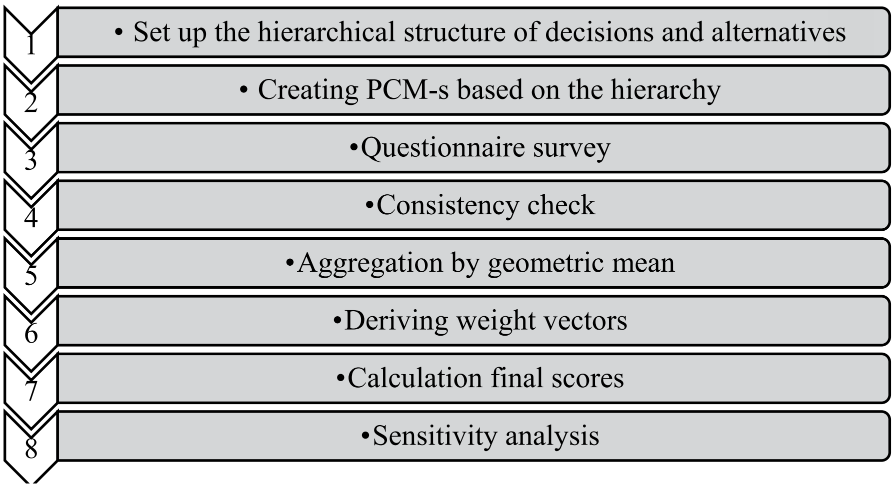

Fig. 1.
The process of applying AHP approach
Source: (own)

3. The Conducted Results

The research has been done to enumerate the public bus transport situation of Budapest city, Hungary. Ten evaluators of transportation experts in Budapest city were the participants of the survey, their answers have been aggregated by using the geometric mean (Saaty, 1994). The number of participants evidently not statically representative ,however, MCDM method provides a deeper insight based on pairwise comparisons than simple statistical survey (Saaty, 1977). The conducted survey based on the hierarchical model and pairwise comparisons, the survey was made in February 2018, and analyzed in March 2018.

Table 4
Scores results of the transportation expert evaluators

Level 1		*Level 2*		*Level 3*	
Supply Quality		***Service Quality***		***Approachability***	
Service Quality	0.55713488	Approachability	0.14264856	Fit connection	0.59315998
Transport Quality	0.24057649	Directness	0.10381691	Frequency of lines	0.19008307
Tractability	0.20228863	Time availability	0.22148324	Limited time of use	0.21675696
		Speed	0.17272793	***Directness***	
		Reliability	0.35932335	Directness to stops	0.23662793
		Transport Quality		Safety of stops	0.76337207
		Physical comfort	0.19813184	***Time availability***	
		Mental comfort	0.45226343	Comfort in stops	0.35450233
		Safety of travel	0.34960473	Need of transfer	0.64549767
		Tractability		***Speed***	
		Perspicuity	0.22853588	Journey time	0.37163943
		Information before travel	0.33101379	Awaiting time	0.2677154
		Information during travel	0.44045034	Time to reach stops	0.36064518

The main scores for different levels have been calculated by Excel, by ignoring the weights of the previous level, the calculated normalized matrix eigenvectors are presented in Table 4. The scores of the proper eigenvectors provide the opportunity to set up a rank order of preferences of public transport on the issues of the system considering the weights of the previous levels as well. Priority order of different elements in public bus transportation systems in terms of their development is presented in Table 5, Table 6 and Table 7.

Table 5
Criteria ranking by transportation experts for Level 1

Rank	Criteria	Score
1	Service Quality	0.55713488
2	Transport Quality	0.24057649
3	Tractability	0.20228863

For first level, as shown in Table 5. all transport expert participants of the analyzed public bus transportation system indicated the development of "Service Quality" is the most essential related issue, however, "Transport Quality" is the scorned most important issue followed by "Tractability" as the most essential related issue.

Table 6
Criteria ranking by transportation experts for Level 2

Rank	Criteria	Score
1	Reliability	0.20019157
2	Time Availability	0.12339604
3	Mental Comfort	0.10880395
4	Speed	0.09623276
5	Information During Travel	0.08909809
6	Safety of Travel	0.08410668
7	Approachability	0.07947449
8	Information Before Travel	0.06696032
9	Directness	0.05784002
10	Physical Comfort	0.04766586
11	Perspicuity	0.04623021

In Level 2. the most critical issue for expert evaluators was the "Reliability", however the second most important issue was "Time Availability" followed by "Mental Comfort", " Speed" and "Information during travel". The last important issues were "Information before travel", "Directness", "Physical Comfort" and the "Perspicuity".

Table 7
Criteria ranking by transportation experts for Level 3

Rank	Criteria	Score
1	Limited Time of Use	0.07965
2	Directness to Stop	0.04714
3	Fit Connection	0.04415
4	Frequency	0.04374
5	Journey Time	0.03576
6	Reaching Time	0.03471
7	Awaiting Time	0.02576
8	Comfort in Stop	0.01723
9	Safety of Stops	0.01511
10	Need for Transfer	0.01369

In Level 3. the most critical issue for expert evaluators was the "Limited Time of Use", however the second most important issue was "Directness to Stop" followed by "Fit Connection", " Frequency" and "Journey Time". The last important issues were "Information before travel", "Comfort in Stop", "Safety of Stops" and the "Need for Transfer".

4. Conclusion

The main objective of this paper was to enumerate public bus transport supply quality factors by applying AHP approach. More specifically, utilizing AHP approach in order to evaluate and rank the most critical factors related to public transport supply quality, public bus transportation system of Budapest (Hungary) was considered as a study case, utilizing the data collected on a questionnaire survey conducted by the transportation experts in Budapest in 2018. The AHP has been proposed in this paper because of its numerous advantages over more traditional statistic models. The paper rises a well-understanding and powerful information for decision makers to the real situation of public bus transportation system in Budapest for future plans. The results detected a real demand to improve the "Service Quality", "Reliability" and "Limited Time of Use". AHP approach based on the dynamic analysis and sensitivity analysis supports and gives decision makers the confidence of the consistency and the robustness however, sensitivity analysis showed our stability ranking of factors. Decision makers in the Budapest transport privately held corporation (BKV), have to share experts' point of view in their future transportation project strategic plans. Applying a three-level-hierarchy, the preference order of the issues will probably be very sensitive to the calculated weight scores of the respective previous level.

In the further work, it will be interesting to extend the evaluators to the public bus transport passengers, in order to illustrate, not only the point of view of transport experts about the level of supply quality, but also how passengers perceive public transport supply quality. This penetration could be used to get more satisfaction from passengers and attract new passengers to the public bus transport system.

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INVESTIGATING PUBLIC TRANSPORT USERS' PREFERENCES TOWARDS PROACTIVE MULTIMODAL TRAVELER INFORMATION SERVICES

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Abstract: This paper presents the first results of a wider research aimed at defining the characteristics of a proactive multimodal traveler information service (MTIS), able to provide real-time information to public transport users, while receiving their feedback, so to record their travel experience and monitor the service quality. The design of a MTIS requires an *ex-ante* knowledge of the characteristics relevant for the users, with the overall aim to maximize its usefulness. A preliminary survey on a specific public transport service has been conducted to investigate users' opinions about the service and their attitude toward the use of MTIS, including their preferences for several quality criteria and functions. Data collected will put the basis for the definition of a MTIS able to satisfy users with the overall aim to increase transit ridership. A structured citizen and stakeholder involvement will be crucial to define the service so to integrate the different needs of transport operators, transit users, administrations, and of the public.

Keywords: transit service quality, public consultation, real-time information.

1. Introduction

Transport policies oriented toward sustainable mobility aim at reducing the imbalance between private vehicle use and transit ridership. In this respect, increasing the quality of public transport (PT), in order to attract more users, is one of the main goals of transport operators and policy-makers (Beirão and Cabral, 2007; Banister, 2008). Data are needed to monitor actual and perceived quality of service, and most of the time the acquisition process is costly. Besides, user perception of service quality could vary according to several variables, including the aim of the trip and the type of service, resulting in heterogeneity also with respect to different lines of the same transport operator (Bordagaray et al., 2014). In this respect, new information and communication technologies can provide a valuable contribution to the improvement of transit service quality, also in the view of providing seamless travels, through continuous data acquisition and provision of *ad-hoc* information to transit users (Caulfield and O'Mahony, 2007). In fact, one of the European Commission's goals set out in the 2011 by the Transport White Paper (goal 9) is, by 2020, to establish the framework for a European multimodal transport information, management and payment system (EC, 2011). In this respect, the public consultation on the provision of EU-wide multimodal travel information services (MTIS) (EC, 2015) under the ITS Directive 2010/40/EU (EU, 2010) was intended to investigate the use of MTIS open to both citizens and stakeholder organizations to respond. The design of a MTIS requires an *ex-ante* knowledge of the characteristics that are relevant for the users, with the overall aim to maximize its usefulness. From one side, users require information for their daily trips aimed at time and effort saving, thus increasing their overall satisfaction (Grotenhuis et al., 2007). From the other side, users can give a valuable contribution both to the accuracy of the MTIS, and to the performance of the PT service, providing useful information and building a collaborative community network (Roche et al., 2012). In this respect, MTIS management should be intended as both top-down and bottom-up, continuously involving users in a proactive way, both in strategic public transport planning and in tactical operation management. This is also consistent with the concept of public participation in transport decision-making processes, which might benefit from the use of collaborative tools such as Public Participation GIS (PPGIS) (Le Pira et al., 2017).

This paper presents the first results of a wider research aimed at defining the characteristics of a proactive MTIS, able to provide real-time information to users, while receiving feedback from them. A preliminary pilot survey has been conducted in Catania (Italy) to investigate users' attitude toward the use of MTIS, and their preferences for several quality criteria and functions, drawing inspiration from the above mentioned EU public consultation (EC, 2015), going in the direction of "EU-wide multimodal travel information services". Besides, perceived quality of a specific PT line is investigated in terms of several criteria, to select the most important parameters and to understand the impact of information on user satisfaction. Data collected will put the basis for the functions deployment of a MTIS able to satisfy users with the overall aim to increase passenger ridership.

The remainder of the paper is organized as follows. Section 2 will provide a review of materials and methods used to assess PT service quality and the concept of MTIS. Section 3 will introduce the case study, with a description of the questionnaire used for the analysis. Section 4 will present and discuss the main results, while section 5 will conclude the paper summarizing the main limitations and future research endeavors.

2. Materials and Methods

PT service quality is strictly interwoven with information provision, being the latter one of the main elements that affect user overall travel experience (Grotenhuis et al., 2007). In the following, the main concepts and literature references related to PT service quality and MTIS will be given so to provide an overall framework for the proposed analysis.

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2.1. Public Transport Service Quality

The European reference standard for PT service quality is the norm UNI EN 13816 (2002), which defines the concept of quality and proposes the indicators to evaluate it. Quality can be assessed by user satisfaction, in terms of gap between quality expected and perceived, and by the service providers, in terms of gap between service quality targeted and delivered. Table 1 reports the quality criteria identified by the norm, among which information is defined as the systematic provision of knowledge to assist the planning and execution of journeys.

Table 1
PT service quality criteria

Quality criteria	Description
Availability	Extent of the service offered in terms of geography, time, frequency and transport mode
Accessibility	Access to the PPT system to assist the planning and execution of journeys
Information	Systematic provision of knowledge about a PPT (public passenger transport) system to assist the planning and execution of journeys
Time	Aspects of time relevant to the planning and execution of journeys
Customer care	Service elements introduced to effect the closest practicable match between the standard service and the requirements of any individual customer
Comfort	Service elements introduced for the purpose of making PPT journeys relaxing and leasurable
Security	Sense of personal protection experienced by customers, derived from the actual measures implemented and from activity designed to ensure that customers are aware of those measures
Environmental impact	Effect of the environment resulting from the provision of a PPT service

Source: UNI EN 13816:2002

In order to evaluate PT service quality, surveys are conducted, e.g. the so called "Customer Satisfaction Surveys" (CSS), asking users to evaluate the perceived/expected quality according to different indicators, the "Mystery Shopping Surveys" (MSS), based on objective observations of the travel experiences by qualified personnel, or the "Direct Performance Measures" (DPM), to monitor the real performance of the service.
In addition to the UNI EN norm, several manuals and guidelines have been proposed, like those by Transportation Research Board (TRB, 1999; 2004) or Transport Research Laboratory (TRL Limited, 2004), or as output of several European research projects (Tyrinopoulos and Antoniou, 2008).
Besides, scientific literature regarding surveys and statistical methods to assess PT service quality is quite abundant. The most commonly used methods are revealed/stated preferences surveys and discrete choice models (e.g. Hensher et al., 2003; Eboli and Mazzulla, 2008; Cirillo et al., 2011), structural equation modelling (e.g. Wallin Andreassen, 1995; Eboli and Mazzulla, 2007; Lai and Chen, 2011), Classification and Regression Tree analysis (e.g. de Oña et al., 2012; 2015), multicriteria analysis (e.g. Nathanail, 2008). In-depth interviews and focus groups have also been used to build a "Service Quality Model" under the concept of "SERVQUAL" and a multiple-item scale for measuring consumer perceptions of service quality (Parasuraman et al., 1985; 1988). De Oña and de Oña (2015) provide a comprehensive literature review on the main methodologies employed with related advantages and disadvantages. In general, the attempt is to measure the gap between the perceived/expected quality of service, which is rather subjective, and the targeted/delivered one, measured by objective parameters, possibly via an overall PT service quality indicator. This indicator, together with information related to specific PT service quality criteria, is fundamental for PT service operators to understand how to improve the service quality by increasing user satisfaction.
In Italy, in 1998 a law introduced the so called "Carta della Mobilità", i.e. the charter of the public services in the transport sector, a stated commitment by the service provider about the service targets and indicators to monitor them. These are explicitly required to run the service contracts with public administrations, in charge of regulating the service through the definition of the minimum quality standards (according with the EEC Regulation 1893/91). Information provision is one of the elements that can increase user satisfaction of their travel experience (Buscema et al., 2009). In this respect, it has been demonstrated that information increases travel choice quality in a multimodal environment (Chorus et al., 2007), and that information provided to PT users, e.g. by dynamic at stop real-time information displays, can have multiple beneficial effects in terms of reduced waiting time, positive psychological factors, increased willingness-to-pay, adjusted travel behavior, mode choice effects, higher customer satisfaction and better image (Dziekan and Kottenhoff, 2007).
In this respect, the role that new technologies can play is fundamental and will be briefly introduced in the next section.

2.2. Multimodal Traveler Information Services

The ever growing advance in information and communication technologies is leading to new opportunities and paradigms in the transport sector, with the aim to make transport "intelligent". The integration of "telematics" with transport engineering and traffic management has led to the deployment of Intelligent Transport Systems (ITS), able to contribute to plan, design, operate, maintain and manage transport systems aimed at improving safety, security, quality and efficiency of the transport systems for passengers and freight, optimizing the use of natural resources and respecting the environment (ITS-EduNet, 2018). They are defined by the directive 2010/40/EU as "advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and 'smarter' use of transport networks" (EU, 2010). There are several types of technology-enabled systems for transport. Zhang et al. (2011) distinguish among: (1) Advanced Traveler Information Systems (ATIS), (2) Advanced Traffic Management Systems (ATMS), (3) ITS-Enabled Transportation Pricing Systems, (4) Advanced Public Transportation Systems (APTS), (5) Vehicle-to-Infrastructure Integration (VII), and Vehicle-to-Vehicle Integration (V2V). The term ATIS generically implies advanced information systems for users, which, in the case of multiple transport modes, also take the name of "Integrated Multimodal Travel Information". One of the main priority actions followed both at EU and national levels is the provision of MTIS. In particular, Italy is focusing on the use of technologically advanced systems for managing the mobility of people, through the availability of integrated multimodal mobility services, which integrate and include ITS for PT fleets, for the tracking of own vehicles and Personal Mobility Assistance systems (MIT, 2014).

Seminal studies on this topic focus on willingness to pay for travel information (Khattak, 2003), web-based transit information systems using GIS (Peng et al., 2000), traveler responses to real-time information about bus arrivals (Dziekan and Kottenhoff, 2007; Zhang et al., 2008). Studies about design and implementation of different tools and applications for real-time transit information and multimodal trip planning have also been proposed (Zografos et al., 2008; Sun et al., 2011). Stated preference surveys are typically used to investigate user attitude toward information (Caulfield and O'Mahony, 2007; Chorus et al., 2013). In fact, it is important to investigate *ex-ante* user preferences for different types of information and information systems, considering the different phases of the trip (pre-trip, at-stop, onboard, pre-trip for return trip) (Caulfield and O'Mahony, 2007). Besides, in the logic of creating "accurate and available across borders to ITS users" EU-wide MTIS, it should be fostered the use of a common framework.

Lastly, users could provide a useful contribution to produce, enrich, update and disseminate information in a bottom-up approach, against conventional top-down approach, in the context of "crowdsourcing" (see, e.g., Volunteered Geographic Information - VGI) (Gal-Tzur, et al., 2014). Coupling ITS with information derived from users (traveler preferences, travel behavior data and VGI) will pave the road to new personalized transport information services, which become essential to improve both the users' experiences and the efficiency of the transport system as well.

In this study, an attempt to elicit user preferences for elements and features of a wide and proactive MTIS is done, while at the same time investigating the most important quality elements in a pilot study that will be described in the next section.

3. Case Study

Catania is a medium-sized city (approximately 300,000 inhabitants) in Sicily (Italy) that suffers from several transport-related problems, mainly due to the high percentage of private car use (about 61% of trips) and a car ownership rate of 69 cars per 100 inhabitants (Legambiente, 2017). In this context, PT could play a fundamental role to rebalance the modal shift, but it is scarcely used due to car predominance and poor transit-dedicated infrastructures, causing inefficiency and unreliability of the PT service (Inturri et al., 2014; La Greca et al., 2011). PT in Catania is operated by two transport companies: the Metropolitan Transport Company (AMT Catania) owned by the municipality, and the Circumetnea Railway (FCE), under the direct control of the Italian Ministry of Transport. AMT runs the urban PT service, with more than 50 bus lines, mostly within the municipal border, while FCE operates a 110 km local railway line, complementary bus services and a 9 km underground metro line in the urban area of Catania, under further extension in the next years.

In order to carry out a preliminary survey on PT service quality and on the architecture of a MTIS, a new bus line service operated by FCE, called "Metro Shuttle", was chosen as case study. It is an extension of the metro line, covering the "last mile" connection from the metro station "Milo" to a big University district, which daily attracts thousands of students and visitors because of the presence of important University sites, health services and a park-and-ride facility. Due to slope and distance between the metro station and the district, several transit service alternatives linking the two transport nodes have been proposed in the last years (Ignaccolo et al., 2017). In the context of a recent agreement among the University of Catania, FCE and the Municipality of Catania for the definition and future implementation of an *ad-hoc* transport system, FCE is currently providing this bus service. "Metro Shuttle" was chosen as survey testbed for two main reasons: (1) it serves approximately half of the University population (with 40,000 students in total), which represents a big part of PT users in Catania, and (2) it is a short-range efficient bus line, which allows to focus on important – but not primary – elements of PT quality, such as information provision, without being, at least in principle, affected by biased judgments due to a low-quality service. In this respect, the relative importance of quality criteria is highly dependent on the overall service quality (Eboli and Mazzulla, 2007). A questionnaire was created for a preliminary investigation of users' opinions, as described below.

3.1. The Questionnaire

The questionnaire is divided into four parts, aimed at exploring: (1) socio-economic characteristics; (2) mobility habits; (3) perceived service quality; (4) MTIS. Users were asked to evaluate the overall service satisfaction by a qualitative scale (from very low to very high) corresponding to a quantitative (1-5) scale, and to rate specific service quality criteria, chosen according to literature review (see section 2.1), and to quality criteria imposed by FCE's "Carta della Mobilità" (FCE, 2016), as reported in Table 2.

Table 2
PT quality criteria

PT Quality criteria
1. Service availability (in terms of time and geographical coverage, frequency, etc.)
2. Accessibility of stops (in terms of easiness to reach them)
3. Customer information (website, service hours, telephone or message, timetables at the terminal, emergency reports, ticket purchase, etc.)
4. Regularity of service (compliance of departure/arrival times with the scheduled ones)
5. Cleaning and hygienic conditions of the bus
6. Travel comfort (air conditioning, shelters, etc.)
7. Facilities for disabled people (low floor platform, etc.)
8. Ticket/pass price
9. On board and at stops perceived security
10. Attention to users (courtesy of the driver and staff on board)
11. Attention to the environment (vehicles with low environmental impact)

Source: own elaboration

Regarding MTIS, starting from the literature review and taking as a reference the survey carried out at European level on EU-wide MTIS (EC, 2015), users were asked to evaluate the importance of different quality criteria and functions of a MTIS on a 5-point qualitative scale, as reported in Table 3. A specific question about service interactivity was added (function "q") to investigate the user attitude to proactively provide volunteered information.

Table 3
MTIS quality criteria and functions

MTIS quality criteria	
i. Geographical accuracy (i.e. is walking information or interchange locations accurate?)	
ii. Time accuracy / up-to-date (i.e. does the information provided accurately reflect reality?)	
iii. Timeliness (i.e. is new information provided when needed? This might include information on planned disruptions to service, service changes etc.)	
iv. Usefulness (i.e. does the information given provide the answer needed?)	
v. Completeness (i.e. is all the service information available?)	
vi. Consistency (i.e. information is consistent between different sources?)	
vii. Inclusiveness (i.e. information sufficient to support the needs of persons with reduced mobility)	
viii. Precision	
ix. Reliability	
MTIS functions	
a. Location searches (addresses, points of interest, stations/stops etc)	b. Nearest stop/interchange
c. Timetable information	d. Coverage (door-to-door queries)
e. Coverage (station-to-station queries)	f. Range of transport modes available
g. Routing information (walk, cycle, drive)	h. Travel time estimates
i. Planned disruption information	j. Prices, tariffs and how to book tickets
k. Interchange facilities (including accessibility)	l. Vehicle facilities (including accessibility)
m. Noise and Air pollution	n. CO2 emissions
o. Real time information (arrival/departure times; unplanned disruption information)	p. Supporting information (lost property; making a complaint etc.)
q. Service interactivity (possibility to evaluate the travel experience or add real time information)	

Source: adapted from EC (2015)

4. Results

Results of the preliminary survey over a sample of 142 interviews, carried out in October 2017 and performed in different locations of the study area, are reported below. As expected, the majority of the sample (80%) is composed of University students, with a small percentage of University employees (7%), and residents in the study area (8%). 56% are males and 44% females, distributed on an average age of 26 (minimum 18 and maximum 59). 37% accesses the

study area on a daily basis (more than 3 times per week), while the 47% attends with a weekly frequency (1 to 3 times per week), and the 66% of them is composed of regular PT users.
For what concerns the overall satisfaction related to the PT service, 40,1% is quite satisfied, while 38,7% is very satisfied. Overall, the majority of respondents is satisfied with the Metro-Shuttle service provided by FCE. In numerical terms, the average level of service satisfaction is 4,06 (out of 5), with a standard deviation of 1.00. With respect to quality criteria, evaluated on a scale from 1 to 5, users are on average quite satisfied (average> 4) with price, service availability, cleaning, travel comfort and accessibility of stops (Fig. 1). On the other hand, they feel less satisfied with facilities for disabled people, perceived security, attention to the environment and the level of information (average values of the indicators between 3,60 and 3,72). In any case, considering that the minimum satisfaction value is 3,60, corresponding to a medium/fairly satisfactory quality level of the semantic scale, it can be concluded that the quality perceived by users is on average quite high, both in relation to the general indicator, and with respect to the quality criteria analyzed.

Fig. 1.
Results of perceived quality in terms of PT quality criteria
Source: own elaboration

With respect to MTIS, 90% of respondents stated that they know some of them, in particular Google Maps, but only 22% often uses them, while 45% occasionally uses them and 33% almost never or never. The quality criteria and functions considered as the most important for a MTIS are respectively: precision, reliability, time and geographical accuracy (Fig. 2a); timetable information, location searches, travel time estimates, planned disruption information (Fig. 2b). On the contrary, they consider information related to vehicle facilities and service interactivity as less important functions. This last result is a bit unexpected, but can be explained by the underestimation of the potential of bottom-up user-generated information to increase the usefulness of the service, due to the limited experience with proactive MTIS. In this respect, it has been demonstrated that information harvested from social media to complement, enrich (or even to replace) traditional data may hold great value and incur lower costs (Gal-Tzur et al., 2014).

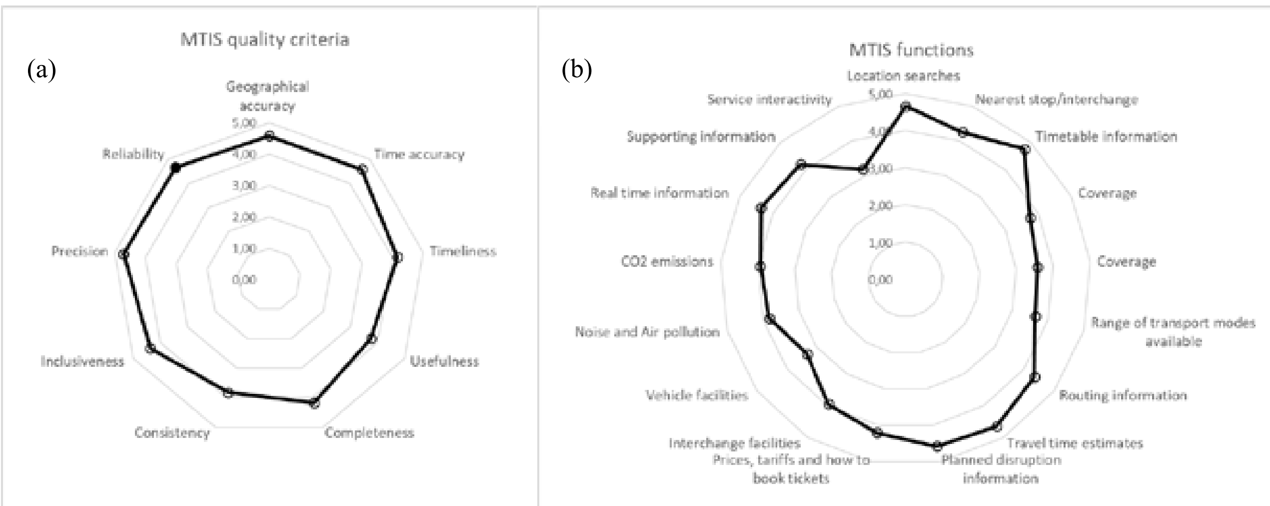

Fig. 2.
Results of MTIS quality criteria (a) and functions (b)
Source: own elaboration

In order to investigate the impact of the use of MTIS on the perceived quality of PT, and the preferences with respect to MTIS quality criteria and functions, we segmented the sample according to three categories: (1) frequent MTIS users (22%), (2) occasional MTIS users (45%), (3) non-users (33%), i.e. those who almost never, or never, use them for their trips. Some differences emerge in the perception of PT service quality (see Table 4). In particular, accessibility of stops (criterion 2), customer information (criterion 3), and, especially, regularity of service (criterion 4), perceived security (criterion 9) and attention to the environment (criterion 10), are more positively evaluated by those who use MTIS, while they show a negative variation (with respect to the mean value obtained for the overall sample) for those who never use MTIS. On the contrary, criteria 5-7, i.e. cleaning, travel comfort and facilities for disabled people are ranked higher for those who never use MTIS, and lower for MTIS users. These differences can be interpreted as follows: in general, the criteria "more" positively evaluated by MTIS users are related to "basic" service characteristics, whose information can be provided by MTIS (e.g. departure/arrival times, accessibility to stops, attention to the environment), while those valued as "more" important for MTIS non-users are "contingent" parameters (e.g. air conditioning, cleaning) that mostly depend on their specific travel experience. In this respect, it seems that MTIS users perceive as most satisfactory "basic" and structural PT service characteristics. This is also confirmed by the highest values of the parameter "overall satisfaction", with respect to those who never use them (4,13 and 4,09 for frequent/occasional users vs. 3,98 for non-users).

Table 4
PT quality criteria for the segmented sample (% variation of each indicator with respect to the overall sample)

PT quality criteria*	1	2	3	4	5	6	7	8	9	10	11
MTIS Frequent users	-0,6%	1,7%	1,1%	5,3%	-1,8%	-5,2%	-3,6%	-5,0%	5,0%	2,2%	6,2%
MTIS occasional users	1,0%	1,3%	2,0%	6,2%	-2,6%	-2,3%	-3,6%	1,0%	5,5%	3,9%	-3,4%
MTIS non-users	-1,0%	-2,9%	-3,6%	-12,1%	4,8%	6,7%	7,4%	2,0%	-10,8%	-6,7%	0,5%
*for a full definition of criteria, please refer to Table 1											

Source: own elaboration

No clear patterns emerge from the preferences related to MTIS quality criteria and functions for the segmented sample. The only exception is the parameter "usefulness" that is ranked as more important by those who use MTIS and, thus, who already know their potential utility, with respect to those who never use them.
In conclusion, the preliminary analysis carried out shows that the overall quality of the Metro Shuttle service is quite good, especially with respect to price, availability, cleaning, comfort and accessibility. Furthermore, the need to guarantee an information service for efficient multimodal mobility (MTIS) emerges in order to increase PT use, which is currently limited, and to primarily guarantee some elements, namely precision and reliability of the service and some functions, including timetable information, research of places of interest and travel time estimates.

5. Conclusion

This paper presented a preliminary survey to investigate the prerequisite of a MTIS to increase transit ridership and its service quality. An attempt to elicit user preferences for elements and features of a wide and proactive MTIS was done, while at the same time investigating the most important quality elements in a pilot study related to a specific "metro feeder" bus line in Catania (Italy). Results show that information provision is not one of the most-highly scored PT quality parameters, pointing the need for improving it, and that MTIS are not very used, even if the majority of interviewees knows at least one of them. Besides, they pointed out the importance of precision and reliability for a MTIS to be effective, with information related to timetable, places of interest and travel time estimates, while considering less important the interactivity of the service, i.e. the possibility for the users to add new information and collaborate with each other. In this respect, awareness about the potential of user-generated information, both to measure the service quality and to enrich the information provided, should be raised, e.g. via specific incentives. Besides, some differences emerge when segmenting the sample in MTIS users/non-users, showing the former more satisfied with PT basic characteristics and general service quality, and valuing the usefulness of MTIS as more important with respect to non-users. This preliminary analysis, although limited to a small sample and restricted to a unique bus line service, paves the way for a deeper study related to the definition of a wide MTIS. Future research will extend the analysis, e.g. to other categories of PT users, such as those of extra-urban trips, and by using advanced methods (e.g. multicriteria analysis). Besides, it will also be interesting to investigate transport authorities' and operators' points of view, as done in the public consultation by EU, in the overall effort to increase PT service quality and ridership taking advantage of new technologies and of the collaboration with users.

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OPERATING-ECONOMIC EVALUATION OF LONG-HAUL PASSENGER TRAIN ROUTES

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Abstract: Creating a single market of railways in the European Union leads to liberalization of railway passenger transport, what increases the competition level of transport companies. The purpose of market transformation is sustainable economic development besides increasing quality of transportation and people mobility. Liberalization of passenger transport market is current trend therefore transport companies tend to attach more importance to economic aspects. Basic objective of each transport company is to decrease the costs and increase revenues from transportation. From economic point of view, transport companies should evaluate all routes, which they operate trains on. Comparison of costs and revenues would show them the economic efficiency of the route. Preconditions of operating-economic evaluation are analysis of passengers' habits and transport availability in the region. Other important part is the train technology, which consists of timetable, plan of the vehicles circulation and run of the train requisites. Tariff rates have got a profound impact to revenues. The route could be economically effective only in case, when the revenues are higher than costs. The article focused on methodology for evaluating the operation of long-haul passenger trains from economic point of view. General methodology is then applied to case study about long-haul passenger trains in Slovakia.

Keywords: railway transport, passenger transportation, transport economics, train route.

1. Introduction

Primary function of the transport system is offering transport for passengers on regional, national-interregional and international level. Very important role of the railway passenger transport is providing transport services for passengers, who travel for long distances. There are several types of long-haul passenger trains, which jointly create integrated transport system. Quality of this transport system depends on train routes topology, timetable of trains, number and location of all stations, where these trains stop. Liberalized transport market, where the demand is meeting with offer, is evolving dynamically nowadays therefore there is a possibility to find some opportunities, how to improve transport availability in selected areas and make the railway transport more attractive for the traveling public. Design of new long-haul passenger trains routes is current challenge because new routes can offer new direct and fast transport connections among such towns and cities, where these connections are missing nowadays.

2. Operating-Economic Evaluation of Long-Haul Passenger Train Routes

Passenger transport is divided into individual and public. Individual passenger transport includes walking, cycling and car transport. Public passenger transport includes railway, road, water, air, city and unconventional transport. From spatial point of view, passenger transport is divided into local, regional and long-haul, which is then divided into interregional transport (in one country) or international transport (among two or more countries). From operation point of view, passenger transport is the sum of acts for providing mass transport of passengers which includes boarding, selling and checking the travel tickets, transfer of passengers' luggage, ensure all individual needs of passengers and organizing of other complementary services. From economics point of view, passenger transport is classified into tertiary sphere – services. It means that there are not any material production values, but it is reflected in costs. In general, passenger transport has got a great social and political importance. Legislative fundamentals of organizing and managing the passenger transport are constituted in higher legal standards and internal regulations of transport companies (Dedik *et al.*, 2017). Passenger transport is generally considered as an activity, which arises as the consequence of spatial division of places, where people are in exact time and their need to move. Motivators for moving could be commuting (job or education), dealing with personal or working matters, travelling for vacation (hiking, sport, health, cultural and social facilities), visiting relatives and friends. Requirements for transport of passengers originate in their need to move, while the passenger transport is dependent on the willingness of travelling. In passenger transport, there are mostly individual passengers, so it is difficult to determine all transport requirements (Pečeny *et al.*, 2016). Basic and general factor, which has got a significant impact to the transport of passengers, is demography. Specifically, the most relevant aspects are the progress of population quantity, economic and social indicators, standards of living, age structure, employment rate and disposable income. Regularity of transport offer is also key factor, which depends on structure of passengers and their reasons for travelling (Stoilova, 2018). Other specific factors are spatial accessibility of transport hub and price for transportation. Influences on transport offer are geography, transport infrastructure, transport vehicles and environment. Transport infrastructure factor consists of its structure, length, density, throughput, availability to residences and overall quality (Gašparik *et al.*, 2016).

2.1. Customer Aspects of Railway Passenger Transportation

Key element in railway passenger transport is a customer – passenger, who requires the transport from one place to another. A basic precondition for accomplishing the main requirement – transport, is making the complete offer which provides not only transport, but also other associated services. Practically, there are many associated criteria of transport, for example safety, duration, price, reliability, comfort and complementary services. Safety is the dominant criterion and it is guaranteed normative by licences, permissions, certificates and verifications. Safety is measured by indicator of accidents per one billion passenger-kilometres – number of passengers transported per one kilometre. Transport duration means the exact time of passenger movement from one place to another and it is closely related with speed. It does not mean only the speed of the transport vehicle, there are other periods, such as time to go from home to the station, time to buy the travel ticket, boarding time, transport time, time to get off the train and time to reach the destination point. In case, where the traveller combines the trains, time for waiting to another train is also counted. Transport price is the criterion, which is dependent mostly on economic indicators. In market economy, there are three key factors: costs, demand and competition. These factors are dependent on each other and they are also influenced by national economy, political situation and demography. Internal costs of the transport company are influenced by strategic objectives, economic situation and legislation. Transport demand reflects the range, how the transport company can affect the price for transport. Higher demand means opportunity to increase the price for transport, because travellers want to use the trains. Lower demand forces the transport company to decrease the transport price, because they must enhance the number of passengers in trains. Transport demand is highly influenced by macroeconomic indicators, such as GDP, employment rate and population economic activity rate. Another factor with significant impact is competition, which means other railway companies but also other means of transport, such as road, air or water transport. The transport company must deeply analyse and compare the price for transport with other transport companies, which offer the same or similar transport services (Gnap *et al.*, 2006). Other factors with significant impact are reliability, offer of travel possibilities, vehicle occupation and coherence of transport system. Reliability is relative, because it depends on transport time and distance, while it proportionally decreases with mode of transport combination, for example train-bus. The most reliable are direct connections. Offer of travel possibilities has got a significant impact to quality of the whole transport system and structural modifications in passenger transport. It can be evaluated from spatial and temporal density. Spatial density means number of tariff point per some area, while temporal density means number of links per some time unit. Connectivity of passenger trains and other means of transport can be distinguished also from temporal and spatial point of view. Temporal connectivity is such sequence of arrivals and departures of different passenger trains and other means of transport, which allows changing the different passenger vehicles easily regarding necessary time. Spatial connectivity means the distance between two passenger vehicles, among which the passenger is moving. Long-haul passenger trains are intended to transport passengers mainly for long distances. Their routes usually connect regional centres with higher population. Regional passenger trains are adjusted to long-haul passenger trains transport system, therefore people from smaller towns and villages can also use long-haul passenger trains, which do not stop in their town or village. It is important to synchronize arrivals and departures of all connected trains in all points, where passengers can get on, get off and change the vehicle. Elimination of needless waiting can be reached by higher offer of trains, buses and other passenger vehicles, which are used in passenger transport system. Preconditions of perfect connectivity in railway passenger transport are: dominance of passenger, timetable dependent on passengers' needs, synchronized arrivals and departures in all points of the transport system, harmonised conditions for all operators in the transport system, high reliability and punctuality. Disadvantages of perfect connectivity in railway passenger transport are: overcrowding of transport vehicle may occur, increased number of trains could reduce the throughput of railway and preference of busses (more flexible) (Singhania *et al.*, 2017). The transport accessibility in some area is dependent on availability of passenger trains in the centre of the area, and other transport hubs in this area. Transport hub is a place, where passengers enter, change or exit the transport system. Considering to long-haul railway passenger trains, transport hubs are all stations and stops, where these trains usually stop. The route of the train consists of exact number of transport hubs. All transport hubs are characterized by localization and discesion. Localization is variability of transport hubs on the route, which means the exact number of stations and stops, where long-haul passenger trains stops. Discesion is mutual layout of transport hubs on the route to each other. Railway passenger station is transport hub – a starting and finishing point for flows of passengers. Passengers can change the train type from long-haul train to regional train or contrariwise or simply enter or leave the system of railway transport (Kudlač *et al.*, 2017). Current trend is to optimize connectivity in railway passenger transport by reduction of transfer time – starting at home and finishing in the transport destination. Minimizing of waiting time will increase quality of passenger transport in general. Emphasis must be put on reliability of all included vehicles, because delays could have profound consequences to the entire system. In central Europe, there is a modern trend of establishing integrated passenger transportation systems in selected regions. Cores of these systems are terminals, where passengers can change vehicle and the mode of transport, for example get off the bus and get on the train. These terminals are hubs, whence all routes and lines from some region or district are connected. New terminals will improve transport accessibility in the selected region. Operators, who participate in the integrated passenger transportation system, are more effective and they notice increased demand for transport services (Torok, 2017). In the figure 1, there are illustrated flows of passengers between train types which arrive from different directions and depart to different destinations. Points A, B, C, D, E and F represent trains whereas point X represents input to the transport system and point Y represents output from the transport system where passengers use another mode of transport instead of railway transport.

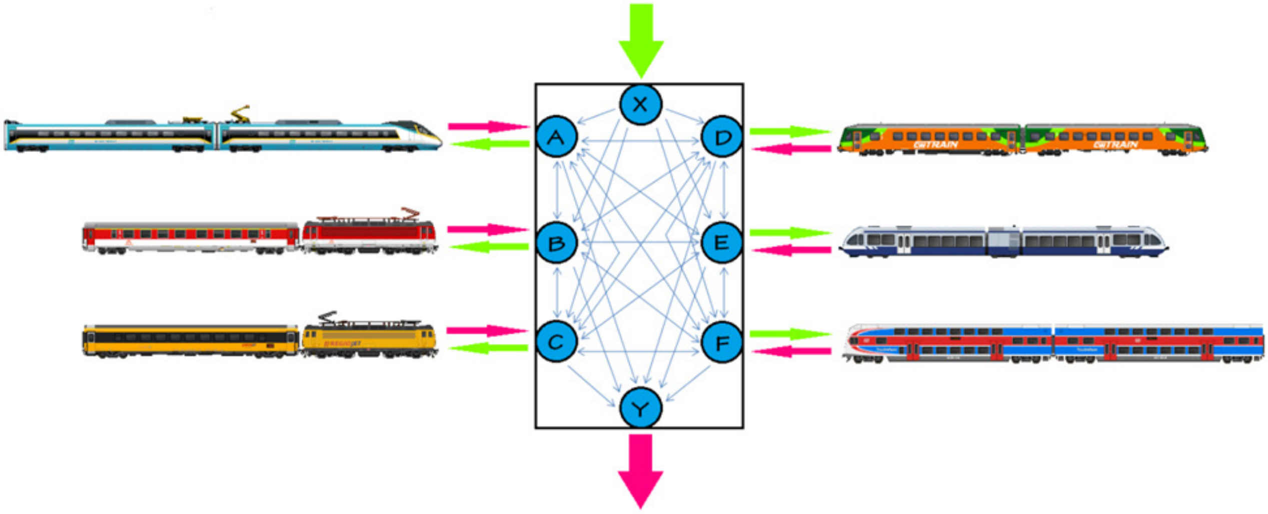

Fig. 1.
Simple scheme of railway passenger station with marked passenger flows there
Source: authors

Travel comfort is also very important for passengers, especially nowadays. It consists of vehicle construction, interior hygiene, physiological and psychical influences. Subjective feelings and experiences has also significant impact along with current mood of each passenger. Overall subjective feeling is the result of different conditions with different seriousness. Practically, there is an enormous difference when the passenger travels to celebration or funeral. Qualification of these subjective feelings with some methods has not been successful yet. Other complementary services with some impact to quality of traveling are services provided on board or in stationary facilities. For example, travel ticket office, info office, waiting room, toilets, wireless internet connection, post office, shop, restaurant, café and luggage storage are standard services provided in stationary facilities. On the other hand, there are services provided on board of the vehicle, for example luggage transport, bicycle transport, seat reservation, wireless internet connection, catering, electric socket, toilets, compartment for children, couchette, restaurant car, visual and acoustic information. Staff behaviour is also very important, because their function is not only checking the travel ticket, but also provide information about traveling and they must induce a good feeling among passengers. Entire quality is defined as an ability to satisfy all requirements of customers. Specific signs for services in transport are insubstantiality, impossibility to store, inseparability, variability, complexity and uniqueness. Level of service quality can be perceived as a disharmony among expectation and perception. Customers – passengers have got different priorities which relate to quality of service. They usually remember low quality and high quality is a standard for them. The main challenge is to identify the passengers' needs and satisfy them in all cases, because every transport is realized in different conditions. (Figlus *et al.,* 2017)

2.2. Long-Haul Passenger Train Route Technology

Technology for operation of long-haul passenger trains is created by the transport company and passengers usually do not know it. They know only the timetable, what represents transport offer – number of connections on the route. Temporal position of trains, which are listed in the timetable, must be attractive for passengers. This can be made by harmonisation of departures and arrivals. It means that the departure time from all transport hubs on the route is always in the same minute, but the hour is different. Passengers could easily remember all departures and it also improves the transport accessibility in the selected area from temporal point of view. It means that there is the same time gap between departures of trains and thanks to periodicity of departures, the transport accessibility is increased. Timetable is created separately for both directions of trains. It must include all trains, their departures, stations and stops names, trains numbers and distances. Transport time between each station and stop must be determined by technical specifications of selected vehicle, which operates on the route. Number of vehicles, which are necessary for operation of all trains included in timetable, is defined in vehicles circulation. It is divided into operation days and there is showed the sequence of trains for each vehicle and the following day. All technological acts are considered. Thanks to vehicle circulation, all vehicles have got same or very similar number of driven kilometres. Other part is a run of the train requisites. Train requisites are subjects, which are necessary to be supplemented into the vehicle, to create an object, which can independent movement in the transport process. Train requisites are vehicle-drivers and stewards. Sequence of the train requisites is regularly repeated schedule of their working time. Working time for vehicle-drivers and stewards are generated separately. Sequence of the train requisites must respect higher legal standards, mostly Labour Code. Thanks to sequence of the train requisites, the exact number of staff – vehicle drivers and stewards, is known. From economic point of view, there must be operating costs calculation. Costs are financial representation of company sources consumption for realizing services per time. Internal costs of the transport company arise from operation of trains on railways. Thanks to calculation, the exact amount of these costs is known. In railway passenger transport, the

calculation unit is the service – transporting of passengers. It can be defined by quantity (number of trains, vehicles), time (staff working time, time of traveling) or other way (passenger-kilometres, train-kilometres). In the case study, there are these costs: vehicle costs (price for vehicle, repairs and maintenance, insurance, operational cleaning), railway infrastructure access, staff costs (wages of vehicle-drivers and stewards), traction energy consumption and other indirect costs (management, marketing, travel ticket selling system, information system etc.). Sum of all costs, which are converted to one typified train on the route, is the base for making the tariff charges.
Railway vehicle costs are calculated this way:

$$r^{RV}_{trkm} \frac{D_Y + \Sigma RM_Y + OC_Y + INS_Y}{\text{Ø annual vehicle kilometrage}} \qquad (1)$$

where:
r^{RV}_{trkm} – railway vehicle costs rate for train-kilometre [€/trkm]
D_Y – depreciation of vehicle per year [€]
Σ RM_Y – entire costs for repairs and maintenance of vehicle per year [€]
OC_Y – entire costs for operational cleaning of vehicle per year [€]
INS_Y – entire costs for vehicle insurance per year [€]
Ø annual vehicle kilometrage – average kilometrage of railway vehicle per year [km]

$$C_{RV} = \Sigma trkm \,.\, r^{RV}_{trkm} \,.\, NRV_{tr} \qquad (2)$$

where:
C_{RV} – entire railway vehicle costs per route [€]
Σ trkm – sum of train-kilometres per route
r_{RVtrkm} – railway vehicle costs rate for train-kilometre [€/trkm]
NRV_{tr} – number of railway vehicles in the train on the route [vehicles]

Staff costs are calculated this way:

$$r^{S}_{emph} = \frac{price\ for\ working + equipment}{\Sigma\ work\ time} \qquad (3)$$

where:
r^{S}_{emph} – staff costs rate for employee-hour [€/emph]
price for working – all month company's costs for the employee [€]
equipment – month costs for equipment of employee [€]
Σ work time – entire month work time of employee [hours]

$$C_S = t_r \,.\, CR_S \,.\, r^{S}_{emph} \qquad (4)$$

where:
C_S – staff costs per route [€]
t_r – train ride time [hours]
CR_S – conversion ratio: train ride time □employee-hour
r^{S}_{emph} – staff costs rate for employee-hour [€/emph]

Traction energy consumption costs are calculated this way:

$$C_{TEC} = \frac{\Sigma gtkm \,.\, mc_{TE} \,.\, s_{TE}}{1000} \qquad (5)$$

where:
C_{TEC} – entire traction energy consumption costs per route [€]
Σ gtkm – gross-tons-kilometres per route
mc_{TE} – measurable consumption of traction energy per thousand gross-tons-kilometres
r_{TE} – traction energy rate [€]

From operating costs calculation, tariff rates can be appointed. The tariff reflects valuable relations among operator and passengers. These rates must include internal goals of the transport company (increasing profit, decreasing costs, market share etc.), social sphere (quality and offer of public transport, reducing regional gaps etc.) and environmental aspects. Current transport demand and complementary transport offer are also important part of setting tariff rates. Fare is based on costs and appropriate profit and it is also dependent on transport demand and competition. Discounts are provided by the transport company according to its transport politics and marketing strategy. Operating costs and transport revenues are compared in the operating-economic evaluation. Revenues are result of multiplying number of passengers with tariff rates, separately for each segment on the whole route. Comparison of costs and revenues express the economic efficiency of the route – revenues must be higher than costs. If the revenues are not higher than costs, operation of long-haul passenger trains is not efficient from economical point of view and the transport company must find external financial sources or simply remake the route.

2.3. Operating-Economic Evaluation of Zilina – Nove Zamky Route

Route begins in town Zilina, which is situated in northern Slovakia. Than the route continues through towns Povazska Bystrica, Puchov, Dubnica nad Vahom, Trencin, Banovce nad Bebravou, Chynorany, Topolcany, Nitra, Surany and terminates in town and important transport hub Nove Zamky. Towns Zilina, Trencín and Nitra are regional centres, so these towns have got great catchment areas. Important transport hubs, in addition to Nove Zamky, are Puchov, Chynorany and Surany, where other trains routes are detached.

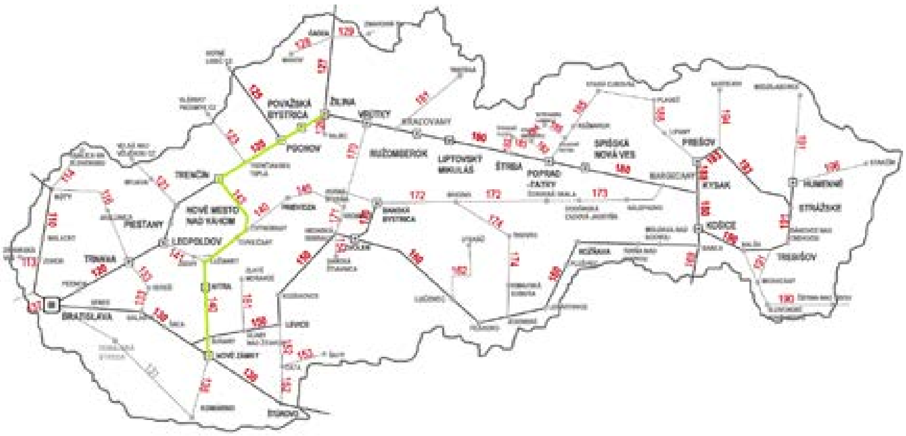

Fig. 2.
Railway network map of Slovakia with marked route Zilina – Nove Zamky
Source: http://www.slovakrail.sk/fileadmin/dokumenty/NAD_2016/mapa.PNG; edited by authors

Operation of long-haul passenger trains on the route Zilina – Nove Zamky is ensured by VT 643 Talent made by company Bombardier. This vehicle is appropriate for this route, because it suits to quality criteria for passenger transport. There are approximately 160 seats. Nowadays, these vehicles provide operation on route from Bratislava to Komarno in Slovakia and it is also very common in other countries worldwide. All technical parameters of this vehicle are included in timetables. There are also technical parameters of tracks, where this vehicle would be in operation. Traveling time of each train respects these technical parameters.

km	Train		**R 630**	**R 632**		**R 634**	**R 636**		**R 638**
0	**Žilina**		5 40	8 40		11 40	14 40		17 40
32	Považská Bystrica		6 10	9 10		12 10	15 10		18 10
44	Púchov		6 21	9 21		12 21	15 21		18 21
66	Dubnica nad Váhom		6 35	9 35		12 35	15 35		18 35
79	**Trenčín**	o	6 47	9 47		12 47	15 47		18 47
	Trenčín		6 49	9 49		12 49	15 49		18 49
114	Bánovce nad Bebravou		7 31	10 31		13 31	16 31		19 31
128	Chynorany		7 49	10 49		13 49	16 49		19 49
138	**Topoľčany**	o	7 59	10 59		13 59	16 59		19 59
	Topoľčany		8 01	11 01		14 01	17 01		20 01
171	Nitra		8 32	11 32		14 32	17 32		20 32
197	Šurany		8 56	11 56		14 56	17 56		20 56
207	**Nové Zámky**	o	9 05	12 05		15 05	18 05		21 05

Fig. 3.
Timetable of trains in direction from Zilina to Nove Zamky
Source: authors

km	Train	R 631	R 633		R 635	R 637		R 639
0	**Nové Zámky**	6 50	9 50		12 50	15 50		18 50
10	Šurany	7 00	10 00		13 00	16 00		19 00
36	Nitra	7 25	10 25		13 25	16 25		19 25
69	**Topoľčany** o	7 55	10 55		13 55	16 55		19 55
	Topoľčany	8 03	11 03		14 03	17 03		20 03
79	Chynorany	8 14	11 14		14 14	17 14		20 14
93	Bánovce nad Bebravou	8 31	11 31		14 31	17 31		20 31
128	**Trenčín** o	9 11	12 11		15 11	18 11		21 11
	Trenčín	9 13	12 13		15 13	18 13		21 13
141	Dubnica nad Váhom	9 27	12 27		15 27	18 27		21 27
163	Púchov	9 41	12 41		15 41	18 41		21 41
175	Považská Bystrica	9 52	12 52		15 52	18 52		21 52
207	**Žilina** o	10 20	13 20		16 20	19 20		22 20

Fig. 4.
Timetable of trains in direction from Nove Zamky to Zilina
Source: authors

Transport times of all trains are summarized in the table 1. This summary is necessary for operating costs calculation, where the costs for one typified train are calculated. Typified train means the train, whose transport time is average.

Table 1
Transport time of trains on the route Zilina – Nove Zamky

	Train:	R 630	R 631	R 632	R 633	R 634	R 635	R 636	R 637	R 638	R 639
	Departure:	5:40	6:50	8:40	9:50	11:40	12:50	14:40	15:50	17:40	18:50
	Arrival:	9:05	10:20	12:05	13:20	15:05	16:20	18:05	19:20	21:05	22:20
	Duration:	3:25	3:30	3:25	3:30	3:25	3:30	3:25	3:30	3:25	3:30
	Conversion:	3.42	3.50	3.42	3.50	3.42	3.50	3.42	3.50	3.42	3.50
	Sum per day:	34:35:00									
	Conversion:	34.58									
	Average per day:	3.46									

Source: authors

Next step is vehicles circulation. It shows the exact number of vehicles, which are necessary to realize the timetable. There are three vehicles, which are necessary for operation of all trains on the new route from Zilina to Nove Zamky. During night, two vehicles are in the station Zilina and one vehicle is in the station Nove Zamky.

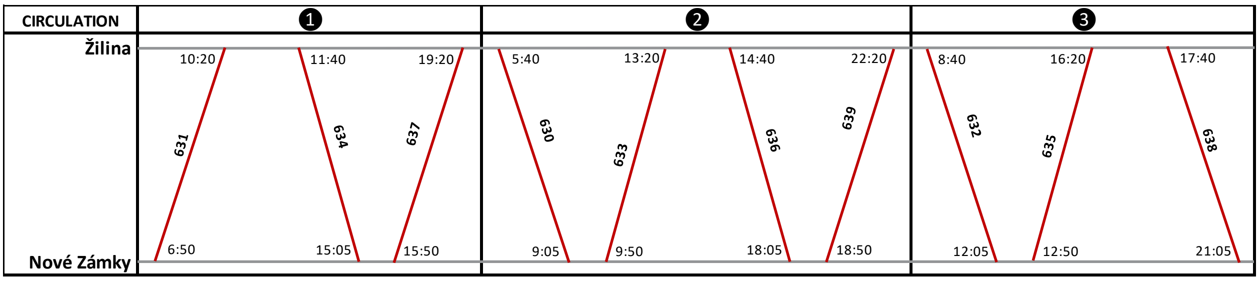

Fig. 5.
Vehicles circulation on the route Zilina – Nove Zamky
Source: authors

Vehicle circulation is the base for determine driven kilometres of vehicles. It also influences operating costs calculation, because all vehicle costs are divided with average kilometres.

Table 2
Driven kilometres of vehicles on the route Zilina – Nove Zamky

KILOMETRAGE OF VEHICLES	❶	❷	❸	Σ day	Ø day	Σ week	Ø week	Σ month	Ø month	Σ year	Ø year
	621	828	621	2070	690,00	14490	4830	62100	20700	753480	251160

Source: authors

Other important part is the sequence of the train requisites. Train requisites in passenger railway transport are vehicle drivers and stewards – the necessary personnel of the train. There are one vehicle-driver and two stewards in each train. Their starting and termination point is Zilina. According to the designed sequence of the train requisites, there is the necessity to ensure accommodation for the staff in the station Nove Zamky.

<table>
<tr><th colspan="13">SEQUENCE OF VEHICLE-DRIVERS</th></tr>
<tr><th colspan="3">Necessary</th><th colspan="10">Sequence day</th></tr>
<tr><td rowspan="9">Starting point</td><td rowspan="9">ŽILINA</td><td rowspan="9">8.94</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="2">5</td></tr>
<tr><td colspan="2">630/633</td><td colspan="2">636/639</td><td colspan="2" rowspan="2">TV</td><td colspan="2">634/637</td><td colspan="2" rowspan="2">TV</td></tr>
<tr><td>5:00</td><td>14:00</td><td>14:00</td><td>23:00</td><td>11:00</td><td>20:00</td></tr>
<tr><td colspan="2">6</td><td colspan="2">7</td><td colspan="4">8</td><td colspan="2">9</td></tr>
<tr><td colspan="4">632/635/638/631</td><td colspan="4" rowspan="2">TV</td><td colspan="2" rowspan="2">TV</td></tr>
<tr><td>8:00</td><td>22:00</td><td>6:00</td><td>11:00</td></tr>
<tr><td colspan="8">Working time (hours)</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="2">Σ day</td><td colspan="2">Ø day</td><td colspan="2">Σ month</td><td colspan="2">Ø month</td></tr>
<tr><td colspan="2">46.00</td><td colspan="2">5.11</td><td colspan="2">1380.00</td><td colspan="2">153.33</td></tr>
</table>

Fig. 6.
Sequence of vehicle-drivers on the route Zilina – Nove Zamky
Source: authors

<table>
<tr><th colspan="15">SEQUENCE OF STEWARDS</th></tr>
<tr><th colspan="3">Necessary</th><th colspan="12">Sequence day</th></tr>
<tr><td rowspan="12">Starting point</td><td rowspan="12">ŽILINA</td><td rowspan="12">15.94</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="4">4</td><td colspan="2">5</td></tr>
<tr><td colspan="2">630/633</td><td colspan="2">632/635</td><td colspan="2">634/637</td><td colspan="4" rowspan="2">TV</td><td colspan="2">636/639</td></tr>
<tr><td>5:30</td><td>13:30</td><td>8:30</td><td>16:30</td><td>11:30</td><td>19:30</td><td>14:30</td><td>22:30</td></tr>
<tr><td colspan="2">6</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">10</td><td colspan="2">11</td></tr>
<tr><td colspan="4">638/631</td><td colspan="2" rowspan="2">TV</td><td colspan="2" rowspan="2">TV</td><td colspan="2">630/633</td><td colspan="2">632/635</td></tr>
<tr><td>17:30</td><td>22:00</td><td>6:00</td><td>10:30</td><td>5:30</td><td>13:30</td><td>8:30</td><td>16:30</td></tr>
<tr><td colspan="2">11</td><td colspan="2">12</td><td colspan="2">13</td><td colspan="2">14</td><td colspan="2">15</td><td colspan="2">16</td></tr>
<tr><td colspan="2">634/637</td><td colspan="2">636/639</td><td colspan="4">638/631</td><td colspan="2" rowspan="2">TV</td><td colspan="2" rowspan="2">TV</td></tr>
<tr><td>11:30</td><td>19:30</td><td>14:30</td><td>22:30</td><td>17:30</td><td>22:00</td><td>6:00</td><td>10:30</td></tr>
<tr><td colspan="8">Working time (hours)</td><td colspan="4" rowspan="3"></td></tr>
<tr><td colspan="2">Σ day</td><td colspan="2">Ø day</td><td colspan="2">Σ month</td><td colspan="2">Ø month</td></tr>
<tr><td colspan="2">82.00</td><td colspan="2">5.13</td><td colspan="2">2460.00</td><td colspan="2">153.75</td></tr>
</table>

Fig. 7.
Sequence of stewards on the route Zilina – Nove Zamky
Source: authors

Economical part of the design consists of operating costs calculation. There are many enumerations, because all costs must be identified and quantified. Railway vehicle costs rate is quantified by formula (1). Value of vehicle: 5 million €; years of using: 20; Repairs and maintenance: 49 022 € per year; Operational cleaning: 9 600 € per year; Insurance: 24 370 € per year; Annual vehicle kilometrage: 251 160 km. Resultant railway vehicle costs rate is 1,33 €/trkm. Staff costs are calculated separately for vehicle-drivers and stewards. Firstly, the costs rate must be calculated. Key part is price for working – all costs of the transport company for one employee. All staff costs rate is quantified by formula (3). Stewards are less qualified than vehicle-drivers; therefore, price for working is lower. Equipment costs are higher, because stewards are communicating with passengers, therefore they must have always clean and modern uniform for good propagation of the transport company. Vehicle-drivers' value for working: 2 500 € per month; vehicle-drivers' value for equipment: 45 € per month; vehicle-drivers' average work time: 153,33 hours per month; resultant vehicle-drivers' costs rate is 16,60 €/emph and time conversion ratio is 1,33. Stewards' value for working: 1 400 € per month; stewards' value for equipment: 75 € per month; stewards' average work time: 153,75 hours per month; resultant stewards' costs rate is 9,59 €/emph and time conversion ratio is 1,19. Basic precondition for the operating costs calculation is determination and summarization of all necessary inputs and other transport indicators, which are important parts for the calculation. There are other necessary inputs: number of vehicles per typified train is 1; gross weight of the train is 92 tons; distance is 207 kilometres; average travel time is 3,46 hours; there are 1 vehicle-driver and two stewards in each train; price for diesel is 0,95 €/liter. Average vehicle-drivers' work time is 4,6 hours per train; average stewards' work time is 4,1 hours per train. Important transport indicators are: sum of the trainkilometres is 210; sum of the gtkm is 19 044; diesel consumption is 9,575 liters/1000gtkm. When all inputs and transport indicators are known, the operating costs can be calculated. Costs per typified train are quantified by formulas (2), (4) and (5). Costs for infrastructure and indirect costs are quantified separately, according to methods hereinbefore.

Table 3
Operating costs per typified train on the route Zilina – Nove Zamky

COSTS (€)		
Vehicle	278,42	22,94%
Infrastructure	243,07	20,02%
Vehicle-driver	76,35	6,29%
Stewards	78,67	6,48%
Diesel	173,23	14,27%
Indirect	364	30,00%
Sum	**1213,91**	100,00%
converted to 1 seat	7,59	
converted to 1 placekm	0,036652	

Source: authors

Revenues are calculated by multiplying of transport flows and tariff rates on each transport relations. Transport flows are determined by passenger counting in trains. Final and the most important part is the operating-economic evaluation, where revenues are compared with operating costs. Economic efficiency of the route is the result of this comparison and the operation of trains on the route is efficient in the case, when the result is higher than zero – revenues cover all costs.

Table 4
Comparison of revenues and operating costs on the route Zilina – Nove Zamky

ROUTE: ŽILINA - TRENČÍN - TOPOĽČANY - NITRA - NOVÉ ZÁMKY		
Sum of operating costs per train	1213,91	€ without VAT
Costs per 1 seat	7,59	€ without VAT
Sum of revenues per train	1922	€ with VAT
minus VAT	1537,6	€ without VAT
Result	323,69	€

Source: authors

3. Conclusion

Railway passenger transport, as important part of transport system connected with mobility of people, is evaluated from operating-economic point of view. Operation part means technology, what consists of timetable, vehicle circulation, the run of the train requisites and passengers flows analysis. Internal costs calculation and revenues quantification represent economic part of the evaluation, which is very important for the transport company nowadays. Operating-economic evaluation of the long-haul train route in the case study above shows the efficiency of the route, because revenues per train are higher than costs per train. The transport company can operate trains on the route according to submitted technology and external sources are not necessary.

Acknowledgements

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RESEARCH OF TRACK GEOMETRY QUALITY INDICATORS IN TRANSITION AREAS OF THE RAILWAY SUPERSTRUCTURE

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Abstract: The modernization of corridor tracks of the Slovak railway network has increased their technical quality. To determine the quality durability, experimental sections with unconventional railway superstructure were diagnosed: a ballastless track construction in the vicinity of a ballasted track construction. Experimental sections are parts of the Corridor No. V of the Trans-European Transport Network (TEN), on the railway line of the Railways of the Slovak Republic (Železnice Slovenskej republiky – ŽSR) Bratislava – Žilina. The paper deals with the application of diagnostic methods for determining the quality of the decisive parameters of the track geometry. The results of the diagnostics focus on the specification of the weak spots of the construction, which represent the parts of the railway line limiting its service life. Within the experimental sections, the areas with limited quality are the transition areas between the ballastless and ballasted track. The traffic load reaction of the construction is manifested by errors in one of the decisive parameters of the track geometry: track level. The presented research results represent a prediction of the track geometry quality development that helps to optimize the time of the implementation and the method to recover the track geometry quality in the transition areas.

Keywords: railway track geometry, quality, diagnostics, degradation, prediction, ballastless track, transition area.

1. Introduction

During its operation, the railway track is normally loaded by two types of externalities: traffic and non-traffic load. The traffic load is caused by rolling stock, maintenance cars and work units. At the same time, the rail track is affected by climatic factors, especially high and low temperatures, temperature changes, rainfall and snowfall. The railway track reacts by gradual quality degradation of its individual structural components.

The railway infrastructure manager evaluates the quality of the railway track during operation, applying various track quality indicators. The key indicators represent the material and geometric quality of the railway superstructure components and the quality of the track layout and the track geometry. The methods and tools for determining and evaluating the track quality indicators are in line with the current operating conditions of the structure: the track category by track speed and the load transported per year.

The Department of Railway Engineering and Track Management (KŽSTH) of the Faculty of Civil Engineering, University of Žilina, has been researching the problem of determining the operational quality of track geometry since 2012. At present, this research is conducted at three experimental sections (ES) (Fig. 1). The respective experimental sections are specific as they include a track superstructure consisting of a conventional ballast bed structure, ballastless track and transition areas between them.

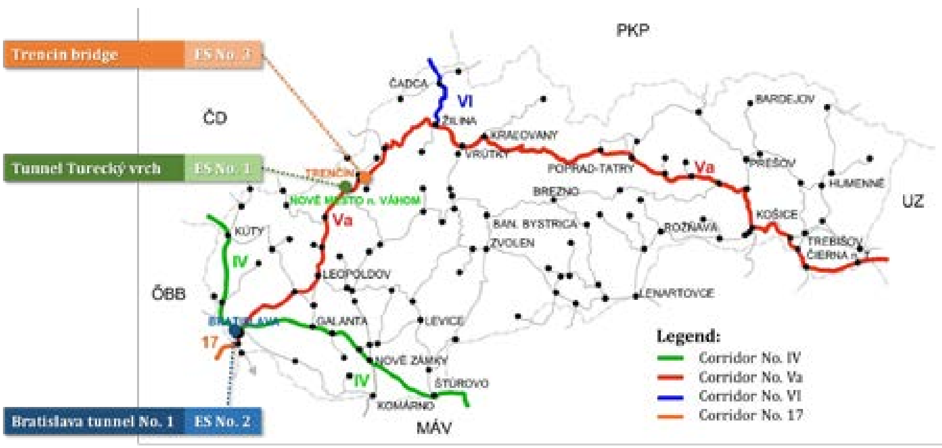

Fig. 1.
Experimental sections in the Slovak Railways network

The research aims in the experimental sections are as follows:

- to determine the development of track quality indicators,
- to identify the ‚weak‘ spots of the structure, i.e. places with the the fastest quality degradation,
- to create degradation-prediction models of particular quality indicators and their combinations, in order to determine the optimum time of maintenance and repair work implementation in real operating conditions.

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2. Track Geometry Quality in Transition Areas of the Railway Superstructure

The following parts of the paper present the results of monitoring and comparison of track geometry development in two sections with a similar structure:

1. Experimental section no. 1: the area of the Turecký Vrch Tunnel between the railway stations Nové Mesto nad Váhom and Trenčianske Bohuslavice, and
2. Experimental section no. 3: area of the railway bridge over the Váh river in Trenčín.

The experimental section no. 2, in the area of the Bratislava Tunnel no.1, differs from the above mentioned sections no.1 and 3. in these parameters:

- ballastless track structure (ŐBB-PORR type),
- transition area structure (combination of a bonded ballast bed and a rail skeleton with concrete sleepers),
- track speed (speed zone SZ1; $V \leq 60$ km/h).

The experimental section no. 1 is located near the portals of the Turecký Vrch Tunnel, on a double track Nové Mesto nad Váhom – Púchov, of the total axis length 1 775 m. According to the operating track speed, both rails were included in SZ4 ($120 < V \leq 160$ km/h). The railway superstructure consists of a conventional ballast bed structure and a ballastless structure RHEDA 2000® type that leads through various types of the track foundation. It starts on an earthwork in front of the southern portal and passes through the entire tunnel. Behind the northern portal, the ballastless structure continues on two bridges and an earthwork. The end of the ballastless structure and its transition to the ballast bed structure was solved by a transition area on both ends. Its structure consists of a reinforced concrete tub, 20.000 m long, with a longitudinal bottom slope. To monitor the track geometry quality, the experimental section no. 1 was divided into four experimental subsections, namely:

- 1.1 in the track no.1, or 2.1 in the track no. 2 in the area of the sourthern tunnel portal; the length of subsections is 175.000 m each (from km 102.360 000 to km 102.535 000),
- 1.2 in the track no.1, or 2.2 in the track no. 2 in the area of the northern tunnel portal; the length of subsections is 640.000 m each (from km 104.200 000 to km 104.840 000).

The experimental section no. 3 is located in Trenčín on a new railway bridge over the river Váh, between the railway stop Zlatovce and railway station Trenčín. The double track railway bridge, 343 m long, consists of seven fields and is a part of the double rail track Nové Mesto nad Váhom – Púchov. Based on the track speed, both track were included into SZ4 ($120 < V \leq 160$ km/h). The railway superstructure consists of a conventional ballast bed structure and the ballastless structure RHEDA 2000®. The ballastless structure begins at earthwork near the railway stop Zlatovce and passes through the entire bridge. In the direction of Trenčín, the ballastless structure continues on earthwork. The end of ballastless structure and the transition to the ballast bed structure is on both ends solved by the application of a transition area. The transition area is formed by a reinforced concrete tub, 20.000 m long, with a longitudinal bottom slope. To monitor the track geometry quality, the experimental section no. 3 is divided into two experimental subsections, namely:

- 3.1 in the track no. 1; the subsection length is 770.000 m (from km 122.112 500 to km 122.882 500),
- 3.2 in the track no. 2; the subsection length is 767.500 m (from km 122.115 250 to km 122.882 750).

The purpose of the experimental track segmentation, as mentioned above, was determining and monitoring the development of the track geometry quality. The segmentation of the experimental sections no. 1 and no. 3, conducted in compliance with the valid Slovak legislative, is stated in *Fig. 2*. The respective figure also provides information on the position of the railway superstructure and substructure, and on directional conditions. The directional conditions are a key parameter for the quality evaluation of the track geometry.

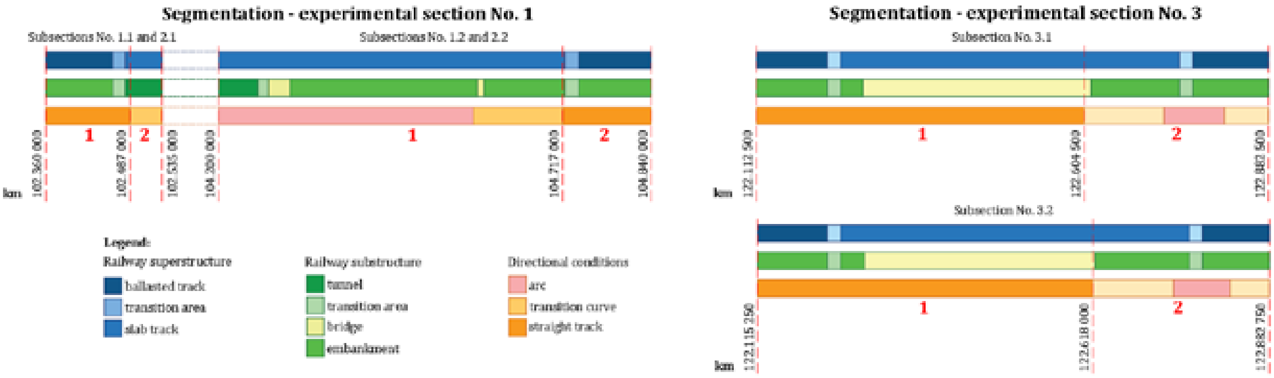

Fig. 2.
Graphic overview of a diagnostic segmentation of experimental sections no.1 and 3
Source: (Šestáková, 2017)

2.1. Methods and Tools of Determination and Evaluation of Track Quality Indicators

The diagnostics of respective experimental sections focuses on verification of operating quality of the track geometry. It does not depend on supervising and monitoring strategies and the technical equipment of the railway infrastructure manager. It is carried out by applying the conditions and methods, primarily stated in (STN EN 13848-1 + A1, 2009), (STN EN 13848-4, 2011, STN EN 13848-6, 2014, STN 73 6360-2, 2015 and ZSR SR 103-7, 2017). The diagnostic tool is a measuring trolley KRAB™–Light®. It is an electronic device with continuous scanning and recording of measurement, designed to diagnose the track geometry. The measured parameters are recorded every 0.250 m. It is a contact measurement – by contact of the measuring device with the rail skeleton (rail) of the diagnosed track, in an unloaded state. (The device weight is approx. 36 kg). Based on the scheme of continuous measurement, it is possible to divide the basic track geometry quantities into two groups (*Fig. 3*):

1. Quantities of the geometric order of the track, represented by measured deviations from the designed position and
2. Quantities of the construction order of the track, determined by direct measurement on the rail.

	Geometric order of the track (deviations from projected placement)	Construction order of the track (direct measurement of the track)
Horizontal direction	**Alignment (*SK*)**	**Gauge (*RK*)**
Vertical direction	**Top (*VK*)**	**Cant (*PK*)**

Fig. 3.
Diagnostics of operational quality – basic track geometry quantities
Source: (Commercial Railway Research Ltd., 2002)

The quantities track gauge (RK) and cant (PK) are direct measures in the respective track cross-section. They are directly (absolutely) measurable as so-called real geometry, in the whole wavelength range $\lambda \in \langle 1 \text{ m}, \infty \rangle$. The parameter track gauge serves for calculation of the parameter change of gauge (ZR), for 1 m of the track. From the cant values, it is possible to deduce twist (ZK) on prescribed bases (for ŽSR ℓ = 3.000, 6.000 or 12.000 m).
The quantities of deviations of the track alignment (SK) and top of the line (VK) can be only determined indirectly. They characterize the roadway of rolling stock, represented by spatial curves that are also measurable in all the wavelength area. As direct measurement is not possible, curve continuity created by track alignment and top of the line are determined. The evaluation of the curve continuity is conducted on the principle of measuring the versine on the chord, by the measuring device KRAB™–Light®. Such a measurement is referred to as relative. With respect to wavelengths, the signal is filtered not to contain long waves.
The evaluation of diagnostics is conducted using standardized values of monitored parameters in (STN 73 6360-2, 2015 and ZSR SR 103-7, 2017). It focuses on occurrence of local errors of these parameters. The errors are detected after exceeding the standard values. The standard values are prescribed by allowed deviations, or allowed maximum values of quantities of the geometric track quality:

- before the structure enters into service, the limit values are:
  - installation limits, or the values of track geometry quality quantities for accepting construction work,
- during operation, the limit values are:
  - maintenance limits, or the values of track geometry quality quantities for (AL) alert limit or (IL) intervention limit,
  - safety limits, or the values of track geometry quality quantities (IAL) immediate action limit.

A comprehensive (section) track quality evaluation by the measuring trolley KRAB™–Light®, in the conditions of Slovak Railways company, as in (ZSR SR 103-7, 2017), is regulated by several structural quality indicators:

- evaluation using the section quality number (QN),
- evaluation using the standard deviations (SDV) of quantities SK, RK, PK, VK,
- indicative (non-binding for the railway infrastructure manager) evaluation using quality marks (QM) of quantities SK, RK, PK, VK.

2.2. Quality of Track Geometry Parameters and Identification of Places With the Fastest Decreasing Quality

The section course of relative deviations related to the central lines of decisive quantities SK (SL and SP for the left and right rail) and VK (VL and VP for the left and right rail), provides the railway infrastucture manager with the primary information on the track geometry quality. As at present the measurement graphs serve the railway infrastructure manager for evaluating the track geometry quality and planning its repairs, the comprehensive graphic record of measurements is a simplest option for monitoring the track geometry quality degradation.
The graphs of section courses of relative deviations (SL/x, SP/x, VL/x and VP/x), related to the central lines of quantities SL, SP, VL and VP, as in (Šestáková, 2017), demonstrate the history of measurements and relation of deviation values to the defined evaluation levels. However, it is not possible to capture the trends of future development. The determination and the subsequent track geometry quality evaluation in the particular subsections of

the experimental section no. 1 have been conducted since 2012, once in six months. The first track geometry measurement of the experimental section was conducted as a measurement for acceptance of construction work on the track (marked MSO), other measurements are defined as operational diagnostics (marked PO1 to PO11).
The measurement results indicate that the worst quality was reached by the quantity VK, on the boundary of the transition area and the ballastless track. In the subsections of the experimental section no. 1, a repair intervention was carried out in the part of structure with a ballast bed and also in the transition area (repair of the track alignment and top of the rail), after MSO measurement in summer and autumn 2012, after PO4 measurement in autumn 2014 and before PO10 measurement in autumn 2017.
After repair interventions, the changes of this quantity are not manifested as errors. However, the graphic evaluation clearly indicates that the shape of errors is becoming more prominent and the peak values of the VL and VP deviations are approaching the AL. The quality degradation is fastest in the experimental subsections 1.1 and 2.1 (*Fig. 4* and *Fig. 5*).

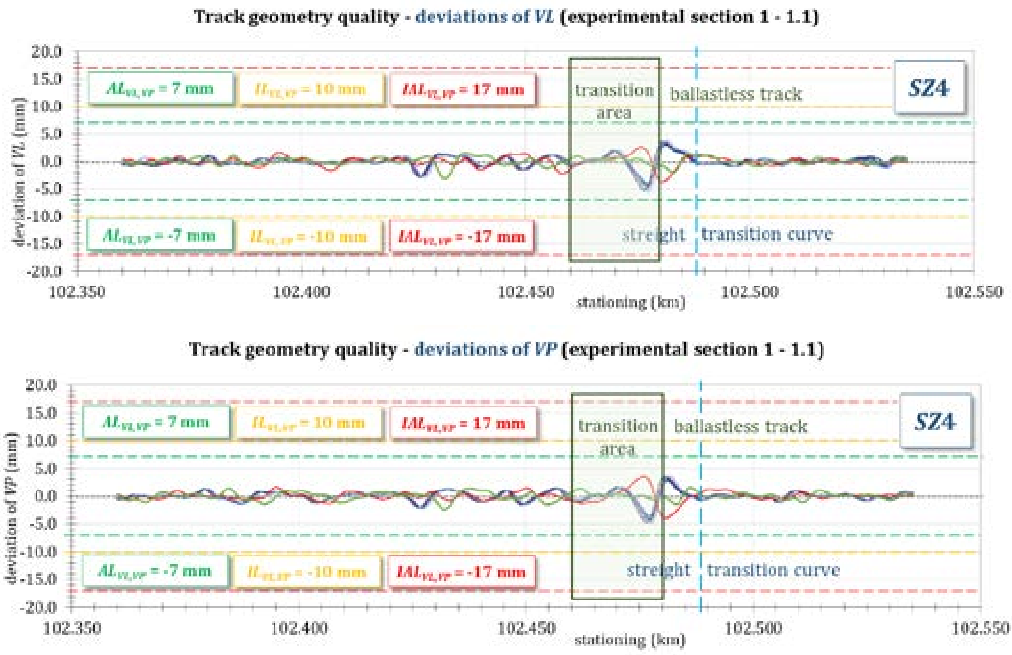

Fig. 4.
Experimental section 1 – 1.1: section course of the deviations of top level of left and right rail

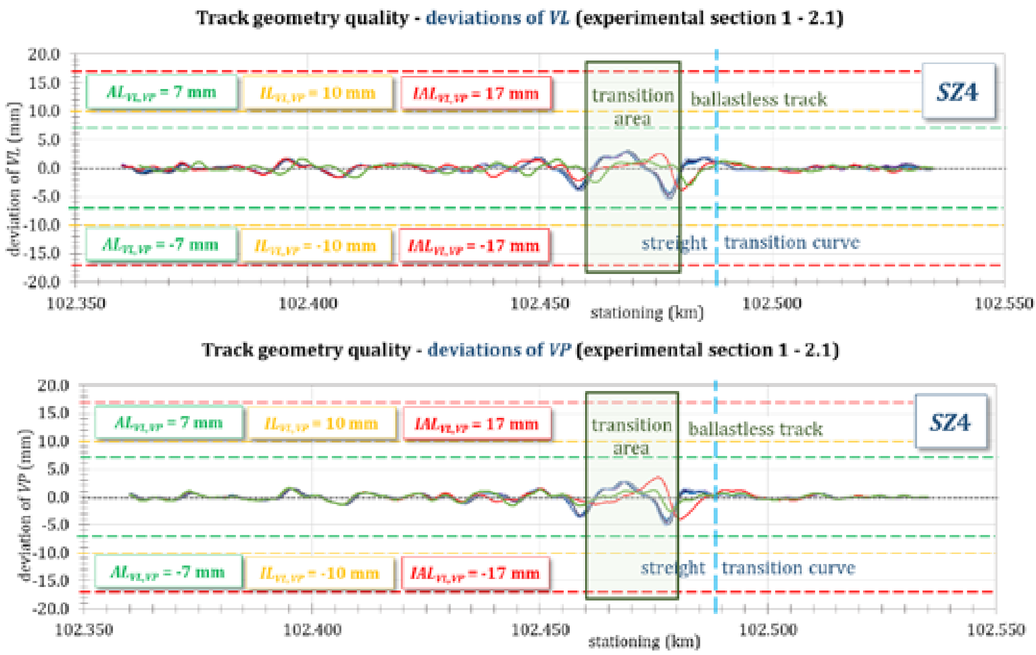

Fig. 5.
Experimental section 1 – 2.1: section course of the deviations of top level of left and right rail

The diagnostics and the subsequent evaluation of the track geometry quality in the experimental section no. 3 have been carried out since July 2017, in two subsections. A 6-month periodicity of measurements is assumed. The first measurement in

the track no. 1 was carried out as a measurement for acceptance of construction work on the track (MSO). The first track geometry measurement in the track no. 2 can be considered an operation measurement (PO1) because it was conducted approximatelly 70 days after the start of this track operation. The section evaluation of experimental subsections 3.1 and 3.2 has been so far conducted for three measurements (track no. 1: MSO, PO1, and PO2; track no. 2: PO1 to PO3). The railway infrastructure manager has not published any information on repair work implementation in the experimental subsections.
Also in the case of this structure, the graphical evaluation clearly demonstrates that the quality degradation is fastest with the VK parameter, on the boundary of the transition area and the ballastless track (*Fig. 6* and *Fig. 7*).

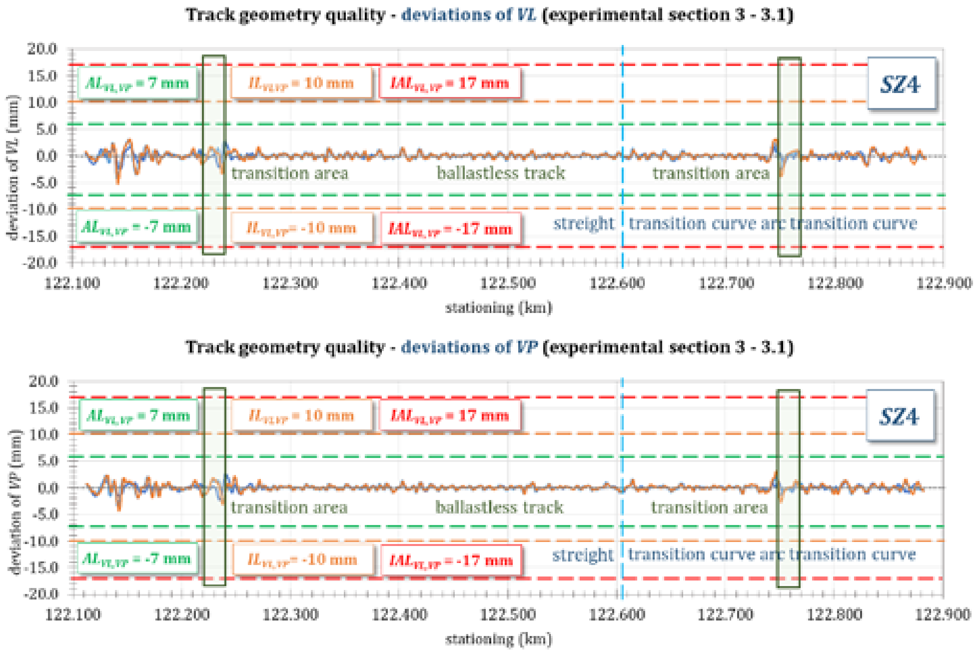

Fig. 6.
Experimental section 3 – 3.1: section course of the deviations of top level of left and right rail

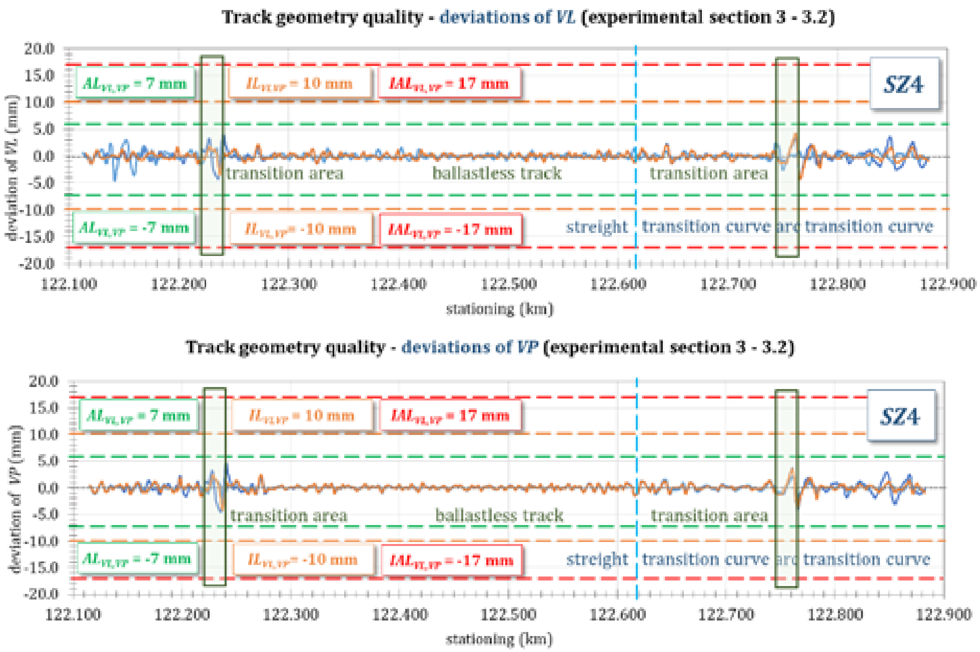

Fig. 7.
Experimental section 3 – 3.2: section course of the deviation of top level of left and right rail

2.3. Development of Track Quality Indexes

For efficient decision-making on necessary track repairs, it is necessary to obtain representative data on the entire evaluated section. The quality of track geometry parameters, expressed in various ways, affects the quality of each evaluated section. This quality is expressed by the track quality index.

To provide a comprehensive overview of information on the experimental section quality, graphs depicting the development of priority (SDV a QN) and auxiliary (QM) track indexes were created. *Fig. 8* to *Fig. 11* show section quality indicators for the quantity with the worst quality: VK (SDV and QM) and QN of each evaluated section. The arrangement of quality indexes correlates with the respective measurement of the track quality geometry of the experimental section and with the segmentation of evaluated sections.
The graphical progress of section quality indexes copies the structural degradation by operation and the implemented quality rehabilitation only in the experimental section 1 – 1.1. During operation between two repair interventions, the values of all indexes worsened but after implementing the repair intervention, all the indexes improved. In the experimental section 1 – 2.1, it is not possible to state the improvement rate of quality indexes, depending on implemented repair intervention. The course of quality indexes in the experimental sections 3 – 3.1 and 3 – 3.2 has so far had the mutually opposite quality development, but to objectively determine the trends, it is necessary to apply more diagnostic data from other measurements.

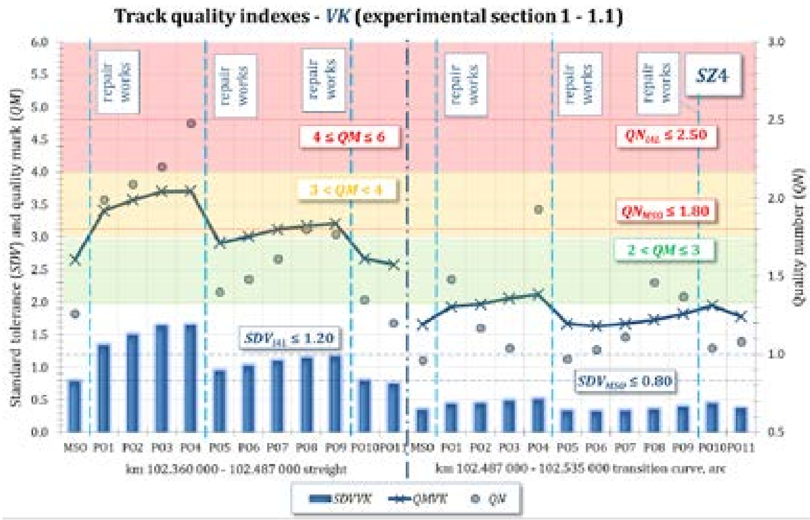

Fig. 8.
Experimental section 1 – 1.1: quality indexes of track geometry for deviations of the top level of track

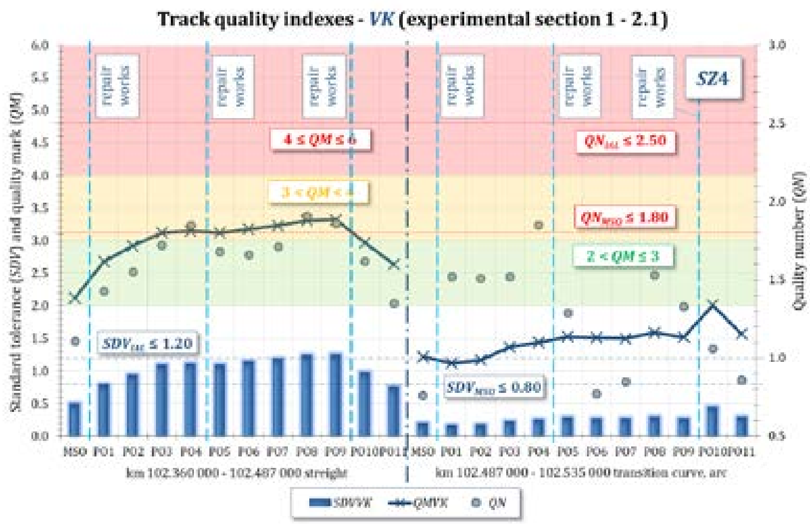

Fig. 9.
Experimental section 1 – 2.1: quality indexes of track geometry for deviations of the top level of track

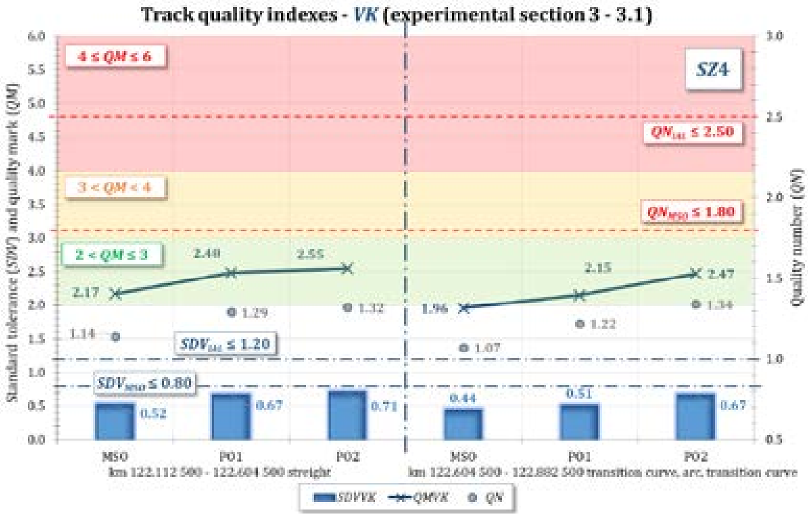

Fig. 10.
Experimental section 3 – 3.1: quality indexes of track geometry for deviations of the top level of track

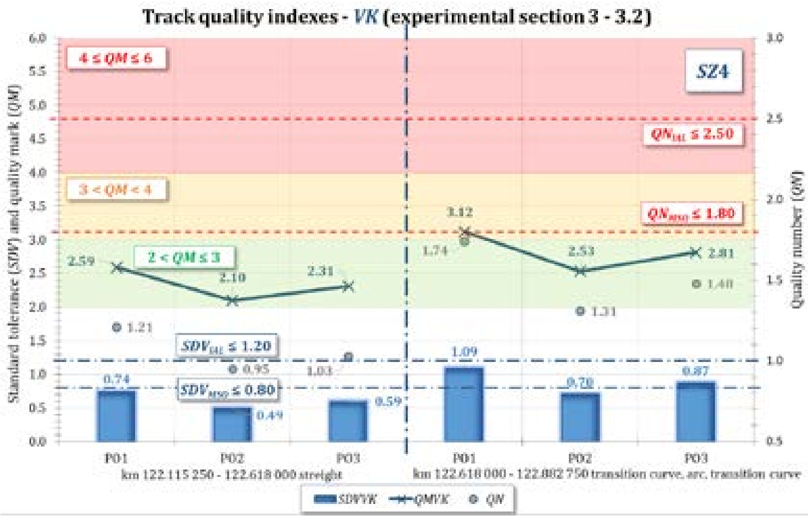

Fig. 11.
Experimental section 3 – 3.2: quality indexes of track geometry for deviations of the top level of track

2.4. Degradation – Prediction Models of Quality Indicators

The process of track repair planning in Slovakia is regulated by the local error evaluation, values of respective deviations of determining variables and the section quality number. The maintenance system is defined as a safety system, i.e. after detecting a local error, or exceeding the limit QN value, a repair is conducted. The operating quality evaluation only serves as information on exceeding (not exceeding) the defined quality indicators.

To early detect the trend of quality degradation of the structure and to plan preventive repair work, it is possible to apply models of degradation and prediction of the future quality development. The diagnostic data, gained by quality monitoring of the track geometry in the experimental sections no. 1, 2 and 3, are continuously used for developing degradation-prediction models of the track geometry quality. The models use regression and correlation tools of generally available software (MS Excel©). To ensure reliability and safety of railway operation, (STN EN 13848-6, 2014) states the following decisive quantities: deviations of track alignment and top level of the track (rails): SK (SL, SP), or VK (VL, VP). (Šestáková, 2017) includes a design, assessment, and evaluation of several prediction methods of quality development for these quantities. With respect to available data and their structure, the models for subsections of the experimental section no. 1 have been so far processed. The evaluation of quality indicators of the track geometry, considering the development continuity disrupted by repairs, focuses on the period after the repair completion, i.e. operational measurements PO5 to PO9. The subsequent data collection cycle started with the operational measurement PO10 – after implementing the last activity focusing on rehabilitation of track geometry quality. *Fig. 12* demonstrates the time course of the section quality number – PO5 to PO9 before the repair intervention in 2017, PO10 and PO11 after the repair intervention in 2017.

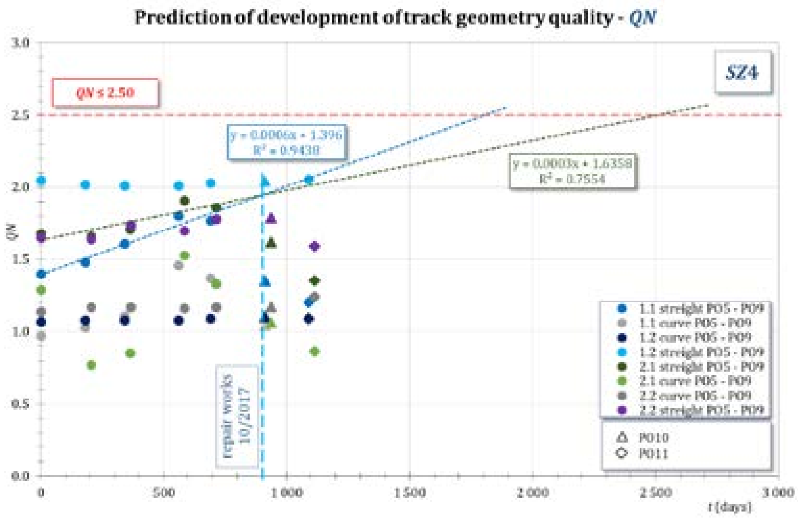

Fig. 12.
Experimental section 1: prediction of quality number development in time

The model dependencies confirm that the subsections 1.1 and 2.1 in the segment 1, i.e. the transition area section, are of the lowest quality. The quality of the transition area is thus a decisive factor for planning and implementation of repair work in the respective section. The evaluation of track geometry quality development, according to the dependency of the section number on time, is based on the development of QN values. These values were collected in PO5 (time $t_0 = 0$), PO6, PO7, PO8 and PO9 measurements, in eight segments of the experimental section no. 1. The segment with the fastest degrading quality is determined by the time t, which flows from the time t_0. In this time, the QN value reaches the standard value of limit QN, as defined in (ZSR SR 103-7, 2017). To determine the regression equation of dependency of the quality number and time, 5 values representing 5 measurements are used for each segment of the evaluated section. The graphic representation of relations of correlation and regression analysis of QN/t is demonstrated in *Fig. 12*. It describes diagnostic segments whose quality, with regard to the development of the maximum quality number value, is the fastest degrading one. The results of the regression and correlation analysis of the relation of the section quality number and time confirm the linear dependency of these quantities in the experimental section no. 1. According to the statistical model of QN/t , the evaluated quantity should have reached the limit values for SZ4 in the time of the upper limit of the expected service life of the track geometry repair. This expected service life was 5 years for the track no. 1 or 6.5 years from the time t_0 for the track no. 2. However, this time horizon is shorter than the time of achieving the value of maximum deviation (local error occurrence) of decisive quantities $|SL, SP|_{max}$, or $|VL, VP|_{max}$ on the intervention limit, i.e. 7.5 years from t_0, assumed in prediction models $|SL, SP|_{max}/t$, or $|VL, VP|_{max}/t$ (Šestáková, 2017). The model also clearly indicates that the railway infrastructure manager did not allow the track geometry quality decrease to the limit QN value and carried out the repair intervention approximatelly in the half of the predicted lifetime of a previous repair intervention.

3. Conclusion

The KŽSTH conducts the data collection from experimental sections to identify the places of the structure with the fastest degrading quality and to create degradation-prediction models of structural quality. In the experimental sections no. 1 (railway tunnel Turecký Vrch) and no. 3 (railway bridge in Trenčín), the final quality is affected by degrading track geometry quality in transition areas of the ballastless track, particularly of the parameter of the deviation of the top level of the left and right rails. The given situation calls for the implementation of track repairs in a shorter time than the supposed durability of the repair quality. To optimize the repair time, prediction can be found useful as a product of mathematical models compiled from real-time diagnostic data. The error repair, and especially awareness of causes of the error occurrence, must contribute to the structural quality improvement. Further KŽSTH research thus focuses on examining and modeling the reaction of transition area structure to the traffic load. The results of the initial research stage were published, e.g. in (Ižvolt *et al.*, 2017). To optimise the structure, its dynamic behaviour was modeled and analysed with the help of a 3-D model in ANSYS software. The values of vertical shift, vertical speed and vertical acceleration are determined here. Subsequent steps of this part of research are modeling, and comparing the behaviour of a real transition area structure to the optimised solution, e.g. a transition area with reinforced rails, a transition area with sleepers and under-sleeper pads, or a transition area with a bonded ballast bed. The result of numerical modeling of these structures will be a specification of the most suitable technical solution (design modification) of transition areas in the experimental sections no. 1 and no. 3.

Acknowledgements

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IMPROVEMENT OF NORTH AMERICAN RAIL ACCESSIBILITY

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Abstract: For persons with reduced mobility in North America, there are many obstacles to the use of the existing railway infrastructure. These obstacles range from railroad platforms to non-accessible wagons. In order to enable access to the operator's existing offers, various solutions have to be identified. In addition to the classic technical answers, the aim is to show how an organized assistance system improves accessibility to trains. The services are intended to meet the requirements and wishes of customers and enable people who were previously excluded from using the railway to use it. In addition to the customer's wishes, the requirements and resources of the transport company must be taken into account. An online survey was conducted in Canada and the USA to determine the prevailing wishes and current problems of customers in North America. In it, the existing challenges of using the trains were asked about the limitations, ranging from mobility aids to prams, which customers have and which solutions they would prefer. The vast majority of those questioned consider the suggestion of support from a railway employee to be very helpful. Most of the technical support facilities are also rated positively. To clarify how existing systems are structured and which services are offered, a detailed benchmark of these systems is carried out. The services range from simple operation of the platform lift to comprehensive support through the station and customer care during every phase of the journey. To this end, railway companies from Europe and Australia are compared with each other. Based on the wishes of customers and the benchmark carried out, compact recommendations for action are developed for the Canadian railway operator VIA Rail. The starting point of these recommendations is a route chain analysis with the corresponding different scenarios. Based on the benchmark, a maximum variant is developed that covers all customer wishes. This corresponds to a customer-oriented solution, which is accompanied by large financial expenditures. In addition to the maximum variant, a catalogue of requirements with minimum requirements for an assistance system is listed.

Keywords: rail accessibility, PRM, costumer’s need.

1. Introduction – Nowadays Situation in Canada

Canada is the second largest country in the world with around 36.5 million inhabitants. During the 19th century the railway helped to develop the great country and connected the big centers. Since the 1930ies the importance of rail has fallen in favor of road transport. Today the remaining passenger train company is VIA Rail. This company is owned by the state and is operation different routes all over Canada. The main corridors are on the east side of the country between the areas of Toronto to Quebec.

VIA Rail operates 450 stations all over Canada. These stations can be classified into “permanently staffed”, “temporary staffed”, “steadily unstaffed” and “requested stops”. Permanently staffed stations offer a wide range of services to their customers, starting with staffed ticket counter, shopping facilities and also a support for PRMs.

The boarding situation in the stations varies widely. There are stations with platforms at rail level or with height adjustment. In combination with older rolling stock this situation causes passengers major problems when boarding the train. To reduce these problems for everyone, especially for PRMs, the Canadian government charged VIA Rail to improve this situation.

The simplest and most sustainable solution for the future would be to modify all platforms, so that level boarding is possible everywhere. However, this is not possible due to the different clearance profiles of freight and passenger trains. The next possibility is to implement elevators on every train to enable the boarding with a wheelchair. This solution would cause a huge amount of investments and would last for a long time.

To improve the boarding situation for the passengers immediately support by rail staff or others would be quick to implement. On the one hand, costumer’s wishes and needs have to be taken into account, on the other hand, the organization of the system should be suit a train company. For this purpose, customers were surveyed and a benchmark of existing systems was carried out. Recommendations for the development of a possible assistance system are derived from these findings.

2. Costumer’s Needs

2.1. Previous Surveys

The understanding of costumer’s needs is the base of good developments. Therefore a survey was started with the help of various disability organizations with the focus on PRMs. As a reason for not using the train connections, 55% of the respondents stated that there are too few barrier-free possibilities for travelling. Another 11% stated that they were unable to make a possible trip due to the lack of accompanying persons. This means that 66% of respondents are excluded due to the lack of support for travel by train (See figure 1).

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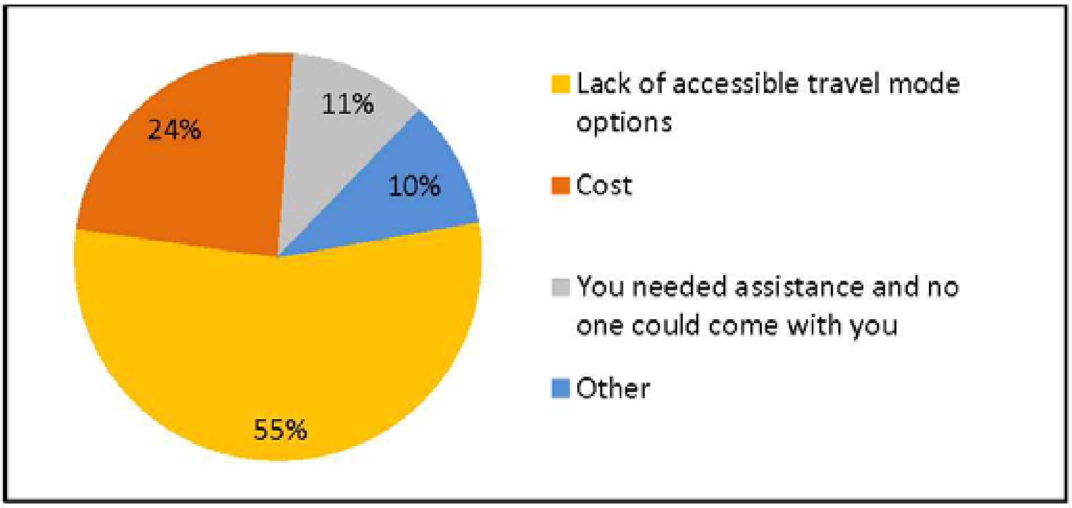

Fig. 1.
Primary reasons not to travel long distances
Source: (Chawla, et al., 2016), page 8

For those who travelled by train, overcoming horizontal or vertical distances proved to be the greatest challenge for 59% of respondents (see figure 2).

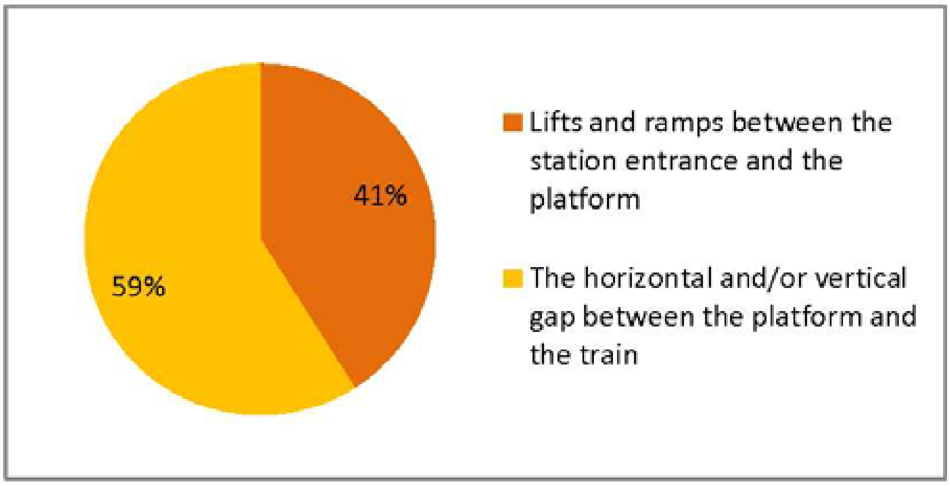

Fig. 2.
Which topic is most important to you regarding the accessibility of VIA-Rail trains?
Source: (Chawla, et al., 2016), page 11

2.2. Current Survey

The actual made survey only had 64 participants. Because of this manageable number the survey wasn't representative, but gave an idea if the American costumer struggle with the same problems like the Europeans Regardless of the type of problems boarding the train the participants had to rate the given answers to "How useful would the following types of assistance have been for boarding the train" with "very useful", "useful", "somewhat useful" and "not useful". The general usefulness of a wheelchair lift/ramp was checked. 35% of respondents are opposed to the technical solution. Most of the support for the proposed solutions came from the train crews. 57% of respondents see this type of help "very useful". 43,5% of the survey participants rated the help of train passengers as "not useful". In contrast 21,7% of respondents rated them as "very useful".

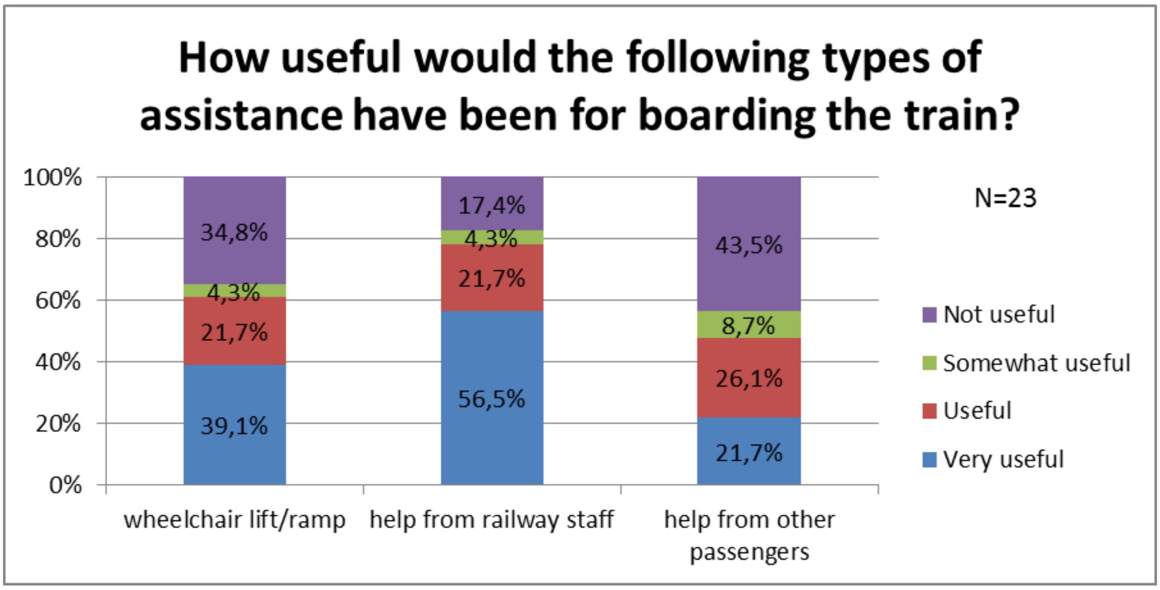

Fig. 3.
How useful would the following types of assistance have been for boarding the train?
Source: (Schmutz, 2017), page 39

Not only physical impaired person were asked. Travelers with large luggage, baby prams and combinations of both were also interviewed. The preferred help of all groups is that with the organized help of the train stuff. All groups of respondents are very hostile to the help of other travelers.
¾ of the travelers with big luggage would accept support from the train stuff and 67% would not like the help of other passengers.

3. Benchmark of Existing Systems

In order to be able to design a suitable support system, it is essential to analyze existing systems in addition to customer requirements. Therefore representatives of various railway companies were interviewed and missing information was supplemented with the help of various sources. 15 of 17 companies are rail operators. Two others, the Swedish Trafikverket and the Italian Rete Ferroviaria Italiana, are rail infrastructure managers.

Table 1
Participating firms

No.	Full company name in local language	State	Short form
1	Österreichische Bundesbahnen	Austria	ÖBB
2	Deutsche Bahn	Germany	DB
3	Schweizerische Bundesbahn	Switzerland	SBB
4	Železničná spoločnosť Slovensko	Slovakia	ZSSK
5	Magyar Államvasutak	Hungary	MAV
6	Renfe Operadora	Spain	Renfe
7	Société nationale des Chemins de fer français	France	SNCF
8	Rete Ferroviaria Italiana	Italy	RFI
9	ScotRail	Schottland	SR
10	Danske Statsbaner	Denmark	DS
11	Chemins de Fer Luxembourgeois	Luxembourg	CFL
12	Trafikverket	Sweden	TV
13	Queensland Rail	Australia	QR
14	Nederlandse Spoorwegen	Netherlands	NS
15	České dráhy	Czech Republic	CD
16	Irish Rail/ Iarnród Éireann	Ireland	IR
17	Nationale Maatschppij der Belgische Spoorwegen Sociéte nationale des Chemins de fer belges	Belgium	NMBS

Source: (Schmutz, 2017), page 50

The analysis is divided in two main parts. First costumer-orientated indices were requested. Later, indices were queried which are operator’s interest.

3.1. Customer-Orientated Indices

3.1.1. Offered Services

Table 1 gives an overview of the services offered in different countries.

Table 2
Services offered by railway companies

Operator	Boarding, departure, transfer aid	Guidance at the station	Assistance with a pram/luggage	Door-to-door service	Booking support, general information	Rental wheelchair	Standing orders	Additional information
Acces Plus (SNCF)	X	X			X			
Atendo (Renfe)	X	X	X		X	X		Wheelchair has to be booked
CD	X	X			X	X		Wheelchairs are stored at selected station
CFL	X	X						
DB	X		X		X			Luggage service can be booked
DSB	X	X		X	X			
IR	X							
MAV	X	X	X					No exact service catalog
NMBS	X							
NS	X	X			X			
ÖBB	X	X	X		X		X	
QR	X							Orientation and practice day interphones in tagged area
Sala Blu (RFI)	X	X	X		X	X		Wheelchair has to be booked
SBB	X				X		X	
Scot Rail	X	X						
TV	(X)	X						Boarding service has to be organised by operators
ZSSK	X	X						

X … accurate
(X)… partly accurate

Source: (Schmutz, 2017), page 53

Each offer includes boarding, departure and transfer aid. 12 out of 17 companies offer guidance at the station as part of their catalogue of services.
In Denmark a Door-to-Door service is offered. DSB takes over the guidance through the station and boarding, departure or transfer aid. Transport and escort to and from the stations will be provided by other organisations.
Baggage assistance is explicit offered by 5 out of 17 companies. Nevertheless it is possible for PRMs to get assistance while boarding the train and their carried luggage. There are different limits for the number of pieces of luggage and the weight. SBB and NS are the exceptions of this approach. The SBB has the rule, that supported people has to use for example the own luggage transport service. Therefore they must check in their baggage and it will be delivered to the desired destination the day after next. NS does not offer any solutions for luggage transport.

3.1.2. Entitled to Use the Offered Services

In the present study, the companies were asked to which groups of people they provide their services. Each company has their own index. Physically impaired persons, permanent or temporary, are included in every index. The index can be extended individually by the following categories: visually-impaired, hard of hearing, elderly people, travellers with kids, pregnant women, mentally retarded people, passengers with big luggage or bikes.
As an exception NMBS offers their service to “anyone who thinks they need help”.
In order to obtain a standardised and classified classification of the stakeholder groups, further investigations were carried out in chapter 4.

3.1.3. Temporal Booking Conditions

That anyone can use the offered services the companies need different lead times. For national support the range of time is from 30 minutes before schedule departure time up to 48 hours. Lead times may also vary within a country. For example Atendo can offer their service within 30 minutes at permanently staffed stations. At not permanently staffed station the lead time is extended to 12 hours. These temporal differences between the centres and the periphery are reflected in most of the companies examined.
For international journeys the interested person has to request the service 48 hours in advance. Exceptions are trips from Denmark to Germany, where a lead time of 72 hours is required.

3.1.4. Meeting Between Clients and Support Staff

There are two fundamentally different approaches to organize the meeting between customers and staff. First, the meeting point is explicitly agreed upon with the service request. A prominent point often serves this purpose. But some companies also installed some extra items. Swedish TV has installed extra signs as meeting points in the stations or the Belgian NMBS has clearly visible assistance columns.
The other way of arrangement is that customers have to arrive at the platform on their own, without any help from staff.

3.2. Operator's Interests

In addition to customer requirements, key figures such as number of customers, costs, organization etc. are of interest to the potential new operator.

3.2.1. Number of Customers

The number of services for PRMs is related to the annual number of passengers and the total population of each country. In order to make an adequate comparison of the individual railway companies, these parameters were collected and compared in Table 3. As you can see the share of PRMs in the total number of passengers of a railway company is always below 0.1%.

Table 3
Annual passenger numbers, Number of PRMs and population

Operator	Annual passenger numbers	Number of PRMs	%	Population of the country [2016]
Atendo	472.400.000 [2016]	291.703 [2016]	0,06%	46.440.100
CD	171.500.000 [2016]	11.629 [2016]	<0,01%	10.553.800
CFL	22.500.000 [2015]	824 [2016]	<0,01%	576.200
DB	4.400.000.000 [2016]	924.000 [2016]	0,02%	82.175.700
DSB	182.000.000	77.200 [2016]	0,04%	5.707.300
IR	42.800.000 [2016]	25.000	0,05%	4.724.700
MAV	145.000.000 [2016]	13.783 [2016]	< 0,01%	9.830.500
NMBS	-	100.000		11.311.100
ÖBB	244.000.000 [2016]	17.000 [2016]	<0,01%	8.690.100
Sala Blu	872.000.000 [2015]	150.000 [2016]	0,02%	60.665.600
SBB	458.400.000 [2016]	142.000 [2016]	0,03%	8.327.100
SNCF	1.241.078.000 [2015]	887.000 [2016]	0,07%	66.760.000
TV	214.000.000 [2015]	17.000	<0,01%	9.851.000

Source: (Schmutz, 2017), page 74 and (Eurostat, 2018)

3.2.2. Organization of the Service Divisions

Each company has its own way of integrating the service unit into its existing organization. The following section shows examples of organizational variants of different providers.

3.2.2.1. Sala Blu

The Sala Blu system has an office structure with a total of 14 offices spread over Italy. Each office operates independently within its assigned territory. Requests for assistance across these borders of the individual areas are processed and help is made available. The employees are assigned directly to the offices, but are still employed by RFI. The services of the employees responsible for providing the services at the station are ordered externally. These are in contractual relationship with RFI and are also paid by RFI.
There is also a separate department within the RFI Group which is responsible for PRM matters and barrier-free topics.

3.2.2.2. TV

In Sweden, staff is provided by a private company which takes care of all enquiries concerning the PRM support program. Trafikverket informs the private company about enquiries, which in turn informs its employees via an SMS system. These employees are employed on a contract basis and for the respective individual order. Housewives, unemployed or retired persons are used for this.

3.2.2.3. ÖBB

The subsidiary "Mungos" takes over the additional tasks of the offered service on behalf of ÖBB Infrastruktur. The employees work in regular operations as cleaners or as security personnel at the stations. In some cases, local staff, such as a tunnel maintenance officer, may take over the support tasks. This means that no additional personnel is required.

3.2.3. Costs for Companies

The costs were asked in the course of the expert interview. It was reported by 4 out of 17 companies.
The representative of **Trafikverket** estimated the cost of the support system at roughly one million euros per year.
At **ÖBB** the costs are not explicitly visible. These are part of different sub-areas. The subsidiary company receives an expense allowance of approximately EUR 100.000 per year for operating the lifts.
At **SBB** the costs are approximately eight million Swiss francs (7.220.00 euros (currency conversion: 25th July 2017, 6pm MEZ)) per year. These are divided as follows:

- Six million Swiss francs for personnel costs;
- One million Swiss francs for the service hotline;
- 0.7 million Swiss francs for IT and system costs;
- 0.3 million Swiss francs for equipment such as furniture and folding ramps.

For the **RFI**, the cost of the Sala-Blu office system amounts to 25.5 million euros per year.
These are divided as follows:

- Twelve million euros for externally purchased services;
- Twelve million euros for staff in the Sala Blu offices;
- 1.5 million euros for "other" costs (IT equipment, purchase of lifts, etc.).

3.2.4. Specifics/ Special Offers

On the website of **ScotRail** two explanation videos are offered to PRM. In these a gentleman in a wheelchair explains in easy language how the use of the railway network in a wheelchair works. The major cities in Scotland, Edinburgh and Glasgow are the focus of the explanations.
Atendo offers its customers a brochure in very simple language. In it the service of Atendo is explained in a simple way and with many pictures. This brochure is aimed not only at customers with reading and learning difficulties, but also at people with limited knowledge of the Spanish language.

4. Persons with Reduced Mobility

In general, there is no uniform definition of people with disabilities. Each country defines this for itself in the corresponding laws. In the EU there is a uniform definition for rail transport, which is laid down in the TSI-PRM. This defines PRM as follows:
'Person with disabilities and person with reduced mobility' means any person who has a permanent or temporary physical, mental, intellectual or sensory impairment which, in interaction with various barriers, may hinder their full and effective use of transport on an equal basis with other passengers or whose mobility when using transport is reduced due to age.
The aim of this and others definitions is to enable equal participation in social life.
Regardless of the general definition, the provision of adequate help requires categorization. A person with limited vision needs other assistance than a wheelchair user. To classify the different types of aid, the classification of Vienna Airport can be used as a basis (see Table 4).

Table 4
Categories of PRM of Vienna International Airport

WCHR – wheelchair ramp	Person who is able to climb and descend steps and can move independently in the cabin, but needs an aid for longer distances
WCHS – wheelchair steps	Person who cannot climb steps himself, but can move in the cabin on his own and needs an aid for longer distances
WCHC – wheelchair cabin seat	person is completely immobile and needs help in the cabin and in the airport building, the use of special seats in the aircraft is required
BLND – blind passenger	visually impaired person

DEAF – deaf passenger	hearing impaired, hearing and speech impaired person
BLND/DEAF – blind & deaf passenger	visually and hearing impaired person who depends on the help of an accompanying person
DPNA – disabled passenger needing assistance	Person with a mental disability who travels alone and needs assistance up to the seat in the aircraft

Source: Vienna International Airport 2018

The route through a railway station presents similar challenges as at an airport. An overview of the individual stations and scenarios on the way from the station entrance to the train is shown in Figure 4. First the passenger comes from the park & ride facility, with public transport etc. to the station. Afterwards the station hall has to be crossed, where again four different scenarios can be distinguished in Canada. The next section is the way to the platform. The design can vary accordingly. At the platform, a distinction must also be made between raised and non-raised platforms.

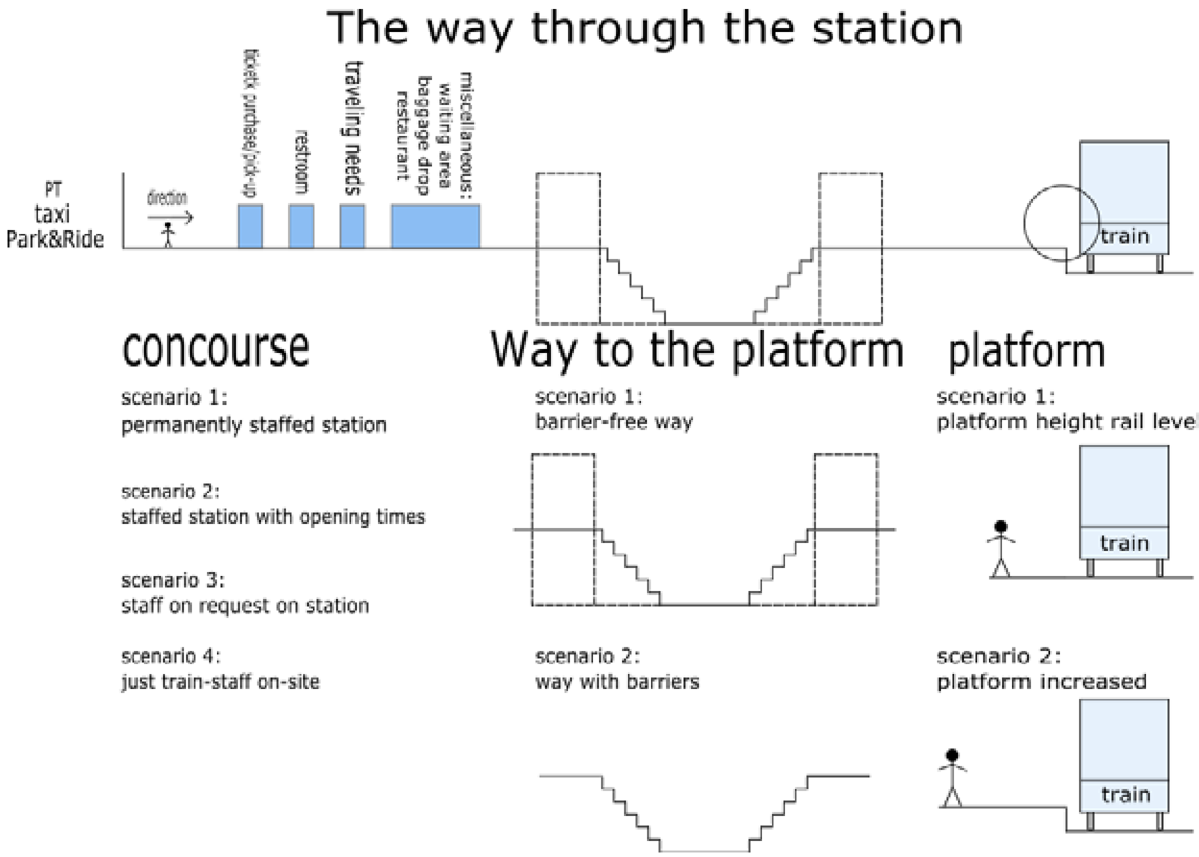

Fig. 4.
The way through the station
Source: (Schmutz, 2017), page 84

5. Recommendations

Recommendations for the development of a service system are a balancing act between the targeted support and the Canadian boundary conditions of the extensive country have to be created.
For the maximum variant, the construction of an office infrastructure in the centers, Toronto, Montreal, Edmond and Vancouver is recommended. In addition to direct on-site assistance in the stations, the offices are responsible for organizing assistance spread across the country, training external staff, travel arrangements for PRMs, etc. Thus, in addition to direct on-site support, these offices are to be an extended travel organizer especially for PRMs.
Outside this location, people are hired according to the Swedish model, who offers assistance when needed. They should also live or work in the vicinity of the station. This enables efficient use of local personnel resources and long travel distances can be avoided.
In stations where the platforms are on the same level as the rails, an appropriate lift must be provided. However, these lifts must be operated by trained personnel.
For stations where the platform is not barrier-free, for example, a stair-lift must be available for overcoming heights.
In addition to the pre-registered help, the possibility of spontaneous help for everyone should be made possible. Following the Australian model, a certain area on the platform is marked with floor markings. People waiting there should be actively approached by the train staff and, if required, supported when boarding the train.

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MARITIME TRANSPORT VERSUS RAILWAY TRANSPORT IN TRANSPORT OF CONSUMER GOODS BETWEEN THE FAR EAST AND CENTRAL EUROPE

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Abstract: In the last few years the countries of the Far East have belonged to the biggest producers of consumer goods due to the cheap labour force and other benefits that these countries offer. These consumer goods that are transported into containers between the place of production and the place of consumption are carried particularly by maritime transport due to a high volume of goods and their transport costs. In a transport of goods between the Far East and Central Europe, it is necessary to search for new solutions which would optimise these routes. The current maritime shipping route passes through the different maritime canals and straits such as the Strait of Malacca, the Strait of Hormuz, the Bab-el-Mandeb or the Suez Canal that are located between the North Atlantic (the Mediterranean Sea) and the Indian Ocean. On the other hand, there are two other alternative routes how to carry these goods. The first one is carried out by railway transport and runs from China, through the Trans-Siberian Railway of the Russian Federation or Kazakhstan, the Ukraine / Belarus to the countries of Central Europe. The second one that is also called the Northern Sea Route leads along the coast of the Russian Federation through the Arctic Ocean. This route that is open for vessels op to half of the year depends particularly on meteorological conditions. The basic goal of the paper is to analyse the current maritime shipping route between the Far East and Central Europe and alternative routes that are carried out by railway and maritime transport and to compare them from the different points of view with using a decision-making method.

Key words: maritime transport, containers, decision-making method.

1. Introduction

Developing countries located in the Far East have become the biggest producers of consumer goods in the world. Brand manufactures located in the developed countries have moved their subsidiaries in this part of the world due to cheap labour force and maximize profit. Most of these goods are transported into containers due to their protection against damage, loss and stealing and easier handling in sea ports. The countries of the European Union have belonged to the biggest consumers of these goods. Maritime transport has got the biggest share in transport of these goods. The main trade route between the Far East and Europe passes through some maritime canals and straits such as the Suez Canal, The Bab-el-Mandeb, the Strait of Hormuz or the Strait of Malacca. Some of them are very risky for maritime vessels due to piracy therefore it is necessary to find new solutions how to carry these goods.

There are other two alternative trade routes, both of them have some advantages and disadvantages. The first alternative is transport of goods by railway transport and leads from China through the Trans-Siberian Railway of the Russian Federation or Kazakhstan to the countries located in Europe. On one hand transport time of railway transport is shorter in the comparison with maritime transport, on the other hand it is more expensive. The second one is transport of goods by maritime transport and leads mainly through the Arctic Ocean along the coast of the Russian Federation. It is depended on the weather condition because voyages of vessels are available only half of the year.

In a near future the selection of an appropriate trade route will depend on not only transport time and price but also on political and economic development in the world, development of the international law or global warming (meteorological conditions) (Stopford, 2009), (Tengler, et al., 2017).

2. The current system of container transport in maritime transport

In 2016 about 686.8 million TEUs were carried by container vessels in the world, 76 % of total volumes were full containers, and 24 % were empty containers (UNCTAD, 2017). In the world there three main container trade routes:

- Transatlantic (North America - Europe),
- Transpacific (Far East – North America),
- Europe – Asia. (Stopford, M. 2009).

In the paper we will focus on the container trade route that links European and Asian countries. On this trade route there are big differences in the volume of transported containers. In 2016 about 26.1 million of TEUs were transported between Asia and Europe. On one hand 15.5 million of TEUs were transported to Europe, on the other hand 7.6 million of TEUs were transported to Asia. As you can see most consumer goods are made in the Far East.

In 2016 world container port throughput increased by 1.9 per cent, with volumes totalling 699.7 million TEUs. Asia accounted for 64 % of world container port throughput. Remaining container cargo flows were handled by European container ports (16 %), North American ports (8 %), Developing American ports (6 %), African container ports (4 %) and Oceanian container ports (2 %).

The top 20 container ports handled a total of 317.5 million TEUs, nearly 50 % of the world total. Between these ports there were 16 ports in Asia (Shanghai – rank 1, Singapore – rank 2, Shenzhen – rank 3), 3 ports were in Europe

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(Rotterdam – rank 12, Antwerp – rank 14, Hamburg – rank 17), only one was in the USA (Los Angeles – rank: 18). China had the biggest share of container ports, some of them (port of Shanghai, Qingdao and Ningbo) had to struggle with congestions that ware caused by the increased volume of containers, liner alliance network, poor weather and the deployment of larger container vessels (Review of Maritime Transport, 2017).

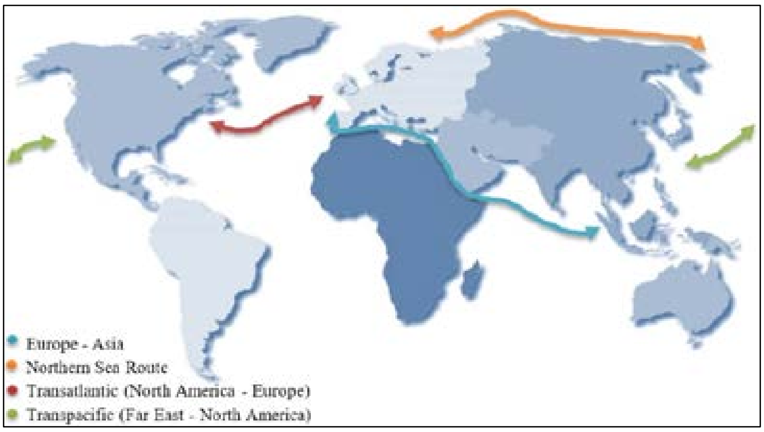

Fig. 1.
The main container trade routes and an alternative route between Asia and Europe
Source: authors

2.1 The Canal and Straits on the Trade Route between the Far East and Europe

Maritime canals are built due to saving of transport times between the different parts of the world. They do not only reduce them but they also help to decrease transport costs. In the last few years some of them have undergone the reconstruction therefore they wanted to adapt the requirements of present maritime transport. Straits are naturally formed, narrow, waterways that connects two larger bodies of water (an ocean and a sea or two seas).
Maritime Silk Road / Route is the route that links the Far East to Europe. There are some canals and straits (the Suez Canal, The Bab-el-Mandeb, the Strait of Hormuz, the Strait of Malacca) that are important key points in maritime transport due to transport of oil, raw materials and containers.
The Suez Canal provides a much shorter route between the North Atlantic and the Indian Ocean than the alternative route round the Cape of Good Hope. The Canal that is located in the northeast part of Egypt links the Mediterranean Sea at Port Said with the Red Sea at Suez. It was opened for international navigation in 1869 after 10 years of the construction. The present Canal is about 193 kilometres long; transit of vessels in both directions (bypasses) is possible in the length of 113.3 km. It is the longest canal without locks in the world and is navigable 24 hours a day. The Canal consists of the canal, its bypasses and three lakes such as Lake Timsah, Great Bitter Lake and Small Bitter Lake. Navigation of ships starts at Port Said which lies on the coast of the Mediterranean Sea, and then vessels pass through the canal, its bypasses and three lakes to the Egyptian sea port Suez which lies on the coast of the Red Sea. Transit of vessels takes about 11 hours. The two convoys of vessels pass through the Canal daily, the one convoy sails from the north and the one convoy sails from the south.
The term Suezmax is used for the largest ships that can sail through the Suez Canal. Their deadweight is up to 240 thousand tons and their maximal beam is up to 50 metres. These ships also have some limitations such as:

- the draught - ships which draught is more than 20.1 metres (66 feet) cannot sail through the Canal,
- the air draft – ships which are higher more than 70 metres cannot sail because of the Suez Canal Bridge.

The Bab-el-Mandeb is a strait located between Yemen on the Arabian Peninsula, and Djibouti and Eritrea in the Horn of Africa. It connects the Red Sea to the Gulf of Aden. It is a strategic link between the Indian Ocean and the Mediterranean Sea via the Red Sea and the Suez Canal due to transport of oil and containers.
The Strait of Hormuz that links the Persian Gulf and the Gulf of Oman is an important chokepoint because of transport of oil by tankers between the oil fields located in the Persian Gulf and Asian markets (China, India, Japan and South Korea). The Strait is from 50 to 80 km wide but navigation is limited to two 3 km wide channels. Each channel is exclusively used for inbound or outbound traffic.
The Strait of Malacca belongs to the busiest and most important waterways in the world. Over 50,000 vessels such as container vessels, tankers and bulk carriers pass through the Strait per year. Tankers and bulk carriers transport raw materials such as coal, iron ore to manufacturing centres in Southeast and Northeast Asia. About a quarter of all oil carried by sea passes through the Strait, mainly from the Persian Gulf suppliers to Asian markets such as China, Japan, and South Korea.
The strait is about 500 miles (800 km) long but it is very narrow and shallow. It runs between Sumatra Inland and the peninsula of Malaysia and links the Indian Ocean and the South China Sea. The Strait of Malacca belongs to the most vulnerable places due to attacks of pirates.

The term Malaccamax is used for ships which can sail through the Strait of Malacca. The limitation for vessels is their draught (25 metres) (Stopford, 2009), (Rodrigue, 2013).

3. Transport of Containers Between the Far East and Central Europe (Case Study)

In our case study we focused on transport of spare parts for Kia Motors Slovakia into containers (the weight of a container was about 11 tons) between the port of Busan, the biggest port in South Korea and Žilina, the Slovak Republic through three different European sea ports (Koper, Bremerhaven and Gdansk). Transport of containers was carried out by maritime and road / railway transport. We compared all three alternative routes from two points of views, such as transport price and delivery time. Transport time depended on the length of a shipping route and the speed of means of transport. Transport price included transport of a container by maritime transport, port and terminal charges, delivery of a container from the port of unloading to Žilina, returning of an empty container. It did not include import customs clearance, other import charges, extra costs such as storage, demurrage, custom control, strikes. The research was made in the middle of April 2018 in the cooperation with a private forwarding company that gave us the data (Čecho, 2018).

3.1. The First Alternative Route

The journey of containers started in the port of Busan, South Korea where they were loaded on the container vessel and were transported by maritime transported to the port of Koper, Slovenia through the Strait of Malacca and the Suez Canal. Then, they were loaded on the trucks or waggons and were transported to Žilina, Slovakia. The first alternative route took about 26 days and cost 1.435 EUR (Čecho, 2018).

Fig. 2.
The first alternative route between Busan and Žilina through Koper
Source: authors

3.2. The Second Alternative Route

The second alternative also started in the port of Busan, South Korea where containers were loaded on the container vessel and were transported by maritime transported to the port of Bremerhaven, Germany through the Strait of Malacca and the Suez Canal. Then, they were loaded on the trucks or waggons and were transported to Zilina, Slovakia. The second alternative route took about 32 days and cost 1.616 EUR (Čecho, 2018).

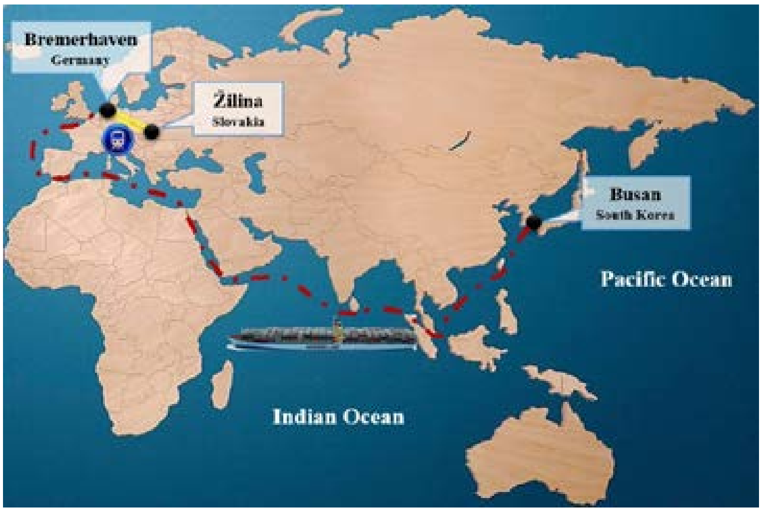

Fig. 3.
The second alternative route between Busan and Žilina through Koper
Source: authors

3.3. The Third Alternative Route

The third alternative route also started in the port of Busan, South Korea where containers were loaded on the container vessel and were transported by maritime transported to the port of Gdansk, Poland through the Strait of Malacca and the Suez Canal. Then, they were loaded on the trucks / waggons and were transported to Zilina, Slovakia. The third alternative route took about 34 days and cost 1.405 EUR (Čecho, 2018).

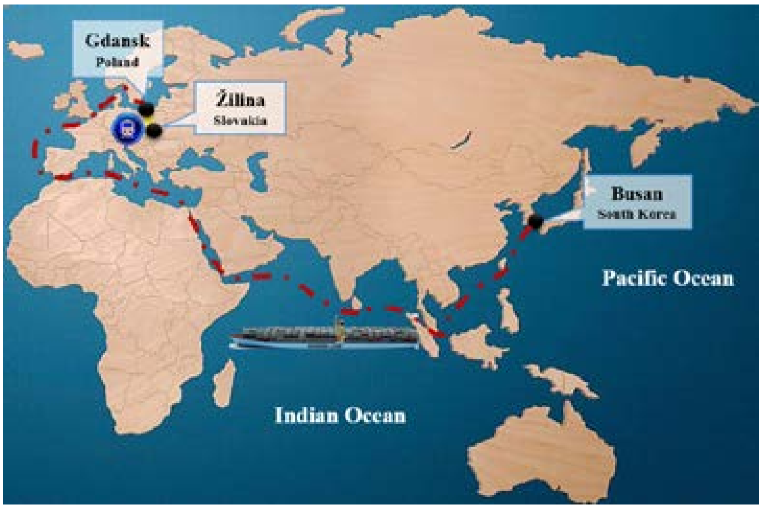

Fig. 4.
The third alternative route between Busan and Žilina through Koper
Source: authors

3.4. The Comparison of the Alternatives

At the end of our research we compared the alternative routes (see Table 1) from the different points of views. From a view of transport time the shortest route was the route that led through the port of Koper (the first alternative) due to its position. It is the closest port to the port of Busan.
From a view of transport price, the cheapest route was the route that led through the port of Gdansk (the third alternative). It depended on a carrier, a transport route, its length, port charges, etc. The final decision has to made by a customer which alternative he / she will choose (Čecho, 2018).

Table 1
The comparison of the alternative routes

Alternative	**1st**	**2nd**	**3rd**
Transport time	1.435 EUR	1.616	1.405
Transport price	26 days	32 days	34 days

Source: (Čecho, 2018)

4. Alternative Transport Ways of Containers Between the Far East and Central Europe

4.1. Transport of Containers by Railway Transport

In case of railway transport there are two main railway routes that link Asia to Europe. The first one (the Trans-Siberian Railway) leads especially through the Russian Federation to Europe, the second one leads partly through Kazakhstan and the Russian Federation. These two routes link European states such as the Netherlands, Germany, Poland, Belarus and the Russian Federation to China. Generally, transport takes about 15 days, it depends on transport relations (Mašek, et al., 2015), (Nedeliaková and Panák, 2016).

Nowadays, there are two main railway routes between the Far East (China) and Europe. The first one (the Trans-Siberian Railway) leads especially through the Russian Federation to Europe, the second one goes partly through Kazakhstan and the Russian Federation to Europe. These two routes link European states such as the Netherlands, Germany, Poland, Belarus and the Russian Federation to China. Generally, transport takes about 15 days, it depends on transport relations (Klapita and Liu, 2018), (Zitrický, Černá, Abramović, 2017), (Gašparík, Abramović, Halas, 2015).

On 13 November 2017 the first container train that carried 41 TEUs between China and the Slovak Republic came to the container terminal of the port of Bratislava. The journey of the train that had started in Dalian in China led through China, the Russian Federation, the Ukraine and the Slovak Republic. It was about 11 thousand kilometres long and took 17 days. During the journey containers had to be transhipped twice due to the different gauge between China and Russia and the Ukraine and the Slovak Republic. The train carried goods (electronics and machine parts) worth than 3 million dollars.

Nowadays, this type of train does not arrive in the port of Bratislava, the Slovak Republic. It passes through Slovakia and finishes its journey in Budapest, Hungary (Klapita and Liu, 2018).

4.2. The Northern Sea Route

The Northern Sea Route is the shortest sea route between Europe and Asia. It runs along the Russian Artic coast from the Kara Sea, along Siberia to the Bering Strait. It does not include the Barents Sea like the Northwest Passage on the Canada side. It is under the control of the Russian Federation and its legislation. Before 1991 it was used in the domestic scale for transport of raw materials. Nowadays, international carriers can also use it as a transit route.

In a near future this route might become a new sea route between Europe and Asia. As the result of global warming Artic ice caps started melting a few decades ago, the parts of this route are free of ice for a few months per year. This process is probably going to increase traffic on this route. In 2016 nineteen vessels that carried 214.500 tons of cargo transited through this route. At least six vessels received icebreaker assistance during their transits. Seven ships travelled westbound from Asia to Europe, and 12 vessels travelled eastbound. Coal accounted for around 155.000 tons of cargo representing more than 70 percent of the total. The remaining cargo consisted of paper pulp, iron ore, oil products, frozen meat and fish, as well as general cargo. (Holm, 2018)

In spite of the fact that this route is shorter than the alternative route through the Suez Canal it has got some disadvantages such as dependence on the weather conditions – navigation times takes about a few weeks, the assistance of icebreakers, sea ports do not have appropriate rescue equipment, negative influence on ecosystem, etc. (Medvecká, 2018).

5. Conclusion

The basic goals of the paper were to focus on the current state of container transport and alternative ways between Central Europe and the Far East. The countries of the Far East have become the leaders in the production of consumer goods in the world. Europe with America belong to the biggest consumers of these goods. In 2016 between the top 20 world container ports there were 16 ports in Asia, and nine of them were in China.

The paper consists of two parts. In the first part we presented the case study that was aimed at transport of spare parts for Kia Motors Slovakia between Busan, South Korea and Žilina, the Slovak Republic. The shipping route led through Maritime Silk Route, its maritime canal and straits.

In the second part we presented alternative transport ways between the Far East and European states. The first one links China to Europe by railway transport. In the comparison with maritime transport, railway transport is faster, transport time is reduced at least about half of it. On the other hand, it is more expensive than maritime transport. The second one is cargo transport along the coast of the Russian Federation by maritime transport through the Arctic Ocean. The route is under the control of the Russian Federation and its legislation. Before the 1990s it was accessible to domestic vessels for transport of raw materials. Nowadays, international seagoing vessels can pass through it. This route that is depended on the weather conditions is open only a few weeks per year. In a near future its use will depend on political and economic development in the world, the development of the international law or global warming

Acknowledgements

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THE NEWEST INFORMATION SYSTEMS FOR PUBLIC PASSENGER TRANSPORT IN SLOVAKIA – CASE STUDY

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Abstract: Public passenger transport needs to collaborate in customer-friendly, suitable and last but not least comprehensible way. This is one of the fundamental preconditions how to reach the customer, achieve sustainable transport system and support environmentally conscious approach. The main aim of the paper is to highlight the necessity of the existence of modern information systems for specific conditions of transport operation. The paper involves the newest approach of both state and private rail passenger transport operators in information systems which have been developed as a prerequisite for travel companion applications in Slovakia. Private undertakings operate trains and buses in the consistent network of train and bus connections not only in Slovakia but in almost all European countries. The article includes practical examples of an interface for buying and reservation tickets. It gathers also a special offer for commercial trains or examples of showing the current train delay between stations. The case study is strengthened by the interesting results of a questionnaire survey concerning the principal idea of providing high-quality services. This paper is based on particular results of the European Commission H2020 project - 730842 Governance of the Interoperability Framework for Rail and Intermodal Mobility (GoF4R).

Keywords: travel companion applications, public passenger transport, customer approach.

1. Introduction

Currently, information technology is increasingly penetrating into all areas of our lives. It plays an important role in production, services and in management processes, representing a considerable facilitation and accuracy improvement of activities. This also applies to rail transport.

With this development, however, comes in direct proportion an issue - design and configuration of all systems and information flows so that the user, in this case a customer of rail company, always has the necessary information in an appropriate form, both in terms of receiving all the necessary information, as well as preventing overload with information which is not necessary. It is the only way to achieve truly effective use of information and consequently the right decisions in dealing with different tasks (Blaho *et al.,* 2017).

In early 2002 there was a legislative change in organizing of transport on railways in Slovakia that supported the creation of new organizations. It went hand in hand with an entry of new rail operators on the liberalized transport market. The state rail passenger transport operator Železničná spoločnosť Slovensko was launched and several years after, two new private operators RegioJet and LEO Express entered the market. Also this aspect has resulted in the emergence and development of new information systems, which had to observe the specified standards designed to communicate with each other.

According to Senec, every customer´s decision is based on information. It is important that someone uses the right information at the right place at the right time (Senec, 2016). This is the role of the information system built on continuous improvement basis. Such a system must harmonize procurement of information and its use.

Foreign literature says (Schwalbe, 2015), when building quality information system, it is necessary to take into account these essential requirements:

- processed information must be updated and specific,
- reports should be brief, simple and economical,
- information system must allow the timely recognition of vulnerabilities and deviations,
- information system and its subsystems must build on common sources of information
- information must be objective and correct in every respect,
- information should preferably be given a visually and must above all be comprehensible.

Customer oriented approach is important in public passenger transport. Companies have to create a mechanism, which will ensure the update and satisfaction of customer's needs (Vojtek *et al.,* 2017). When talking about customer approach, measures for increasing process quality should be derived from so-called continual improvement principle.

Plans, vision, strategy and targets must be up to date if the customer modification occurs. An information system should be oriented on the current customers and create conditions for gaining potential customers. Travel companion applications should repeatedly look for new ways and simultaneously offer products to the widest potential market (Dávid *et al.,* 2016). Modern strategy for obtaining potential customers must be kept as project plans where appropriate methods of modern planning with typical software support can be appointed (Kudlac *et al.,* 2017).

The case study focuses on the information systems providing services in both state and private rail passenger transport operators that have been generated as a prerequisite for travel companion applications in Slovakia. It concerns examples of an interface with highlighting newest offers (Czajkowska, 2015). The main aim is to underline the urgency of modern information systems for specific conditions of rail passenger transport operation.

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2. Information System for Public Passenger Transport of State Rail Passenger Transport Operator

Železničná spoločnosť Slovensko, ZSSK is a state rail operator in Slovakia, the leading operator of the passenger rail transportation services and the member of many important institutions at the European or worldwide level. It has a joint online journey planner and reservation system. The system allows filtering connections based on various parameters of the means of transport (train category, train services, transfer time, number of transfers). For searches to find links, the application allows to view the route details as well as the occupancy and ticket price for the connection.

By selecting a specific connection, the user enters the purchasing process, choosing a discount type, seat reservation, passenger data. Additionally, the web application allows purchasing prepayment tickets and the possibility to return tickets online. In the mobile version, there is a simplified eMIL online sale that allows for a quick purchase of a domestic train, especially for smartphone access. The example of ZSSK interface for buying tickets is shown in the Fig. 1.

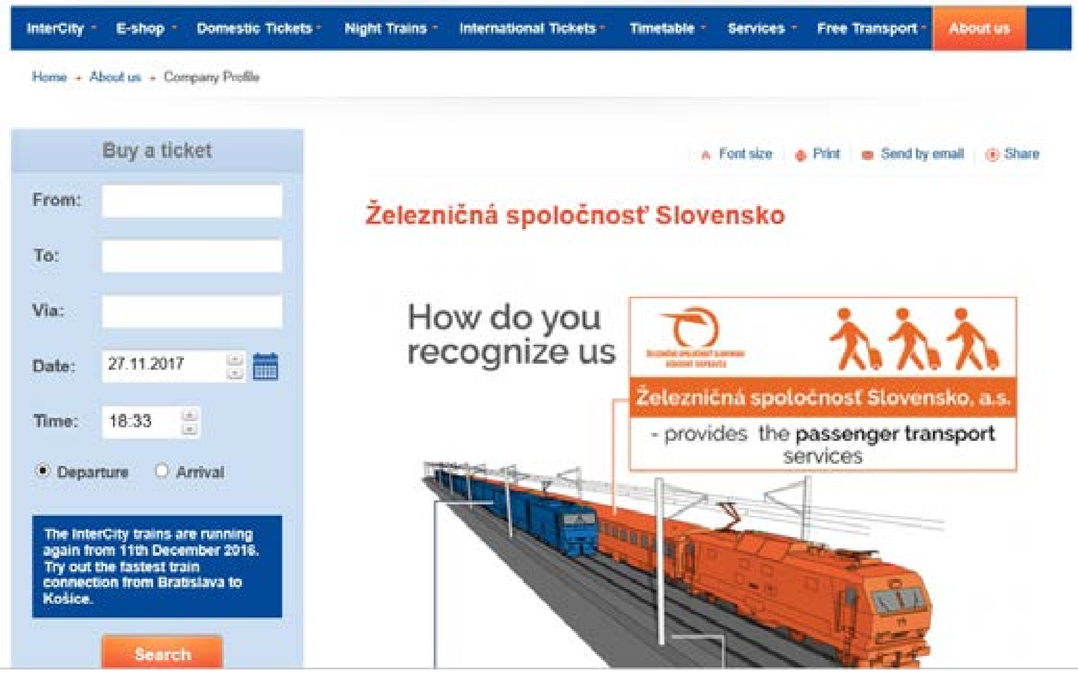

Fig. 1.
Example of ZSSK Interface for Buying Tickets
Source: Internal ZSSK sources

Special offer includes InterCity trains as commercial trains. An example of an offer for InterCity trains with activated filters describes Fig. 2. This offer concerns also showing the current train delay between stations.

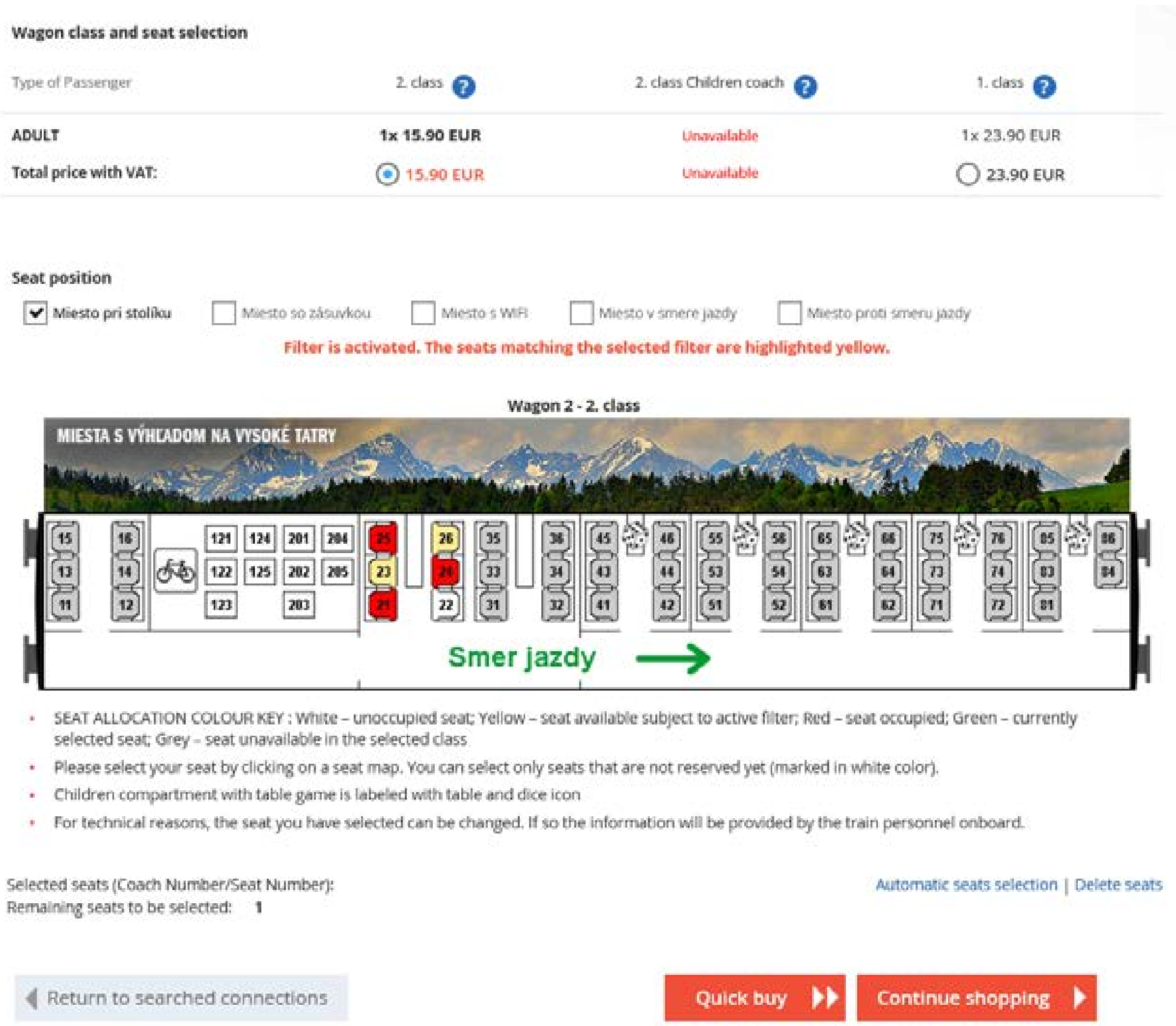

Fig. 2.
Example of an Offer for Intercity Trains
Source: Internal ZSSK sources

2. Information System for Public Passenger Transport of Private Rail Passenger Transport Operators

The paper describes the newest approach in operation of information systems in services of two private rail passenger transport operators RegioJet and LEO Express.

2.1. Regiojet Information System

RegioJet is a private rail operator in Slovakia. It has a joint online reservation system for the purchase of tickets for public passenger rail and bus transport. Currently, it operates a commercial trains InterCity on the route Prague - Ostrava - Košice and on the route Prague - Brno - Bratislava. The company operates performances in the public interest on the route no. 131 Bratislava - Dunajská Streda - Komárno. It provides purchasing tickets on the internet through a structured journey planner.
The reservation system allows selecting the route from point A to point B, calculating the travel costs for the intended carriage and also online ticket purchase by different payment methods. The system is capable of depicting the intended transportation with several types of transport - rail, bus transport including traveling by foot as illustrated in the figure. It includes all the rail and bus connections of RegioJet company. The Fig. 3 shows an example of RegioJet interface for buying tickets with extra options.

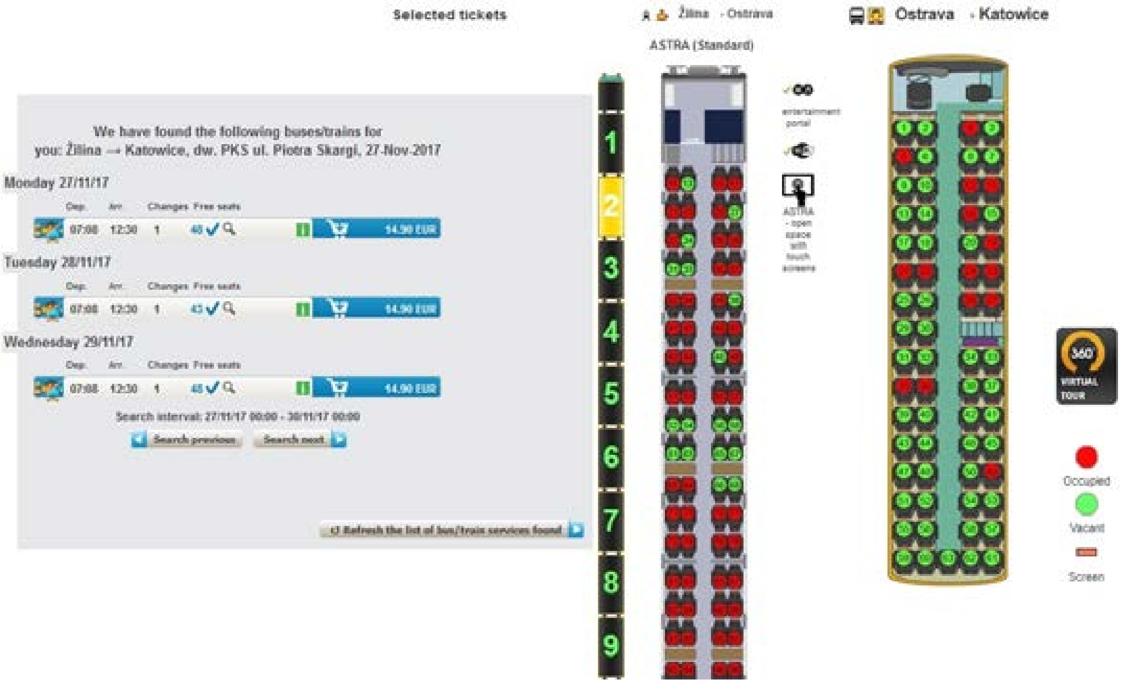

Fig. 3.
Example of Regiojet Interface for Buying Tickets
Source: Internal RegioJet sources

The prices shown are the sum of all persons entered. The times shown are always in the local time zone of that stop. The system also allows tracking the current delay between the stations.
Besides this journey planner, the company allows to purchase tickets by mobile application, that is freely available for digital distribution platform Google Play from company Google or for operating system iOS from Apple Inc. The mobile app is always available in phone's setting language.

2.2. LEO Express Information System

The second company LEO Express has a joint online reservation system for the purchase of tickets for public passenger rail and bus transport. The company provides purchasing tickets on the internet through a structured journey planner. The tickets can be paid by LEO crowns or by credit/debit card. LEO Express has its own Loyalty program. LEO Crowns, the currency of the account for which the customer can buy tickets in the reservation system and in future the customer will be able to buy refreshments, tours and other interesting services.
As LEO Express is implementing its portfolio in several European countries, its reservation system for the purchase of passenger tickets for public passenger rail and bus transport has an advantage. It is available in six national languages. An example of LEO Express interface for reservation tickets as characterized in Fig. 4.

Fig. 4.
Example of LEO Express Interface
Source: Internal LEO Express sources

The reservation system allows to select the route from point A to point B, calculate the travel costs for the intended carriage and also online ticket purchase by different payment methods. The system is capable of depicting the intended transportation with several types of transport - rail, bus transport including traveling by foot as illustrated in Fig. 5. It includes all the rail and bus connections of LEO Express company.

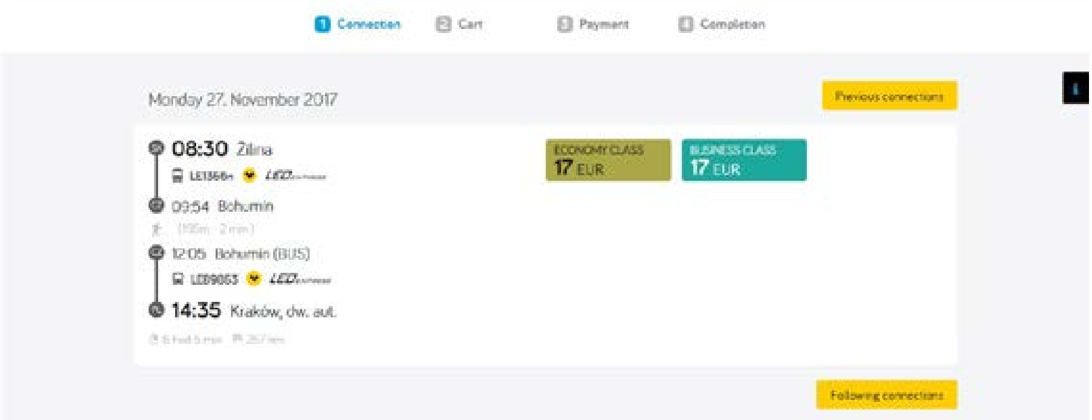

Fig. 5.
LEO Express Interface for Buying Tickets with Extra Options
Source: Internal LEO Express sources

For operational reasons, it may happen that the company is forced to cancel a service. In such a case, it will return full fare and additional 50% of the fare as a compensation.
Besides this journey planner, the company allows purchasing tickets by phone. The tickets can be purchased 48 hours or less before the scheduled departure of the train.

3. Results of a Questionnaire Survey

In the first half of 2018, a survey was carried out between the customers of the state rail passenger transport operator. The quality of online travel planner and reservation system services has been the subject of this research. Among other issues, the results show the criteria that are critical to customers in assessing whether the online journey planner and reservation system is a customer-friendly one. The customers were addressed personally; 860 customers of state operator customers were asked. The following criteria were considered by customers as the most important (sorted by customer by importance):
- Accuracy – a degree to which the information is reliable and error-free.
- Accessibility - usability, convenient access, availability, support, ease of operation, use or search.
- Representation - clarity, interpretability, concise expression, compatibility, arrangement, readability, justification.
- Coverage - a criterion that includes the breadth and depth of processing of a particular type of information.
- Credibility – reputation, the objectivity of consistency.

The Fig. 6 shows the results of the research which main aim was to know about satisfaction with services. The more percentage the criterion has gained, higher satisfaction with the service is for the customer.

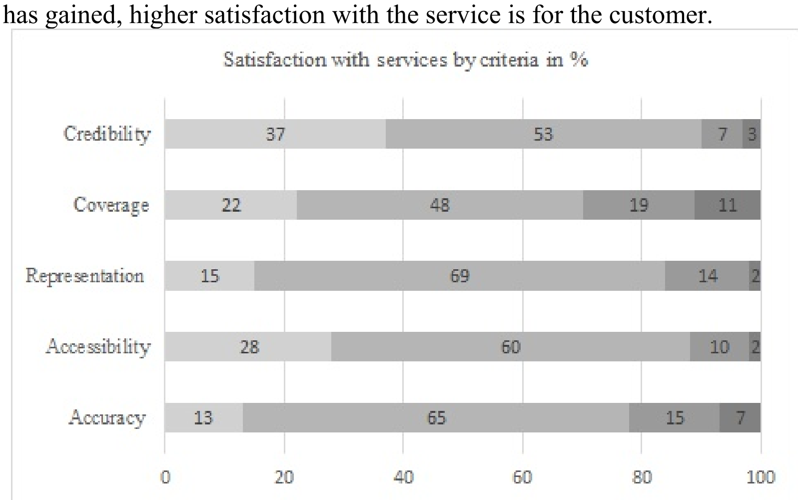

Fig. 6.
Satisfaction With Services by Criteria in % According to State Rail Passenger Transport Operator Customers
Source: KEGA, 2018

At the same time, it also decides whether the customer will use the service in the future (where 88% of respondents said they would definitely use the services again; 12% of respondents said they had problems with orientation in the information system so they will not use service again, they will prefer buying tickets personally in stations). Individual definitions of the criteria were explained to customers. This has made the survey intelligible.

3. Conclusion

According to the research, providing good quality services when booking and selling travel documents in public passenger transport is one of the decisive factors of customer decision-making. At the same time, it is an instrument to improve competitiveness. Customers are interested in different aspects of service quality. The more convenient the service, the easier it is to operate, the more intriguing is the travel companion application.

The results of this case study shows that improving the quality has significant potential in information technologies. Information systems quality improvement is difficult in terms of their necessary interconnection so that the customer gains the most benefit. It is long-term and never-ending process. Customer requirements are diverse and persistently changing. Apparently, if rail companies want to succeed on market, they are forced to invest all their effort to quality and try to constantly satisfy the needs for their customers which can be done only by perfect knowledge.

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TRAFFIC OPTIMIZATION IN TENT'S INDUSTRIAL RAILWAY BY USING OPEN TRACK AND KRONECKER ALGEBRA

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Abstract: This paper presents simulation and optimization model of a railway transport system in industrial railways of the major power plant in Serbia. Power plant “Nikola Tesla”, located in Obrenovac is the main power supplier in Serbia. It is a coal-fired power station, and the transport of coal is by railways. With an average daily transportation of 90.000 tons, it is one of the lines with highest transport in Europe, where more than 60 pairs of trains operate daily. The simulation model of the industrial rail network for coal transportation was built in OpenTrack simulation software. Analysis of the system uses the simulation model for experimenting with the organization of train routes and timetables. Simulation model is also used as a source of the input data for Kronecker Algebra in order to optimize railway operations in industrial railway system.

Keywords: railway operation, TENT, optimization, simulation, industrial railway, Kronecker algebra, open track.

1. Introduction

Power plant "Nikola Tesla" represents the backbone of electric power system in Serbia and with a share of about 50% of the total electricity production what makes it one of the most important strategic components in the whole country. It is also the largest producer in South East Europe.
As coal is needed for the production of electricity, it is also necessary to transport coal from the mines of the Kolubara mining basin. This transportation is done by an industrial railway, which is in the integral part of the thermal power plant "Nikola Tesla". The entire railway system of this company consists of infrastructure, rolling stock and traffic organization, ie people.
In order to determine the effects of improving the infrastructure, the Open Track software package was used to simulate train movement which accurately depicts the real situation on the ground. Of course, it all depends on the quality of the input data. This software was used to check the feasibility and stability of timetable. Thereafter, IVT format is used to create tracks.csv files for Kroneker Algebra.

2. Open Track Railway Simulation Software

OpenTrack was developed at the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems (ETH IVT). The project's goal was development of a user-friendly railroad simulation program that can run on different computer platforms and can answer many different questions about railway operations. (Huerlimann, 2001). Figure 1 illustrates the three main elements of OpenTrack: data input, simulation, and output.
OpenTrack is a microscopic synchronous railway simulation model. As such it simulates the behavior of all railway elements (infrastructure network, rolling stock, and timetable) as well as all the processes between them. It can be easily used for many different types of projects including testing the stability of a new timetable, evaluating the benefits of different long-term infrastructure improvement programs, and analyzing the impacts of different rolling stock.

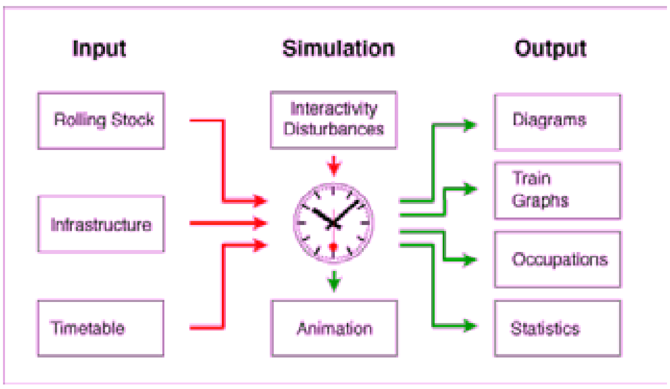

Fig. 1.
Main Elements of Open Track
Source: (www.opentrack.ch)

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2.1. Input Data

OpenTrack administers input data in three modules: rolling stock (trains), infrastructure, and timetable. Users enter input information into these modules and OpenTrack stores it in a database structure. Once data has been entered into the program, it can be used in many different simulation projects. For example, once a certain locomotive type has been entered into the database, that locomotive can be used in any simulation performed with OpenTrack. Similarly, different segments of the infrastructure network can be entered separately into the database and then used individually to model operations on the particular segment or together to model larger networks.
Train data (locomotive and wagons) is entered into the OpenTrack database with easy to use forms displayed using pull down menus. Infrastructure data (e.g. track layout, signal type/location) is entered with a user-friendly graphical interface; quantitative infrastructure data (e.g. elevation) is added using input forms linked to the graphical elements. Following completion of the RailML data structure for rolling stock and infrastructure, OpenTrack will be modified to enable train and infrastructure data to be directly imported from RailML data files.
One advantage of OpenTrack is that it enables users to adjust many variables that impact railroad operations. For example, users can simulate the impact of weather on traction by specifying the adhesion scenario (good, normal, bad). OpenTrack then estimates locomotive traction power using a percentage (also user-defined) of that calculated using the Curtius and Kniffler formula. (Huerlimann and Nesh, 2003) While OpenTrack provides standard default values for all variables, having the ability to adjust variables makes the program quite useful.

2.2. Open Track Simulation Process

In order to run a simulation using OpenTrack the user specifies the trains, infrastructure and timetable to be modeled along with a series of simulation parameters (e.g. animation formats) on a preferences window. During the simulation, OpenTrack attempts to meet the user-defined timetable on the specified infrastructure network based on the train characteristics. OpenTrack uses a mixed continuous/discrete simulation process that allows a time driven running of all the continuous and discrete processes (of both the vehicles and the safety systems) under the conditions of the integrated dispatching rules.
The continuous simulation is dynamic calculation of train movements based on Newton's motion formulas. For each time step, the maximum force between the locomotive's wheels and the tracks is calculated and then used to calculate acceleration. Next, the acceleration function is integrated to provide the train's speed function and is integrated a second time to provide the train's position function. (Huerlimann and Nesh, 2003)
The discrete simulation process models operation of the safety systems; in other words, train movements are governed by the track network's signals. Therefore, parameters including occupied track sections, signal switching times, and restrictive signal states all influence the train performance. OpenTrack supports traditional multi-aspect signaling systems as well as new moving block train control systems (e.g. European Train Control System - ETCS signaling).
OpenTrack is a dynamic rail simulation program. As such, the simulated operation of trains depends on the state of the system at each step in the process as well as the original user-defined objective data (e.g. desired schedule).
A simple way of describing dynamic rail simulation is that the program decides what routes trains use while the program is running. For example, when building the network, users identify various different routes that trains can use between two points; OpenTrack decides, during the simulation, which route the train will use by assigning the train the highest priority route available. If the first priority is not available, OpenTrack will assign the train the second highest priority route and so on.
OpenTrack's dynamic nature allows users to assign certain attributes to specified times in the simulation. Thus, users can assign a delay to a particular train at a given station and time, rather than being limited to assigning a delay at the start and using it through the entire simulation. Similarly, users can define other types of incidents (e.g. infrastructure failures, rolling stock breakdowns) for particular times and places.
Finally, dynamic simulation enables users to run OpenTrack in a step- by-step process and monitor results at each step. Users can also specify exactly what results are displayed on the screen. Running OpenTrack in a step-by-step mode with real time data presented on screen helps users to identify problems and develop alternative solutions.

2.3. Output Data

One of the major benefits of using an object oriented language is the great variety of data types, presentation formats, and specifications that are available to the user. During the OpenTrack simulation each train feeds a virtual tachograph (output database), which stores data such as acceleration, speed, and distance covered. Storing the data in this way allows users to perform various different evaluations after the simulation has been completed.
OpenTrack allows users to present output data in many different formats including various forms of graphs (e.g. time-space diagrams), tables, and images. Similarly, users can choose to model the entire network or selected parts, depending on their needs. Output can be used either to document a particular simulation scenario or as an interim product designed to help users identify input modifications for another model run.

3. Kronecker Algebra for Railway Operation

One of the constantly present problems in railway systems is the problem with deadlocks. Since there were no applicable solutions in the middle of 20th century, computer scientists tried to solve this problem by implementing Kronecker algebra in the analysis (Mittermayr *et al.,* 2012).
Before going into solving deadlock issue, a proper definition is needed. Stallings (2001) defines Deadlock as ‘an impasse that occurs when multiple processes are waiting for the availability of a resource that will not become available because it is being held by another process that is in a similar wait state’. There are four preconditions for a deadlock to occur according to Coffman (1971); in other words, if one of these conditions is not met, there will not be a deadlock. There is a mutual exclusion, where a resource can only be used by one process at a time. Second, hold and wait includes processes already holding resources and requiring additional resources held by other processes. Third, the so called no preemetion, no other than the process itself can release the resource. Finally, the circular wait that requires at least two processes to form a circular chain in which each process waits for a resource that is being held by the previous process in the chain. Clearly, these four conditions can be applied to railway systems.
After defining conditions for deadlock occurrence, possible ways to deal with deadlocks can be identified. These are deadlock prevention, or removing one of the above mentioned conditions in order to prevent deadlock from even occurring; deadlock avoidance, or decision about resource allocation in advance; and finally, after deadlock detection, termination and restart of the process. For the railway systems, only deadlock avoidance is applicable (Mittermayr *et al.,* 2012).
Kronecker algebra is a mathematical model that consists of Kronecker Sum and Kronecker Product. For the explanation of these two operations, set of matrices (1) is defined:

$$M = \{M = (m_{i,j})\, m_{i,j} \in L\} \quad (1)$$

where L denotes a set of labels with $\langle L, +, 0 \rangle$ being a commutative monoid and $\langle L, *, 0 \rangle$ a monoid (Mittermayr and al., 2012). For this case, only matrices $M \in M$ with o (M) referring to the order of matrix. Additionally, n-by-n (2) matrices will be used.

$$Z_n = (z_{i,j}) \text{ where } \forall\, i,j : z_{i,j} = 0 \qquad (2)$$

Kronecker product is denoted by $A \otimes B$ and results in mp-by-nq block matrix, as it can be seen in (3). Matrix A in this case being m-by-n and matrix B p-by-q matrix. As already mentioned above, Kronecker product is used for modelling synchronisation.

$$A \otimes B = \begin{pmatrix} a_{1,1}B & \cdots & a_{1,n}B \\ \vdots & \ddots & \vdots \\ a_{m,1}B & \cdots & a_{m,n}B \end{pmatrix} \quad (3)$$

Kronecker sum of matrices A of order m and matrix B of order n, denoted by $A \oplus B$ (4), is a matrix of order mn defined by

$$A \oplus B = A \otimes I_n + I_m \otimes B \qquad (4)$$

where Im and In (n-by-n matrix with ones on the main diagonal and zeros elsewhere) denote identity matrices of order m and r, respectively.

Application of Kronecker algebra in optimization of railway traffic flow lies in its functionality to detect and avoid any deadlocks within the whole analysed railway system, not just on one section. To put it differently, it can is represented as a matrix that includes all possible train movements in a system. In other words, deadlock-free solutions are overall best calculated solutions that take schedules, delays and different types of restriction on the tracks into account (Volcic, 2014). Whereas Kronecker Sum calculates all possible interleavings of all trains not using the same track section, Kronecker Product ensures that those using common track sections can sequentially enter only free sections, namely, sections previously released by another train. Kronecker Algebra delivers results as a matrix. However, these can be represented as a graph, especially time-speed diagram.

4. Modeling TENT Railway Network

According to earlier analyzes (Pejic, 2016), it is established that a bottleneck occurs on a section between Brgule and Vreoci. Conclusion was that it is necessary to install a passing loop between these two stations in order to increase the bandwidth of the railway. An additional improvement is that the station Tamnava will no longer be a front end station but transitory, and there will be the possibility of passing trains that go from the direction of Brgule to Vreoci, and vice versa, through it. With the installation of the passing loop, this should significantly contribute to the increase of the number of trains on the network.

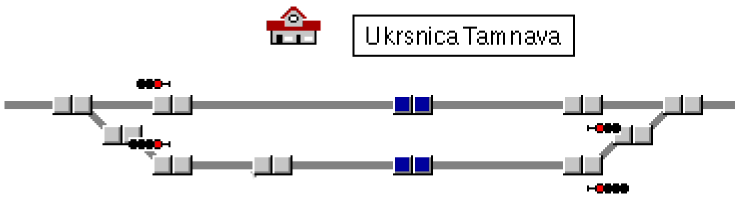

Fig. 2.
Infrastructure in Open Track: Passing loop Tamnava

The simulation model was developed in the Open Track software, taking into consideration the TENT railway network, ie rail used for coal transportation from "Kolubara" mines to power plants in Obrenovac and Vorbis. There are six stations in the model (two loading, two unloading, and two transient stations) with three lines: Vreoci – Obrenovac – Vreoci, Tamnava – Obrenovac – Tamnava and Stubline – Vorbis – Stubline). From Vreoci to Obrenovac, trains are marked with odd numbers (1, 3, 5, …), and in that direction, trains are loaded. Empty trains running in the opposite direction are marked with even numbers (2, 4, 6, …). Loaded trains from Tamnava to Stubline are marked with a T and odd number next to it (T1, T3, T5, …). If the trains continue to Obrenovac, they retain the same number, and if they continue with a separate line to Vorbis they take new number marked V and an odd number (V1, V3, V5, …). Empty trains from Vorbis have even numbers with the letter V (V2, V4, V6, …), and run under that name to Stubline, where they take the T letter with the even number if they continue to the loading point at Tamnava station or only the even number if they continue to the loading place at Vreoci.
In this model, the simulation time is 12 hours, as is the time of the shift of the railway staff, more precisely from 07-19h. The aim of this simulation is to see the concrete effects achieved by reconstructing the station and the junction Tamnava. The model was made in accordance with the future condition after the reconstruction.
According to the foreseen technology, the rail transport will be carried out with 7 tugs. Two trains start driving in the stations of Obrenovac, Tamnava and Vreoci, and one in Vorbis. To carry out transport, there would be 14 sets of 27 special-type wagons.
The aim of the simulation is to determine whether it is possible to apply all of these improvements at all and to analyze the driving time by relations and to find out the specific effects that have been achieved, or how much this change will affect the average driving times, including all holdings for any reason. So, first, a simulation will be done to collect data of driving times, waiting at signals etc.
From Vreoci to Obrenovac, trains are marked with odd numbers (1,3,5, ...), and in that direction, trains are loaded in that direction. Empty trains running in the opposite direction are marked with even numbers (2,4,6, ...). Loaded trains from Tamnava to Stublin are marked with a T and an odd number next to it (T1, T3, T5, ...). If the trains continue to Obrenovac, they retain the same number, and if they continue with a separate line to Vorbis take new numbers marked V and an odd number (V1, V3, V5, ...). Empty trains from Vorbis have even numbers with the letter V (V2, V4, V6, ...), and traffic under that name to Stublina, where they take the T code with the steam number if they continue to the loading point at the Tamnava station or only the pair number if they continue to the loading place in Vreoci.
Figure 5 shows the proposed segmentation of infrastructure for the application of Kronecker Algebra. As a generic rule, so called Kronecker blocks are between main signals (home, exit or block). Additionally, at cross overs on double track lines there is another separation. Application of these rules for the TENT railway network delivers 45 Kronecker blocks. In station areas the so called counting semaphore is used to handle the number of station tracks where trains can be stored running in one direction.

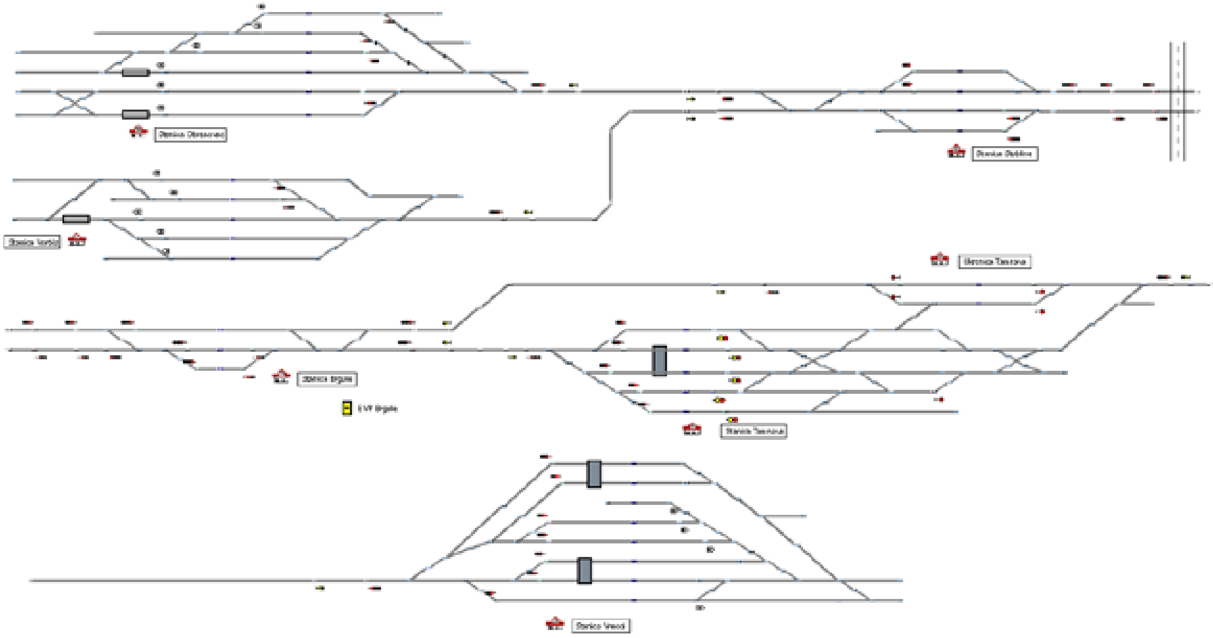

Fig. 3.
Infrastructure in Open Track: TENT Railway Network

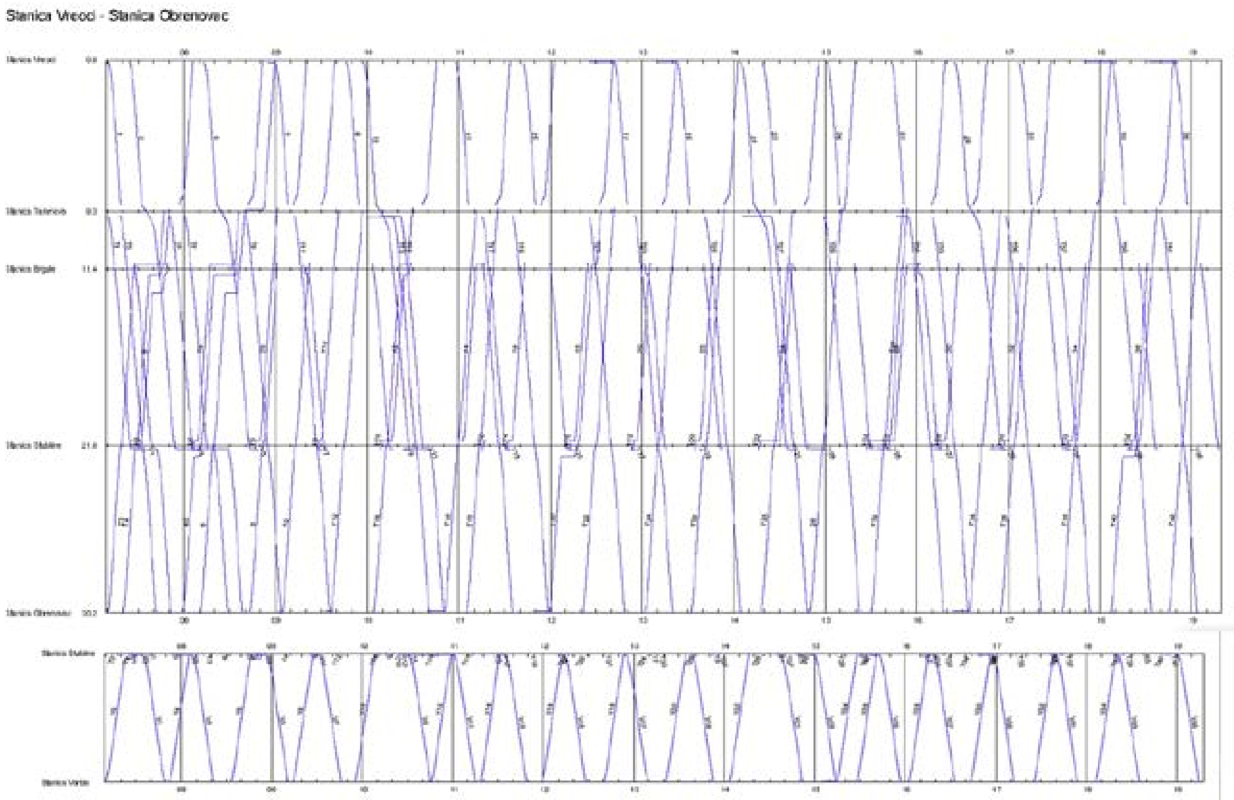

Fig. 4.
Train Graph: Obrenovac – Tamnava – Vreoci and Vorbis – Stubline

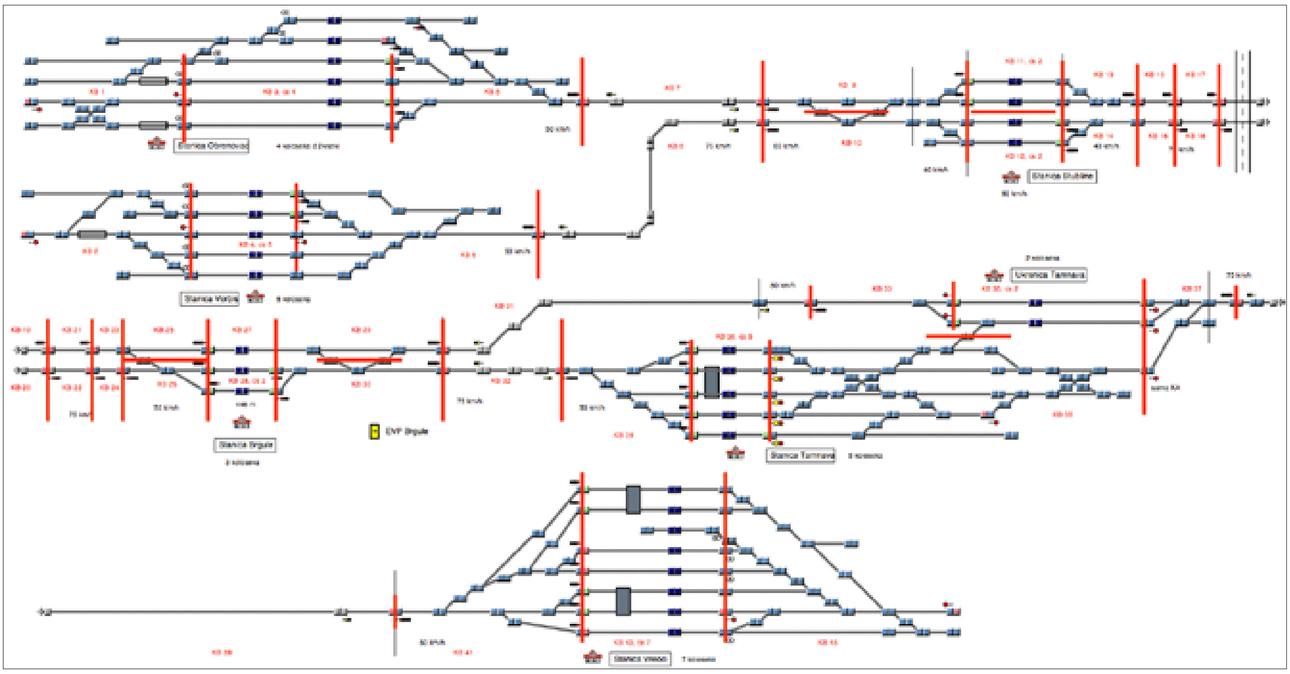

Fig. 5.
Segmentation of Infrastructure for Kronecker Algebra

4. Conclusion

While OpenTrack is a state of the art tool in simulation of railway operation, Kronecker Algebra for optimization of railway operation is a new field of research. Data available in an OpenTrack project can be also used as an input for an algorithm based on Kronecker Algebra to optimize railway operation in terms of delays and/or energy consumption. This paper presents the work carried out so far in OpenTrack and how a segmentation would look like as an input for Kronecker Algebra. Further work will be dedicated to enhance the existing data converter from OpenTrack into Kronecker Algebra. Finally, optimization of railway operation offers the opportunity to significantly reduce delays and energy consumption.

Acknowledgements

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BARRIERS TO TRANS-NATIONAL PASSENGER RAIL SERVICES IN THE WESTERN BALKANS – THE QUANTITATIVE BACKGROUND

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Abstract: Railway infrastructures and services in former Yugoslavia countries have been in a downward spiral ever since the country began to dismantle in the early 1990ies. Even if there have been scattered initiatives and investments to lift provided services to appealing levels after the war, a continuous downward trend can be identified in all important performance indicators. Not only have the numbers of services dwindled, especially on cross-border relations, service speeds have so, too. For example, the number of the passenger trains on the route Ljubljana – Zagreb – Beograd decreased from 16 in 1989 to 1 in 2018. Numerous lines have been put out of service or not back into service after war-attributed abandonment. A negative apex is marked by the cessation of cross-border passenger services to/from Bosnia and Herzegovina with the winter 2016 timetable change. In the research presented in this paper, taking Croatia and Bosnia and Herzegovina specifically as our survey objects, we embark on the task to specify and quantify this decade(s)-long deterioration in contrast to a dynamic railway development in other European countries witnessed during the same period. To begin with, we present a quantitative framework to make the deterioration comprehendible in various dimensions, from train numbers via efficiency and productivity indicators to commercial speed development of services. This study is a preliminary research to serve as a basis for a planned larger project, ultimately aiming at reducing the identified barriers in a long term.

Keywords: railways; Western Balkans; railway deterioration; Croatia; Bosnia and Herzegovina; barriers; railway operation.

1. Introduction

In Yugoslavia, historically railways played an important role both for passenger and freight, while recently in the successor states it has rapidly degraded. In Europe in general, railways started their decline with the rise of motorization after World War II. Only from around 1980 on, a modest renaissance has been observed, based mostly on commuter rail in metropolitan areas and high-speed rail (HSR) services (Givoni, M. 2006; Preston, J. 2009; Marti-Henneberg, J. 2012). The latter have been constantly developed in Western and Central Europe since the 1970ies (Haase, R. 1997), often at the expense of regional and branching rail services (Brezina, T. and Knoflacher, H. 2014).

The middle of the 80ies of the 20th century represents the golden age of railways in today's Croatia. In the passenger transport service, a network of business trains ("Poslovni vlakovi") had been established between important centres in Slovenia, Croatia, Bosnia and Herzegovina and Serbia. The business train comprised of 1st class and restaurant coaches. In addition to the train staff (head of the train and conductor), stewardesses were on the train as well, serving passengers drinks, food and daily newspapers on their seats. The standard business trains were at a high level, the service offered could be compared with the service offered in the Trans Europe Express (TEE). There was also a network of night trains, both within Croatia and in the most interesting destinations in Europe. As a rule, the train had several sleeping wagons and couchettes, 2nd class wagons and, if necessary, wagons for transporting cars. The most famous train from this era was P 100/101 "Sava Express" that was running Ljubljana – Zagreb – Belgrade (Abramovic, B. 2016).

The general decline of passenger rail service attractiveness of this time was superposed by the impact of the Yugoslav Wars (1991 to 1995) – federal states becoming independent nations with a heavy toll of lives and an increase in open mistrust between (political) actors, in some cases observable until today. In Western and Central European countries such a decline in rail service appeal was perceived as well, but HSR infrastructure was built and services were introduced to oppose this trend. In contrast, in Yugoslavia's successor states a lot of rail installations from pre-war times were either (heavily) broken (lines, rolling stock) or had lost passenger potential (borders, ethnicities). Numerous lines have been put out of service or have not been put back into service after war-attributed abandonment. So instead of improving their services similar to other European countries, the railway sectors of the successor states were and often still are challenged to re-establish and maintain services under the now changed, i.e. more difficult conditions.

After the Yugoslav wars, in Croatia efforts have been put into rebuilding destroyed lines and establishing passenger transport. In spring of 2003 eight new DB 612 Regio Swinger trains arrived at Croatian Railways to start running in summer on the line from Zagreb to Split with just under five hours.

In 2000 the Croatian government decided to build an extensive network of highways. This move has proven extremely bad for future railway development in Croatia. Because of very bad condition of electric multiple units (EMU), in the beginning of 2014 HŽPP ordered 47 new EMUs for urban, suburban and regional transport. The challenge of today is to organize railway transport in rural areas to cater for many commuters from rural to urban area, especially in the circuit around the City of Zagreb (Sipus, D. and Abramovic, B. 2017). For passenger transport, one important question raised is the amount of infrastructure charge fees on regional and local lines (Abramovic, B. and Sipus, D. 2016).

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Lack of financing is often counted as immediate reason for service suspension or reduction, but good coordination and governance with strategic positioning of railways among other transport modes are also in lack.
Here our project initCOSEERAIL – initial research and design for COSEERAIL (Challenges in improved Organizations in South-Eastern European RAILways) – steps in. Aiming at initializing a later, larger project within the Western Balkans target region, our pilot surveys focus on (a) the desktop-research based quantification of deterioration of railway operations and (b) the elicitation and identification of current competence distributions and obstacles in railway development. An overview of organizational and institutional barriers for development of railway in these two countries is provided by the analysis of 11 qualitative interviews with stakeholders in various railway-related institutions in the territorial entities. This qualitative identification of barriers will be expounded in a later paper.
In this paper, the materials used and the methods applied for the quantitative pilot survey are shown in section 2. Section 3 shows the results while section 4 discusses them and draws conclusions.

2. Materials and Methods

To pursue the main goals of this preparatory research, long-term (1985 – 2015) statistical data (key performance indicators) of infrastructure and operations in Croatia and Bosnia and Herzegovina were collected. In addition timetable data (timings of trains at key stations) for selected lines were collected for the same period of time. Due to war disruptions and the country's split-up, data availability and comparability was initially considered a substantial challenge, but turned out to be less of a problem.
In Croatia, the sources of archive documents and annual statistics books of Yugoslav Railways (JŽ) and Croatian Railways (HŽ) were: (1) the Central railway library of HŽ Infrastructure, (2) the Croatian Railway Museum, and (3) the Croatian Bureau of Statistics. In addition, two professional journals originating from Yugoslav rail operations were investigated: (1) Željeznice u teoriji i praksi (Zagreb, 1985 – 2015), and (2) Železnice u teoriji i praksi (Beograd, 1985 – 1990). The Croatian Railway Museum also provided a collection of paper print pocket timetables ("Knjižica voznog reda – kurir") for the period 1985 – 1991 (JŽ) and 1992 – 2015 (HŽ and HŽ Passenger transport).
Likewise sources have been utilized in Bosnia and Herzegovina's (BiH) entities of Federacija Bosne I Hercegovine (FBiH) and Republika Srpska (RS): Institute of statistics of RS, statistical bulletins of years 2009 – 2015 (available online at www.rzs.rs.ba) and Federal office of statistics of FBiH, statistical yearbooks of years 2009 – 2015 (available online at www.fzs.ba).

3. Results

3.1. Key Performance Indicators

Due to war-attributed disruptions, figures of infrastructure, rolling stock inventories, employment and services provided mostly lack consistency over the (early parts of) 90ies. Fig. 1 shows the continuous timeline of passengers and freight transported in Croatia. Two developments are clearly visible: (1) the massive drop in the 1990-1992 period and (2) the massive spike in 2009. The latter resulting from the fact that between 2005 and 2011 a joint ticket of HŽ passenger division and City transport of Zagreb (ZET) was in use. For an additional 10 Kuna (around 1.35 euro) one could include railways into the monthly ticket. But for statistical purposes each additional ticket was counted as 40 train rides per month. In this era there was no explicit counting of passengers, so the results were ghost passengers, as can be proven by the company's profit and loss account report (PLA).

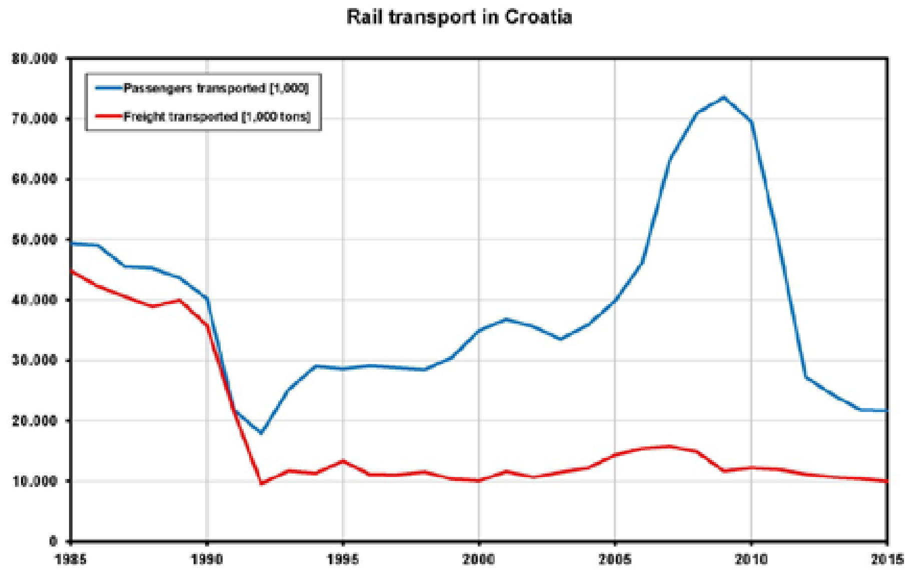

Fig. 1.
Timeline diagram of passengers and freight transported in Croatia

As passenger-km data are available as well for all three territories, we can calculate the average passenger trip length per year Fig. 2. The trends show three different behaviours: from an average of about 80 km, Croatia's figure dropped to around 30 km in the first decade of the 21st century only to rise again to around 40 km after year 2010. The average trip length for RS increases continually from 1996 (20 km) to level out at around 70 km in 2015. On the other hand, the figure for the FBiH shows some erratic zig-zagging between 45 an 90 km, which posed doubt on the quality of input data, only to set into a slow decline after 2005 to around 60 km.

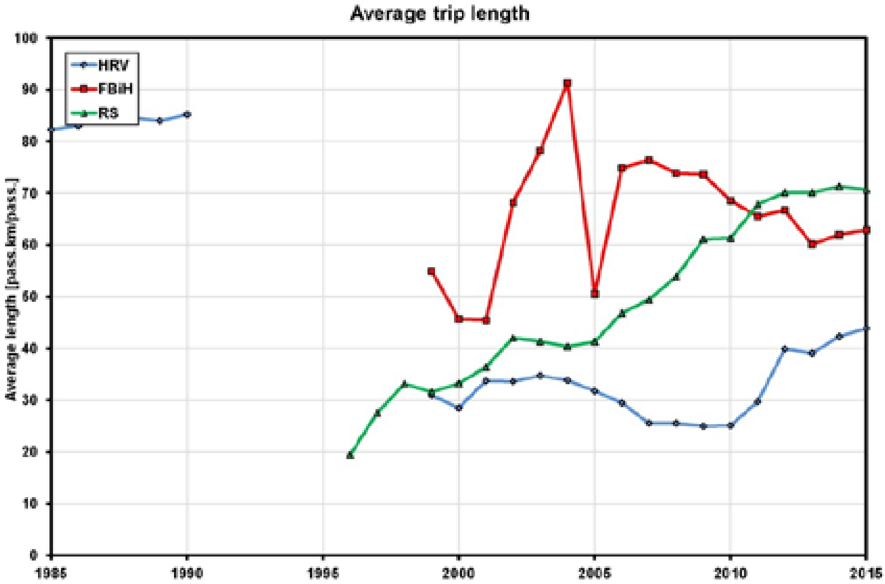

Fig. 2.
Timeline diagram of average passenger trip lengths for all three territories, calculated by dividing the passenger kilometre figures by passenger numbers

While absolute figures may have been prone to inconsistencies over the massive cataclysms, a relative perspective may prove to be more fruitful. In Fig. 3, personnel efficiency (number of passengers is normalized by the amount of employees), clearly the calculative spike of Croatian passengers from Fig. 1 strikes through. Nevertheless, for both territories a clear, underlying downward trend is visible. The amount of people transported per employee is constantly decreasing.

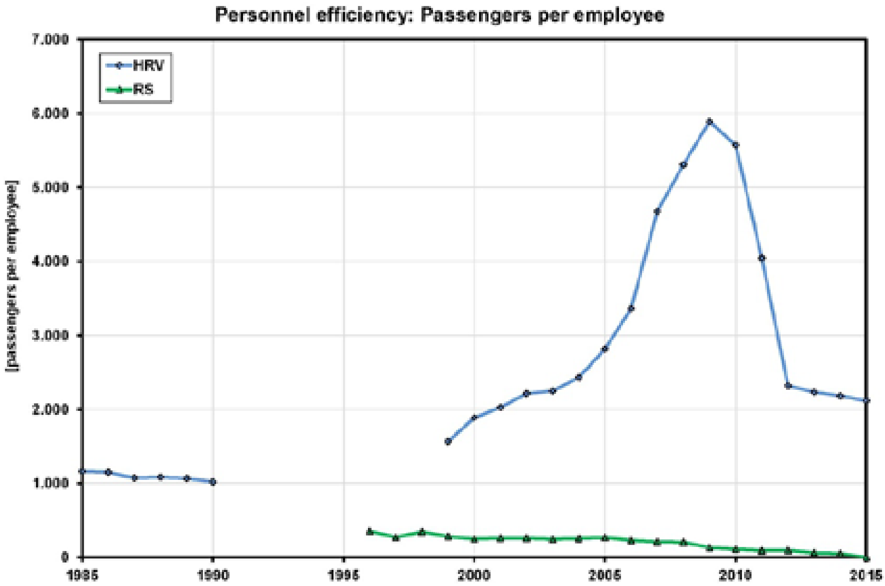

Fig. 3.
Timeline diagram of personnel efficiency (number of passengers divided by employees)
Note: For FBiH, no employee numbers were available.

From the availability of locomotive inventory data and employees we derive the measure of organizational productivity (Fig. 4.). With the exemption of the outlier in 2009 and including some up and downs, the amount of locomotives per employees has slowly been decreasing, thus increasing organizational productivity.

Fig. 4.
Timeline diagram of organizational productivity (number of locomotives in inventory per 1,000 employees)
Note: For FBiH, no employee numbers were available.

What has been the situation in terms of infrastructural supply? We have normalized the annual line lengths with the annual number of stations and stops. The average stop distance in Fig. 5 shows a consistent decline in distance for Croatia between 4 and 6 km, while Bosnian figures show some deviant notion: FBiH distance is around 10 km, while RS distance shows a spike to 12 km with an immediate drop 5 km. The explanation of such bouncing behaviour remains open, with flawed data being a viable option.

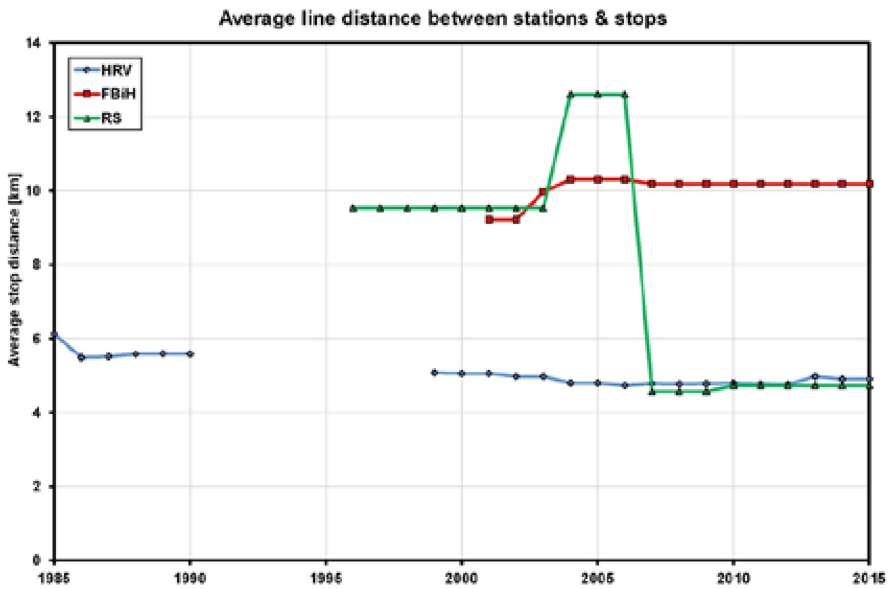

Fig. 5.
Timeline diagram of average distance between stations and stops (line length divided by number of stops and stations)

3.2. Timetables

The second line of desktop research utilizes timetable data. When comparing the timeline of the Yugoslav mainline (Fig. 6.), two developments are clearly visible: An underlying, general decline of passenger trains is superseded by a war-caused dent. The latter appears to recover from the mid 1990ies, only to incorporate into the downward spiralling trend in 2005.

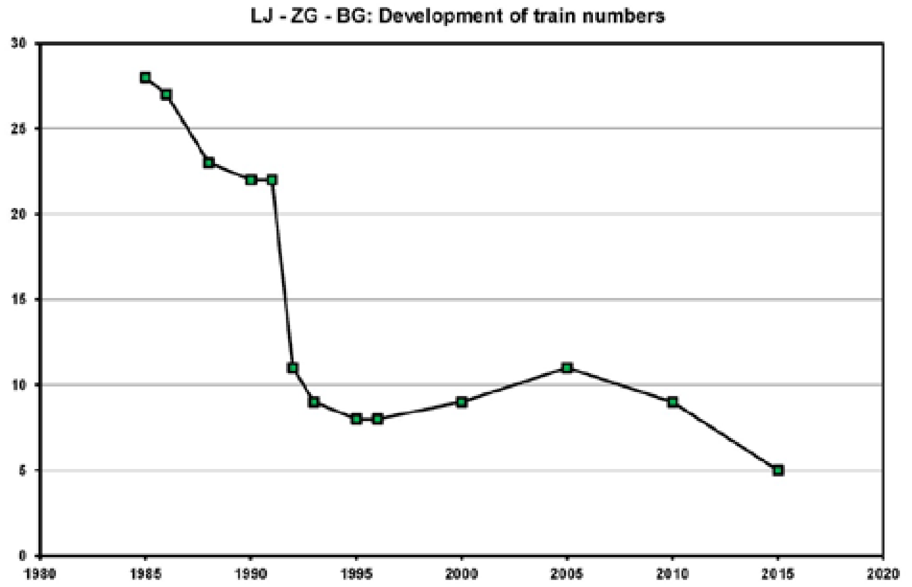

Fig. 6.
Number of (long distance) passenger trains (one direction) given in the specific year's timetables for the Yugoslav mainline Ljubljana – Zagreb – Beograd

The decline of the passenger railway system is most prominently visible when comparing train numbers in timetables. While in the middle of the 1980ies 28 passenger lines were running southbound on the mainline from Ljubljana over Zagreb to Belgrade (Fig. 7), only 5 trains where left in 2015 (Fig. 8). Out of these, only 2 remained between the second to and the largest city of former Yugoslavia. The train trajectories (between ZG and BG the nodes of Slavonski Brod and Vinkovci are included) show a variety of speeds with the fastest train from Ljubljana (P101, 75.8 km/h) almost "catching" the slowest train from Zagreb when arriving in Beograd. With a speed of 49.4 km/h through the narrow and winding Save river valley between Ljubljana and Zagreb, train B1615 "Salona" from Ljubljana to Split is the slowest train. In 2015, little variety around train B315's 64.2 km/h was left (Fig. 8).
When plotting the speed of every train per section of line (Fig. 9), the variety is even more clearly visible. Depending on intermediate stops, highly variable speeds per section are visible.

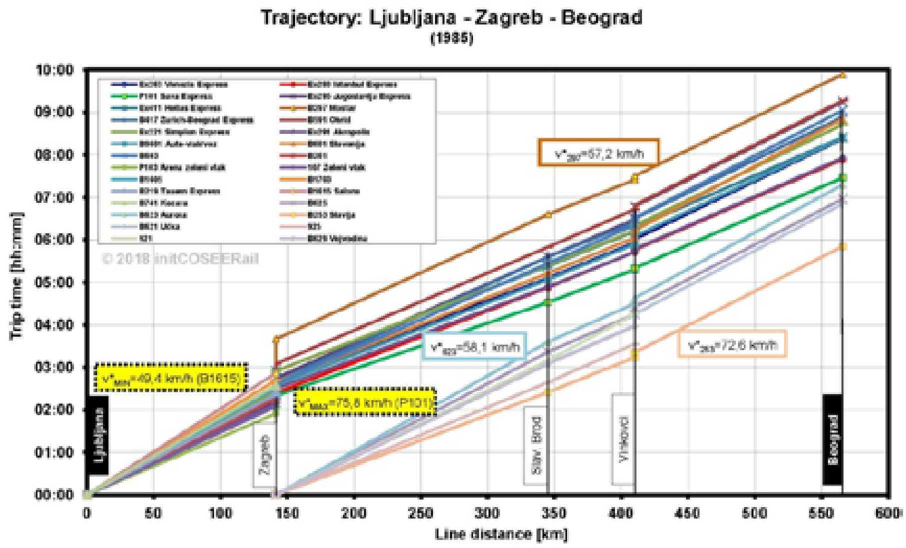

Fig. 7.
Trajectories of passenger services on the main line in direction Ljubljana – Zagreb – Beograd for the year 1985

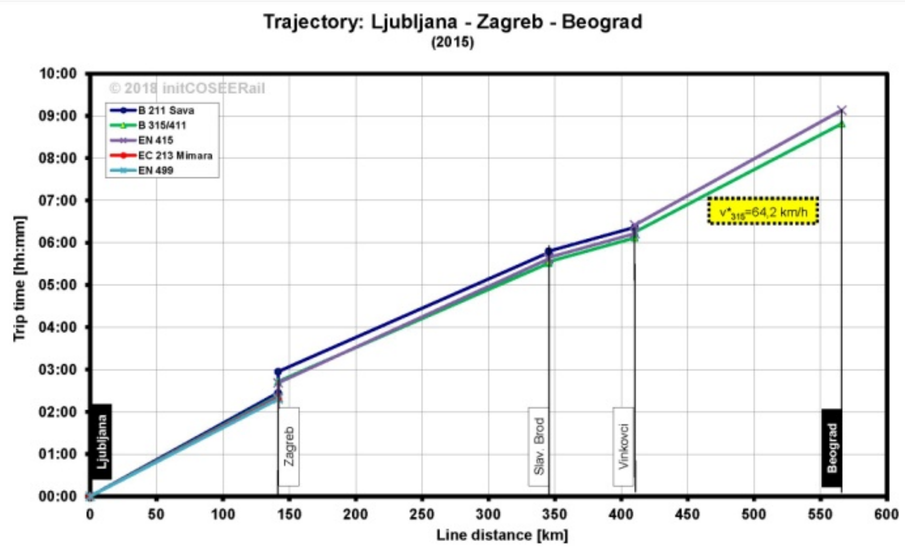

Fig. 8.
Trajectories of passenger services on the main line in direction Ljubljana – Zagreb – Beograd for the year 2015

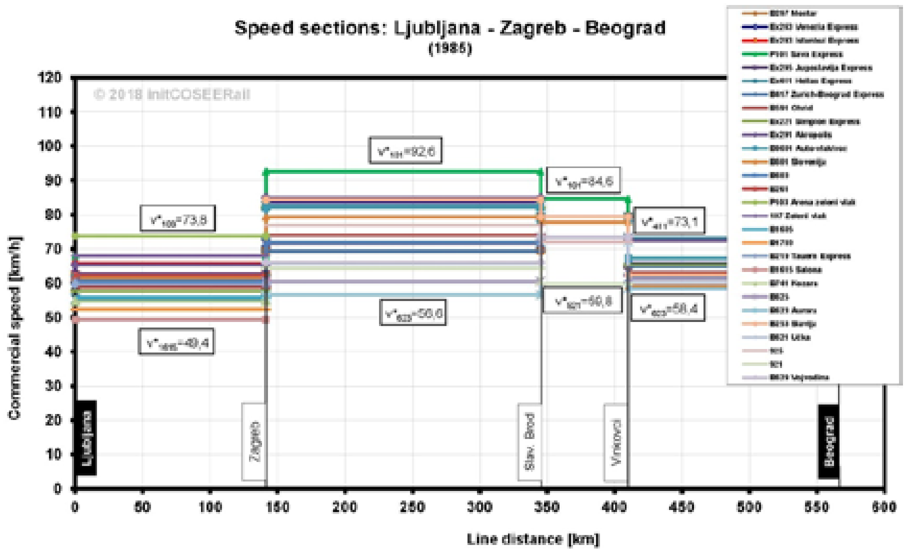

Fig. 9.
Ljubljana – Zagreb – Beograd: Commercial speeds of all services by line section for the year 1985

Not only have train numbers changed over the years, so have speeds. Table 1 shows the number of trains and the average calculated speed for available years between 1985 and 2015 for the two selected mainlines Ljubljana – Zagreb – Beograd (LJ – ZG – BG) and Zagreb – Banja Luka – Sarajevo (ZG – SA), and the two regional lines Ogulin – Knin (OG – KN) and Doboj – Tuzla (DO-TZ).

Table 1
Available number of trains (n) and average commercial speed (v [km/h]) for the 4 lines of inquiry between 1985 and 2015.

		1985	1986	1988	1989	1990	1991	1992	1993	1995	1996	2000	2005	2010	2011	2013	2015
LJ – ZG – BG	n	28	27	23		22	22	11	9	8	8	9	11	9			5
	v	64,0	64,5	68,1		76,5	74,5	63,2	63,5	61,4	62,6	61,5	64,0	61,9			62,6
OG – KN	n	7				9					5	3	2	3			3
	v	41,9				42,9					46,2	46,1	54,4	49,2			70,9
ZG – SA	n	6			5										2		1
	v	73,6			72,8										59,9		57
DO –	n	6			6											2	

TZ	v	50,7			48,0											37,8	

In Fig. 10. the variation of commercial speed for line LJ – ZG – BG is drawn with boxplots, depicting: minimum, average minus standard deviation, average, average plus standard deviation and maximum values. In general, boxes and bars show a decrease of variability, with the exception of 2005, which is in line with expectations due to a decrease of train numbers n. The OG – KN line, which is a section of the Zagreb – Split link, shows a different profile in contrast to LJ – ZG – BG (Fig. 11.). There as well the amount of trains has decreased, but not as dramatically as on the main axis. Nevertheless, improvements of the line and the addition of tilting trains (in contrast to conventional night train(s)) have increased speeds.

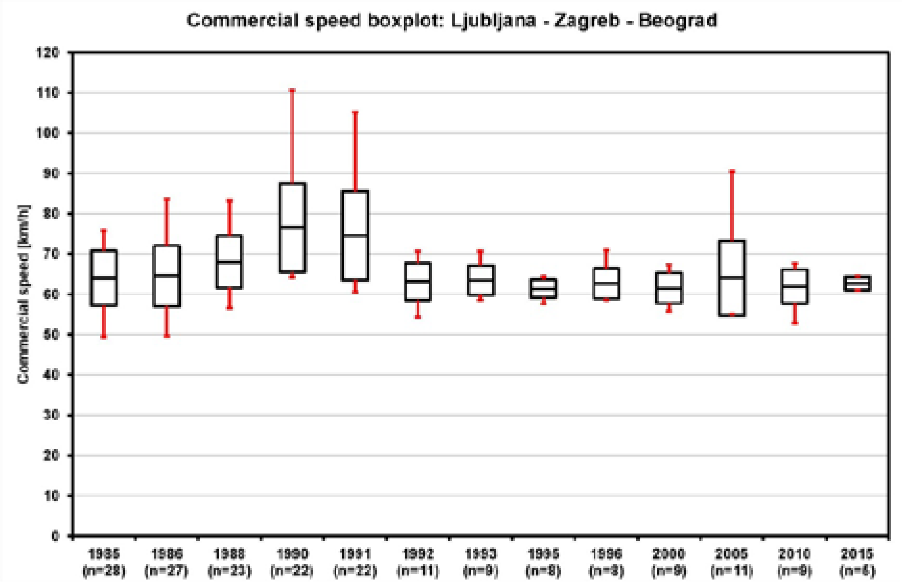

Fig. 10.
Timeline diagram of commercial speed development: boxplot of min, max, average and average +/- standard deviation for Ljubljana – Zagreb – Beograd

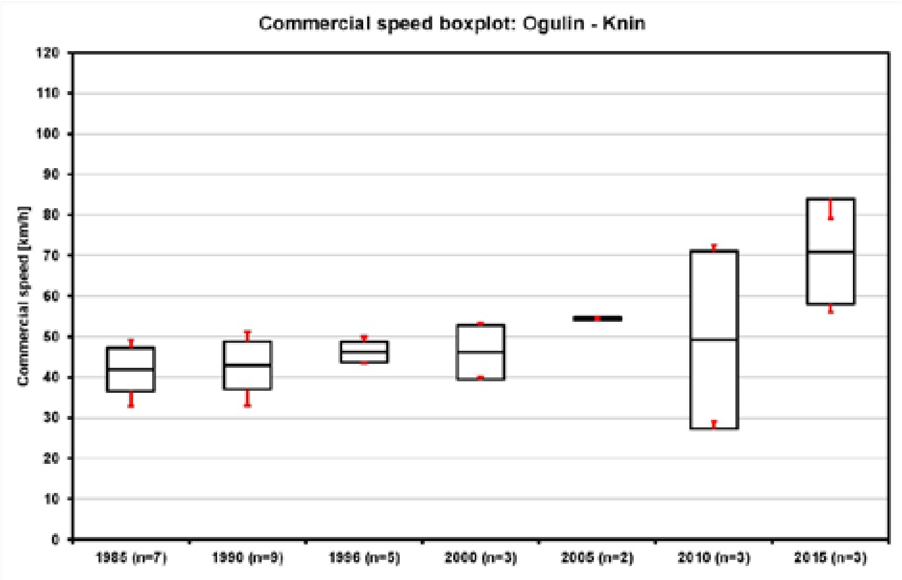

Fig. 11.
Timeline diagram of commercial speed development: boxplot of min, max, average and average +/- standard deviation for (Zagreb –)Ogulin – Knin(– Split)

4. Discussion and Conclusion

While data availability proved to be better than apprehended, general reliability of data is still an issue. Distinct sections of data sets exist, where data reliability is obviously highly questionable, such as the assumption-based spike in HŽ passengers in year 2009. Thus validation of statistical data appears to be important for the future project, because too often official national statistics do not reflect reality properly. Beyond that, a decline in passengers and train services could be observed in all surveyed territories, beginning even in the pre-war years. As described in the introduction, in

Europe and world-wide, a general loss of railways' share of trips has been observed during the second half of the 20th century. In Yugoslavia this trend has been very likely stipulated even more by the 1987 ruling to allow the import of private automobiles.
Our findings show that this decrease in passengers has gone hand in hand with a sometimes just slight increase of their average trip length on a network, where stop density remained more or less constant. Meanwhile organizational productivity increased slightly, while personnel efficiency has been on a constant decline ever since, albeit some divergence can be distinguished.
For RS and FBiH a general decrease in passenger volumes can be certified, which has been slightly counterbalanced very recently (after the survey period) by finally putting the Talgo trainsets into service.
In the follow-up paper on our qualitative findings from stakeholder interviews, barriers in cooperation will be identified. But already in terms of data, barriers show up as well. Even though ŽFBH and ŽRS run joint train services in a common nation, the official RS timetable contains timings of these trains only within RS but not in FBiH.
To conclude: there has been a decrease of railway significance in most of the post-Yugoslav republics in general and Croatia as well as Bosnia and Herzegovina in special.
Our findings resonate well with common sense perceptions on service frequency and quality when using railways as mode of transport in the follow-up states of former Yugoslavia.
Together with the later to be presented quantitative research results, this quantitative background not only poses directions for further research, but most promisingly also poses directions for the envisaged follow-up project COSEERAIL aiming to tackle the reversal of this trend towards insignificance.

Acknowledgements

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RATIONALISATION OF THE TRANSPORT CHAIN IN RAILWAY TRANSPORT UNDER CONDITIONS OF THE EUROPEAN RAILWAY MARKET

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Abstract: Railway transport is one of important modes of transport in the EU's economic area and is a basic element of European integration. The importance of its position stems also from goals of EU's transport policy and the White Paper on Transport. Railway transport is an essential element in building sustainable economic development in the European space. The EU's Common Economic Space has a major impact on the formation and organisation of transport chains in railway transport. Formation of a single market by Directive 2012/34/EU and introduction of interoperability measures for the European railway system result in a considerably easier organisation of international transport chains and new opportunities for carriers and their customers. If there is a need to cross the internal EU borders, it is not necessary to change the carrier or to carry out operational processes at border stations, and it is possible to avoid customs proceedings. These factors allow a more efficient management of transport processes in the market environment and provide opportunities for the use of railway transport in the European transport market. Of course, for the effective adjustment of the railway transport chain it is necessary to know all its variables from the origin station to the destination station. The paper is aimed at rationalising the selected railway transport chain under the conditions of the European railway market. The selection of the transport route is optimised not only in terms of the quantity and type of transported goods, or the transport characteristics of individual transport routes, but also from the cost point of view. The transport chain is proposed on the basis of applied pricing methodology, taking into account the competitiveness of railway transport in the EU transport system. The proposal for the transport chain is then comprehensively processed from the point of view of a required number of wagons, locomotives and staff included.

Keywords: transport chain, rationalisation, railway transport, transport market, goods, price.

1. Introduction

The goal of this paper is to propose a transport chain in railway transport for engine transportation between Kia Motors Slovakia, s. r. o. ("KMS") and Hyundai Motor Manufacturing Czech, s. r. o. ("HMMC"). In the past engine transportation between the enterprises was carried out by railway transport service provided by the carrier ZSSK Cargo, a. s ("ZSSKC"); nowadays engine transportation is provided by road transport. The reason why this type of transport was abandoned is that engine transportation was not profitable for the carrier because transport volumes were too low and the price for transportation was on a marginal economic level (Skrucany, 2017 and Vrabel, 2017). There were 6 - 7 covered wagons transported daily and these transportations were not interesting for the carrier from the proceeds point of view. Another issue with these transportations provided by railway transport is the fact that the KMS company is not equipped with a side loading platform on the KMS railway siding, and the loading technology for engine pallets is time consuming as well as challenging in terms of the number of employees needed to carry out manipulation operations. These time and technical challenges were reflected in carrier's costs. Due to this reason engines have been transported by road transport since 2014. The new transport chain proposal comes out from a detailed analysis of logistic processes in selected enterprises, analysis and report of new technological procedures for processing wagon consignments (adjustment of technology to new conditions), configuration of the fleet, proposal for wagons and locomotive circulation, and calculation of costs for these transportations.

2. The Methodology of Transport Chain Configuration in Railway Transport

To address the observed problem there will be a scientific methodology used in the paper. The methodology is divided into several parts and its primary goal is to propose an optimal transport chain in railway transport in context of the engine commodity. In order to achieve this scientific methods and individual steps will be used. The first part of the methodology outlines the observed problem of the proposal, which deals with restoration of transportations provided by railway transport, and the objective of the research. During the research phase the current state of engine transportation by road transport is analysed. Moreover transport volumes of engine production as well as bottlenecks of engine transportation by railway transport under original conditions are analysed, too. Collected information, complexity and depth of examined indicators were the basis for creating a research plan which exactly identified individual phases, methods and procedures. In order to meet the goal there are optimisation criteria - transport price, technological difficulty, fleet and time of the transport - set in the methodology (Kulka, 2016; Rievaj, 2017). The following part of the methodology is executional and includes own data collection, data processing for further interpretation (performances analysis, stock analysis, carrier's fleet analysis, cost tariffs analysis, fixation capability and transport instruments analysis, etc.), and conclusions drawing which validate, invalidate or complete basic indicators while creating a transport chain. The proposal for a transport chain between the KMS and HMMC enterprises forms a final part of the methodology and represents a sequence of steps to ensure an optimal way of engine transportation by railway transport.

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3. The Analysis of the Current State of Engine Transportation

Kia Motors Slovakia, s. r. o., as the only automotive plant in the central Europe, which produces engines for its cars, ships more than 50% of engine production to its affiliate company HMMC in Nošovice, Czech Republic. Besides the above mentioned 50% production export it also ships some small volumes of engines into countries outside of the European Union.

In the past the company shipped 150 engines per month into India by means of road freight transport. Today the enterprise distributes 1,500 - 2,000 engines into Turkey each month. In this case pallet units are transported in containers by combined transport: road - rail - waterways. According to customer requirements both petrol and diesel engines are dispatched.

Currently engines are transported to the HMMC in Nošovice by road freight transport 8 - 14 times a day. We are speaking about the transportation of 96 engines (diesel and petrol ones) by semi-trailer. These transportations are provided by the road carrier DAVID Trans, s. r. o. Since these are international transportations, the engine transportation by road transport is subject to Convention Marchandise Routière (CMR). Conditions of the CMR convention apply to the transportation, and for each transportation a consignment note CMR is written out. Every day the road carrier provides 8 - 14 transportations by five semi-trailers depending on the required amount as well as on the engine type - diesel or petrol. Transportations are mostly provided during workdays. On Saturdays and Sundays only exceptional transportations are carried out.

Nowadays engines are transported by road transport using the Just in Sequence system, i.e. the transportation is carried out in small batches with the latest possible delivery time. The main reason why this system is utilised is to use those engines in the HMMC production line in the shortest time possible. Transported engines are routed directly to the inwards warehouse of the HMMC, where consignments from various supply sources are collected and completed. Engines get ready for an instant use in the production process here. Since it is necessary to take into account some buffer stock to ensure regularity and mainly safety of shipments, during a 3-shift operation engines are usually transported 16 hours before they enter into the production process.

The transportation by road freight transport starts in the manufacturing plant Kia Motors Slovakia, s. r. o., and continues along the road No. 583 to Žilina. From Žilina it continues along the international road E75 to Třinec, Czech Republic. In the Czech Republic in the village Horní Tošanovice the route passes onto the road E462 and in Dobrá it leaves the road E462 and passes onto the road No. 648, which leads into the industrial zone of Nošovice. The entire route is 86.2 km long. Duration of transportation under ideal transport conditions, where the average transport speed is 70 km/h, is approx. 1:43 h. The time of transport, distance in kilometres as well as the amount of toll-road fees are given using a route planner available on the site www.routenet.nl. The following figure shows an approximate duration of the transportation from Teplička nad Váhom to Nošovice, Czech Republic, plus the run transport distance with the toll-road fee calculated to the date of March 22, 2018.

The transport session in road transport is impeded with transport congestions on the passage Žilina - Čadca due to D3 highway construction and unbearable cumulation of cars in road transport in the border town Čadca, which is a crossing among the Czech Republic, Poland and Slovak Republic.

The transport route by road freight transport is burdened with toll-road fees. The toll-road fee price for road transport on the route Teplička nad Váhom - Svrčinovec - Mosty u Jablunkova - Nošovice is calculated using a route planner Routenet on its web page and is provided in the Figure 14. On this route 59.60 km out of total 86.2 km are charged. Toll-road fees on this route form altogether 6.55 EUR per transportation by semi-trailer with the emission class EURO V calculated to the date of March 22, 2018. For the sake of comparison the amount of the toll-road fee gained by means of freely available calculators to the same date on the site www.e-myto.sk for the Slovak Republic is presented in the attachment B and the amount of the toll-road fee on the site www.mytocz.eu for the Czech Republic is presented in the attachment C. The total amount of toll-road fees using calculators is 3.6 + 2.851 = 6.45 EUR. This amount of toll-road fees differs from the amount calculated using Routenet by 0.10 EUR.

The transportation starts in Kia Motors Slovakia, s. r. o., in the engine warehouse. Here engines are loaded onto semi-trailers, which are shunted to a designated place by a driver of the transport company DAVID Trans, s. r. o. The loading of pallet units with engines is realised using a lift truck that is operated by an employee of the KMS company. The destination of such a transport is the inwards warehouse of the HMMC, where consignments from various sources are collected and completed. Since the HMMC enterprise has not provided any more information, we are not able to specify this transport point in more detail. The price for transport of 1 semi-trailer transporting engines from the KMS into the HMMC on the route long 86.2 km is set to 94.82 EUR, i.e. the total price for transport of 12 semi-trailers per day is 1,137.84 EUR.

4. The Analysis of Engine Production Development in Kia Motors Slovakia

Production automotive plants in Slovakia have covered more than 50% of all Kia brand sale in Europe. Most of cars have been exported to Great Britain (16%), Germany (9%) and Russia (9%). In year 2016 the plant produced 611,334 engines. This number represents an increase by 5% when compared to the year 2015, when 582,223 engines were manufactured. Nearly half of the CI engine production is exported by Kia Motors Slovakia to its affiliate plant Hyundai Motor Manufacturing Czech in Nošovice, Czech Republic. The mostly produced aggregate unit has been a diesel engine with 1.7 l cubage, which has been ordered for vehicle installation by 24% customers. The conducted analysis makes it clear that it would be more effective to cover the increased engine production in Kia Motors Slovakia by railway transport. Its benefit lies in the option to ensure the increased transport capacity, transport continuity and price for transportation while transporting large and regular volumes.

5. A Proposal for Engine Transportation Procurement by Railway Transport

The aim of this part of the paper is to propose an optimal transport chain for the engine commodity between the KMS and HMMC enterprises, which had its application in the past. The transportation procurement by railway transport was stopped because transport volumes were low and the price for transport was on a marginal economic level, since 6 - 7 covered wagons were transported per day. The proposal for a transport chain will stem from the actual development of KMS engine production, from eliminated risks during engine transportation in the past, from the configuration of a new fleet, from the technology of shipments processing in railway transport, from technical-operational analysis of a railway line, from the transport time and costs for these transportations.

5.1. Technical-Operational Characteristics of a Session

A transport session of railway transport starts on a railway siding of Kia Motors Slovakia, s. r. o.; it continues through Žilina railway station ("RS"), Čadca border transitional station ("Čadca BTS") into Mosty u Jablunkova RS, then to Český Těšín and afterwards to Dobrá RS near Frýdek-Místek, where it connects to the engine unloading location - railway siding of Hyundai Motor Manufacturing Czech, s. r. o. The following figure 1 shows a graphical representation of a transportation route by railway transport in territory of the Slovak Republic.

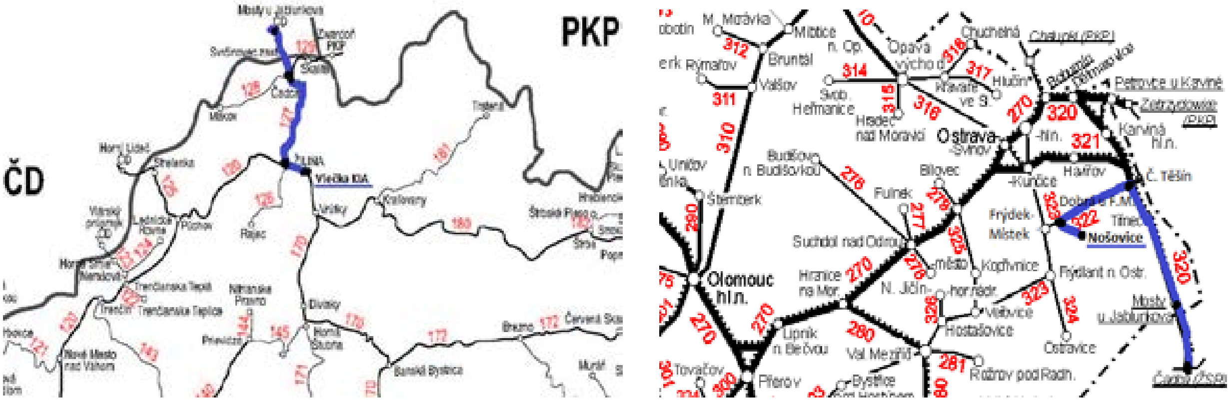

Fig. 1.
Maps of Transport Route in SR and CR
Source: (Tkáčiková, 2018)

The origin point of the transport session is the KMS railway siding. The owner of this railway siding is also its operator - Kia Motors Slovakia, s. r. o. This railway siding serves for the supply of empty wagons designated for passenger cars transportation, for the transfer of wagons loaded with products onto and off the KMS railway siding, and simultaneously for the supply and transfer of wagons loaded with intermodal transport units. The KMS railway siding has one loading platform built on concrete foundations. This platform helps to load products of the KMS onto railway wagons. The railway siding is operated by a proper operator of the interlocking plant Odbočka Váh by a dispatcher from Žilina-Teplička RS.
The destination point of the transport session is the railway siding of the HMMC. This railway siding is connected from a regional railway track Frýdek-Místek - Český Těšín with a switch No. 101 until the gates of the HMMC with a total length of 301 m. The railway siding is connected to Dobrá RS near Frýdek-Místek. The railway siding is mainly utilised for expedition of finished cars and gearboxes as well as for import of steel scrolls, engines and car components for the affiliate plant Kia Motors Slovakia, s. r. o. The railway siding is equipped with two front platforms for car loading, and with railway tracks for steel scrolls and engines unloading, and containers trans-loading. The SŽDC company functions as a railway siding operator and as a transport operator on the railway siding. The GLOVIS company functions as a railway siding controller.

5.2. Engines Loading and Unloading

The KMS produces approx. 2,565 engines during its daily operation. Approx. 50% of the total amount of produced engines is distributed to the HMMC enterprise in Nošovice, Czech Republic. This daily amount varies at about 1,092 engines and is impacted with customer requirements, i.e. requirements of the HMMC.
The loading of pallet units with engines designated for the HMMC starts on a railway siding. There from the containers stock a KMS employee loads an empty 40′ container on a prepared towing unit with a chassis. A driver of the towing

unit shunts the container to a platform within the loading place, i.e. in front of the engine warehouse in the KMS. The KMS employee performs the loading of pallet units into the container. It is necessary to load 14 pallet units into one container, i.e. in one 40´ container there will be 84 engines loaded on R CKD pallets. This number is smaller than in the transportation in semi-trailers by road transport, where COMMON pallets are used, however, in case of minimum daily purchase of 1,092 engines one extra container is needed when compared to semi-trailers.

After pallet units are loaded into the container, the operator of the towing unit with the chassis transports the container to the railway siding. On the KMS railway siding there is another employee, who operates a handling device. Using the device he fastens the container and then he loads in onto a prepared railway wagon. To ensure a continual cycle the operator of the handling device loads an empty container onto the chassis of the prepared towing unit and the circulation of containers can be repeated.

The distance between the railway siding and the engine warehouse is 1.1 km. The time window for container loading on the railway siding is not given; the railway siding is utilised according to the needs. Due to this reason containers with loaded pallet units will temporarily be stored in the container stock at the railway siding, where they will be available to KMS personnel for loading onto shunted wagons. This solution is chosen in order not to block the railway siding for needs of other suppliers or customers.

On the HMMC railway siding engines are unloaded by GLOVIS firm, which has three handling devices for containers trans-loading available. These containers are unloaded onto a storage area of the railway siding and afterwards containers prepared for the KMS will be loaded. Containers with engines, which are designated for the production, will be transported by the towing unit with the chassis into the factory building of MOBIS Automotive Czech, s. r. o., where these engines are lifted from pallets using a manual crane, are mounted to axles and transported into the production floor in Hyundai on a conveyor belt.

5.3. A Proposal for a Fleet Configuration

A fleet configuration which is needed for procurement of engine transportation between the KMS and HMMC enterprises comprises of transport means and instruments, which engines must be loaded onto, as well as of locomotives and railway wagons.

Locomotive Configuration

Transportation route includes passages which are electrified and non-electrified. For engine transportation in this session more locomotives will be used due to electrification divergence. To transport engines from the KMS railway siding into Žilina RS and from Český Těšín RS onto the HMMC railway siding we suggest to use a locomotive, series 742, since these passages are non-electrified. In case of the passage Žilina RS - Český Těšín RS, which is electrified, a locomotive, series 183, or locomotive, series 131, will be used.

Wagon Configuration

To transport engines we suggest using a rail vehicle, series L - Lgs. It is a flat wagon intended for transportation of 40´ containers. It allows an effective utilisation of its length and weight of charge. It is equipped with four strong fastening mandrels and guiding elements enabling an accelerated container loading. The wagon complies with conditions set for inland as well as international transport. ZSSK Cargo company has had these wagons for rent since 2016 and the price for the rent of a wagon is 16 EUR/day (VAT included).

The weight of a 40´ container fully loaded with diesel or petrol engines is 23,300 kg, or 16,580 kg (respectively). Together with its own wagon weight the gross weight is 34,100 kg, or 27,380 kg (respectively). Since the transportation is performed on railway lines of C3, or D4 category and selected railway wagons together with containers satisfy maximum weights of charge of the railway line classes, we may note, that the burden of wagon axles and the ratio of their burden conform to UIC loading guidelines. The following part of the paper verifies the statement regarding the satisfaction of maximum weight of charge for the given railway line class.

Axel load of wagon Lgs:

$$E_1 = \frac{P * a}{l} + \frac{T}{2} = \frac{23{,}3 * 4}{8} + \frac{10{,}8}{2} = 17{,}65 \text{ t} \quad (1)$$

$$E_2 = (P + T) - E_1 = (23{,}3 + 10{,}8) - 17{,}65 = 16{,}45 \text{ t} \quad (2)$$

Ratio of wagon axel load Lgs:

$$\frac{E_1}{E_2} = \frac{17{,}65}{16{,}45} = \frac{1{,}07}{1} \quad (3)$$

The production development implies that there will be 13 wagons transported per day - they will be transported as a wagon group, which will be waiting in Žilina-Teplička RS for a train loading gauge (a normative for the length and weight of a train). Individual normatives have to conform to following principles: normative of a train length within freight transport is a maximum train length, which may be considered on individual railway lines (line passages) while constructing a route of a train; and a normative of a weight is established with regards to maximum pulling power of a planned locomotive so no permanent damage occurs to it.

The length of a train with 13 wagons is 201.2 m and maximum gross weight is 564 t. The HMMC railway siding is 301 m long, i.e. the number of wagons meets restrictions of the HMMC railway siding, thus it is not necessary to detach wagons in the connecting station of Český Těšín RS.

Transport Means and Instruments Configuration

A transport means utilised for engine transportation will be an R CKD pallet of the following dimensions: 2,280 x 1,600 x 930 mm and weight of 200 kg. It is possible to load 6 engines (diesel or petrol) onto these pallets. They are spatially adjusted to transportation in containers and can be stacked into two layers for the transport sake.

Pallet units in a container will be put cross the container nose until the container door into two layers. Loaded pallet units are not specially fastened during the transportation. One ISO 40´ container can be loaded with 14 pallet units of dimensions 2,280 x 1,600 x 930 mm, where the weight of a pallet unit is 1,400 kg (diesel engines) and 920 kg (petrol engines). The weight of loaded pallet units then ranges from 12,880 kg (for pallet units loaded with petrol engines) to 19,600 kg (for pallet units loaded with diesel engines). The weight of a container will be 16,580 kg (for a container loaded with petrol engines) and 23,300 kg (for a container loaded with diesel engines). Containers utilised for the transportation are rented from a company, which offers such services, and the price for the rent of a container is 6 EUR/day.

To transfer loaded containers between the engine warehouse and the railway siding within the KMS enterprise container chassis Schmitz Cargobull S.CF GOOSENECK 40´ from Schmitz Cargobull company will be used; it may be used for 2 x 20´ containers or 1 x 40´ container. The table 1 presents basic parameters of the chassis.

Table 1

Basic Parameters of the Chassis

Total weight of intermodal unit	44, 000 kg
Total technically weight	39, 000 kg
Load of axle	27, 000 kg
Load of turntable	12, 000 kg
Weight of chassis	5, 200 kg

Source: (Tkáčiková, 2018)

The container chassis described above will perform circulating transportations of 40´ containers only within the KMS enterprise between the railway siding and engine warehouse.

5.4. Circulations of a Fleet Designated for Engine Transportation between the KMS and HMMC Enterprises

From the territorial scope point of view these will be regular international transportations of engines by railway transport, which will be performed on a daily basis (Mesko, 2016; Lizbetin, 2016). It is necessary to establish circulations of the fleet which are significant in terms of establishing the transport time, number of workers and cost calculation (Dolinayova, 2015).

Wagons Circulations

A selected carrier providing the operation of the KMS railway siding shunts wagons for loading into the KMS enterprise at 3:00 PM. The drive in an empty state from Žilina RS to the KMS railway siding takes 10 min. Then loading of prepared containers from the handling area of the railway siding onto prepared railway wagons follows. The loading time is approx. 40 min. Afterwards operations, which can be divided into transport and transportation ones, are performed. Duration of these operations is approx. 1 hour. The drive in a loaded state from the loading place in the KMS enterprise to the unloading place in the HMMC enterprise takes 28 hours. Total circulation of wagons since shunting until unloading at the HMMC is 38.5 hour. Wagon circulation is on the figure 2.

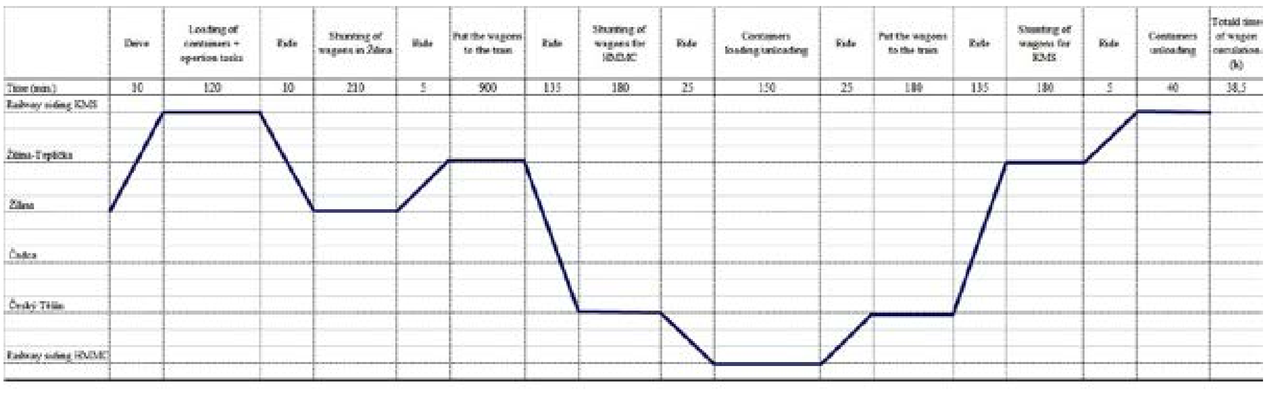

Fig. 2.

Wagons Circulations

Source: (authors)

Locomotives Circulations
Circulation of locomotives is in this case divided into 3 parts: circulation of a locomotive, series 742, between the KMS railway siding and Žilina RS, circulation of a locomotive, series 183, between Žilina RS and Český Těšín RS, and circulation of a locomotive, series 742, between Český Těšín RS and the HMMC railway siding. Total time of locomotive, series 742, circulation in territory of the Czech Republic takes approx. 8 hours. After unloading containers on the HMMC railway siding it is necessary to enter into a new transportation contract dealing with the transportation of containers from the HMMC railway siding to the KMS enterprise. Total time of locomotive, series 183, circulation takes approx. 10 hours. In this case there is no whole train, however, a composition of wagons. Locomotive, series 742, provides circulations for the KMS railway siding for 12 hours a day regardless the customer. Total time of locomotive, series 742, circulation is approx. 6 hours.
The figure 3 shows one of the circulations - locomotive, series 183, from Žilina RS - Český Těšín RS.

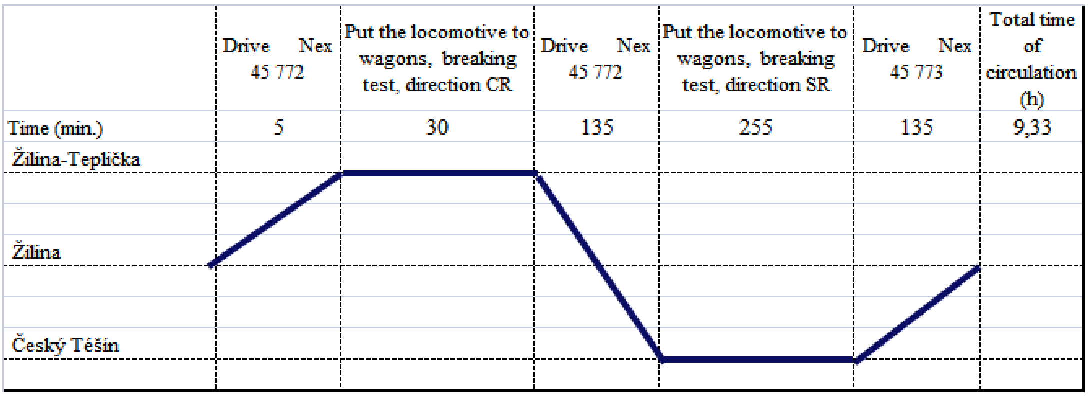

Fig. 3.
Locomotive Circulations
Source: (authors)

5.5. The Analysis of Transport Aspect in Engine Transportation Procurement by Railway Transport

On the basis of railway transport train diagrams for the Slovak Republic and Czech Republic for the period 2017/2018 it was found out that on the railway line No. 106 in territory of the Slovak Republic the busyness is 178 trains per day (70 passenger and 108 freight ones) and in territory of the Czech Republic on the railway line No. 320 the busyness is 98 trains per day (44 passenger and 54 freight ones) and on the railway line No. 321 the busyness is 38 trains per day (38 passenger and 0 freight ones). An infrastructure manager has a free capacity to include a train transporting engines between the KMS and HMMC into the train diagram. At first engine transportations will be performed as so called "ad hoc" transportations. These are transportations beyond the train diagram or trains as necessary. Upon termination of the current valid train diagram period it will be possible to include the proposed train into a new train diagram as a freight train Nex with its custom number.

5.7. Calculation of Costs for Engine Transportation

In calculative classification of costs there are calculation formulas used, where an enterprise may use several formulas, for example a formula for organisational units, for individual business areas, etc (Skrinjar, 2015). The basic classification of costs in the calculation formula is their classification into direct and indirect costs (Dolinayova, 2015).
Two carriers will participate in the transportation; Slovak carrier ZSSK Cargo, a. s., which will provide the transport from the KMS railway siding into Český Těšín RS, and the carrier ČD Cargo, a. s., which will provide the transport from Český Těšín RS onto the HMMC railway siding. To calculate costs in railway transport some model rates due to sensitive carriers' data protection are used. These rates were set on the basis of real rates of selected carriers and technical articles focused on calculations in railway transport. For the sake of better cost identification calculations are divided into the following three groups: cost calculation for the KMS railway siding, cost calculation for the HMMC railway siding and cost calculation for the route from the siding station of Žilina-Teplička RS into Český Těšín RS.
Model rates needed for cost calculation:

• Rate for the rent of a railway wagon Lgs	16 EUR/day
• Rate for a locomotive, series 742	4.5 EUR/km
• Rate for a locomotive, series 183	1.1 EUR/km
• Rate for a train driver	16 EUR/hour
• Rate for a switchman	13.023 EUR/hour
• Specific consumption of a locomotive, series 742	0.2 kWh
• Specific consumption of a locomotive, series 183	0.14 kWh
• Rate for kWh of a locomotive, series 742	11.01 EUR

• Rate for kWh of a locomotive, series 183 16.8 EUR
• Gross weight of a wagon 34.1 t
• Weight of a locomotive, series 742 64 t
• Weight of a locomotive, series 183 120 t
• Secondary operations of a locomotive - φ 15%

Calculation of Costs from the KMS Railway Siding into the Siding Station of Žilina-Teplička RS:
Total amount of the fee for using the railway infrastructure within the Slovak Republic is 89.43 EUR.
Total costs for the drive of a handling train from the KMS railway siding into Žilina-Teplička RS are 356.80 EUR.
Calculation of Costs from Žilina-Teplička RS into Český Těšín RS:
Total amount of the fee for using the railway infrastructure within the Czech Republic is 83.22 EUR.
Total amount of costs for the passage Žilina-Teplička RS - Český Těšín RS is 414.26 EUR.
Calculation of Costs from Český Těšín RS onto the HMMC Railway Siding:
Total amount of the fee for using the railway infrastructure within the Czech Republic is 60.84 EUR.
Total costs for the drive of a handling train on the passage Český Těšín RS - HMMC railway siding is 308.24 EUR.
Costs for Containers
Total costs = 1,365.30 + 409.59 = 1,774.89 EUR

The resulting calculation of costs for 1 transportation from the KMS to the HMMC enterprise by railway transport set costs in a transport session up to 1,774.89 EUR for the transportation of 13 wagons. Costs for transport of 1 ton freight are 6.96 EUR and costs for 1 km are 17.07 EUR. This amount includes all necessary fees. The price for transportation can then be determined either through addition of a carrier's profit or through setting a tariff for regular transportations.

5.8. The Price for Engine Transportation

The calculation of the suggested price for engine transportation is based on cost calculation with addition of an appropriate profit of the carrier, which is on the level of 15% out of total costs, i.e. the price for transportation = 1,774.89 * 1.15 = 2,041.12 EUR. The price for transportation of 1 ton freight is 8.01 EUR and the price for 1 km is 19.63 EUR.

6. Conclusion

As part of proposing an optimal transport chain for engine transportation between the KMS and HMMC enterprises some possible risks were identified, their scope per a given transport chain was analysed and solutions for their elimination were suggested. Subjects participating in this transport chain may be exposed to some of the following hottest risks:

- Risk of empty runs of transport means - this risk could not have been avoided because pallets used in the transportation were not constructed for gearboxes transportation from the HMMC into the KMS enterprise.
- Risk of insufficient capacity on a transport road - this risk was resolved with an analysis of railway lines busyness, and after the conversation with the infrastructure manager it was found out that the space for transportation establishment was sufficient.
- Risk of a single railway line Český Těšín RS - Dobrá near Frýdek-Místek - this risk was resolved with an analysis of a railway line busyness, followed with a finding that the space for railway siding train establishment was sufficient.
- Risk of a non-electrified railway line Český Těšín RS - Dobrá near Frýdek-Místek - this risk was resolved thanks to using a non-electrified locomotive, series 742, which provides transport of wagons from Český Těšín RS onto the HMMC railway siding as a railway siding train.
- Risk of number of wagons prepared for transport each day - it is necessary to provide loading of at least 13 wagons per day.
- Risk of wagon layover in Čadca BTS - since engine transportation will be performed on the basis of an agreement between two selected carriers, layover in Čadca BTS due to locomotive change is not needed.
- Risk of locomotive change in Dobrá RS near Frýdek-Místek - this risk was resolved in Český Těšín RS, where locomotive change will happen, and thus a subsequent change in Dobrá RS near Frýdek-Místek will not be required.
- Risk of lack of capacity on the HMMC railway siding - elimination of this risk is challenging, since the HMMC railway siding is utilised by other customers, too, and transport volumes are not available.

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SIMULATION OF RAILWAYS USING GENERAL-PURPOSE SIMULATION TOOLS

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Abstract: The general-purpose simulation tools could be in some case used instead of the specialized simulation tools to support the decision-making by problem solving of railway infrastructure managers or operators. In our paper, we introduce three examples of simulation models created in some well-known general-purpose simulation tools. We will mention advantages and disadvantages of used simulation tools. We will define some recommendation when deciding concerning simulation tool that should be used for a simulation study to create the simulation model in effective way.

Keywords: computer simulation, decision support tools, railway operation.

1. Introduction

Today, planning in railways cannot be easily performed without using of decision support systems. In this paper, we consider mainly the computer simulation. Two other techniques are mathematical models and geographic information systems.

Over the years, development of ICT have enabled wide use of simulation models. Simulation models can be used in different phases and types of railway control, planning and management. In the process of planning, simulation models are used for getting relevant information when working on strategic and tactical decisions. Typically, these decisions require the information on how will some planned system work in future with given various input parameters. Simulation models are in that case used to analyze and test new modifications, ideas and solutions, for timetables or trains, that could be introduced to existing or new railway infrastructure.

Making a choice from the amount of simulation packages that is available for rail yard simulation modelling is bewildering for the newcomer to the field. An extremely careful decision of simulation package selection can take as many as six months (Banks, 1998).

There are three possibilities when choosing an environment or a simulation tool to build a simulation model. The first possibility is to create the simulation models by program code in some general programming language (Java, C++, Fortran) or specific simulation programming language (GPSS, Simula). The second possibility is to create the simulation model using one of many general-purpose (commercial) simulation packages. The third possibility is to use specialized railway oriented simulation software.

2. General-Purpose Simulation Tool

Basic approach in modelling of railway operation is modelling the train movement as discrete events. Trains are dynamic entities that can carry specific data as attributes. Entities are passing through blocks (processor) creating an event that changes state of variables, outputs or occurrence of next events (Milinkovic et.al 2015). This approach also requires a lot of knowledge and time for completing the model.

There are tens of the general-purpose simulation software available. Some of them offer specific libraries and tools developed just for simulation of the railways systems. The most favorite general-purpose simulation solutions are MATLAB – SIMULINK, Arena, AnyLogic, FlexSim, etc.

For example, FlexSim (www.flexsim.com) has a 3d environment and built in library that can simulate the logistic processes. Specialized version of this software (formerly FlexSim CT) is Flexterm (http://www.flexterm.com/), a software package solution that provides 3D simulation for the analysis of terminals. The FlexTerm Rail Module was developed to simulate various rail sequences and train processes. It allows for a complete visual representation of custom built rail processes, and is a tool for communicating complex rail sequences.

Similarly, the AnyLogic simulation package is oriented to general simulation problems but has a rail library developed for simulation of complex rail systems (https://www.anylogic.com). The AnyLogic Rail Library allows users to model, simulate, and visualize the operations of rail yards and rail transportation. Classification yards, rail yards of large plants, railway stations, rail car repair facilities, subway stations, airport shuttle trains, and even tram networks can be modeled with this library. It also helps users with operations planning, fleet management, and train and maintenance scheduling. In rail models, trains move according to the logic set in a flowchart, while each railcar and locomotive in a model are agents with their own states and properties. This, along with other libraries' interoperability, provides capabilities for precise simulations of complex railway systems.

In Matlab, creating a simulation model of a train movement is based on a discrete events too (Milinkovic et al., 2015; Grubor et al., 2013). Typical model of train movement in Matlab is created in Simulink, tool that includes the SimEvents tool for simulation of discreet event systems. Simulation model has a combination of blocks for discreet modeling and basic Simulink blocks.

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In following text, we describe our experience with creating three different simulation models. Two of them were developed in AnyLogic simulation tool, in frame of bachelor project (Kurjak, Iliaš) at University of Žilina, Slovakia. Third model was developed in MATLAB.

3. AnyLogic Simulation Tool Environment

In AnyLogic, as in many other general-purpose simulation tools, model developer creates flowcharts by adding the blocks from the library palette to the graphical diagram, connecting blocks together, and tuning the parameters of the blocks. Each block defines some operation (activity) that will be performed, e.g. creating of new customer, customer delay, blocking/unblocking customer. There are several different libraries, collections of blocks, that user can use. Application of AnyLogic simulation tool was described earlier in (Márton, 2014).

3.1. Simulation Model of Railway Station Svit – Pedestrian Simulation

Simulation model of railway station Svit was developed to support decisions in frame of student content of international conference Forum of Rail Transport 2018, in March in Bratislava (Slovakia). Participating teams had task to prepare study for rehabilitation of station building that was constructed based on project for Bata Company from 30ties in 20th century. Station building has very valuable architecture, but it is currently closed for passengers. City government of Svit city would like to revive this station building in cooperation with its owner, Railways of Slovak Republic. Student projects could prepare some proposals how to combine using of station building for transport and cultural events too.

In our simulation model, components of several AnyLogic libraries were used – Process Modelling, Pedestrian, Rail, Agent, Presentation, Analysis. Processes modeled in this model are oriented to pedestrians (passengers) and their movement in station building and in underpass to platforms and Svit city. Flow charts that have been built using blocks from Pedestrian library describe movement of passengers from train to other train or to station building for example. Flow chart developed using Rail library defines arrival and departure of trains. Simulation experiments were defined in cooperation with project company Reming that was sponsor of student content. Trains arrivals and departures were modeled too, but in restricted scope. We used only three tracks in model. Trains arrived and departure to assigned tracks. No switches were used. Modelling of switches and train movements through station head was not necessary.

Each experiment was used to find minimum transfer time between three trains. Movement of disabled passengers was included. In the first experiment, passenger move only using underpass and stairs. In the second experiment, disabled passengers can use lifts. In the third experiment, passengers can use ramps. Visualization of Svit station is in figure 1. Simulation model is shared at AnyLogic Cloud (https://goo.gl/Xsk2Av).

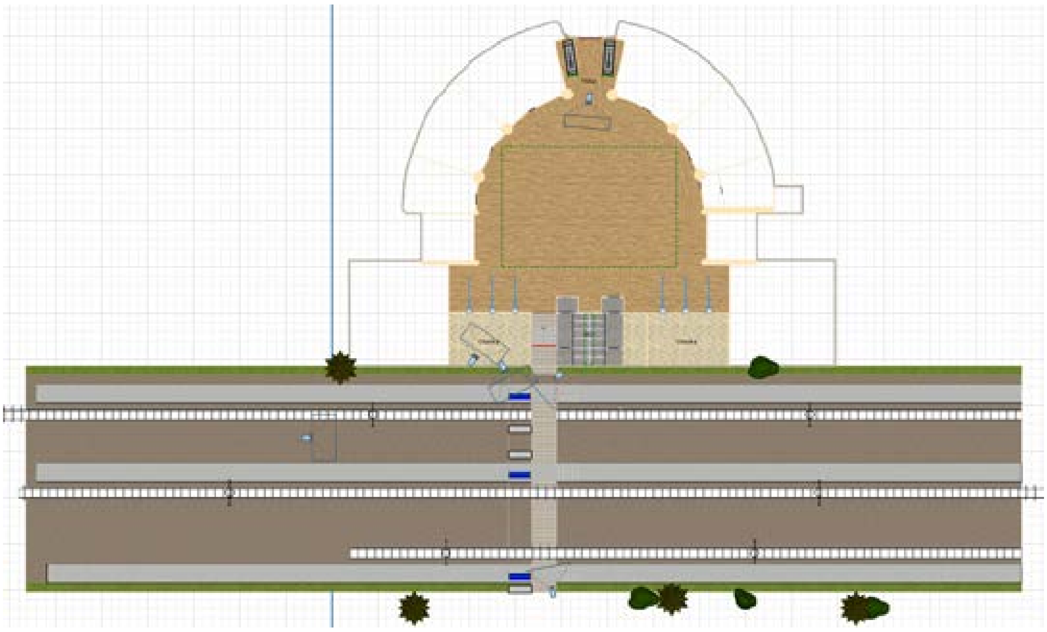

Fig. 1.
Design of Svit station simulation model in AnyLogic
Source: Peter Márton

3.2. Simulation Model of Regional Line Žilina - Rajec

Simulation model of regional line Žilina – Rajec was developed in frame of bachelor project. This model is still under development. Railway line Žilina – Rajec is single-track line with length of 21 km. Train running starts in Žilina or Rajec. There are 10 stops between Žilina and Rajec. Two of them are stations where trains running in opposite directions can pass each other. Table 1 shows simplified description of Žilina – Rajec line, including timetable of one train. Travelling in one direction takes about 40 minutes. Maximum speed is 50 km/h. Train speed is restricted based on line topology and many level crossings.

Table 1
Simplified description of Žilina – Rajec line

Stop	Passing	Km	Arrival	Departure
Žilina	Yes	0.400		14:47
Žilina záriečie	No	2.485	14:51	14:51
Žilina – Solinky	No	4.664	14:54	14:55
Bytčica	Yes	5.974	14:57	14:58
Lietavská Lúčka	Yes	7.697	15:00	15:01
Porúbka	No	10.808	15:06	15:06
Poluvsie	No	13.749	15:10	15:10
Rajecké Teplice	No	15.750	15:13	15:14
Konská pri Rajci	No	16.643	15:15	15:16
Zbyňov	No	17,910	15:18	15:18
Kľače	No	19.412	15:21	15:21
Rajec	Yes	21.285	15:24	

Source: Timetable, Railways of Slovak Republic

In this simulation model, components of several AnyLogic libraries were used – Process Modelling, Rail, Agent, Presentation, Analysis. Processes modeled in this model are oriented to trains and their movement. In current model version, there are only passenger trains. Freight transport is covered by one pair local (pick-up) trains that run based on demand of customers. Flow chart developed using Rail library defines arrival and departure of trains from Žilina and Rajec. Railway infrastructure is defined by using tracks, switches and stop positions. It was necessary to develop a logic that do not allows to run two trains in one line section. Simulation experiments were defined in consideration of expected traffic development between Žilina and Rajec. There are huge congestions on road connecting these two cities every morning and evening. Rail transport can help to solve this situation, but it means to offer trains every 30 minutes instead of every 1 hours. Trains should be longer, with more places for passengers. Using our simulation model, we would like to offer decision support tool for preparing alternatives of timetable. Currently, simulation model of actual traffic is completed. Student will continue to develop models with experiments from September 2018.

We try to keep this model so realistic as possible – for example by respecting of speed limits. Timetable is loaded from excel file. We would like to develop this model to be flexible by adding new trains, to be able to save time when models for experiments will be developed and to indicate bottlenecks and deadlocks quickly. We would like to develop model that could be modified for another regional line without some complicated modification of model blocks. Figure 2 shows part of simulation model logic.

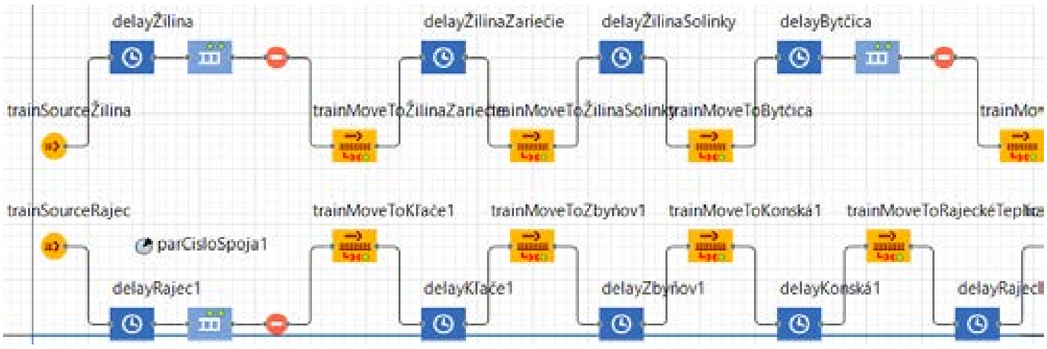

Fig. 2.
Part of simulation model of railway line Žilina - Rajec in AnyLogic
Source: Peter Márton

3.3. Simulation of Discrete Events of Train's Movement in MATLAB

Basic concept of the model is a queuing theory, where queues and servers are connected to create subsystems of the train traffic system, with gates to allow or deny a change of state. Open gate is allowing an entity to enter to a next object. Entities represent a train in model, and gates are signals or other conditions that enables the train movement. Movement of trains is guided by subsystems that contain blocks (queues and servers) and objects that register the movement of the entities and previously stored parameters (Figure 3).

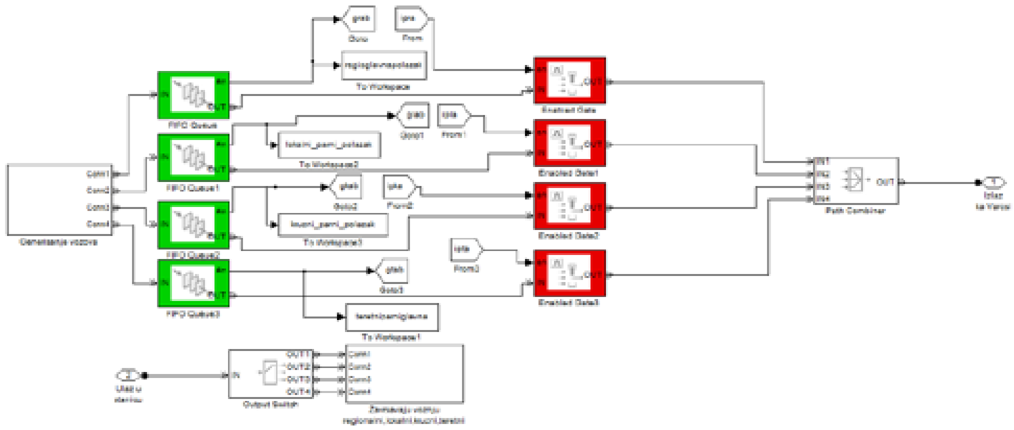

Fig. 3.
Matlab SimEvents model of rail station Pancevo Glavna
Source: Grubor et.al, 2013

When simulating the train movement on a section of the network, or line, the model is composed by hierarchy, i.e. the model has subsystems that represents the stations or a section between the stations. For the single track railway lines there is a need to model the traffic of the trains by implementing all of the rules, procedures and spacing of trains. A simulation model developed for single-track section of a railway line must be also defined by station tracks and train routes. As an input data for a timetable we define train categories on the line as well as their speed profiles, acceleration times and times for passenger operations in the stations. Following of trains or trains spacing is organized by station section block, that is, there is only one train on a section between two stations. Dwell time for passenger trains can be defined, as well as platform assignment. Traffic is managed by stations for passing and overtaking. These stations can be determined before simulation, or during simulation by a module for decision support, i.e. a dispatcher optimization module. The rules implemented in the dispatching optimization module are prioritizing the train by various parameters assigned to trains before simulation and dynamically, during simulation (train category, length of journey, planned connections to other trains, traction requirements, specific conditions, etc.)

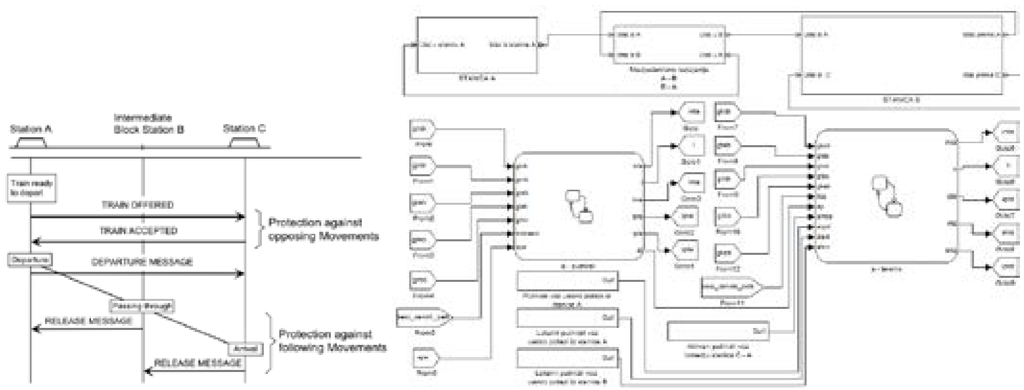

Fig. 4.
Procedure for train movements on single track line and simualtion model of a single track line
Source: Sanjin Milinković

Simulation model has properties that correspond to typical general decision-making logic of a train dispatcher for a single-track line. This includes route conflicts situations for same or different priorities (categories) trains. Dispatcher logic is included in the decisions regarding overtaking of trains, passing of trains different categories and spacing of trains. Specific state in the system is a moment when the dispatcher asks for a permission to dispatch train from the station, because received permission includes the information that there is no trains of any priority that will cause a conflict (Fig.4).

3. Conclusion

Using of the decision support tools is very widespread by railway companies in developed countries [3]. Verification of tactical or strategical decisions made by managers of railway companies is very important because of the decisions have influence to effectiveness for several years or even decades. Researchers of the University of Žilina and the University of Beograd are active in field of development of simulation and mathematical models of railway operation, not only theoretical research but in cooperation with railway operator too. University of Žilina and University of Belgrade renewed their cooperation in the railway traffic and engineering in 2011. The bilateral research project that started in 2017 is focused on the increasing of effectiveness of the railway transport services using the decision-support systems.

In this paper, we describe some examples, how general-purpose simulation tools can be used to create simulation model that includes railway operation.

There are different reasons to use the general-purpose simulation tools for developing of models with railway operation. This could be for example “first decision” of researchers at universities because they use often general-purpose simulation tools for development of other simulation models. Researchers are more familiar with theory of modelling and simulation and they easier understand formal structure of models, e.g. that simulation model consists from several components. These components are defined from different points of view, e.g. service – as customers and resources. One reason to try to develop simulation model in the general-purpose simulation tool first could be unwillingness to buy additional simulation tool in case that research team own already another one.

In generally, our experience shows that it is possible to develop simulation model of railways in environment of the general-purpose simulation tool. However, there are some limits. The general-purpose simulation tools offers their railway oriented block libraries to create railway components of models. These railway components present some way of extension of basic process modelling but do include even basic logic that is obligatory for all railway models – logic of signaling and interlocking. This logic must be created by model developer additionally. On the other hand, possibilities of animation in the general-purpose simulation tools are limited, even they offer 3D view on processes.

We mention that the general-purpose simulation tools are often used by researchers. Other possible user could be railway experts from railway companies. For them, it could be difficult to use the general-purpose simulation tools. It is very likely that they will prefer to use specialized railway oriented simulation tools (e.g. OpenTrack, RailSys, Villon). Even, when we asked students that developed simulation models in AnyLogic tool, they answered that they would prefer to use some specialized simulation tool in case that they can decide about it when developing their bachelor project simulation models again. Of course, it depends on specific case (expert, modeled system). We can define some basic reasons, why railway experts probably prefer railway oriented simulation tools:

- User environment is designed to enable easy development of model. In the general-purpose simulation too, it is often designed similar as for programming languages. Railway experts are not very familiar with it.
- Basic and advanced logic of signaling and interlocking system is integrated. Railway expert do not need to develop it, as in case of the general-purpose simulation tools.
- Basic and advanced processes of railway operation are predefined. Railway expert does not need to create flowcharts to describe them.
- Evaluation of simulation results is easier and simulation outputs are presented in way of graphs, tables and figures that are similar to official railway documents. In the general-purpose simulation tools, it is necessary to develop logic for registering important events and evaluation of important processes additionally.

Acknowledgements

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SAFEWAY TO SCHOOL – STUDY OF TERRITORY TO ENHANCE SAFETY IN BLANSKO

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Abstract: Due to the growing share of parents who drive children to schools and kindergartens, the risk of accidents or traffic conflicts during morning around schools increased. A typical example is the Rodkovsky Street in the town of Blansko, near the kindergarten, primary school and high school. Upon the request of the city, several measurements and surveys were completed on this street, ending with safety inspection in the area. Several options how to increase safety in the area were proposed.

Keywords: school, safety inspection, traffic sign.

1. Introduction

The subject of interest is the Rodkovsky Street in Blansko. The section starts at the intersection of Sadova Street and Rodkovsky Street and ends at the elementary school. The street has a specific type of traffic, especially during morning hours, when the kindergarten, primary and secondary schools children incoming. The specificity of the area is the proximity of the Blansko hospital, because of which parking vehicles are left in the nearby streets early in the morning (before the beginning of the school) (Johnova et al., 2009).

Fig. 1.
Subject of interest Rodkovsky Street in Blansko
Source: mapy.cz

2. Accidents and Traffic Conflicts

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Accident analysis was conducted for the last three years, i.e. from 01/2015 to 12/2017. The main source was the Single Transport vector map. It is necessary to note that statistics do not include accidents where damage was less than 100 000 CZK. There were two traffic accidents during the selected period. The first one was at the intersection of Rodkovsky Street and Vrchlickeho Street. The accident happened in October 2015 and it was a collision with a parked vehicle. The more detailed circumstances of the accident are not known as the driver has escaped from the accident.
The second accident happened at the intersection of Rodkovsky and Sadova streets. The accident happened in April 2016 in the morning (7:15). This was a pedestrian accident where the driver of the vehicle did not give priority to the crossing pedestrian. The pedestrian was slightly injured in an accident (Ministry of Transport, 2006).
The local investigation was carried out on several working days in the area. From the analysis of traffic conflicts, a large number of pedestrian traffic conflicts with vehicles were recorded. It is very problematic especially the turning around of vehicles at the intersection of Rodkovsky and B. Nemcova streets. During every school day at the peak hours, about 20 vehicles turned around at the junction.

3. Measurements of Intensity and Speed

In the given area, a directional survey was conducted at the intersections of Rodkovsky x Sadova and B. Nemcova x Rodkovsky. In addition, statistical radars measuring speed and intensity were fitted in three places (see picture). The radars were installed from 6 November 2017 to 13 November 2017. From the following graphs (intensity during the week, intensity during the day), it can be seen that the difference in traffic intensity during working days (school days) and the weekend is significant. In addition, measurements confirmed the peak hourly intensity 7:00 to 8:00.
Speed measurement has shown no violation of speeding. Mainly because static radars were placed near junctions and pedestrian crossings where drivers naturally slow down. At radar 1, an average speed of 26 km/h was recorded, V85% 35 km/h and the highest measured speed was 64 km/h. At radar 2, the measured average speed was 16 km/h, V85% 21 km/h and highest measured speed 33 km/h. The radar 3 recorded an average speed of 19 km/h, V85% was 24 km/h and the highest measured speed 40 km/h.
At radar 1, the most frequently recorded speed was between 20 and 30 km/h. At radar 2 and radar 3, the most common speed was between 10 and 20 km/h. Therefore, drivers run very slowly in measured locations.
In addition, intersectional movements at the junction near the school were analyzed from camera records. The most usual direction was the turning from B. Nemcova Street (where parents drop their children) on Rodkovsky Street. The second most frequent way is to drop off children directly in front of the school and then turn around at the intersection of Rodkovsky x Vrchlicky streets.

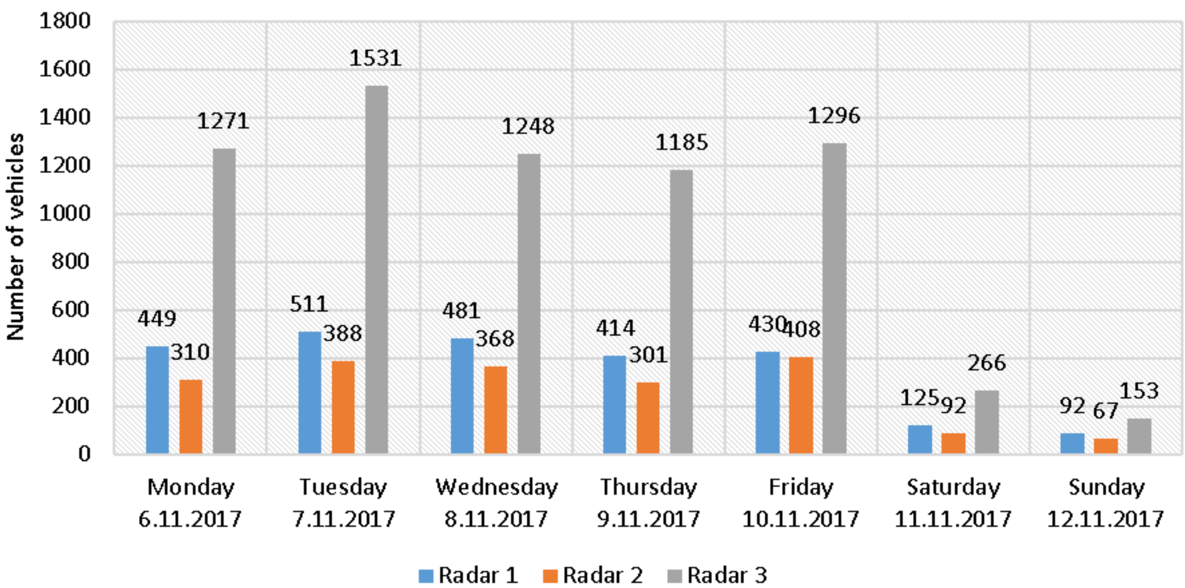

Fig. 2.
Intensity in places with radar
Source: authors

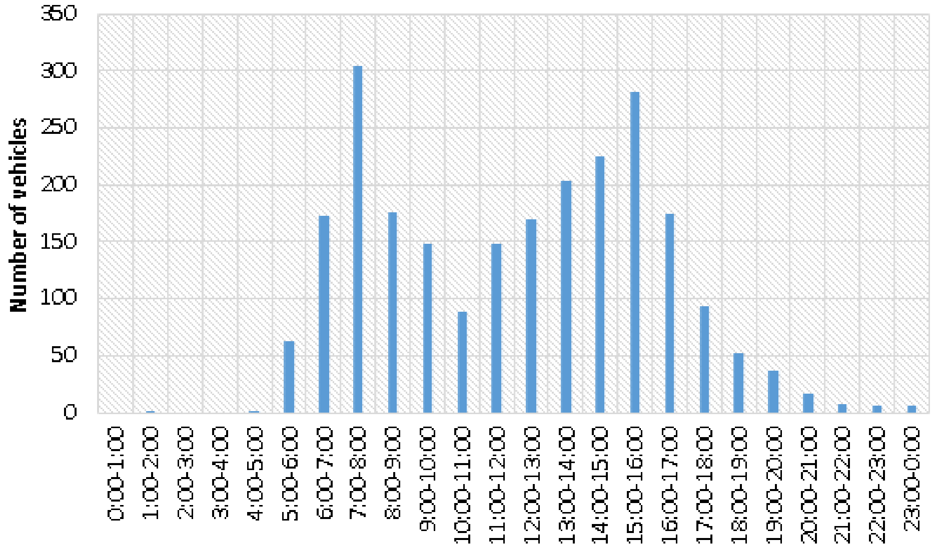

Fig. 3.
Intensity during the day
Source: authors

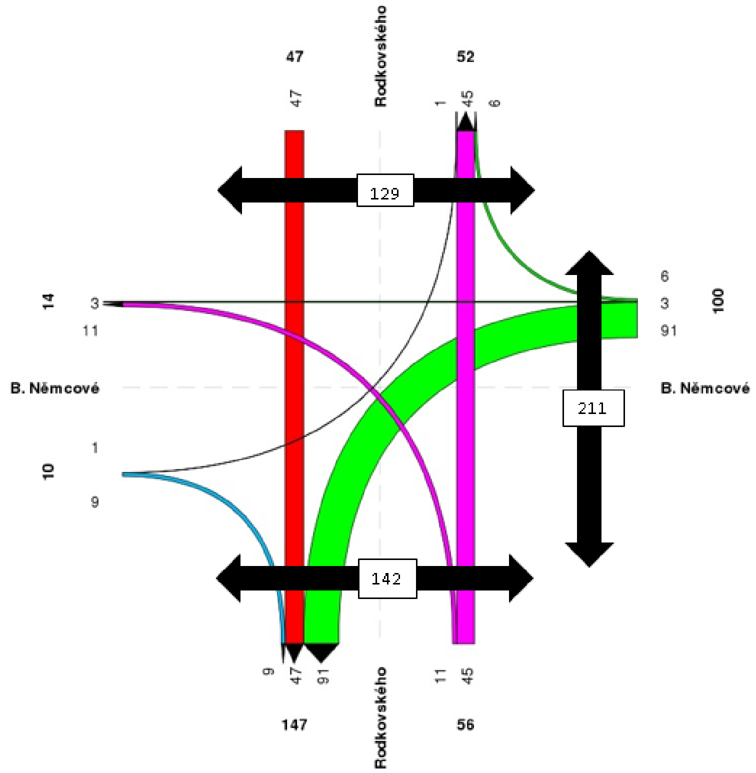

Fig. 4.
Intensity of intersection of Rodkovsky x B. Nemcova
Source: authors

4. Safety Inspection

Several security risks have been detected within the area, such as non-barrier-free modifications, etc. However, these risks have only been evaluated as low importance. Significant safety risks pointed out were vehicles turning around at the intersection and insufficient sight distance at the pedestrian crossings (Pokorny et al., 2013).
The inspection revealed a lack of clear sight distance on a pedestrian crossing on Rodkovsky street due to parked vehicles. Given that children frequently use the pedestrian crossing during the morning, this risk is quite significant. During the local investigation, the sudden braking of the vehicle was recorded several times due to the pedestrian entering the crossing (Pokorny et al., 2012).

Fig. 5.
Insufficient sight distance at the pedestrian crossings
Source: authors

A very dangerous risk in the given territory is the inappropriateness of the vehicle movements at the intersection of Rodkovsky x B. Nemcova streets and many turning vehicles from Sadova Street. Due to the number of pedestrians in the morning and the number of vehicles, many traffic conflicts were observed during a local investigation. The great advantage is that the drivers run within the area at a very low speed, mostly because of the expected pedestrian movement or unexpected vehicle movements. A similar problem is also at the intersection of Rodkovsky x Vrchlicky, where the intersection is used to turning around of vehicles driven by parents who drop off their children directly in front of the school and continue towards next junction where they turn around. In addition, children frequently cross this intersection because it is on the direct trajectory from the bus stop to the school (Johnova, et al., 2008).

5. Conclusion

To improve safety during the safe journey of children to school, two options of measures in the area are proposed. A common recommendation for all the proposed options is to reserve the right parking lane in B. Nemcova (in the section between the intersection with Sladkovskeho and Rodkovsky streets) for the "Kiss and Ride" parking marked by the IP13e traffic sign Parking K + R with an additional table E13 with the text "APPLY DURING WORKING DAY 7:00 - 8:00". This measure should ensure as many as possible parking places for parents of the primary school and the kindergarten pupils. Moreover, it should get rid of long-standing vehicles such as patients of the nearby hospital. A 15m parking reserved for the school bus will be retained. An appropriate complementary measure would be to indicate the length of validity of parking by the horizontal traffic sign V12d. If the capacity of the lane is insufficient, it is possible to reserve the parking strip on the opposite side of the street in the same mode.
Other measures common to all solutions is to reserve for parents who bring children into kindergarten. Part of the parking lane in Rodkovsky Street would be reserved by the traffic sign IP12 Dedicated parking with the additional table E13 with the text "APPLY DURING WORK DAY 7:00 - 17:00".
Option 1
The traffic safety would clearly benefit the most by making Rodkovsky Street one way in the section between Sadova Street and B. Nemcova Street with exit to Sadova Street. Option 1 would need the following measures:

- Installation of traffic sign IP4b One-way traffic on Rodkovsky street at the junction with B. Nemcova street.
- Installation of the B2 road sign Prohibition of the entry of all vehicles on Rodkovsky Street at the junction with Sadova Street.
- Installation of B24a traffic signs Prohibition of turning to the right and B24b Prohibition of turning left on Sadova street at the intersection with Rodkovsky street.
- Installation of traffic sign C2f Commanded direction to the right and to the left at the exit from Zizkov Street to Sadova Street.
- Longitudinal parking will be legalized on the right side (the left-hand side in the direction of travel) of the section of Rodkovsky Street. The parking lot will be marked by a vertical traffic sign IP11c Parking (longitudinal parking) accompanied by horizontal traffic sign V10a Parking space longitudinal. Due to the sufficient width of the main transport area, it would be possible to set the width of the lane to 2.5 m (instead of the standard 2.0 m) to increase the safety of pedestrians crossing the street.

Thanks to the one way part of the Rodkovsky Street, it will be possible to legalize the parking space even on the right side in the direction of travel. The number of such stalls depends on the width of the road between the rims, which can be precisely determined after the street is surveyed. However, when parking on both sides, it is necessary to consider the width of the parking lanes set to 2.0 m. It is always necessary to maintain the width of a traffic lane at least 3.5 m, which is necessary to allow the passage of emergency vehicles. In the vicinity of the junctions, it is necessary to take into account the swept paths of vehicles (14,95 m long bus, 10,1 m long supply truck and 9,95 m long waste truck).

Fig. 6.
Option 1
Source: authors

Option 2
Another option how to solve the unfavorable traffic situation is to leave Rodkovsky Street as a two-lane two-way local road along its entire length, prohibiting turning around of vehicles at junctions. Option 2 would need to include the following measures:

- Installation of the B25 traffic sign Prohibition of turning around in front of the intersection of Rodkovsky and B. Nemcova streets and Rodkovsky and Vrchlického streets (in the direction of driving from Sadova Street). This mark would probably have to be supplemented by the additional table E9 Vehicle type with the symbol "PASSENGER VEHICLE".
- Other vehicles would turn around at the blind end of Rodkovsky Street. Since the entire street width (about 14.0 m) is located on the grounds that are in the possession of the Blansko city, it is possible to use one of the existing exits as a turnabout. For example, a separate exit to house no. 1000 already meets the parameters for passenger cars, which was verified by swept paths.

From the suggested options, we recommend implementing Option 1, which clearly settle the traffic movements in the area of school facilities. The disadvantage of Option 1 is that it can raise the number of vehicles turning around at the intersection of Rodkovsky and Vrchlicky streets. If the number of such vehicles rises, it is possible to realize partly

Option 2, which will prohibit the turning around of vehicles at the junction, and the vehicles will be allowed to turn around only at the turnabout.

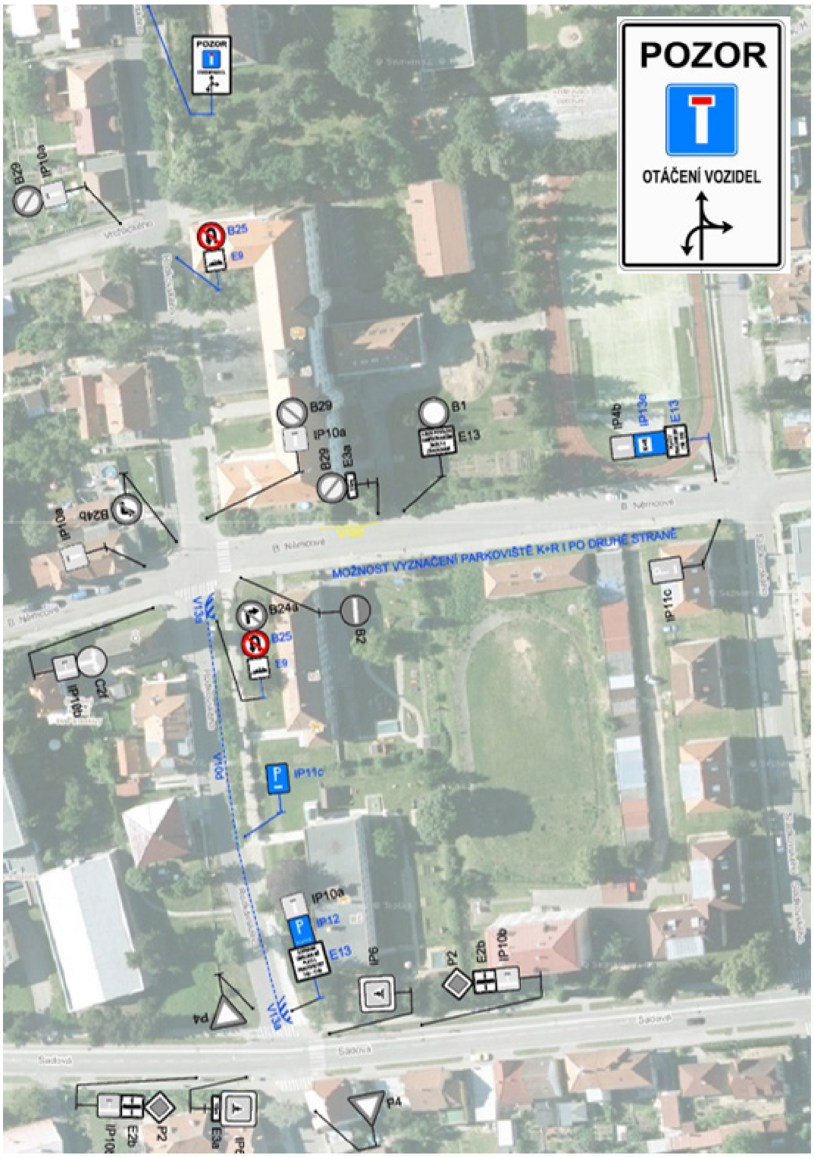

Fig. 7.
Option 2
Source: authors

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STATISTICAL ANALYSIS OF DRIVING STYLE AND ITS EFFECT ON CARGO SECURING

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Abstract: This article deals with evaluating a transport experiment in the training of drivers on roads paved with granite block. The data measured consists of magnitudes of acceleration coefficients obtained over one-second intervals in three axes and is statistically analyzed. A variance analysis is performed by multiple comparisons to verify the equivalence hypothesis of the mean values of acceleration coefficients (their magnitude in absolute value) separately for each of 14 drivers for each coordinate (axis). The results of the analysis show certain specific pairs of drivers whose driving style show significantly varied magnitudes of those acceleration coefficients in some axes. Emphasis is placed on the influence of driving style on the acceleration coefficients generated with regard to cargo securing. The model further compares the effect of these variable magnitudes of acceleration coefficients on cargo securing and identifies recommendations for optimization.

Keywords: transportation, cargo securing, driving style, acceleration coefficient, statistical analysis.

1. Introduction

The issue of cargo securing is very topical in Europe, as evidenced by an estimate by the European Commission's Transport Department that reports up to 25% of truck accidents occur due to inadequate or insufficient cargo securing (European Commission – DGET, 2016). Under conditions prevalent in the Czech Republic during 2016 25% of 11,177 accidents would be caused by trucks (Police, 2016), ie. a total of 2,794 traffic accidents.
In the total number of 21,386 traffic accidents in the Czech Republic during 2016, (Transport Yearbook, 2016), an estimate of the proportion of truck accidents in the context of cargo securing would account for over 13%. For comparison, the number of accidents where alcohol was detected in the driver's blood is a highly discussed area. Such accidents amounted to 1,802 in 2016, which is just over 8% (Transport Yearbook, 2016). In relative terms, alcohol behind the wheel represents a much smaller problem than accidents due to incorrect or insufficient cargo securing.
In general, cargo securing depends on three basic factors:

- Road,
- Vehicle,
- Driver – Driving style (Lehrer, 2015).

Standards, manuals, and other publications deal with road issues in a broader sense and develop the area of cargo securing primarily in the "user plane", ie. for specific applications in practice. Normalized acceleration coefficients are taken from the empirical studies conducted on the statistical sample of roadway surfaces (see below). The aim of these approaches is then to find acceptable, optimal methods of securing the cargo on vehicles. The object of that modification is primarily cargo and its securing in connection with the necessary knowledge of how the vehicle is affected by the roadway during transport.
The basic source of policies and calculations for cargo securing is EN 12195-1:2011 *Load restraining on road vehicles – Safety – Part 1: Calculation of securing forces* (EN 12195-1, 2011) norm. The problem of cargo securing is further elaborated, for example, by examples of good EU practice in the 2014 *European Best Practice Guidelines on Cargo Securing for Road Transport* (European Commission – DGET, 2014). A related source is also the practical handbook for the packing of handling-transport units from 2014, which emphasizes the correct packaging, fastening, safety and health at work *IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units (CTU Code)*.
These examples of good EU practice do not include the transport of dangerous, excessive and oversized cargo. For dangerous cargo, the document references the standard European agreement *ADR European Agreement concerning the International Carriage of Dangerous Goods by Road* (ADR, 2016 and excessive and oversized to separate examples of good EU practice *European Best Practice Guidelines for Abnormal Road Transport* (European Commission – DGET, 2016).
Among the monographs dealing with the issue of cargo securing, including the application of the approaches and formulas from EN 12195-1:2011, respectively, among the above-mentioned manuals it is useful to include a book by Tone Lerher from 2015; *Cargo Securing in Road Transport Using Restraining Method with Top-Over Lashing*. The author deals with both the general rules of road-load consolidation and the fastening of cargo using fastening straps, namely "Top-Over Lashing". Equally important is the case study portion of the monograph, where an analysis of attachment efficiency is carried out taking into account the key parameters of the calculation, e.g. the dynamic coefficient of friction or the angle at which the strap attaches to the plane of the load compartment of the vehicle (Lehrer, 2015).

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Another monograph, *Safe Packaging and Load Securing in Transport,* written by Grossmann and Kassmann from 2007, also present in their book, in addition to packing functions, various methods of securing cargo that include models for fastening cargo using fastening straps (Grossmann and Kassmann, 2007).
The specifics of the problem of fastening of oversized cargo are discussed in a monograph by Wieslaw Galor et al. from 2011; *Carriage and Securing of Oversize Cargo in Transport*. It also contains a number of general issues related to cargo securing, with an emphasis on the specifics of each mode of transport (Galor et al., 2011).
The issue of the roadway, specifically its surface during the transport, is further discussed in a number of expert publications, e.g. the authors Jagelčák (Jagelčák, 2007) and Cieśla and Hat-Garncarz (Cieśla and Hat-Garncarz, 2013).
The examination of the vehicle and the dynamics of its movement represent the broadest area in those specialized articles published in professional journals and conference proceedings. Specific types of vehicles are taken into account, using technical parameters as a rule from the manufacturer. Vehicles with and without loads are examined under varied conditions (e.g. at different speeds, overcoming defined obstacles). Mathematical tools (Stodola, 2016) or most often simulation software (e.g. MSC.ADAMS) are used to create models. These include articles by Neumann (Neumann, 2015), Zong (Zong, 2017) and Garcia (Garcia, 2003).
Articles focusing on the style of driving typically fall into transport psychology and have no links to economic aspects. An exception is the study of the Transport Research Center for the Ministry of Transport of the Czech Republic, which discusses the overall economic losses of road accidents (CDV, 2016). The subject of this article will be an analysis of driving style of drivers in the training of drivers using statistical tools.

2. Cargo Securing – Transport Experiment

Our transport experiment was carried out on a training polygon in Vyškov-Dědice using a Tatra T-810 DO AŠ with a simulated load of 2,160 kg. The vehicle was in very good condition with a mileage of 34,000 km. The transport experiment was attached to the training of drivers, which was attended by a total of 14 drivers on that day. The fifteenth professional driver was not subject to the model, as he only provided transport of those drivers to the polygon. Those sections passed by the professional driver are shown in the graph in figure 1 by red rectangles and are not subject to statistical analysis in section 3. The transportation experiment is further explained in the article (Vlkovský *et al.,* 2016).
The main goal of the transportation experiment in this article was to determine the impact of driving styles on the transport of simulated cargo by off-road vehicles, especially the impact of average speeds on the magnitude of shocks generated during transport, including acceleration coefficients in individual axes (formally called c_x, c_y, c_z). The magnitude of those acceleration coefficients directly relates to the expected magnitudes of the inertia forces that affect the cargo, the vehicle and its crew during each shipment. Higher values of inertia forces than expected (see calculations resulting from the data and formulas EN 12195-1:2011) may cause cargo loosening and cargo damage, as well as damage to the vehicle or to other technical instruments such as fastenings. Loose cargo may lead to road accidents or cause such accidents in connection with disproportionate vehicle speeds or incorrect driving styles.
Within the framework of the transportation experiment, drivers traveled a 2.8 km long polygon. Four of the drivers crossed the polygon in only one direction and they have been formally designated as d_1 – d_4:

- d_1 – ride there (figure 1 – sector 1, first part),
- d_2 – ride back (figure 1 – sector 1, second part),
- d_3 – ride there (figure 1 – sector 2, first part),
- d_4 – ride back (figure 1 – sector 2, second part).

The remaining 8 drivers (formally labeled d_5 – d_{14}) crossed the training polygon both there and back. Each of the 14 drivers crossed the section (s) at a speed and style according to his capabilities and experience. Each ride then differs by the shocks generated as expressed by the acceleration coefficients and average speeds (see below).

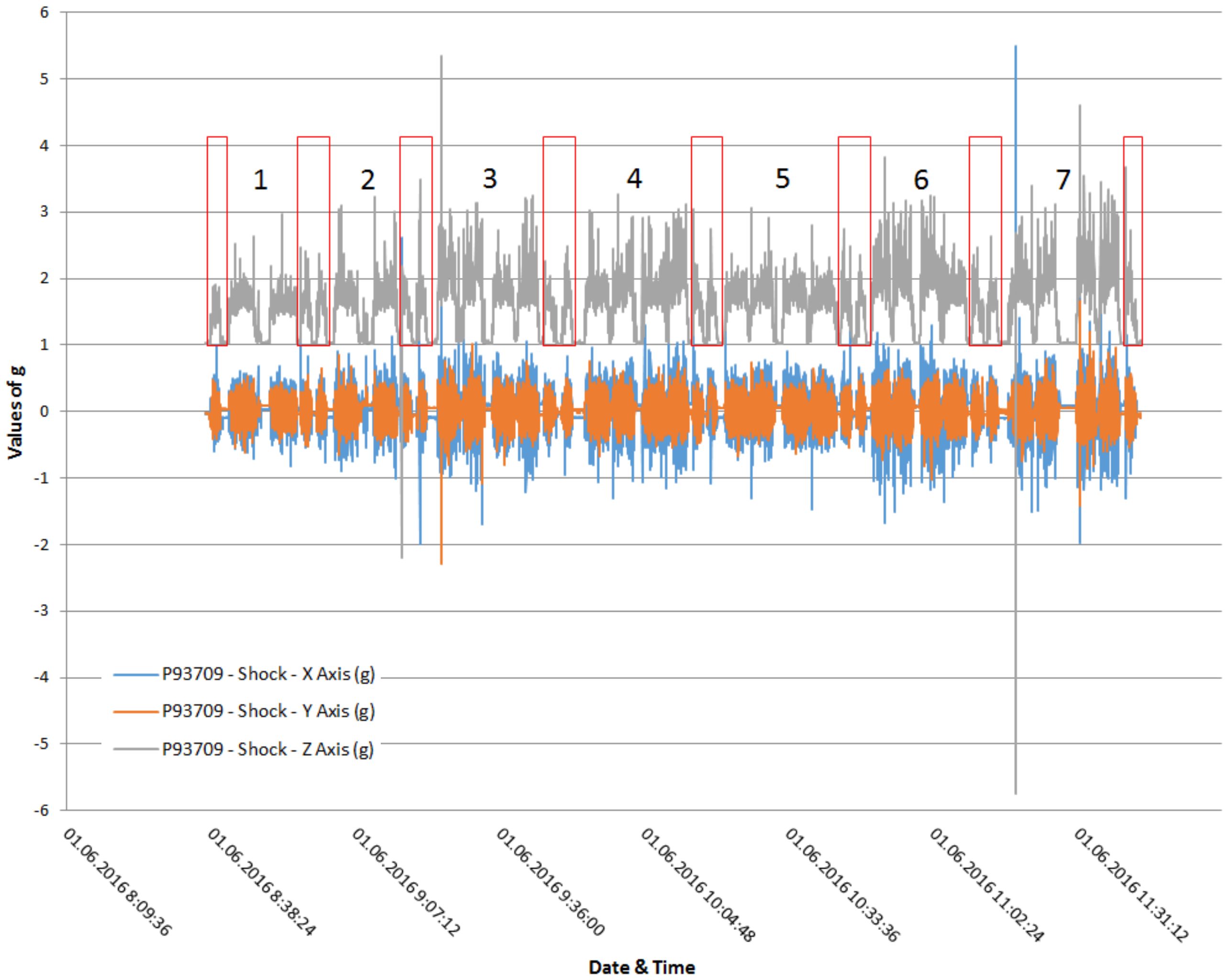

Fig. 1.
Graph of The (Shock) Acceleration in Particular Axes
Source: (Vlkovský, et al., 2016)

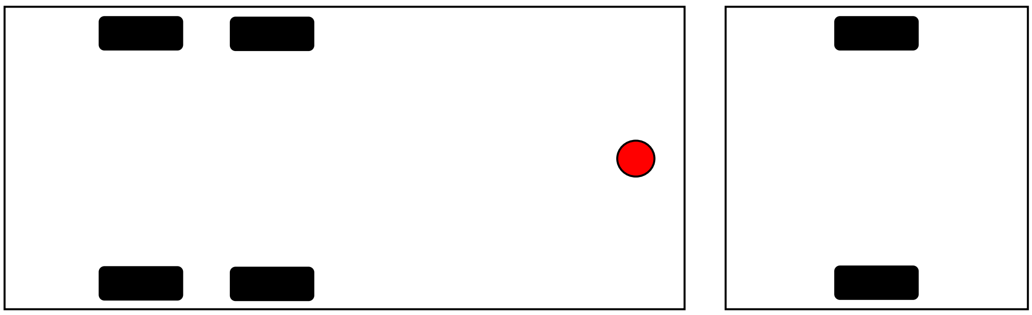

Fig. 2.
Placement of the Measuring Device on the T-810 DO AŠ Vehicle
Source: own

A three-axis accelerometer with the OM-CP-ULTRASHOCK-5 datalogger and a calibration certificate located in the front of the vehicle's load compartment (see figure 2) was used for measurement, where the measuring device could be conveniently placed using 4 neodymium magnets. It is clear from the graph in Figure 1 that the z-axis is shifted upwards by gravity acceleration. The measuring device records only values from 1g to 5g in the axis, although the official manufacturer's range is ±5g (Jakar, 2017). Therefore, two measurement errors outside the accelerometer measuring range can be found between the measured z-axis values:

- at 9:16:22 with a value of $c_z = -2.20$,
- at 11:18:52 with a value of $c_z = -5{,}75$.

Among the shocks generated by the driving style of each driver are very large differences in many cases that are visible to the naked eye in the graph in Figure 1 below. These differences are mainly due to various speeds which, together with the shocks in the individual axes (acceleration coefficients), are further investigated within the statistical analysis. Based on the time each driver required to pass the section and his knowledge of the length of the polygon, an average vehicle speed was indicated. In the direction forwards of the practiced polygon, the average speed ranged between: 25.4 – 42.0 km.h^{-1}, when backwards in the interval: 30.8 – 41.0 km.h^{-1}.

3. Statistical Evaluation

For the statistical evaluation, 24 sections of the polygon were measured by the 14 drivers in attendance. These sections are differentiated according to whether the transport was accomplished in a forwards or backwards direction. Some drivers completed only one direction and one section, while some drove both forward and backward. Depending on the sections passed (forwards and/or backwards), the drivers are marked as follows:

- drivers 1, 3, 5 – 14 as d_1, d_3, d_5 – d_{14} in the direction there,
- drivers 2, 4, 5 – 14 and d_2, d_4, d_5 – d_{14} in the direction back.

Within the framework of our statistical evaluation, variance analysis (ANOVA) was performed, with the distinguishing factor being the driver (d). The quantities tested were gradual absolute acceleration values (acceleration coefficients) in the axis x – c_x, in the axis y – c_y and in the axis z – c_z.
The hypothesis tested on the equivalence of the mean values of the tested quantities (in all three axes and in both directions) was rejected for each driver by $p < 2.10^{-16}$. This means that, for individual drivers, the difference in mean values of acceleration (acceleration coefficients) is statistically significant at a level α = 0.05. The Bartlett test of homogeneity of variances (Anděl, 2005) was also rejected, as it was also found that $p < 2.10^{-16}$.
From the above it follows that, for individual drivers, the differences in measured acceleration values (acceleration coefficients) are also statistically significant at the α = 0.05 level. In addition, it was determined in which driver pairs the differences in the mean acceleration coefficient (acceleration coefficients) in the individual axes are statistically significant. This was done by Tukey multiple comparison of means in HSD (honest significant difference) modification, which is intended for different numbers of observation of n_i and n_j in the compared groups (for individual drivers). The zero hypothesis $H_0\colon \mu_i = \mu_j$ is tested, compared to the alternative hypothesis $H_1\colon \mu_i \neq \mu_j$ ie. zero hypothesis claims, that mean values of compared groups i and j do not differ. The test criterion has a form:

$$Q = \frac{|\hat{\mu}_i - \hat{\mu}_j|}{S*},$$

where the standard deviation S∗ had a form:

$$S* = \sqrt{\frac{S_E}{2(N-I)}\left(\frac{1}{n_i} - \frac{1}{n_j}\right)}$$

The Q test criterion is compared again with the tabulated critical value $q_{1-\alpha}(I, N-I)$. If the value of Q is less than the critical value, then we do not reject the zero hypotheses concerning the equivalence of the mean values of the two groups being compared. This method is described e.g. in (Dubjaková, 2009). Statistical analysis was performed by using The R project for statistical computing.
The results of the statistical analysis – a multiple comparison of the mean values of the measurement set in the forwards direction are summarized in Table 1. Empty cells or missing letters (X, Y, Z, or x, y, z) indicate the absence of a statistically significant difference between the compared drivers, in one of these axes.
It is clear from Table 1 that driver d_1 and d_3 performed significantly "defensively", with lower acceleration coefficients than other drivers (d_5 – d_{14}) in all three axes. On the contrary, the "most aggressive", with the highest acceleration coefficients compared to most other drivers, were driven by drivers d_{14} and d_{11} as well as d_{12}.

Due to the relatively large variance in average passage speeds for some of the pairs of drivers, it was easy to assume that higher speeds would generate more shocks and higher acceleration coefficients in all axes measured. When comparing the results from Table 1 and the corresponding average speeds, this hypothesis is valid for most cases.

Only a few exceptions were identified when it was the opposite, as a slower driver generated an higher average acceleration coefficient in the axes than the faster driver:

- d_6 – d_5 in the z axis,
- d_7 – d_5 in the z axis,
- d_9 – d_5 in the x and z axis.

On the other hand, the significantly more "defensive" driving of drivers d_1 a d_2 against all other drivers corresponds to a significantly lower average speed. The average speed of drivers d_1 a d_2 was 26.0 km.h^{-1}, while the average speed of the drivers d_5 – d_{14} were more than 39% higher (36.1 km.h^{-1}).

Table 1
Comparison of Individual Drivers in Three Axes, Including Average Speed – Forwards

		d_j												v_j
	i\j	**1**	**3**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**[km/h]**
d_i	**1**	-		xzy	xzy	xzy	xzy	xzy	xzy	xzy	xzy	xzy	xzy	26.5
	3		-	xzy	xzy	xzy	xzy	xzy	xzy	xzy	xzy	xzy	xzy	25.4
	5	XYZ	XYZ	-	Z	Z	Z	X Z	X Z	xzy		Z	xzy	34.3
	6	XYZ	XYZ	z	-					xzy	x z		xzy	36.1
	7	XYZ	XYZ	z		-				xzy	xzy		xzy	34.5
	8	XYZ	XYZ	z			-			xzy	xzy		xzy	34.2
	9	XYZ	XYZ	x z				-		xzy	xzy		xzy	34.9
	10	XYZ	XYZ	x z					-	xzy	xzy		xzy	31.3
	11	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	-		XYZ		42.0
	12	XYZ	XYZ		X Z	XYZ	XYZ	XYZ	XYZ		-	X Z	y	39.8
	13	XYZ	XYZ	z						xyz	x z	-	xzy	34.2
	14	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ		Y	XYZ	-	39.8
v_i	**[km/h]**	26.5	25.4	34.3	36.1	34.5	34.2	34.9	31.3	42.0	39.8	34.2	39.8	-

Legend: d_i, respectively d_j indicates i-th, respectively j-th driver
v_i, respectively v_j indicates i-th, respectively j-th average speed on a given section
X, respectively Y, respectively Z indicates higher value at i driver, than at j driver
x, respectively y, respectively z indicates lower value at i driver, than at j driver
Source: own

The results of the statistical analysis - multiple comparison of the mean values of the set of measurements in the reverse direction are summarized in Table 2.

Table 2
Comparison of Individual Drivers in Three Axes, Including Average Speed – Backwards

		d_j												v_j
	i\j	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**[km/h]**
d_i	**2**	-	x z	xyz	xyz	x z	xyz			xyz	x z	xyz	xyz	30.8
	4	X Z	-	xyz	z		xyz			xyz		yz	xyz	33.5
	5	XYZ	XYZ	-		XYZ		XYZ	XYZ		XYZ	X Z		38.8
	6	XYZ	Z		-	X Z		X Z	XYZ		Z		xyz	36.9
	7	X Z		xyz	x z	-	xyz			xyz		y	xyz	32.1
	8	XYZ	XYZ			XYZ	-	XYZ	XYZ		XYZ	Z		41.0
	9			xyz	x z		xyz	-		xyz		x z	xyz	32.5
	10			xyz	xyz		xyz		-	xyz		xyz	xyz	32.2
	11	XYZ	XYZ			XYZ		XYZ	XYZ	-	XYZ			39.7
	12	X Z		xyz	z		xyz			xyz	-		xyz	33.2
	13	XYZ	YZ	x z		Y	z	X Z	XYZ			-	xyz	33.9
	14	XYZ	XYZ		XYZ	XYZ		XYZ	XYZ		XYZ	XYZ	-	39.4
v_i	**[km/h]**	30.8	33.5	38.8	36.9	32.1	41.0	32.5	32.2	39.7	33.2	33.9	39.4	-

Legend: d_i, respectively d_j indicates i-th, respectively j-th driver
v_i, respectively v_j indicates i-th, respectively j-th average speed on a given section
X, respectively Y, respectively Z indicates higher value at i driver, than at j driver
x, respectively y, respectively z indicates lower value at i driver, that at j
Source: own

Among the drivers who drove in the backwards direction there were not such extreme differences in average speeds as among those driving forwards. This is why the results cannot be clearly identified as "defensive" or "aggressive" drivers, as has been the case in several circumstances in the forwards direction

Nevertheless, it is clear from Table 2 that among the "more aggressive" driving with greater acceleration (values of acceleration coefficients) in all axes are among drivers d_{14}, d_5, d_8 and d_{11}. Thus the "defensive" drivers are d_2, d_{10} and d_9, as well as d_7, d_4 and d_{12}. Yet compared to d_2 they drove with significantly higher accelerations (values of acceleration coefficients) in the x and z axes. The pronounced hypothesis that the faster the driver, the greater the acceleration coefficients generated in all axes, in all cases, is without exception in the backwards direction.

4. Conclusion

Cargo securing is a transport area that is considered solved. Nevertheless, the various aspects of cargo securing are the subject of analysis by a number of expert publications that show that certain areas change over time and have not been given sufficient attention. Cargo securing from a general point of view, is based on road parameters. Empirically determined acceleration coefficients are well developed within the EU.

Yet certain deficiencies are statistically processed and averaged acceleration coefficients in individual axes may not correspond to reality, as evidenced by such publications as Vlkovský WMCAUS, 2017, Vlkovský Highway Engineering, 2017 or Vlkovský and Rak, 2017. A key factor is the assumption of a relatively "straight" road surface, which in fact may only correspond to motorways, highways and 1st class roads, provided they are at least in a relatively good technical condition.

If these conditions are not met, it will be necessary to fix the load for off-road transport, where the actual size of the resulting inertia forces acting on the load, the vehicle and the crew may be considerably larger than the EN 12195-1: 2011 standard and its related manuals. The problem of cargo securing can be analyzed either in actual conditions by measuring by the appropriate measuring device (accelerometer) with sufficient range and accuracy, or mediated through simulations, using MSC.ADAMS (Vlkovsky *et al.,* 2017). Both approaches have their advantages and disadvantages.

Actual measurement requires a strict setting of measurement conditions and a sufficient sample of transport that is always loaded with factors other than the roadway, such as the driving style, the technical condition of the vehicle and other relevant factors. The advantage is always with the output from actual situations on the basis of which practical case studies can be processed. Under actual conditions there are also a number of factors that cannot always be foreseen, but can negatively affect transport, the cargo, vehicle and crew.

The use of simulation software carries the risk of excessive abstraction. Furthermore, simulation-models are based upon the manufacturer's technical parameters, which cannot always be easily verified and, above all, correspond to the new (technically unused) vehicle. Their advantage is the creation of a model where a whole range of factors can be included, and it is consequently very easy to consider the effects of isolated groups of parameters, or to compare with actual situations.

Driving style is the subject of traffic psychology, where other factors are observed than shocks, such as fatigue and driver attention that can be potentially dangerous and cause road accidents. Considering the influence of driving style on the magnitude of shocks generated is not currently the subject of professional publications. Part of the models tested, which typically fall within one of the previous two areas, are the immediate or average speeds that affect the magnitude of the acceleration coefficients and therefore the magnitude of inertia forces generated during transport.

It is clear from the results that speed is a key factor in driving styles. The hypothesis has been confirmed that the higher the speed of the transportation (even in average) higher values of acceleration coefficients are generated. We assume that the minor exceptions identified in table 1 for drivers 6, 7 and 9 (d_6, d_7 a d_9), are mainly due to differences in momentary speeds. In the case of the "brake pedal - accelerator pedal" driving style, we may also assume higher values of the acceleration coefficients than for smooth driving. This area will be the subject of further analysis and transport experiments, along with possibly other potential effects such as driving techniques and steering wheel holding, driver response.

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VISIBILITY INDICATORS FOR INTERSECTION SAFETY INVESTIGATIONS

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Abstract: Visibility criteria are defined similarly in various international sources. Required sight distances usually depend on the traffic situation and on the speed of the major road. Sight fields must be clear of any obstacles. In practice it is unavoidable that some obstacles remain in the sight field. In order to assess the safety of the intersection, the obstacles and the degree of the problem caused have to be characterized numerically. The goal of this paper is to define visibility indicators which are capable to describe the problem caused by obstacles. These indicators are the hidden sight distance, the area of the hidden sight triangle, the hidden angle and the sight angle as well as their 3D counterparts. The paper will describe these indicators, their investigation methods and comparison as well as their application possibilities.

Keywords: road safety, road junction visibility, sight distances, point cloud.

1. Introduction

Intersections are dangerous part of the road network because the paths of different vehicles can cross each other here. Approaching to intersections drivers have to collect information about the traffic regulation, positions of other vehicles and decide quickly about entering the junction or not. If parts of the junctions are hidden, this could be a risky maneuver.

2. Sight Triangles

The sight triangle is the area that needs to be clear to safely cross the junction. According to an international survey by (Harwood *et al.,* 1998) there are different cases of sight triangles for intersections with no control, approach with YIELD control, STOP-controlled approach and drivers turning left or right onto the major road from a STOP-controlled approach. However, most of the guidelines or standards define just two case of triangles for YIELD and STOP–controlled intersections such as the German, the UK and the Hungarian one (Hartkopf *et al.,* 2012; TD 42/95, 1995; Fi *et al.,* 2004). These handbooks are based on similar principle but use slightly different parameters (Table 1.).
The first situation is the STOP-controlled intersection (Fig. 1.). The position of driver eyes is assumed to be three meters from the nearest edge of junction according to the Hungarian guideline. In case of 50 km/h velocity (which is the ordinary speed limit in built-up areas) the required visibility distance is 70 meter in both directions.

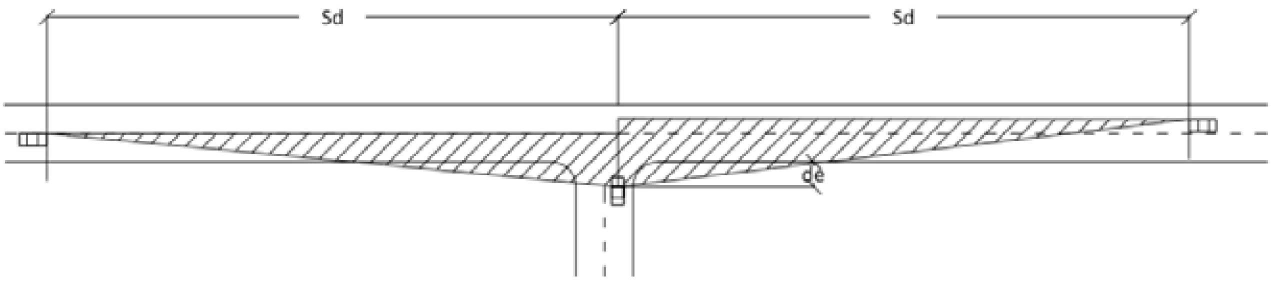

Fig. 1.
Intersection Sight Triangles
Source: own editing

In a YIELD controlled situation the driver's position is assumed to be located ten meters from the intersection and the necessary sight distance is larger. In both cases, the visibility distance was defined as the function of the speed (v) on the main road:

- Sight distance at STOP controlled junctions (Sd_s)
  $2v - 30 = Sd_s$
- Sight distance at YIELD controlled junctions (Sd_y)
  $2.5v + 10 = Sd_y$

v: speed (km/h)

In Table 1. the visibility parameters of three countries are compared.

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Table 1
Visibility Values Comparison Table

Visibility values comparison	UK	Hungary		Germany
Vertical sight field	0.26 m - 2 m	0.8 m-2.50 m		0.8 m-2.50 m
Height of car on major road		1 m		1 m
Height of driver's eye				
Car	1.05 m	1 m		1 m
Lorry	2 m	2 m		2 m
Distance of vehicle from the edge of junction (de)				
STOP control	9 m	3 m		3 m
Bicycle crossing		4.5 m- 5 m		3 m-5 m
YIELD control	15 m	10 m		15 m
YIELD control and significant lorry traffic		20 m		20 m
Sight distances along the major road [m]				
Design speed of major road		STOP control	YIELD control	
30 km/h		30	110	30
40 km/h		50	160	50
50 km/h	70	70		70
60 km/h	90	85	210	85
70 km/h	120	110 (175)		110 (200)
80 km/h		135 (210)	260	
85 km/h	160			
90 km/h		170 (250)		
100 km/h	215	200 (300)		
120 km/h	295			
The parenthetic values are suggested in case of 15% percent heavy goods vehicle traffic				

Source: Hartkopf et al., 2012; TD 42/95, 1995; Fi et al., 2004

For roundabouts, different countries use various approaches to visibility investigation. The Hungarian solution is similar to the US one. Roundabout sight distance ensures drivers can safely enter the junction without disturb the flow of traffic within the circulatory roadway. The entry field of view analyzed from 15 meters before the intersection. The left legs of the sight distance „triangle" are based on two conflicting approaches that are typically checked independently. First (d_1)*: "Entering stream, comprised of vehicles from the immediate upstream entry. The speed for this movement can be approximated using the average of the entering speed and circulating speed."* Second: (d_2): *"Circulating stream, comprised of vehicles that entered the roundabout prior to the immediate upstream entry. This speed can be approximated the speed of left turning vehicles "*(Robinson *et al.,* 2000).
Fig. 2. is showing the two positions of sight distances d_1 and d_2 and the manuals can give the length values.

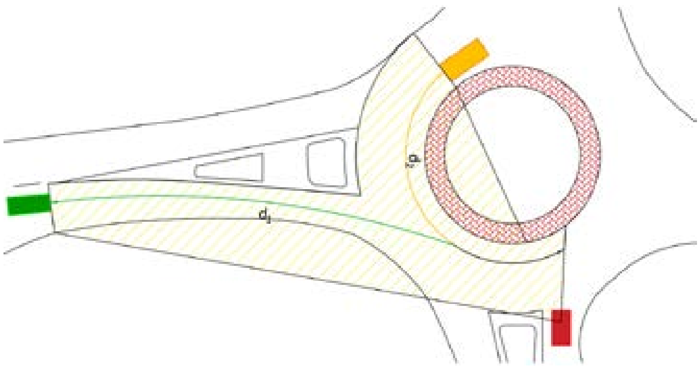

Fig. 2.
Sight Distances at Roundabouts
Source: own editing

According to another approach, the sight distance depends on the inscribed diameter; this approach is applied for example in the UK and in Austria. An interesting point can be found in the UK design manual: *„Excessive visibility to the right* [with left hand traffic] *can result in high speeds, potentially leading to accidents"* (TD 16/07, 2007).

3. Visibility Investigation with 2D Parameters

The previous chapter showed the definitions of the theoretically obstacle free parts of junctions which are required for safe crossing. However in real life in many cases objects or permanent obstacles are within the sight triangle, hiding a part of the investigated area. Temporary obstacles can be the vehicles, pedestrians, vehicles on the roadside, or a waste container that is just being emptied.
The hiding effect of each visual barrier can be edited if we have a plan view of the investigated intersection with the geometric shape of the visual obstacles. After editing, the following indicators can be set:

1. Hidden part of the sight distance (Sd);
2. Hidden part of the sight triangle area (Sa);
3. Angle of the hidden part (α);
4. Directional angle (δ).

The first three indicators are calculated from the total values from guidelines and the junction geometry. Further indicators can be derived by comparison of the total values with their hidden part.

5. Proportion of the hidden part of sight distance to the full sight distance (PSd).
6. Proportion of the hidden part of sight triangle area to the full sight triangle area (PSa).
7. Proportion of the angle of hidden part to the full field view (Pa).

Fig. 3. illustrates the theoretical effect of obstacles to the STOP-controlled sight triangle. On the left side of the picture a bush was created as an obstruction, which reduces the viewing distance of 70 meters to 22 meters. It reduces the field of view by 30 percent. The entering vehicle the on this side is not visible in this situation. On the right side a column was put, its hidden area much smaller than the shadows of the bush. The vehicle on the right is visible.

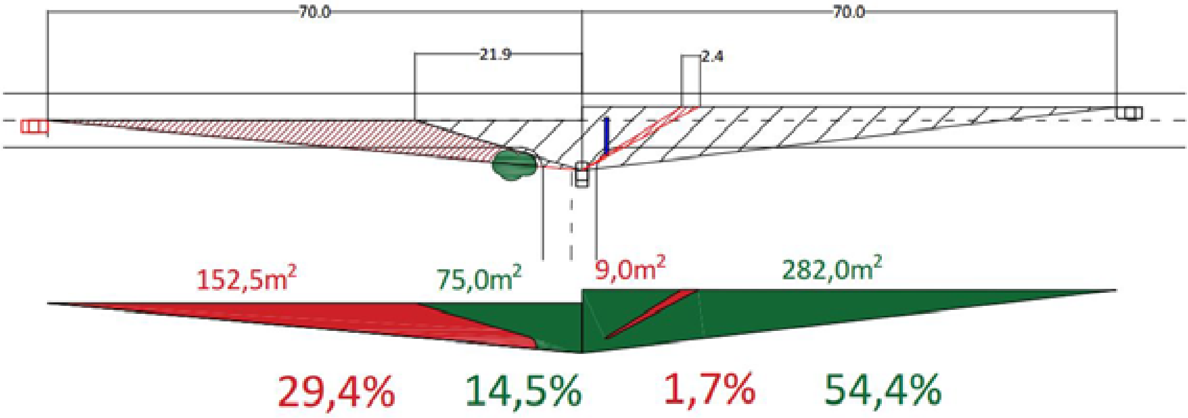

Fig. 3.
Effect of Obstacles to the STOP-Controlled Sight Triangle
Source: own editing

Furthermore, two angles can be defined to analyze the visibility obstacles to get more details. (Fig. 4.)

The angle of the hidden part (α) is a central angle for each object that shows how each obstacle reduces the field of view. From two same size objects the closer one causes larger hide. From two same size objects at same distance, the one on the edge of the field of view creates larger hidden length on the main road. The length hidden by the second blue circle is larger than the hidden length by the first one. For details the directional angle (δ) can be calculated as well.

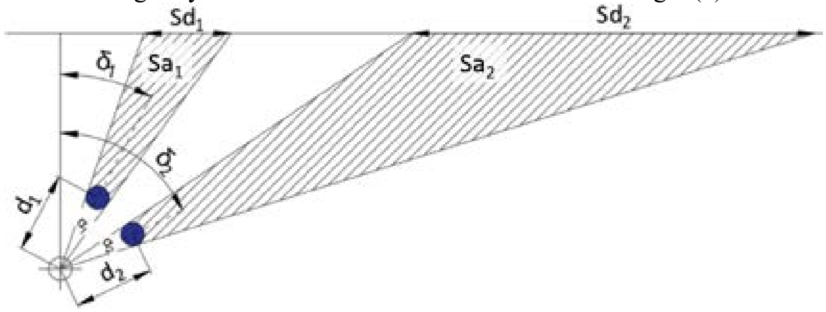

Fig. 4.
Two Dimensional Characteristic Parameters
Source: own editing

According to the situation shown in Fig. 4. the above defined seven indicators were measured or calculated. The results are in (Table 2). The proportion of the hidden part of sight distance and the proportion of the hidden part of sight triangle area are quite similar.

Table 2
Results of the Sample Situation

Visibility parameters	Sd [m]	Sa [m2]	α	δ	PSd	PSa	Pa
Total	140 m	519.4 m2	168°	from: -85° to: +83°	100%	100%	100%
Bush	48 m	152.5 m2	12°	73°-85°	32.3%	29.4%	6.5%
Pillar	2.4 m	9.0 m2	4°	77°-61°	1.7%	1.7%	2.4%

Source: own editing

4. Obstacles Hide Effect

The hidden part of the sight distance (Sd) depends on five parameters. First is the offset from the sight distance line to the driver's point of view. Second is the distance from the point of view to the center of obstacle (d). The rest are angle parameters: angle of the hidden part (α), directional angle (δ) and the junction connection angle (from minor road to major road). With the help of these five parameters the length hidden by the obstacle along the sight distance can be calculated. The angle of the hidden part (α) is definable from the hiding object size and the distance from the point of view.

Reversing the calculation, the directional angle (δ) and the distance from the point of view (d) value pairs can be derived which are able to cause a critical length of the hidden part of sight distance. Critical length on sight distance means a length which is able to totally hide another vehicle from the investigated point. The critical length is shorter in case of bicycle or pedestrian crossing. The next table (Table 3) contains the average sizes of vehicles length.

Table 3
Critical Lengths on Sight Distances

Critical lengths on sight distances	
Pedestrian	0.4 m
Bike	1.5 m
Car	3.5 m
Microcar	2.3 m

Source: own editing

Fig. 5. presents an example to show critical positions of a traffic sign pole with six cm diameter. The investigated situation is a stop controlled crossing, and the value pairs were calculated every 10 degrees directional angles and one-meter steps from the point of view. An ordinary car length of 3.5 m was marked with a red line in the diagram. According to the assumed situation, a pole placed two meters close and visible under 75° directional angle can hide fully a car. In practice, drivers may never notice that incident because the observed vehicle is moving and stays in

shadow for just one moment and the human brain can integrate the missing scenes. Probably a thin pole could not cause significant hiding in traffic, but it is suitable to model the obstacles hiding effect.
The presented seven indicators are characterizing the intersection's visibility just in a horizontal sense and examining the individual visual barriers according to their hiding effect. However visibility is a spatial question. If we look at a tree or a traffic sign, the extent of this objects can vary from bottom to top. In consequence the results of three-dimensional investigation will be different from the plane view. The next part is about the opportunity of the spatial visibility measuring and modelling.

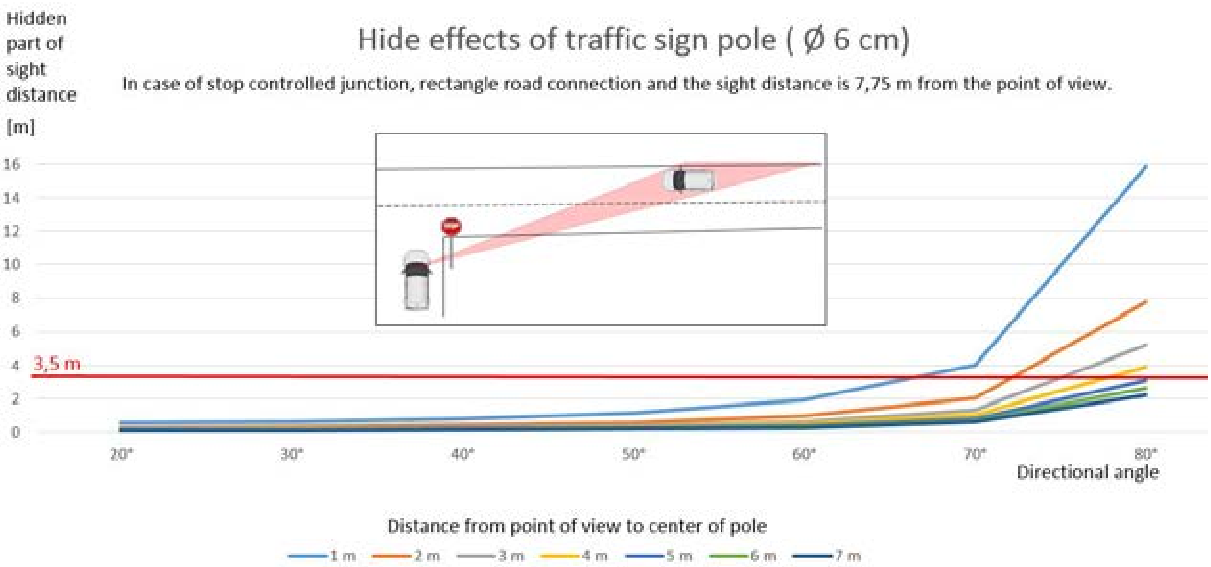

Fig. 5.
Hide Effects
Source: own editing.

5. Visibility Investigation with 3D Parameters

Survey technologies developed recently, like laser scanning and digital photogrammetry, are suitable to collect three-dimensional data to visibility investigation from a real intersection. The methods of remote sensing require fewer workforces and shorter time. The most important advantage of these tools is that the survey does not disturb the traffic, during the process surveyors do not have to enter the junction. Although the office work is longer, the preparation process requires large processing capacity, but tasks can be automatized. Other difficulty is the manual analysis, the point cloud processing software's are not specialized to complex drafting tasks. In Fig. 6. a point cloud model is shown of a railway crossing which was registered by laser scanner. The blue points are visible from the investigated point of view (the head of yellow arrow). To the analysis the Cloud Compare software and hidden point removal plugin was used. (Katz *et al.,* 2007)

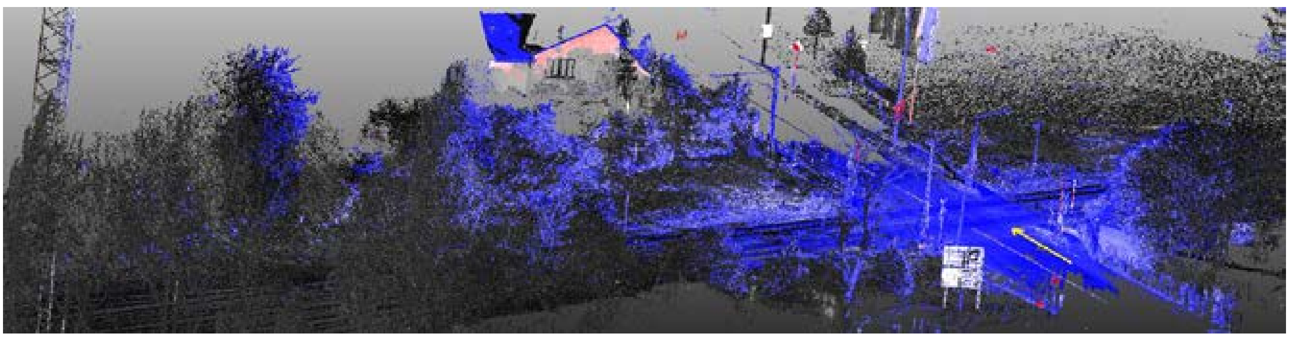

Fig. 6.
Visibility Analysis in a Point Cloud
Source: own editing

To the correct spatial visibility interpretation the two-dimensional indicators need to be extended to 3D. The following values are the horizontal indicators' three-dimensional counterparts except for direction angle, because the zenith is complete to spatial polar coordinates.
Three-dimensional indicators:

1. Hidden area of the sight plane (Sp);
2. Hidden volume of the sight pyramid (Sv);
3. Steradian angle of the hidden part (Ssr);
4. Directional and zenith angles (δ,z);
5. Proportion of the hidden area of the sight plane to the full sight plane area (PSp);
6. Proportion of the hidden volume of sight pyramid to the full volume of sight pyramid (PSv);
7. Proportion of the hidden angle of steradian to the field of view (PSsr).

The last three indicators can be derived from the first three.

Fig. 7.
Sight Plane
Source: own editing

The sight plane (Fig.7.) is a vertical surface in line of the sight distance and its level is between 0.8 m and 2.5 m height. The results of the analyses are hidden areas. If a hidden area is larger than a car, the hide causer object is a visibility obstacle. An example is shown in the next figure (Fig.8.). The red deficient surface is the visible part from the peak of the sight triangle.

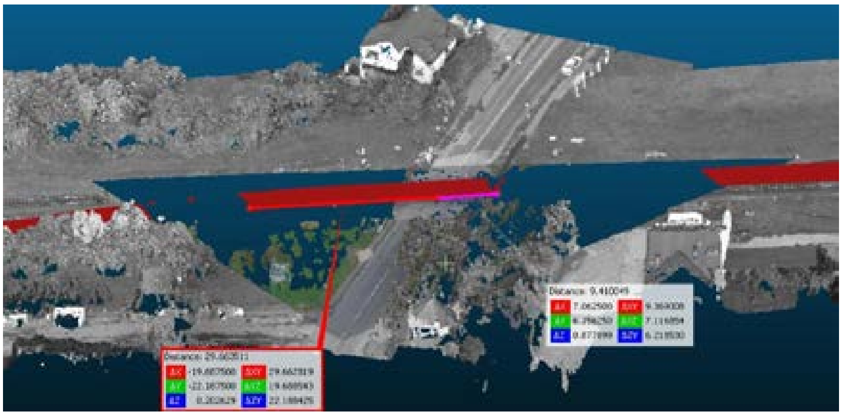

Fig. 8.
Visible Area of the Sight Plane
Source: own editing

These obstacles or a group of objects are problems which are able to fully hide one participant of traffic from the sight plane. Similarly to sight distances, critical area sizes can be defined. If an obstacle can cause larger hide then it is considered to be a visibility obstacle. Table 4. contains the suggested values of critical areas in the sight plane.

Table 4
Critical Areas in the Sight Plane

Critical area sizes in the sight plane	
Pedestrian	0.6 m^2
Bike	1.5 m^2
Car	3.5 m^2
Microcar	2.3 m^2

Source: own editing

The steradian or square degree are indicators to spatially characterize an obstacle from the aspect of how much it hides from the field of view. The advantage of steradian is to avoid units like radian and it is able to represent same hide of a smaller near and a larger remote object, similar than the angle of hidden part (a) in 2D investigation.

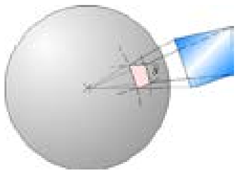

Fig. 9.
Steradian
Source: CC BY-SA 3.0 (From Wikimedia Commons, the free media repository)

The geometry is a body bounded by pyramid which is corresponding to the spatial sight triangle. Result of the investigation is the hidden volume of sight pyramid. The three-dimensional polar coordinates are directional angle (δ) and zenith (z) angle. These two together can define one spatial line. The directional angle is equal to the 2D version value, the angular distance from observer to obstacle. Zenith is a vertical angle from plumb line to the object.

3. Conclusion

Road design guidelines usually define required sight fields at intersections which must be clear of any obstacles. In practice this is not possible in many cases. This paper defines seven visibility indicators which are capable to numerically describe the problem caused by obstacles. These indicators are the hidden sight distance, the area of the hidden sight triangle, the hidden angle, the sight angle, the proportion of the hidden part of sight distance to the full sight distance, the proportion of the hidden part of sight triangle area to the full sight triangle area, the proportion of the angle of hidden part to the full field view as well as their 3D counterparts. The paper gives limit values to these indicators. Using these indicators the degree of visibility obstruction can be assessed.

Acknowledgements

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ROAD NETWORK TOPOLOGY AND ACCIDENTS IN HUNGARIAN CITIES

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Abstract: The paper aims at the investigation of the connection between accidents and the characteristics of urban street networks. There are several methods for the analysis of the street network in the cities. Possible indicators of the road network topology are the ratio of the type of the junctions, average distance between the junctions, and the connectivity and continuity of streets. In this paper cities and zones with different road networks were investigated comparing accident data. The main features of these zones are the location in the cities, the types of the buildings and the land use. Four categories of accidents were analyzed according to the participant: motor vehicle accident, pedestrian accident, bike accident and scooter accident. The results of the ratio and characteristics of the accidents are visualized in diagrams and cartograms. The data comes from accident analysis software and the results of the investigations were made using ESRI ArcGIS software.

Keywords: accident analysis, geographic information system (GIS), road network topology, Hungarian cities.

1. Introduction

The development of the cities and neighborhoods in the past was quite diverse. As a result, the current characteristics of cities and neighborhoods are also diverse. In a previous research the road patterns of housing estates were investigated (Hegyi, 2015). Their design principles and requirements have changed over time. The previous paper analyzed road networks using GIS in order to identify the differences. The indicators were defined on the basis of the nodes of the network (e.g. ratio of T and X junctions, ratio of dead-ends and connectivity index). This paper deals with several zones of eight Hungarian cities. The zones are of different characteristics (e.g. detached houses area, mixed area, housing estate). The road characteristics were investigated according to the topological indicators of the network. The goal of this investigation was to find the eventual relations between the road network topology and the accident frequency in some parts of the selected Hungarian cities. The accidents were categorized according to their participants. The ratios of the accident types are similar in most of the analyzed cities and districts. The bike accidents are high compared to their share in traffic. The road network topology of cities is not homogeneous; therefore the accident data are analyzed in homogeneous areas. Homogeneity refers to the road network topology of the districts and the characteristics of the buildings and land use.

2. Typical Road Networks in Hungarian cities

In the international literature there are some main categories and subcategories of road networks (Marshall, 2005; Wang *et al.*, 2017; Rifaat, 2012). These categories can be found also in Hungary:

- historic cores – irregular road network;
- grid pattern;
- loop pattern;
- cul-de-sac pattern.

The historic cores are the central part of the cities. Their road networks cannot be classified as a single road network category. Nowadays, in many cases these streets are traffic calmed, they are only accessible for pedestrians, cyclists or public transport. Their development largely depends on historical traditions (Ekler, 1994).
The Grid road patterns are an often used topology in cities. Their main features are the nearly regular and perpendicular streets with mostly X junctions. This pattern can be found mainly in detached houses, traditional-built and downtown areas.
The Loop and Cul-de-sac road patterns are mainly in housing estates in Hungary. Due to the intentional reduction of the traffic volume there are lots of dead-ends but these networks are well-pedestrian and bicycle-friendly. In the United States literature this type of networks are used in suburbs (Wang *et al.*, 2013).
Some examples of these types of road patterns in Hungary are shown in Figure 1.

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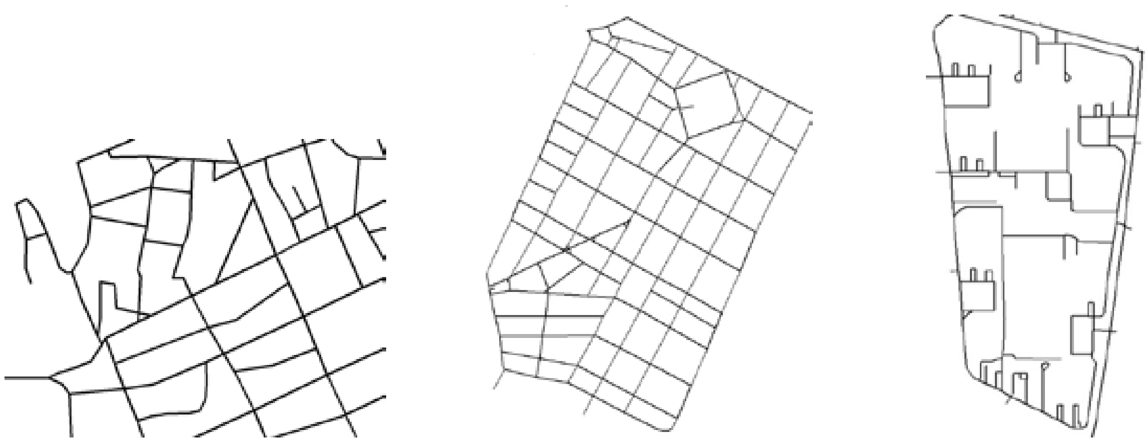

Fig. 1.
Road network of historic downtown in Győr (left), detached houses area in Szeged (middle) and housing estate in Debrecen (right). Scales are different.
Source: Own edition based on OpenStreetMap

3. Database

In this research the road network of eight Hungarian cities (100 000-210 000 inhabitants) were analyzed using Geographic Information System (GIS) tools. The map data come from OSM (OpenStreetMap). This is currently the only one free of charge available, up to date road map. Accident data come from the Hungarian accident analysis software 'WEB-BAL'. This software contains only accidents with personal injuries. These data were exported into an Excel table, based on which a shapefile in GIS was created. The time period investigated was from the beginning of 2011 until the 30.06.2017.

4. Method of Analysis

4.1. Geospatial Features

The road network characteristics were investigated according to the following indicators. These data can be easily calculated by using GIS software. They show the connectivity and the characteristics of the whole road network. The indicators are the following (Marshall, 2005):

- Node = Junction + Dead-end;
- Connected Node Ratio (CNR) = No. of Junctions / No. of Nodes;
- Connectivity index = No. of Links / No. of Nodes;
- Link-Junction Ratio;
- Ratio of T junctions [%];
- Ratio of X junctions [%];
- Ratio of dead-ends [%];
- Network density [km/sq km].

4.2. Accident Data

Accident data were analyzed for each city by accident types in the urban areas. The following categories were used during the investigation:

- motor vehicle accidents;
- pedestrian accidents;
- bike accidents;
- scooter accidents.

Cities do not have homogeneous road network topologies; therefore smaller, homogeneous road network topologies were also investigated. In this case the areas were compared according to their land use, population and location in the city.

5. Results

5.1. Results for the Cities

The population, accidents and the modal share of cyclists of the selected cities are shown in Table 1 (HCSO, 2016; SUMP, 2017).

Table 1
Population and modal share of cyclists in the eight cities

City	Population	Accidents/year	Accidents/year/ 100 000 population	Modal share of cyclists
Debrecen	203059	307	151	8 %
Szeged	162621	266	164	17 %
Miskolc	158101	183	115	5 %
Pécs	145347	185	127	5 %
Győr	129568	205	159	12 %
Nyíregyháza	118058	201	170	8 %
Kecskemét	111724	144	129	8 %
Székesfehérvár	100570	139	139	13 %

Concerning the accidents per population indicator, Miskolc is considered to be the safest city, while Nyíregyháza has about 1.5 times higher index. Each of these cities has a motorway bypass, so through traffic is not believed to be a factor. Further studies are needed to explain the differences.
Concentrating on cyclists, their share has higher differences; in Miskolc and Pécs it is only 5%, while in Szeged, Győr and Székesfehérvár is well over 10%. The low values of Pécs and Miskolc are clearly consequence of terrain; these cities are situated in hilly area. Six of the eight cities are situated in a flat area where bicycle is the ideal means of transport due to terrain and relative small distances. However, bicycle traditions (or the lack of them) also play a role, therefore Debrecen, Nyíregyháza and Kecskemét do not have very high values.
The four accident categories were defined according to their participants. The bike accidents category contains accidents where at least one of the participants is classified in this category. The share of accident types in the cities is shown in Figure 2.

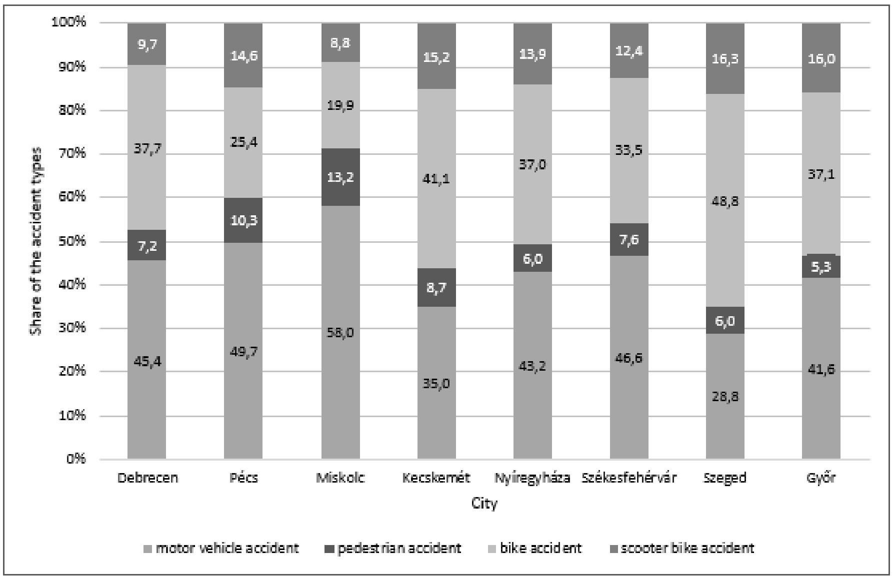

Fig. 2.
Share of the accident types in the analyzed cities
Source: own calculation based on WEB-BAL accident analysis software

For cyclists it is clear that their share in accidents (20-49%) is much higher in each city than their share in traffic (5-17%). E.g. in Debrecen the cyclists' share in accidents is 33.7%, while in traffic it is only 8%. In order to assess the differences, a new indicator was calculated called *Cyclists' risk index*, which is the share of cyclists in accidents / share of cyclists in traffic. The share of cyclists in accidents in Debrecen is 33.7 / 8 = 4.7 times higher than their share in traffic.
Figure 3 shows the cyclists' risk indexes of the cities. The three cities with the lowest risk index (Székesfehérvár, Szeged and Győr) are those where cyclists have the highest share in traffic. This is presumably due to the circumstance that these cities have better cycle infrastructure, and in addition here other road users are more aware of cyclists than in cities with less cycle traffic.

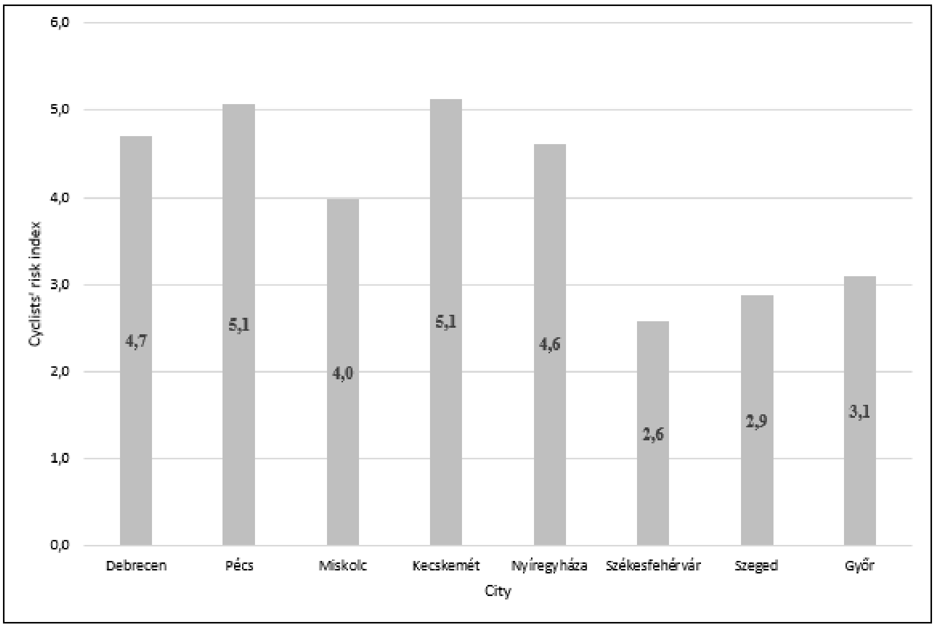

Fig. 3.
Cyclists' risk indexes of the cities
Source: own calculation based on WEB-BAL accident analysis software

5.2. Results for the Districts

The road network topology of the cities is not homogeneous; therefore one of the eight cities (Győr) was selected for more detailed study. Eleven zones were selected, where the number of the personal injury accidents was at least 20 during the analyzed period. The values are between 28 and 87. The main geographical features and the accident data of the investigated districts are shown in Table 2.

Table 2
Main GIS features and accident data in the selected districts of Győr

Main features of the zone	Adyváros	Marcalváros 1	Dél-Nádorváros	Kelet-Nádorváros	Nádorváros	Révfalu	Újváros	Győrszentiván	Ménfőcsanak	Szabadhegy	Sziget
Type of the area	housing estates		traditional built-up areas			mixed areas		detached houses areas			
Area (sq. km)	0.8	0.6	0.7	1.1	0.8	1.2	0.8	6.1	6.7	3.6	0.7
Ratio of dead-ends (%)	37.4	27.1	11.7	14.3	10.4	13.0	6.0	8.8	21.5	14.6	23.9
Ratio of T junctions (%)	59.0	61.0	66.7	63.5	64.6	75.4	74.0	71.9	68.1	69.2	67.1
Ratio of X junctions (%)	3.6	11.9	21.6	22.2	25.0	11.6	20.0	19.3	10.4	16.2	9.0
Connectivity Index (CI)	1.25	1.42	1.67	1.78	1.62	1.49	1.92	1.55	1.30	1.68	1.41
Number of accidents	41	38	63	87	50	36	29	32	39	50	28
Number of accidents / sq km / year	7.9	9.7	13.8	12.2	9.6	4.6	5.6	0.8	0.9	2.1	6.2
Share of motor vehicle accidents	29.6	36.0	38.8	25.7	31.0	35.5	48.0	32.1	40.0	48.8	31.8
Share of pedestrian accidents (%)	11.2	12.0	0.0	7.6	4.8	3.2	8.0	3.6	2.9	9.8	0.0
Share of bike accidents (%)	44.4	44.0	51.0	47.0	52.4	41.9	24.0	39.3	37.1	24.4	40.9
Share of scooter accidents (%)	14.8	8.0	10.2	19.7	11.9	19.4	20.0	25.0	20.0	17.1	27.3

There is a significant difference among districts concerning the ratio of the junction types. The connectivity index, which represents the interoperability of the road network topology, is shown in Figure 4. This index was calculated based on road network accessible by motor vehicles, excluding pedestrian areas.

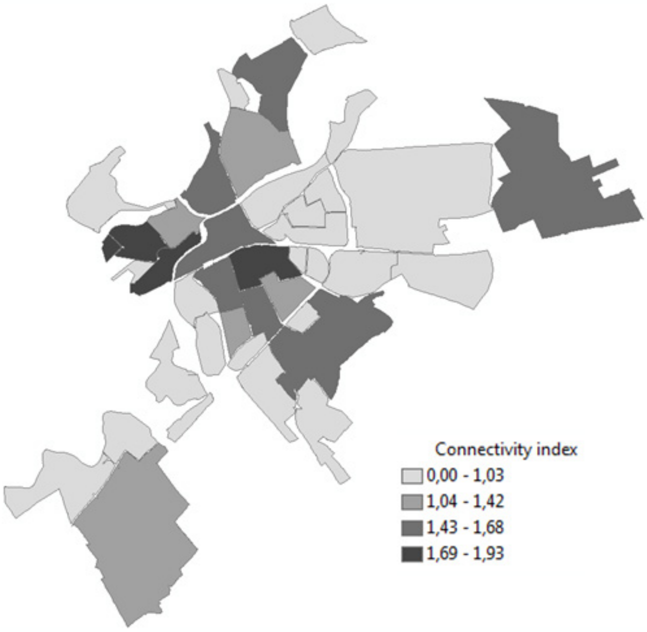

Fig. 4.
The values of the connectivity index in all zones of Győr
Source: Own calculation based on OpenStreetMap

Two housing estates were selected for comparison. They were built in different times (Hegyi, 2015). Adyváros is situated eastward, it is the most densely populated district in Győr and it was built in the 1960s, while Marcalváros I. ten years later. The characteristics of the buildings are similar: mainly four and ten story houses. The road pattern characteristics are different in these zones. This was mainly due to the increase in motor vehicle traffic. The previously constructed housing estate has a lower connectivity index (1.25), but also the later one has a relatively low index (1.42). Both areas have a main road with high traffic. The bike accidents have the highest share (44.4 and 44.0 %), while share of motor vehicle accidents is 29.6 and 36.0 % resp. Despite the different road network topologies, accident characteristics are almost identical.

Fig. 5.
Location of the investigated housing estates
Source: Own edition based on OpenStreetMap

The three selected traditional built-up areas are situated close to the city center. The characteristics of the buildings are mixed: closed-frontage or freestanding. The ratio of dead-ends is lower, and the ratio of the X junctions is higher compared to housing estates. These zones have higher connectivity index (1.67, 1.78 and 1.62) which shows greater interoperability. The order of the accident categories is the same in the three districts: the share of cycling accidents is here the highest in the city, while the share of pedestrian accidents is low. The network topologies of these zones are shown in Figure 6.

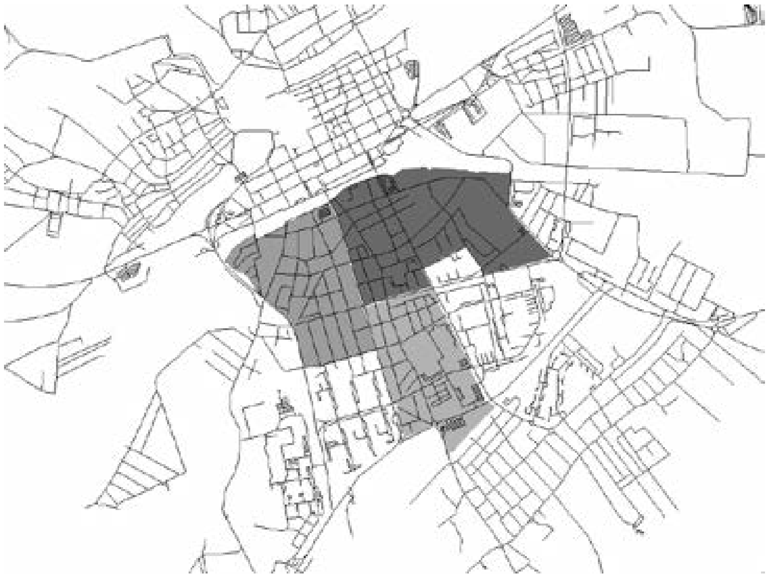

Fig. 6.
The location of the investigated traditional built-up areas
Source: Own edition based on OpenStreetMap

The analyzed detached houses areas are well separated from other districts, their development is similar to each other. Both districts existed as a separate village, and due to the development and growth of Győr, nowadays, they are two districts in the city. Today there is no significant through traffic in these districts. Figure 7 shows the location of the two districts and their road network.

Fig. 7.
Locations of the analyzed detached houses areas in Győr
Source: Own edition based on OpenStreetMap

The sizes of the areas are similar in the both detached houses areas. Győrszentiván is situated in the east part of Győr. It has a grid type road pattern, the ratio of dead-ends is low and the ratio of the X junctions is high. The ratio of the T junctions is similar in the both districts. Ménfőcsanak is situated in the west part of Győr. The road network connectivity is lower than the average of the districts. The main difference of the street network is the high ratio of dead-ends compared to the other district, which is due to the terrain constraints.
The share of the accident types are similar in both districts; motor vehicle accidents and bike accidents are about 35-40 %. In spite of the different network topologies, there are no significant differences between the shares of accident types. The share of pedestrian accidents is quite low, as due to the distances people use bikes or car rather than walking.

6. Conclusion

Comparing the selected eight cities it was found that despite the different geographical conditions, the accident per inhabitant figures are quite similar in these cities. However as cycle usage and accidents are concerned, there are larger differences. A cyclists' risk index was defined as the ratio of their share in traffic and in accidents. It was found that the cities with the lowest risk index are those where cyclists have the highest share in traffic. This is presumably due to the circumstance that these cities have better cycle infrastructure, and in addition here other road users are more aware of cyclists than in cities with less cycle traffic. Other cities could learn from the forerunners.

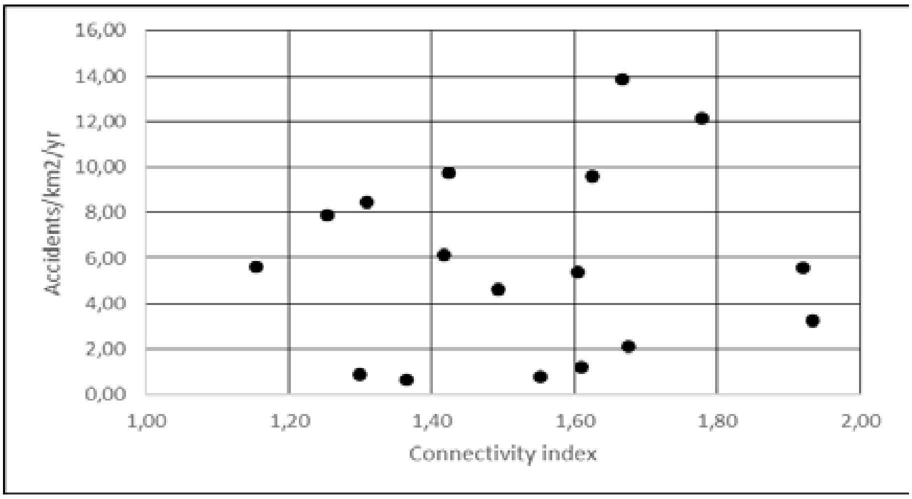

Fig. 8.
Connectivity index and accident densities in the analyzed zones of Győr
Source: Own calculation based on OpenStreetMap and WEB-BAL accident analysis software

Comparing the selected districts in Győr, it was found that there are significant differences among them concerning street patterns and the shares of accident types. To sum up the results for the districts of Győr, Figure 8 shows their relative accident figures (accidents/sq.km/year) against their connectivity index. From this data no correlation between road network topology and accident rate can be found.
In this paper no traffic data were used in order to concentrate on network topology. It was found that the network structure alone is not able to explain differences in accident densities, traffic data are inevitable.

Acknowledgements

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EVALUATING 3-D SIGHT DISTANCE AT URBAN INTERSECTIONS USING A LIDAR-BASED MODEL AND CONSIDERING MULTIPLE USERS

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Abstract: The provision of sufficient available sight distance along the road reduces the potential for conflicts among its users. Consequently, sight distance estimations are significant components of road safety analyses. Evaluating sight distances on existing roads, when not performed in situ, requires up-to-date representations of the roads' geometric properties and roadside elements. For some time now, LiDAR instruments have been used to gather geospatial data needed to generate updated models of the roadways and roadside elements. Digital terrain models (DTM) have been widely utilized to perform sigh distance estimations, despite the fact that these models only account for the road surface and bare terrain. On the other hand, Digital Surface Models (DSM) which provide further information of features, namely vegetation, traffic signs, buildings and other manmade elements, yield inaccurate results when some elements protrude or project over roadway areas like cantilevered signs, tree branches and in the presence of complex above ground features. The authors have previously proposed a methodology to overcome this inaccurate representation of road assets and surrounding elements utilizing Geographic Information System (GIS) tools and 3-D geometries on top of the DTM so as to represent possible visual obstructions. In this analysis, the available sight distance of an urban intersection located in Madrid (Spain), is evaluated considering its prevalent motorized vehicles. Virtual trajectories of pedestrians and cyclists were modelled in order to assess the impact of road surrounding objects in their available sight distance. Furthermore, the separate consideration of 3-D objects allows the possibility of assisting decision making processes concerning the location of urban furniture while assuring proper visibility.

Keywords: LiDAR-derived models, Intersection sight distance, GIS, road safety.

1. Introduction

As it has been stressed in road geometric design guidelines, in order to make road transportation safe and efficient, drivers ought to have the ability to visually discern lengths of road ahead so as to perform specific maneuvers effectively (AASHTO, 2011; Fomento, 2016). Crossing, stopping and passing are just some of the driving tasks that require adequate distances to be accomplished safely and for which road transportation agencies have defined minimum values. These values are meant to be compared against the available sight distance (ASD) and based on their comparison, when requirements are not met, measures are taken, or actions performed. Amongst the different kinds of road elements and settings, at-grade urban intersections are considered to be one of the most complex sections, given that they usually include high traffic volumes and multiple road users in a variety of movements including conflictive ones (AASHTO, 2011). In this sense, by providing sufficient intersection sight distances (ISD) designers intend to allow drivers to identify potentially conflicting vehicles, physical elements and non-motorized users. Along with the ISD, sufficient stopping sight distance (SSD) is a key feature of safe intersection functioning.

Sight distances provided during the design stage are to be verified on in-service roads given that possible changes on speed limits could occur and considering the dynamic nature of road surroundings. These measurements can be carried out in situ, statically (with operators on the road measuring maximum unobstructed sight lines) or dynamically (car following another while checking sight distance values). Off-site estimations have mainly been executed utilizing photo or video-logging and Mobile Mapping Systems (MMS). Some of these procedures consider horizontal and vertical alignment separately which several researchers have found to possibly misestimate the existent ASD (Hassan et al., 1996; Ismail and Sayed, 2007).

With respect to roadside features, urban roads environs experience changes from existing or new vegetation, manmade structures and also from the recent increase, in dimensions and amount, of street furniture as a result of higher connectivity and smartness in several cities.

When measuring the ASD on existing roads off-site and making use of 3-D geospatial data, accurate representations of the road geometric definition and roadside elements are needed and might be obtained from many sources. In recent times, LiDAR systems have been intensively used to acquire information of the roads given that they allow the rapid acquisition of up-to-date and precise data. This scanning technology has shown to be very useful and able to provide georeferenced data with enough resolution and coverage area to perform many transportation analyses. For these and other reasons many authors have utilized LiDAR derived products to carry out ASD estimations. Some of these authors have utilized the resulting point cloud to perform the calculations on them (Campoy Ungria, 2015; González-Jorge et al., 2016) and others generate 3-D models (Castro et al., 2011; de Santos-Berbel et al., 2014; Gargoum, 2017). Researchers making use of digital models can be differentiated by the type of model employed; some utilize Digital

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Terrain Models (DTM's), which only represent the road geometry and bare ground, and others make use of Digital Surface Models (DSM's) which include roadside features along with the terrain. In view of the fact that some data structures used to store DSM's only show one elevation per planimetric position, Iglesias-Martinez et al., (2016) proposed the use of 3-D objects on top of the DTM's in order to establish a more realistic representation of the road and roadside features. Not only this proposed procedure allows the simulation of feature location or removal, useful to evaluate their possible effects on overall sight distance, but also makes possible the consideration of different trajectories. This permits the inclusion of non-motorized road users such as pedestrians and cyclists in the analysis.
The use of Airborne Laser Scanning (ALS), Terrestrial Laser Scanning (TLS) and Mobile Laser Scanning (MLS) systems has been widespread in the transportation field for some time now. Within the literature on sight distance estimations utilizing LiDAR scanners one can notice that each of these systems have been employed: ALS (Khattak et al., 2003; Khattak and Shamayleh, 2005; Castro et al., 2015), MMS (González-Jorge et al., 2016; Olsen et al., 2016) and TLS (Jung et al., 2018). Each system benefits from their different capture mode, area covered, point cloud distribution among other characteristics. In this regard, this study makes use of a TLS's given that urban intersections tend to suffer from elements obstructing the laser beam's way to the pedestrian area and segregated cycling infrastructure due to parked vehicles, passing pedestrians, vegetation, bus stop shelters and other street furniture elements, when covered with MMS.
Considering these facts, the main goal of this paper is to evaluate the available sight distance of an urban intersection, taking into account its prevalent users. This is accomplished exploiting the geoprocessing model based on GIS tools presented by Iglesias-Martinez et al. in 2016 and making use of TLS acquired LiDAR data. In order to account for its main users, as well as their potential obstructions, distinct trajectories and scenarios have been set up. Roadside features are modelled as 3-D objects obtained from a LiDAR-derived model and also as adaptations of tridimensional objects acquired from online libraries.
This paper is organized as follows: the next section provides a description of the procedure utilized, case study, scenarios and users. Results are shown in the third section, and lastly the conclusions.

2. Materials and Methods

As previously mentioned, intersections are complicated road areas requiring reciprocal visibility between users. In order to ensure that accurately, a 3-D procedure that gauges the impact that roadside elements could have on their visibility is carried out. Just as intersection design requires, this evaluation covers the functional roadway and adjacent sidewalks. Resulting ASD values are to be compared with the required stopping and intersection distances in order to assess how safely these maneuvers could be performed in the study area.

2.1. Procedure

The overall methodology comprises the projection of lines-of-sight from the indicated observer to distinct targets, its own path and conflict points. As described by Iglesias-Martinez (2016), this procedure makes use of geospatial analysis functionalities from the ArcGIS software, mainly the Line Of Sight and Construct Sight Line tools. Based on these and other functionalities, a geoprocessing model was built utilizing the ModelBuilder application, also from ArcGIS. This model obtains the observer and target points' precise coordinates from the given trajectory, defined by equally spaced points, and calculates if the terrain surface, road configuration or any aboveground feature interrupts the line of sight from observer to target. The process is carried out launching sight rays repeatedly from the observer's path and onward.
The data required to implement the procedure encompasses the observer's trajectory, the digital model, and optionally 3-D objects standing as potential obstructions. The observer's trajectory was depicted by the theoretical paths of a car, cyclists and pedestrians, defined for each possible movement at the case study intersection. These paths were digitalized from existing cartography of the road and in conjunction with the well-defined cross slope of the road, whose camber indicated its centerline, acquired from the point cloud-derived DTM. The terrain model utilized was generated from the LiDAR point clouds, scanned utilizing the TLS system Leica C10. The equipment was placed in planned locations around the intersection so as to cover the area of interest. These planned location's coordinates were obtained from a prior GNSS survey. Horizontal and vertical point spacing was set to be 0.05 m. The resulting cloud contained 39.1 million points. After the data pre-processing stage, carried out utilizing the software Leica Cyclone 9.0, the resulting registered and georeferenced point cloud was processed utilizing the software MDTopX (Digi21, 2018). Points classified as ground were utilized to generate the DTM. In addition to the DTM, a 3-D multipatch file was obtained from the point cloud encompassing aboveground features such as foliage, surrounding vegetation, street assets and traffic signals (fig. 1). The multipatch geometry, developed by Esri in 1997, is a geospatial data format utilized to portray the outer surface of three-dimensional features (Esri, 2018). The traffic signal and bus stop, considered to be potential obstructions, were obtained from 3-D objects libraries, adjusted to their real measurements (from field measurements), and inserted in their exact position as multipatch files. These modifications were performed utilizing SketchUp (Trimble, 2018) and the positioning in ArcScene.

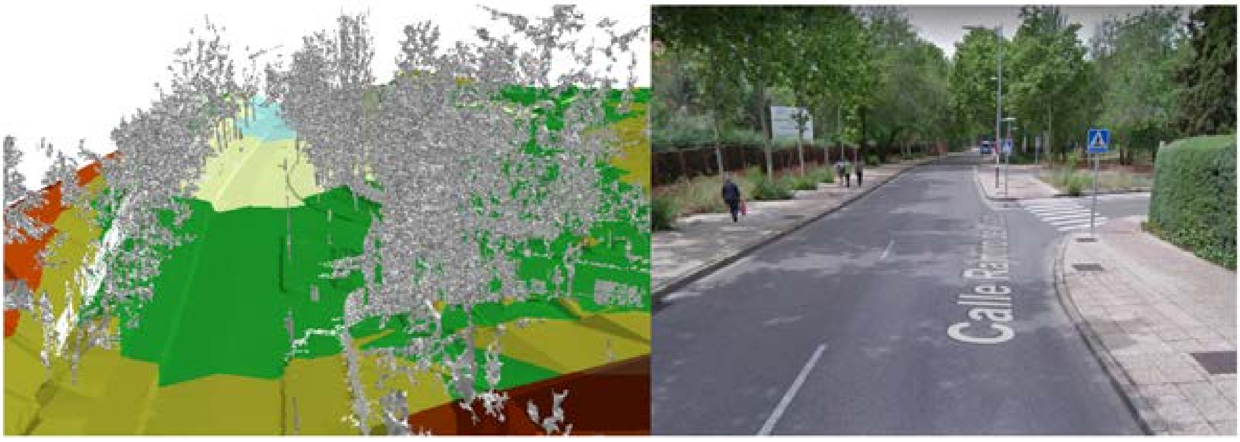


Fig. 1.
Multipatch on top of DTM (grey features)

2.2. Case Study

The 3-way, skewed intersection under study is located in the university district of Madrid (Spain). Intersecting roads are the one-way Ramiro de Maeztu (main road) and the two-way Moreras av. Both roads encompass a mean width of ~6.55 m and posted speed limit of 40 km/h. This raised channelized junction is controlled with stop signals on the minor road. Given the geometry of the intersection and the presence of a one-way road, only right turns and merging movements are possible, hence only diverging and merging conflict points were analyzed. Along the intersection's functional area, the horizontal alignment of both roads is composed by straight segments forming a ~62º skew angle junction. Regarding the vertical alignment, both roads feature grades of 5.3% and 4.2% respectively. This downgrade along Ramiro de Maeztu contributes to operating speed increases, which could reduce the user's time to anticipate and avoid potential conflicts. Figure 2 presents, on the left, an orthogonal and rotated view of the intersection and on the right its conflict points and possible movements. Stop, pedestrian crossing and diverging road signs are located around pedestrian-to-vehicle conflict points, before the minor-to-major road right turn, and in the channelization. The intersection's functional area contains two bus stops along both streets. One is a bus stop shelter and the other is a timetable displayer pole.

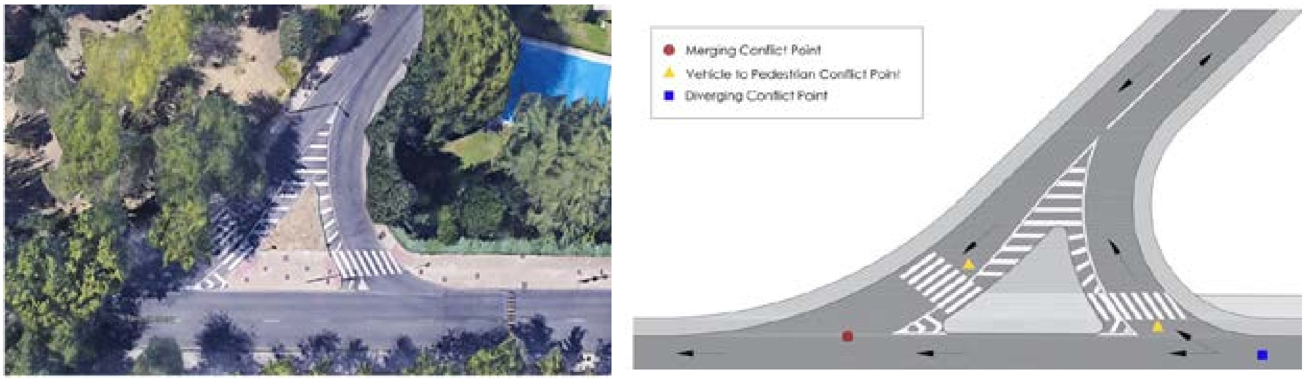


Fig. 2.
Junction under study

As abovementioned, all possible turns at the intersection were evaluated for its customary users and their potential obstructions. Its main users were considered to be pedestrians, cyclists, and passenger cars. Buses were not evaluated due to the advantages in visibility their driving height provides. As typical of an intersection located in a university district, customary pedestrians, transit users, and cyclists are mainly students.

Pedestrians trajectories were defined in the center of the sidewalk. The eye's height of a mobility impaired pedestrian was set to be at 1.5 m high plus another height of 1.7 m.

When sharing the road, cyclists are advised to transit in the center of the lane, but one must consider their meandering movement, required to maintain balance, which will be smaller with greater speeds. For regular speeds, between 15 km/h and 30 km/h, it is considered that the width needed by a cyclist in motion is 1.00 m. Taking these facts into account, two trajectories 1.00 m apart from the center of the lane were contemplated as the virtual trajectories of cyclists, at a height of 1.4 m as specified in the Guide for the Development of Bicycle Facilities (AASHTO, 2012). Drivers trajectories were placed 1.5 m away from the left inner side of the lane.

The first set of cases analyzed correspond to a straight downhill trajectory through Ramiro de Maeztu's street (blue arrow fig.3a). Here, the visibility of observers going downward is assessed in other to determine if the bus stop or traffic signs prevent them from noticing an approaching vehicle downward the Moreras street (red arrow fig. 3a). The second set of cases assessed observers turning right from Ramiro de Maeztu. Here the proper spotting of the pedestrian's crossings was assessed (fig. 3b). The third set of cases evaluated the visibility of observers going into Ramiro de Maeztu's street from Moreras (blue arrow fig. 3c). It was evaluated whether reciprocal visibility among them was provided and if the bus stop-shelter or street signals had any or important effects on it. Forth set of cases assessed pedestrians' visibilities with trajectories defined along the sidewalk; this case evaluated from which distance oncoming vehicles were spotted by distinct types of pedestrians. All sets contemplated 3 scenarios; the first one without bus stop-shelter, so as to evaluate its impact on the junction's functioning, the second one with the bus stop-shelter located at its exact coordinates and a third case where the bus stop is located where it provides the best overall visibility. The bus stop-shelter evaluated is located 35 m from the intersection in the direction sketched in fig 3a.

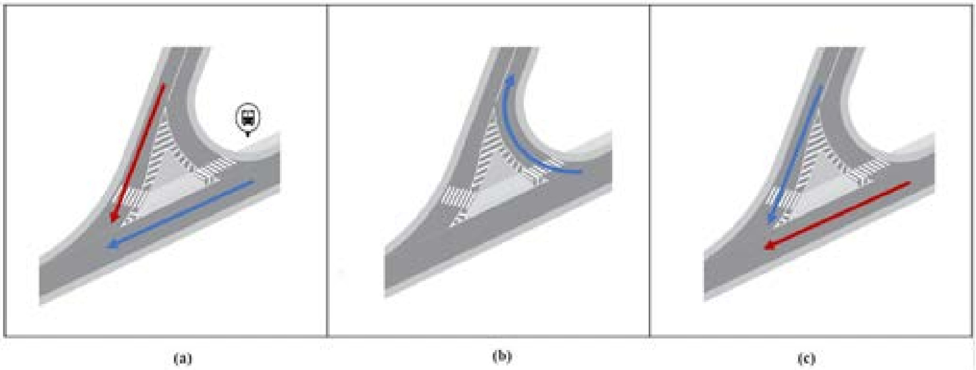


Fig. 3.
Turns under study

Both stopping sight distance (SSD) and intersection sight distance (ISD) where evaluated for drivers and cyclists, comparing calculated values to available ones. Stopping sight distances were carried out considering the observer's height above the roadway at 1.08 m, and that of the target at 0.6 m (AASHTO, 2011). When contemplating a cyclist, the target's height was considered to be 0.15 m (AASHTO, 2012). The SSD was determined in consistency with the expression provided by the AASHTO, equation 1.

$$SSD = 0.278V_t + \frac{V^2}{254\left[\left(\frac{a}{9.81}\right) \pm G\right]} \tag{1}$$

Where: V is the design speed; t is the brake reaction time of 2.5 s; a is the deceleration rate of 3.4 m/s and G the downgrade slope.
As stipulated in the guidelines, clear sight triangles providing a free view of the entire intersection are fundamental for its correct functioning. This triangle was assessed for the right turning from the minor road. The departure point of the triangle on the minor road (Moreras) is recommended to be from 4.4 to 5.4 m from the edge of the major road, according to field observations (AASHTO, 2011). The length of the triangle is defined as the total distance from the main road plus half its lane width (for vehicles approaching from the left); the base of the triangle is defined by the ISD, which can be determined according to the expression provided by the AASHTO (equation 2).

$$ISD = 0.278\, V_{major} \cdot t_g \tag{2}$$

Where V_{major} is the design speed of the major road and t_g is the time wrap for minor road vehicle to enter the major road, which is stipulated to be 6.5 s for passenger cars.

3. Results

This section presents the main findings of the evaluation. A total of 36 cases with different combinations of users, turns and potential obstructions were calculated and are introduced as follows: first SSD results, subsequently the ISD's and lastly pedestrians'. SSD assessments were aimed at locating any obstacle, from the road geometry or roadside elements, that could hamper the observer's perception of a specified target on their path. ISD focused on assessing the observer's capacity of visualizing conflict points which could be on their traversed road or not. Evaluation of pedestrians assessed the possibility of noticing approaching vehicles from a reasonable distance.

3.1. SSD

Stopping sight distance values were obtained for each road utilizing their posted speed limit and downward/upward slope, these values are displayed in table 1. Passenger car drivers' SSD was obtained at 40 km/h and that of the cyclists 30 km/h.

Table 1
Required SSD along the intersection

Observer	Calculated SSD downward main road (m)	Calculated SSD (m) upward minor road	Calculated SSD (m) downward minor road
Drivers	49.03	44.01	48.48
Cyclists	44.06	40.21	43.63

Sight-distance graphs are shown and discussed below for the least favorable cases; each chart shows stations on the horizontal axis and the ASD on the vertical. Figure 4 shows on the left considered stations and the right displays results. The ASD obtained is shown for two scenarios, the blue line denotes those obtained considering the bus stop-shelter and the red one shows the distances obtained without it. The green line exhibits the calculated-required SSD. As seen the turn is provisioned with enough SSD and the impact of the shelter is not substantial, hence scenario 2, with the bus stop relocated, was not presented. Cyclists evaluations carried out for this movement showed similar results, provisioning of the SSD and not exceptional differences caused by the bus stop.

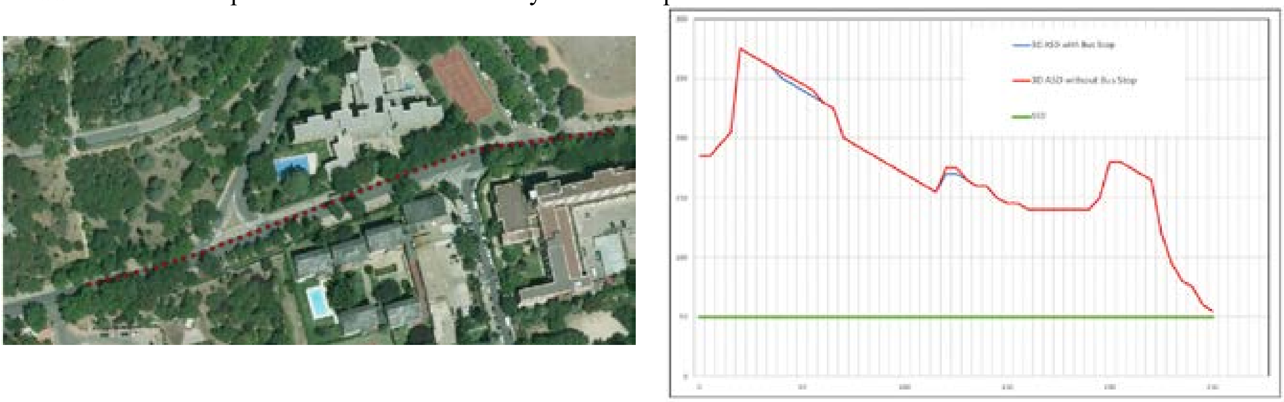


Fig. 4.
Results of the SSD estimations for observers downhill main road

The defined trajectory for the second set of cases, which considered drivers and cyclists turning left from the main road, is displayed in fig. 5 (left). On the right, the outcomes of drivers through the right turning. As before, the blue line shows the values of the ASD estimated considering the bus stop-shelter and the red without its inclusion. The graph shows a logical decrease in the ASD values due to the horizontal curve and roadside vegetation. Cyclists showed similar outcomes for their two considered trajectories, decreasing ASD as approaching the turning and sudden increasing after it.

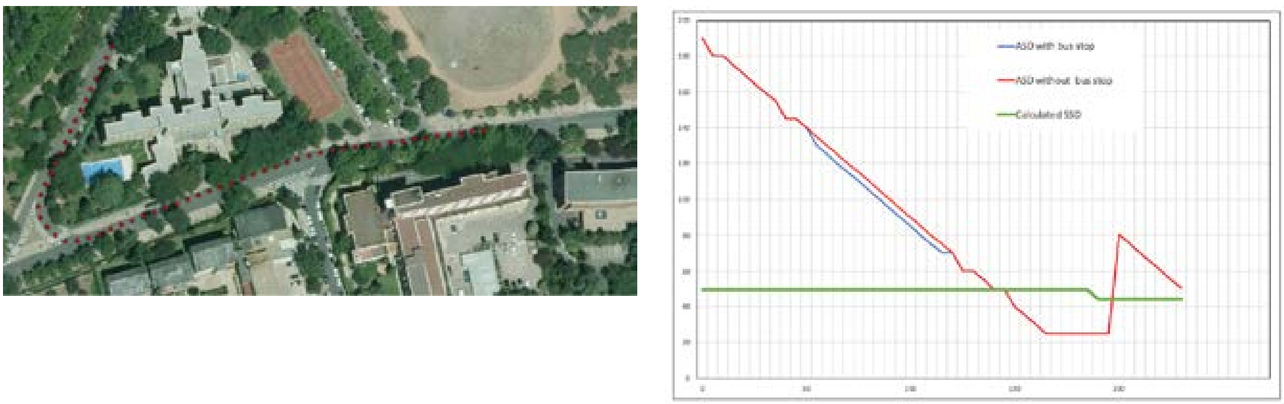
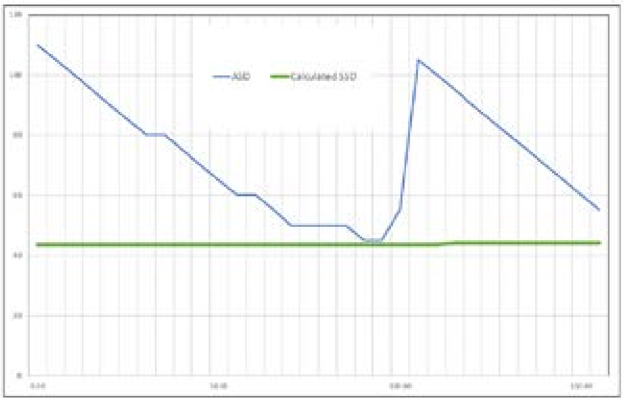


Fig. 5.
Trajectory and SSD results of observers turning right the main road

The third set of cases, which evaluated drivers and cyclists turning right from the minor road is illustrated in figure 6. These graphs show the results of the two trajectories considered for cyclists, both 1 m apart from the center of the lane. It shows reductions in the ASD due to lack of clearance this horizontal curve has. Generally speaking they show the same tendency but differences of 5 and even 10m of visibility arise at some stations.



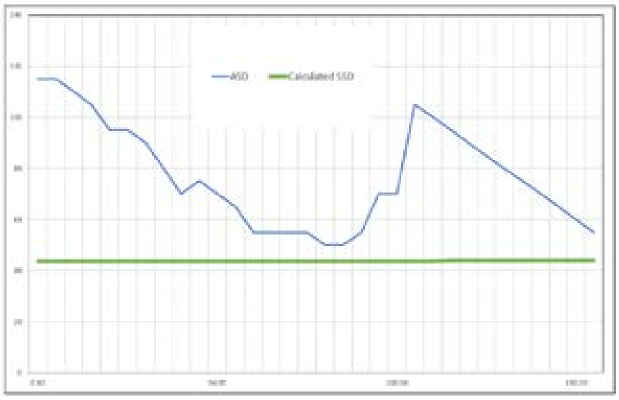


Fig. 6.
SSD estimations considering cyclists turning right from the minor road

3.2. ISD

Departure sight triangles were calculated for the minor road left turn. Also, the estimation of the visibility of conflict points along the different set of cases. These estimations were calculated utilizing object heights of 1.08m, 1.5m and 1.7m (eye's height of drivers and pedestrians, being the objects to be seen).

For the first set of cases, the existence unobstructed lines-of-sight was determined from the driver's and cyclists' paths to the merging conflict point. In addition, a sightline evaluation was performed towards the stop area on the minor road. Results were calculated setting the observers at a distance of 50-70m away from the conflict point. Outcomes showed that all observers were able to spot oncoming vehicles in the stop area, but the bus stop-shelter prevents cyclists riding near the curb to perceive approaching drivers which are located 10-20m before the stop sign.

The second set of cases assessed whether drivers could spot pedestrians crossing at an adequate distance. Results verified that uphill or downhill pedestrians are spotted right in the crossing and before it; both 1.70m and 1.50m are clearly spotted. These results are important because downhill pedestrians could forget to look back for oncoming vehicles before starting to cross. For cyclists, given that their trajectory is prone to more variation within the lane, the proper spotting of pedestrians 50m away from the crossing depends on the location of the pedestrian on the crossing and the position of the cyclist on the lane, due to the bus stop-shelter and crossing sign. A third scenario where the bus station was moved 5 m uphill from the intersection revealed improved visibility values.

The third case estimated the provisioning of a clear sight triangle for approaching traffic down the stop-controlled minor road. The decision point, spot where the driver should start the stopping maneuver, was placed 4.4m from the major road; the base of the triangle was located in the center of the lane, given that vehicles are approaching from the left and the third point was located using the resulting ISD, 72.28m. Figure 7 illustrates the sight triangle. The ISD is pointed at, and inside the triangle are the lines-of-sight projected from the driver's location to stations located on the trajectory of oncoming traffic. All shown lines are unobstructed, hence the sight triangle is provisioned. Additionally, considering the fact that the pedestrian crossing is right before the right turn, drivers will most likely reduce their speed before approaching the turn. ISD for cyclists was found to be 63.24 m and showed similar outcomes.

3.3 Pedestrians' Visibility

Unlike drivers and cyclists, pedestrians do not count with well stablished formulae aimed at the estimation of the sight distances required for their maneuvers (Eassa, 2016).

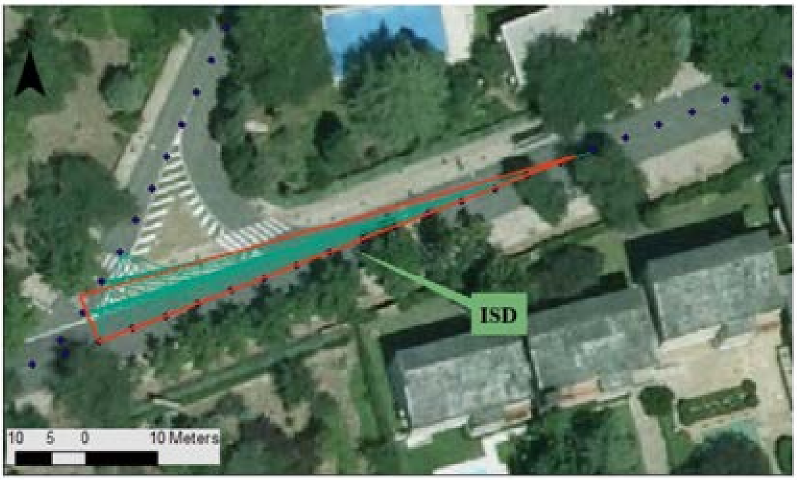


Fig. 7.
Departure sight triangle for the minor road

Sightlines were projected on the pedestrians' path aiming at approaching vehicles. Stations were separated 1m apart contemplating the average stride length and the variability of wheelchairs. Observers evaluated were able to spot oncoming traffic at a distance of 50m from the intersection along both roads. The first pedestrian crossing encounters drivers downwards from Moreras St. and are provisioned with more than 50m of visibility uphill. This was estimated for both ends of the crossing. The second pedestrian crossing provides sufficient visibility for users going upwards, being the bus stop-shelter the hindering element at about 60m. Pedestrians going downwards the main road must look back for oncoming vehicles, which is usually done fast and not carefully.

4. Conclusion

The provisioning of an adequate ASD is indispensable for creating safe driving conditions. Given that urban road intersections include distinct road users and maneuvers, road engineers should provide design elements aiming at reducing potential erratic operations. In this sense, giving the number of elements surrounding urban streets, utilizing a 3-D approach helps to determine the real effect in the visibility that they could infer, and not to mention the possible misestimations that 2-D evaluations might have. In this sense, so as to represent the road environment in the more realistic approach, this procedure permits to utilize DTMs in combination with files containing aboveground features captured by the LiDAR. These represented objects could be manmade elements, vegetation, street furniture and more. This procedure offers important functionalities regarding these potential obstructions. When it comes to urban street furniture and signalization, since these elements' dimensions are straightforwardly known, and effortlessly obtainable as 3-D objects files, the evaluation of the best positioning in terms of safety is achievable.

Urban streets are designed to accommodate distinct users and modes of transport, with this in mind the presented procedure included pedestrians and cyclists. The number of cyclists sharing the roads is increasing, and cities are fostering these attitudes in different ways but not always considering that many urban roads were designed to fulfil requirements of motor vehicles and should be evaluated to accommodate others. Furthermore, sight distances of mobility impaired pedestrians are often obviated. In this sense, results from the estimation of cyclists ASD evidenced how even a slight change in the positioning along the lane produces changes in the visibility and also the possibility of vehicles to spot other users. Pedestrian's maneuvers are often neglected and just as drivers do, pedestrians take many decisions on their crossing behavior based on what they are able to see and infer from the road. These decisions affect directly on drivers maneuvers hence the importance on reciprocal visibility.

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INVESTIGATION OF PRE-CRASH VEHICLE SPEED

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Abstract: The speed at which drivers travel has been shown to have a considerable effect on the number and severity of crashes. Previous studies have examined speed choice of drivers outside of a crash situation, and found speed is influenced by a number of factors and circumstances. The aim of this study was to investigate factors influencing speed choice for vehicles involved in a crash. For the analysis, data from the in-depth crash investigations conducted by CDV – Transport Research Centre from 2011 – 2017 was used. The investigation team documented all relevant information on traffic environment, vehicles and human factor, at the scene. The investigation included an individual interview by a psychologist with crash participants, focused on all relevant information related to causes (traffic situation, actual mental and physical condition of a participant, incidental circumstances, etc.) course (e.g. reactions) and crash consequences (injuries); including basic and sociodemographic information about the participant (sex, age, driving experience, etc.). Pre-crash speed was determined through Virtual crash reconstruction. For the analysis of statistically significant predictors of pre-crash speed, statistical modeling was used. The most statistically significant predictors correspond with the basic road characteristics (speed limit and road type) and roadside environment. The results of this study could be beneficial for the road safety improvement, especially in the field of traffic engineering. It could also provide interesting background for the driver education.

Keywords: pre-crash speed, perception, safety, risk, in-depth crash investigation.

1. Introduction

Speed is one of the most influential risk factors. (Elvik, 2009) Speed choice could be influenced by various factors, especially related to the traffic environment (Aarts, 2006). Traffic environment, traffic condition and roadway geometry and density of information are the primary inputs to the driving task which determine requirement of driver workload and thereby speed perception and choice. (Deller, 2013)

As evidenced by a number of studies, surroundings of the road affect driving speed – open areas have been associated with higher speed. Speed choice has also been influenced by a type of obstacle and also the distance of the obstacle from the road (Tenkink, 1989). Driving speed has been reduced on the tree-lined roads (De Ward, 1995; Shinar, 1974; Edquist, 2009). Transport Research Laboratory (TRL, 2011) ascertained that in the urban area, street trees have only small affect on speed rating - less than 1 mile per hour reduction. Speed reduction connected with the trees presence could be related to the compensatory behaviour because of the vertical contrast in the visual periphery. Driving speed has been also influenced by presence of buildings in the road surroundings (e.g. Van de Kerkhof, 1987). It also depends on the distance from the buildings (Smith, 1981), influence of the height of the building was not proven (TRL, 2011). The effect of road marking on traffic safety differs between studies – for example, literature review by the OECD (OECD, 1990) describes safety benefits, while Kallberg (Kalberg, 1993) and Van der Horst (1983) have observed that the road marking presence caused speed increased. In a study by Daniels et al. (2010), the impact of different types of speed limit signs on driving speed has also been investigated, and statistically significant effect has not been shown.

Road design is also important factor for a speed choice. The geometry of the roadway, particularly the horizontal and vertical alignment that may restrict the sight distance of the driver. As described by Martens et al. (1997) and Duncan (1974) driving speed has been influenced by curvature. Silcock (Silcock et al., 2000) proved that driving speed has been affected by degree of horizontal curve as well as radius. Driving speed has been also influenced by gradient (Duncan, 1974; Marconi, 1977; Brenac, 1989). Ambros et al. (2017) studied factors of speeds in curves and found that increasing length, road width, visibility and enabled overtaking and climbing were associated with an increase of speed; the same relationship held for the influence of the preceding tangent speed on speed in the following curve.

Driving speed has been also influenced by lane width (e.g. Silcock et al., 2000; Vey 1968; Yagar, 1983). Speed reduction has been also revealed on rough road surface (Martens, 1997; De Waard et al., 1995; Van de Kerkhof, 1987; Kennedy and Wheeler, 2001; Wheeler et al., 1997).

Speed perception and distance has been distorted under different weather condition, as evidenced by Reinhardt – Rutland (1989) drivers reduce speed when entering fog. Fildes (1993) has described speed reduction during bad weather, Brilon found speed reduction about 10 km/h during rainy weather, Holdener (1998) reported speed reduction between 5 to 14 km/h.

The results of psychological studies indicate connection between speed choice and some personality characteristics (especially aggressiveness, hostility, competitiveness, impatience). The results of the number of studies have shown that factors related to the driver state as well as individual abilities also play an important role for the speed choice. Exceeding the speed limits is often associated with sensation seeking related to the tendency to take risks (Dahlen, 2005). Drivers with higher risk tolerance tend to drive faster (Milliken et al., 1998; Silcock et al., 2000; Fleiter and Watson, 2005; Fylan et al., 2006). Subjective speed perception could be also significantly influenced by the type of a vehicle or its technical condition.

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There are a number of studies that use statistical modeling of vehicle speeds for estimation of factors influencing speed choice, especially estimation the association between driving speed and geometric design features e.g. (TRB, 2011). Mostly only data about speed from rural two-lane highways have been used. The aim of this study has also been using statistical model for estimation factors influencing speed choice. Compared to the existing studies, unique accident data has been used in the current study. For the purpose of vehicle driving speed analysis, mostly data from naturalistic studies, traffic surveys such as floating cars or simulator studies have been used. In this study, not driving speed of all vehicles at the specific road section have been analysed, but only driving speed of the road traffic accident participants.

2. Data and Methods

2.1. Dataset

For the data analysis, data from the research project Czech In-depth Accident Study (CzIDAS) has been used. CzIDAS was initiated by CDV – Transport Research Centre in 2011 and data collection has been focused on a defined region (mostly South Moravian region). Data about road accidents with injuries, meaning that at least one participant was admitted to the hospital due to accident related injuries, has been collected. The road accidents are chosen according to a statistical selection that aims to produce a representative sample. Currently there are more than 1700 accidents in the database. The in-depth accident investigation teams document all relevant information on the traffic environment, vehicles, and human factors, at the scene immediately after the occurrence of a traffic accident. The investigation includes an individual interview by a psychologist with traffic accident participants, focused on all relevant information related to causes, actual mental and physical condition of a participant, driving habits and practice, and basic and sociodemographic information about the participant. Documentation of the traffic accident site includes photographical and topographical documentation of the vehicles and accident site (route and surroundings). Also physical parameters (friction coefficient, wind speed, etc) has been documented. All data collected during on-spot research has been subsequently analysed. Complete accident analysis also includes a reconstruction using the simulation software Virtual Crash. Based on the detailed information about vehicle deformation, accident site and interview and other relevant information collected in the investigation. The technically acceptable range of the impact speed and pre-crash speed could be calculated.

2.2. Variables

For the purpose of this study, only cases with reconstructed speed and completed participant interview have been used, a total of 261 crashes. The analysed variables were selected with respect to the size of the dataset. Table 1 shows selected categorical variables and their basic characteristics, Table 2 shows selected continuous variables and their basic characteristics. For the categorical variables, the variable with the highest proportion in the sample was selected as the reference variable. The variables used for modelling are not correlated (Multicollinarity has been verified).
In this paper, pre-crash speed was analyze on all types of roads. There are various types of roads in the Czech Republic – motorways, roads (1st, 2nd, 3rd class roads), local roads and other special roads. There are 6 motorways in the Czech Republic, speed limit on motorway is 130 km/h outside the city and 80 km/h in the city. National roads (1st class roads) are designated for long-distance and international transport. The total length is 439 kilometers. 2nd class roads (regional roads) enable transport between districts, 3rd class roads between cities or villages, local roads mainly within municipalities.

Table 1
Categorical variables

Categorical variable		N	Percent
location	urban area	191	73.2%
	rural area	70	26.8%
horizontal curvature	intersection	118	45.2%
	bend	25	9.6%
	straight	118	45.2%
gender	male	202	77.4%
	female	59	22.6%
road type	3rd class road	43	16.5%
	2nd class road	42	16.1%
	1st class road	42	16.1%
	other	5	1.9%
	motorway	7	2.7%
	local road	122	46.7%
vehicle owner	corporate vehicle	52	19.9%
	own	172	65.9%
	borrowed vehicle	37	14.2%
roadside environment	open areas	77	29.5%
	bush	21	8.0%
	forest	10	3.8%

Categorical variable		N	Percent
	single trees	18	6.9%
	tree-alley	18	6.9%
	guard rail	12	4.6%
	buildings	105	40.2%
trip purpose	free time	108	41.4%
	business trip	134	51.3%
	other	19	7.3%
gradient	descent	37	14.2%
	ascent	36	13.8%
	horizontal	188	72.0%
age	65 and more	28	10.7%
	24-30 years old	44	16.9%
	31-34 years old	24	9.2%
	35-39 years old	35	13.4%
	40-44 years old	34	13.0%
	45-54 years old	34	13.0%
	55-64 years old	31	11.9%
	do 23 years old	31	11.9%

Table 2
Continuous variables

Continuous Variable		N	Minimum	Maximum	Mean	Std. Deviation
dependent Variable	pre-crash speed [km/h]	261	5	140	46,8506	22,8634
covariate	road width [cm]	261	300	3700	1040.8744	504.92124
	vehicle age [year]	261	0	26	9,9693	5,89451
	speed limit [km/h]	261	20	130	61,1494	18,93868

The models were developed in the statistical software IBM SPSS. The model has been created with all selected variables, followed by backward-elimination, based on achieved levels of statistical significance in omnibus test.. The omnibus test is a likelihood-ratio chi-square test of the current model versus the intercept-only model. The significance value of less than 0.05 indicated that the current model outperforms the null model.

3. Results

Tests of Model Effects (Table 3) allowed us to determine which model predictors have statistically significant effect. In this study, statistically significant predictors included the location of the accident, the type of road, the area, the width of the road and the speed limit. Road width was selected among important predictors although, since it exceeded the significance level of 0.05 only marginally (below level of 0.1). The model excluded statistically insignificant predictors such as gender, urban / rural, age of the car, purpose of the trip and vehicle owner. The most significant were the effects of the speed limit, the roadside environment and the type of road according to Wald chi-square criteria.

Table 3
Test of Model Effects

Source	Wald Chi-Square	Sig.
(Intercept)	9.316	0.002
accident location	8.229	0.016
road type	11.877	0.037
roadside environment	21.795	0.001
road width	3.053	0.081
speed limit	26.75	0.000

Wald Chi-Square – Wald test criterium, Sig – achieved statistical significance

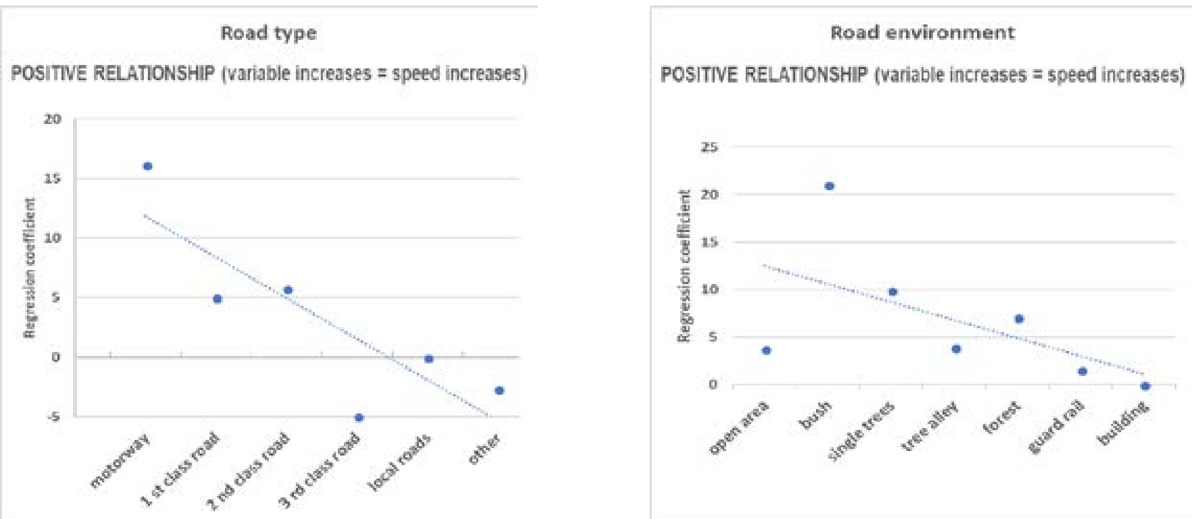
Table 4 shows statistically significant predictors and allows interpretation of the effect magnitude and direction using non-standardized regression coefficients denoted by the B letter. Non-standardized regression coefficients express the influence of the independent variable on the dependent variable without influence of the other variables. In case of continuous variables it is possible to determine the amount of dependent variable change per one unit increase of the independent variable. In case of categorical variables, the coefficients determine the change of the dependent variable compared to the reference category. The positive value indicates the positive relationship, the negative value indicates the negative relationship.

Table 4
Parameter Estimates

Parameter		B	Std. Error	Sig.
(Intercept)		15.42	5.176	0.003
Accident location	intersection	-7.327	2.559	0.004
	bend	-4.214	4.397	0.338
	straight	0	.	.
Road type	3rd class road	-4.942	3.972	0.213
	2nd class road	5.774	3.624	0.111
	1st class road	5.039	3.874	0.193
	Other	-2.691	8.852	0.761
	motorway	16.155	8.980	0.072
	local roads	0[a]	.	.
Roadside environment	open area	3.754	3.102	0.226
	bush	21.015	4.797	0.000
	forest	7.074	7.167	0.324
	single trees	9.912	4.946	0.045
	tree alley	3.912	5.224	0.454
	guard rail	1.529	6.872	0.824
	Building	0[a]	.	.
Road width	[cm]	0.003	0.002	0.081
Speed limit	[km/h]	0.434	0.084	0.000

B – regression coefficients, Sig – achieved statistical significance

For the variable accident site, the straight section was set as reference category. The value of the B coefficient -7.327 indicates that pre-crash speed during intersection crossing was approx. 7 km per hour lower than passing straight section. On the bend the average pre-crash speed was lower about 4.2 km per hour compared to the reference category.
For the variable type of road, an average pre-crash speed was about 16 km/h higher on the motorways than on the local roads. According to the B coefficient, there was also higher speed on the 1st and 2nd class roads compared to the local roads. Pre-crash speed on the 3rd class roads was lower than pre-crash speed on the local roads.
In the variable roadside environment, buildings were the reference category. The largest difference in the pre-crash speed was in case of bushes in the road surroundings (B = 21.015). Average pre-crash speed was also higher compared to the reference cathegory if there is a single tree (B = 9.912). Road width increase as well as speed limit increase was associated with pre-crash speed increase.
Relative effect magnitudes of categories of the most significant variables (road type, roadside environment and accident location – road geometry), based on their regression coefficients, have been illustrated by Figure 1. In case of accident location, the relationship is negative. Pre-crash speed decreases with change of road geometry. In case of road type, pre-crash speed increases if the variable increases. Therefore, the pre-crash speed is higher on the upper class road, the highest pre-crash speed is associated with motorways. The pre-crash speed also generally increases with increasing density of objects.



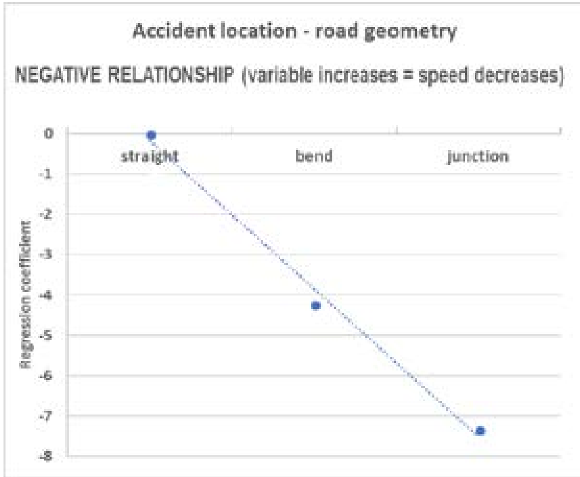


Fig. 1.
Illustration of relative effect magnitudes of the most significant variables in the speed model

The model goodness-of-fit has been verified by determination coefficient R2, which shows the explanatory power of pre-crash speed, modelled using the set of independently selected variables. Independent variables explained about 36 % of pre-crash speed variance.

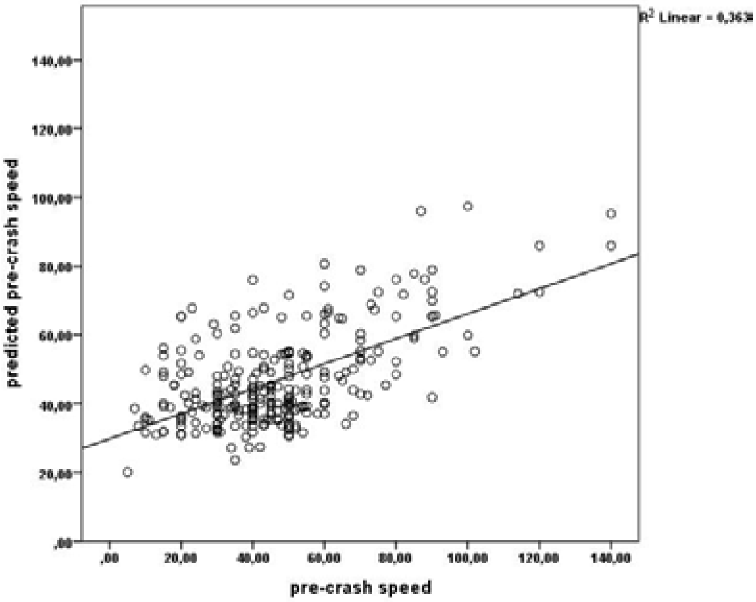


Fig. 2.
Goodness-of-fit of speed model

4. Discussion

Although a number of studies have dealt with driving speed analysis, they mostly used data from naturalistic studies, traffic surveys such as floating cars or simulator studies. For the purpose of this study, unique accident investigation data have been used – i.e. we analyzed pre-crash speeds and driver-related factors. This is also why the obtained results differ in some aspects from previously published results. In addition, while most of current research focused on driving speed on rural roads, the aim of this paper was to analyze pre-crash speed in the whole range of roads.
There have been some limitations of the study because of the dataset. Only completely analyzed accidents (with accident reconstruction in simulation software and driver interview) have been included to the study. Dataset structure have not allowed analysis of some variables – for example very few accidents with bad weather condition have been part of the dataset, so the weather condition have not been analysed, as well as some of the driver personal characteristics. The variable choice was therefore influenced by the dataset characteristics. Based on the literature review, mostly the variables which characterize the transport environment were chosen – as a location, curvature, road type and environment, road gradient and width and speed limit. The speed choice could be also affected by the driver himself/herself, so also basic demographic driver characteristics has been included – age, gender. Speed choice could be also influenced by the purpose of the journey or how is a driver familiar with a vehicle - whether if it own, lent or corporate. Speed perception could be influenced by the vehicle, as the basic vehicle characteristic the vehicle age has been chosen.

For the purpose of this study, pre-crash speed determined through virtual crash reconstruction in the technically acceptable range has been used. This could be the main limitation of this study. In some cases, pre-crash speed could be difficult to examine. Pre-crash speed could be underestimated if braking has occurred without leaving visible tyre marks. This could have an effect on the pre-crash speed examination. Possible underestimation should be consistent across the variables and included in the technically acceptable range.

The most significant effect variables corresponded with the basic road characteristics – speed limit and road type. Drivers speed choice has been influenced by objects immediately next to the road. The lowest pre-crash speed has been associated with buildings in the road suroundings. The presence of building implies the presence of higher information load – presence of other road users especially pedestrians, mostly higher traffic sign density.

As evidenced by previous studies (Tenkink, 1989), open areas have been associated with higher speed. In this paper, the highest speed have been associated with the presence of bushes on the roadside. Bushes do not seem to create the sense of danger due to its constitution compared to tree trunks. In case of open areas, pre-crash speed increased only by about about 3.8 km/h compared to buildings. This may be largely due to differences in datasets. Previous studies have examined open areas on rural roads or motorways. In this study, we have not focused on the specific part of the road without fixed obstacles in the neighborhood. Open areas in this study are very often areas near intersections, because of higher accident risk. For the future practical application, open areas should be more specified, as well as the influence of the fixed obstacle distance.

Pre-crash is very similar to pre-crash speed in forest in case of tree alleys. Reducing speed in the presence of tree alleys may be due to the need of drivers compensatory behaviour due to visual cues with different contrast. As mentioned in (Martens, 1997), the presence of tree alleys may lead to an increase in peripheral visual flow which should increase the driver's perception of their own speed and lead to speed decrease. Driving speed is higher in case of single trees compared to tree alleys.

In terms of road geometry, lower pre-crash speed has been connected with bends and intersections compared to the straight roads. Guard rails have been not only adjacent to high class roads, but they have been placed as a protection near bends very often. This could be the main reason why lower pre-crash speed have been associated with the presence of guard rails.

5. Conclusion

As evidenced by this study, mainly environmental factors affect drivers speed choice. The most important factors are the speed limit, road type and roadside environment, especially the type of fixed obstacle. The highest speed have been associated with the bushes in the road vicinity. The analysis of influence of distance from the fixed obstacle or height of the fixed obstacle to pre-crash speed have not been provided. For the purpose of the next studies, also the distance from the fixed obstacle should be included. Previous studies confirmed, that trees only affected speed it they are closer than 2 meters to the road. In terms of road geometry, drivers will choose higher speeds on straight roads compared to the bends and intersections. Driving speed also decreased on narrow roads.

For the next practical application, the roadside environment should be analysed in more detail – there could be both (guardrail and trees) in some cases. It will be more appropriate to analyze the vegetation and the presence of barriers in two different categories. Future studies could also focus on the most comprehensive analysis of the factors influenced driving speed using more detailed information about personal characteristics as well as information about subjective speed. Also the multilevel modeling could be used.

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ANALYSIS OF DRIVER REACTION TIME FOR PEOPLE SUFFERING FROM PARKINSON DISEASE

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Abstract: Nowadays, determination of driver reaction time is discussed topic in the field of accident analysis. Driver reaction time is the main characteristic of driver behavior, especially in the situation before collision. Based on various studies, the reaction time duration of the driver without significant health problems has been determined. Besides this group, the driving license can be owned by people who suffer from any of the neurodegenerative diseases affecting their motoric skills. The example of this disease can be the Parkinson disease. Parkinson disease relates to a loss of nerve cells in the part of human brain called Substantia nigra which normally product dopamine (neurotransmitter) providing the signal transmission between neurons. The loss of dopamine affects the ability to control movements which might indicate a problem during the driving, especially in the case of brake pedal activation. The main focus of this article is to investigate the driver reaction time of people suffering from Parkinson disease. This study will be focused especially on the entire motoric response period, which will be analyzed primarily using electromyography. Driver reaction time of this specific group of drivers is found out from experiments in a simulated environment. The motoric response of patients with Parkinson's disease during braking will be compared with the motoric response of healthy drivers. Results of this research could be useful for detailed investigation of the driver reaction time of people suffering from the neurodegenerative disease and for comparison of driver reaction time duration between normal healthy drivers and drivers suffering from Parkinson disease.

Keywords: reaction time, accident analysis, electromyography, Parkinson disease.

1. Introduction

Parkinson's disease is a neurodegenerative disease of the central nervous system with the decrease of nerve cells in Substantia nigra (the so-called black substance, part of the brain) that normally produce neurotransmitter dopamine needed to transmit signal between nerve cells. The lack of these nerve cells leads to the gradual loss of the ability to control body movements. Parkinson disease is often characterized by limb tremor when in a resting state, and an inability to initiate and control voluntary movement, e.g. akinesia (Sheridan, 1987; Jackson, 1995).

Reaction time of people suffering by Parkinson disease has been tested for various purposes. As stated in Gauntlett-Gilbert (Gauntlett-Gilbert, 1998), reaction time has been used by many researchers for quantification of performance impairment caused by Parkinson disease. Although reaction time has been a poor index of disease status, it allowed identification of movement deficits that are independent of bradykinesia.

It was utilized that reaction time of people suffering by Parkinson disease has been prolonged. In the case of Parkinson disease Evarts (Evarts, 1981) has established that both – reaction time and movement time as well – direct to prolongation, but they are often impaired independently of each other. Movement time undergoes more substantial disturbance and is more useful than reaction time as an objective indicator of therapeutic efficacy. Godrich (Godrich, 1989) tested reaction time of patients suffering from Parkinson disease in the presence of secondary task (reading aloud). The secondary task slowed control group more than patients suffering from Parkinson disease. In absence of the secondary task, simple reaction time of patients suffering from Parkinson disease was significantly impaired, but choice reaction time not.

In the Czech Republic, drivers suffering by Parkinson disease do not necessarily have to be disqualified from driving. Driving capability assessment have been subjective, currently there is no methodology for medical assessment. Driving is a complex task requiring especially cognitive and psychomotoric functions, which could be affected by Parkinson disease.

Driving ability of patients with Parkinson disease have been tested in Heikkila (Heikkila et al., 1998). Cognitive and psychomotoric laboratory tests and structured on road driving test were used for evaluating the subjects' driving ability. There was correlation between the laboratory tests and driving test and the results of drivers suffering from Parkinson disease were worse compared to the control group. Patients were not capable to evaluate their own ability reliably.

The aim of this study is to analyse the muscle response time of drivers suffering by Parkinson disease during driving, because especially motoric response could be particularly affected by Parkinson disease. Normally, for the purpose of driver reaction time analysis, the whole reaction time or only the movement time has been analysed (e.g. Pierson, 1959; Spirduso, 1975). Reaction time (RT) is the whole time taken to complete a task. Movement time is a period of time in which the limb is moved from accelerator pedal (accelerator release time TA) to the brake pedal (TB), but involves only the visible part of that movement. Compared to the movement time, muscle response time provided a more accurate overview of muscle work and also more objective analysis of the impairment of the physical component of reaction time during driving.

2. Measurement

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Participants of this study were patients with Parkinson disease. For the comparison, drivers without medical and cognitive impairment aged from 25 – 50 were participated in this study. Not every driver with Parkinson disease had a driving licence, so the realization of the experiment in real road traffic has been prohibited. Also the measurements were carried out with older drivers, so safe and simple measurement design has been necessary. Series of experiments were performed on the simulator, which has been implemented by a personal computer. The recognition RT was measured. There was more than only one stimulus. The easiest stimulus is the changing of colors, so there were different colors changing on the computer screen. But only one of this (red color) should have been responded by participant. To eliminate predictability, color order and also the time of color changes were absolutely random. Colors were changed independently on two screens. The angle of screens was established experimentally using theoretical background about field of view of older driver to 90°. Participants were seated in the same position, with both hands on the steering wheel. Measurement should simulate normal driving, so accelerator pedal has been pressed by participant until stimulus occurred. Participant should react by breaking and avoidance maneuver. If they made a mistake, the reaction was excluded. Participants completed at least 10 reactions. Participants were tested individually in a quiet room.

3. Methods

For purposes of this study the muscle activities of the right lower limb and the right upper limb were recorded by wireless surface electromyography electrodes. Thanks to precise muscle activity recording a novel approach for detection of braking intention and evasive manoeuvre was initiated, because there is no other study monitoring human biosignals as comprehensively as this experiment. There were recorded electrical activities of the muscles of right lower and right upper limbs , when lower limb movements accompanied pedal changing during braking and movement of upper limb represented evasive reaction by steering wheel within this experiment.

3.1. Lower Limb Measurement

In an effort to leave the accelerator, motoric functional chain of lower limb’s movements starts by triple flexion of entire lower limb, including flexion of the hip joint, flexion of the knee joint and dorsal flexion of the talocrural joint (proper ankle joint). Follows by internal shift of entire lower limb above the brake pedal accompanied by hip adduction. Closing stage is comprised of triple extension of the lower limb, including hip extension, knee extension and plantar flexion of the talocrural joint. Plantar and dorsal flexions are connected with eversion or inversion according to the type of the kinetic chain. Commonly kinetic chains are divided into “open” and “closed” chain. Basically, during closed kinetic chain (CKC) the distal segments of the chain are fixed and proximal segments are moving. During open kinetic chain (OKC) the situation is inverse, when proximal parts are fixed and distal segments are moving (Wilk, 1996; Chang, 2014). In the open kinetic chain dorsiflexion is connected with the eversion, and abduction; and plantar flexion with inversion, and adduction. In the closed kinetic chain plantar flexion, is accompanied by abduction and eversion; while dorsiflexion is accompanied by inversion and adduction (Rockar, 1995).
As the most appropriate tracked muscles we have found: musculus iliopsoas as a primary mover of hip flexion; musculus gluteus maximus as a primary mover of hip extension; and musculus gracilis as a primary adductor of the hip joint. Postural changes of the knee joint were detected by recording from musculus quadriceps femoris (precisely rectus femoris) as a main mover of knee extension; and musculus semitendinosus as one of knee flexors. Movements of the ankle joint were monitored by measuring of electrical activity of musculus triceps surae as a primary mover of plantar flexion; musculus tibialis anterior as a primary mover of dorsiflexion and foot inversion; musculus peroneus longus as a main mover of foot eversion as well as foot abduction.

3.2. Upper Limb Measurement

Within the upper limb reaction measuring the forearm muscles were detected. Exactly we targeted on the muscles which provoke firm grip of steering wheel firstly and then initiated evasive manoeuvre of the wheel to the left side. Selected muscles for this monitoring were musculus flexor digitorum longus, as a prime mover of finger flexion during the clenching of the wheel and musculus pronator teres as an initiator of forearm pronation connected with turning the wheel to the left side.
All the important movements and tracked muscles are also visible in Tables 1 and 2. Placement of electrodes was carried out in accordance with the SENIAM research group recommendations (Hermens, 1999).

Table 1
Main movements of the lower limb with appropriate muscles

HIP JOINT		ANKLE JOINT	
Flexion	m. iliopsoas	Flexion (dorsal flexion)	m. tibialis anterior

Extension	m. gluteus maximus	Extension (plantar flexion)	m. triceps surae
Abduction	m. gracilis		
KNEE JOINT		FOOT	
Flexion	m. semitendinosus	Inversion	m. tibialis anterior
Extension	m. quadriceps femoris	Eversion and Abduction	m. peroneus longus

Table 2
Main movements of the upper limb with appropriate muscles

HAND AND FINGERS		FOREARM	
Flexion	m. flexor digitorum longus	Pronation (internal rotation)	m. pronator teres

3.3. Biosignal Acquisition

The electromyography signals of muscles of lower and upper limbs were acquired by wireless device Cometa and muscle response were determined. Muscle response time starts at the moment of muscle activation and ends at the moment of first touch of the right lower limb with brake pedal. The end of muscle response time was measured by footswitch mounted on brake pedal (that was a binary signal, where 1 means depressing brake pedal and 0 means releasing brake pedal), the start of muscle response time was measured by EMG device Cometa.

Determination of muscle response time is based on locating the muscle activation site from EMG signal. For this purpose, several methods have been invented. The simplest ones are based on the signal filtering and thresholding. The threshold can be derived from the standard deviation of the resting EMG signal or from the enhanced EMG signal (Hodges et al., 1996; Di Fabio, 1987, Stokes et al., 2000).

Another approach of muscle response time detection offers methods based on testing two hypotheses. First hypothesis H_0 with probability density function p_0 is connected with the resting state of muscle, the second hypothesis H_1 with probability density function p_1 is connected with active state of the muscle. Maximum likelihood method determines which hypothesis is true at any point in time (Micera et al., 1998).

Determination of the muscle activation can be evaluated by using entropy. This method is based on the hypothesis that noise present in EMG signal is represented by high values of entropy and EMG signal representing the contraction of muscle is represented by low values of entropy. Therefore, the start of the muscle activation is based on the empirical histogram of EMG signal (López et al., 2011).

In this case, determination of muscle activation was based on Empirical Mode Decomposition (EMD) and application Teager-Kaiser Operator (TKEO). Empirical Mode Decomposition can serve as the method of pre-processing of EMG signal. EMG signal is decomposed into its Intrinsic Mode Functions (IMF) and for the detection of the muscle activation one of these functions is chosen and enhanced by TKEO. Moments of muscle activation are determined by thresholding of enhanced Intrinsic Mode Function.

3.3.1. EMD

First step of this method is to estimate envelopes for maximum and minimum values of EMG signal. Estimation of these envelopes is based on method of cubic splines. Then the average signal m_1 between envelopes is evaluated and it is subtracted from the original EMG signal. The result of this step can be defined as variable h_1 :

$$h_1 = X(t) - m_1 \tag{1}$$

For a currently calculated signal $h_1$envelopes of maximum and minimum values are estimated by the method of cubic splines. The average signal m_{11} is estimated and subtracted from the signal h1. The next signal component h_{11} is found:

$$h_{11} = h_1 - m_{11} \tag{2}$$

This procedure is repeated until the condition mentioned below (3) is fulfilled. The condition states that the first intrinsic mode function was found if standard deviation of two consecutive signal components $h_{1(k-1)}$ and h_{1k}exceeds the threshold (the average signal m_{1k} is zero or very close to zero).

$$SD = \sum_{\tau=0}^{T} [\frac{|h_{1(k-1)}(t) - h_{1k}(}{h^2_{1(k-1)}(t)} \tag{3}$$

If the condition (3) is met then signal component h_{1k} is stated as the first intrinsic mode function of EMG signal c_1:

$$h_{1k} = h_{1(k-1)} - m_{1k}$$
$$c_1 = h_{1k} \quad (4)$$

Next intrinsic mode function of EMG signal is found very similar. Firstly, the first found intrinsic mode function c_1 is subtracted from the original EMG signal and signal component $r_1$is estimated:

$$r_1 = X(t) - c_1 \quad (5)$$

Second intrinsic mode function is found by envelopes' estimation of maximum and minimum values of signal $r_1$and whole procedure mentioned below is repeated. After the ending of this procedure the original EMG signal can be redefined as, where $r_n$represents the residue of the original EMG signal and it is usually monotonous and without extremes (Huang et al., 1998):

$$X(t) = \sum_{i=1}^{n} c_i + r_n \quad (6)$$

3.3.2. TKEO

For determination of muscle activation the first intrinsic mode function of original EMG signal was enhanced by TKEO. Generally, TKEO is non-linear operator and represents the energy of harmonic signal (Kvedalen, 2003). After introducing approximations of first and second derivations, non-linear TKEO discrete signal is defined as:

$$\psi[x(t)] = x^2(n) - x(n+1)x(n-1) \quad (7)$$

If we work with harmonic discrete signal and its three consecutive samples are expressed and put into equation (7), the result of this operation suggests that TKEO is constant for harmonic signal and if values of amplitude change, its current values change proportionally with the square.

4. Results

The aim of this study was to compare the results of muscle response time for two investigated groups of drivers, drivers suffering by Parkinson disease and health drivers. For this comparison two methods of descriptive statistic were performed. Before statistical analysis the rule of three sigma was applied to all investigated data in order to exclude outdated values.

Firstly, results of our measurement were compared via box plots as it can be observed in picture below. Box plots introduce the median values of muscle response time for each investigated muscle group (tibialis anterior, peroneus longus, gastrocnemius, pronator and flexores group) and their range. Box plots of tibialis anterior, peroneus longus and gastrocnemius for both investigated drivers' groups were estimated from 100-120 measured recordings. Box plots of pronator and flexores for both investigated drivers' groups were counted from 50-60 measured recordings. Within all groups of investigated muscles, the rule of three sigma was applied before statistic processing.

Generally, it can be stated that the range of muscle response time values is smaller in the case of health drivers, reaction time of health drivers has been more consistent compared to the drivers suffering from Parkinson disease.

For all three muscle groups of lower limb (tibialis anterior, peroneus longus and gastrocnemius) of health drivers the median values of muscle response time are lower than in the case of drivers suffering by Parkinson disease.

For muscle groups of upper limb (pronator and flexores muscle group) of health drivers the median values of muscle response time are higher than for drivers suffering by Parkinson disease. The reason for lower median values in case of drivers suffering by Parkinson disease is the fact that the muscle response of upper limb is very often negative as could be seen from picture below. The negative values reflect the situation when the upper limb reaction occurred after the brake pedal was depressed.

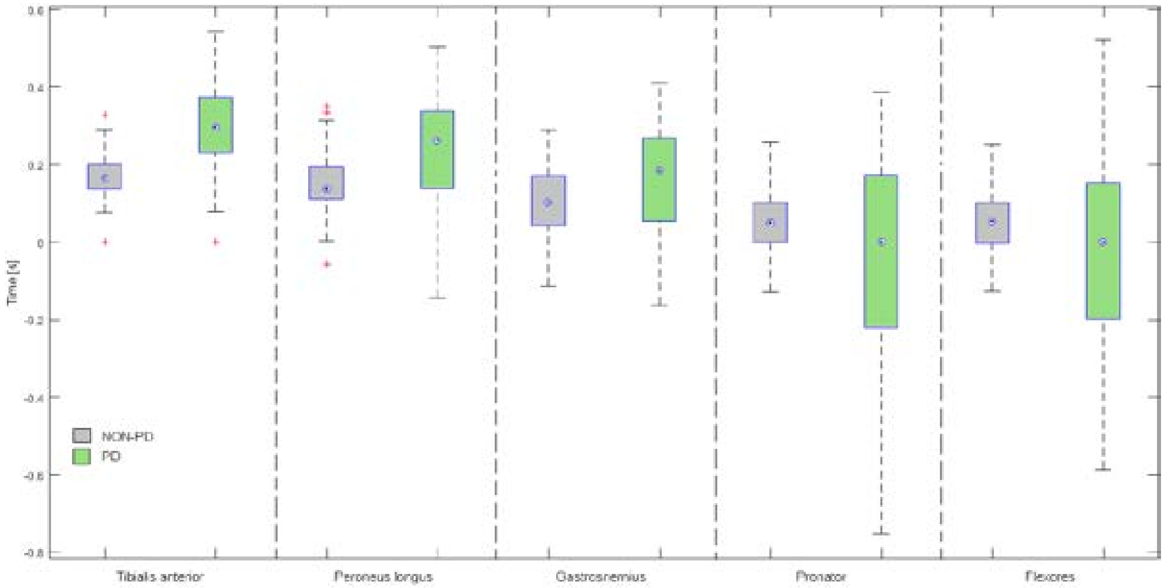

Fig. 1.
Box plots of muscle response time of investigated muscles for NON-PD drivers (health drivers) and PD drivers (drivers suffering by Parkinson disease)

Second statistic method which was applied to acquired data was violin plot (picture below). Five violin plots were created for five muscle groups (TA means tibialis anterior, P is peroneus longus, G is gastrocnemius, PR means pronator and F is flexores). The interpretation is very similar to box plots' interpretation. Within violin plots, median values are introduced for all investigated muscles' group but there are different from median values obtained from box plots. In the case of box plots median values are estimated within each muscle group for both drivers' groups separately. In the case of violin plots median values are estimated for all muscle groups regardless of the surveyed group (that means median values were estimated for each muscle from dataset containing muscle response time values from both drivers' groups). This fact can be used for general comparison how median value of muscle response time for particular muscle of normal (health) driver is changed after adding muscle response time values of drivers suffering by Parkinson disease.

In add, violin plots give information about probability density of muscle response time values at different values. Simplified, violin plot could be taken as a histogram of muscle response time values. Violin plots show full distribution of muscle response time variable. Different distributions of MRT for both drivers' groups are shown in the picture below. It is pretty clear, that distributions of MRT for health drivers are approaching normal distribution (Gauss distribution). Distributions of MRT for drivers suffering by Parkinson disease exhibit less consistency therefore analogy to normal distribution is more questionable.

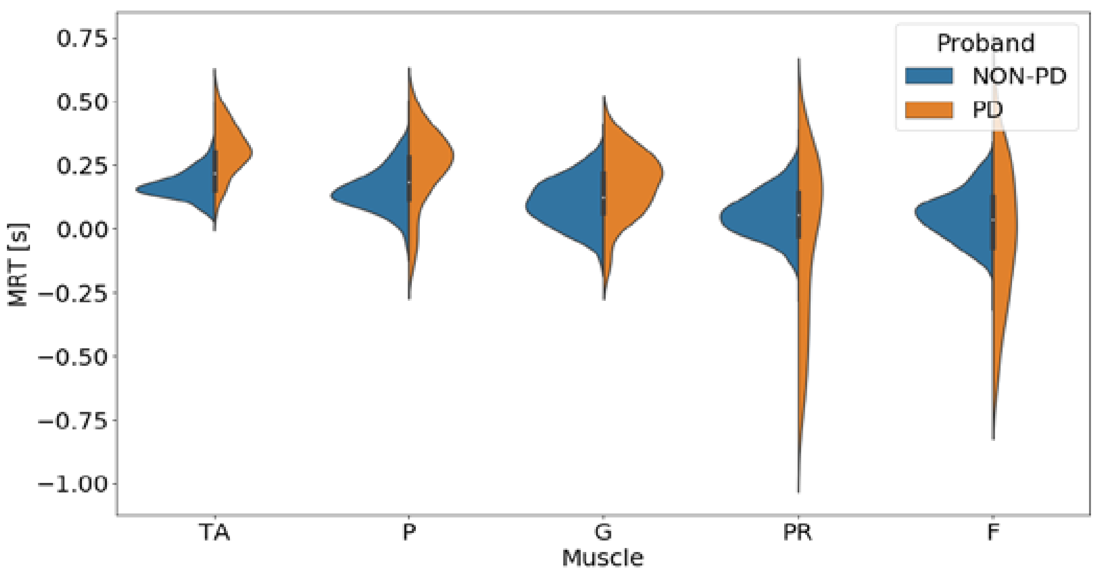

Fig. 2.
Violin plots of muscle response time of investigated muscles for NON-PD drivers (health drivers) and PD drivers (drivers suffering by Parkinson disease)

5. Discussion and Conclusion

As could be seen from obtained results of drivers without medical impairment, the activation time of the individual muscle group of the upper limb could be identical as the activation time of the individual muscle group of the lower limb. However, most drivers respond to the upcoming risk primarily by removing the right foot from the accelerator pedal and then by avoidance maneuver. As could be seen from the violin plots, the activation of tibialis anterior (which has been mostly referred as primary mover), in marginal cases overlap with the muscle activation of the musculus pronator. The distribution of upper limb muscles activation has been mostly below the median values of the musculus tibialis anterior activation. The succession of individual actions, i.e. foot and hand reactions, has been also illustrated by boxplots, decreasing values of median muscle activation as well as the decrease of the entire range of the muscle response time respectively. The muscle response time distribution of drivers without medical impairment has been similar in all analyzed muscle. The sequence of the reactions of drivers without medical impairment to the individual stimuli has a similar character across all analyzed situations.

In case of drivers suffering from Parkinson disease could be seen degradation in all types of muscle response. Compared to drivers without medical impairment, muscle response time of lower limb has been extended in all muscle groups, so the time period between muscle activation and first contact of brake pedal has been prolonged. In the case of the upper limb, medians of muscle activation of drivers suffering from Parkinson disease have lower values compared to control group. This relative reduction in median value has been caused by an increase in the frequency of negative muscular response times of the upper limb, i.e. an increase in situations where the driver responded by avoiding after using brake pedal.

While for healthy drivers the distribution of muscle response was approximately identical only time-shifted, distributions of muscle activation of lower and upper limb differ in case of drivers suffering from Parkinson disease. This task - parallel avoidance and braking could be described as too problematic and comprehensive for drivers suffering from Parkinson disease. They need to subdivide following task into the braking firstly and then avoidance maneuver after brake pedal activation.

For the purposes of road accident analysis as well as for the future research, it is necessary to compare not only the time period of muscle activation but also the overall reaction time, respectively the driver perception reaction time. For the objective comparison and analysis of reaction time of drivers suffering from Parkinson's disease, the dataset of healthy drivers should be extended to older drivers without medical and cognitive impairment i.e. drivers aged comparable to the tested patients suffering from Parkinson's disease.

The obtained results are consistent with the published studies, prolongation of the muscle response time of drivers suffering from Parkinson disease have been demonstrated. Compared to the previous studies, the response of the drivers suffering from Parkinson disease have been analyzed during simulator driving not only during various types of laboratory tests. The muscle activation (the whole period between muscle activation which precedes visible movement) have been analyzed as well. Muscle response could provide more accurate and complex results compared to the analysis of movement time. The aim of this paper was also not only analyzed braking reaction, but also comprehensive reactions using braking and steering. The reaction using both – braking and avoidance reaction – is the most common type of crash avoidance at the intersection. These results provide a unique insight into the ability of Parkinson's driver to handle complex situations in real-life traffic.

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ROAD SAFETY ANALYSIS FOR A TWO-LEVEL JUNCTION ON THE NATIONAL ROAD N. 17 (FOGGIA-LUCERA)

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Abstract: Over the last years, a Y two-level junction on the National Road n. 17, near the city of Lucera (Apulia Region - Italy), was investigated to assess its safety performance. A preliminary safety assessment was conducted by the National Agency (ANAS) which manages the road. Thereafter, some maintenance and safety interventions were realized. However, because of the poor results of the adopted measures, the local municipality required new more effective interventions to improve the level of safety of the road site.
After a new crash analysis based on the data of the main accidents detected during the latest years, the site was re-analysed and an innovative approach to identify more appropriate safety measures was proposed. The results are reported in this study. In detail, an in-depth analysis of the geometry of the junction suggested to investigate the site according to the *Human Factors* theory criteria. The interchange was run in each direction by five drivers, while a couple of observers assessed the driving manoeuvres and speed, supported by mobile cameras and by a GPS device. A third observer analysed each driver performance from an external point of view. A final questionnaire helped the assessment of the driver perception of each segment of the interchange. The investigation was completed with on-site specific measurements. At the end of the analysis, new key elements explaining the poor safety performance of the road junction were detected. As a consequence of the misperception of some sections the road and of the apparent inconsistencies between the drivers' expectations and the road design, low-cost remedies consisting in improving the field of view, the road optical guidance and the drivers' ability to perceive and react were suggested.

Keywords: Road Safety, Human Factors, Driver Behaviour.

1. Introduction

The Italian National Road n. 17 (SS 17) connects Campobasso, in the Molise Region, to Foggia, in the Apulia Region. The interregional road infrastructure is a significant road channel for the South of Italy and it crosses numerous inhabited areas. In proximity to the town of Lucera, the road layout by-passes the town centre. At the 327+200 progressive mileage, the two-level interchange investigated in this paper connects the National Road to the local network. The junction was probably built many years ago at the same time of the present external by-pass. It was partially renovated in 2015 by the Italian Road National Agency (ANAS) which manages the SS 17. However, the recent intervention did not radically modify the pre-existing junction, leaving unsolved some critical aspects concerning the visibility and the space perception along the interchange.
In 2016, the municipality of Lucera required further interventions to fulfil the complete renewal of the junction and identified some potentially hazardous areas.
The analysis conducted in this paper examines the critical patterns of the junction with a double approach based both on the coherence with the *Italian Standards for road intersection design* and on the assessment of the driver behaviour with specific reference to the interchange most critical sections. The suggested improvements are strictly connected to the dual analysis results.

2. General Description of the Road Junction

Nowadays, after the 2015 improvement, the interchange is configured as a trumpet interchange (Fig. 1). Its three legs correspond to the three main directions converging in the road junction: Foggia (Eastbound), Campobasso (Westbound), Lucera (Northbound).
The Annual Average Driving Traffic (AADT) is estimated in about 16,500 vehicles/day.
At the progressive mileage where the interchange is located, the SS 17 cross section consists in a single carriageway (one lane for each direction).
The most recent adjustments regarded the creation of a new direct ramp (Foggia-Lucera direction), the review of the geometry of the cross section (based on horizontal signage and zebra stripes), the creation of a separate two-lane local road beside the northern border of the main road platform. The speed limit along the interchange mainline segment is restricted at 50 km/h. The available crash data (2013-2018) show a modest recurrence of non-fatal accidents (with injuries) along the main road located in the western area of the interchange (Lucera-Campobasso ramp - Westbound) and in the eastern area of the road junction (entrance ramp from Lucera to Foggia - Eastbound). These data are statistically insignificant and do not allow the definition of a continuous safety performance function (SPF).
At the current conditions of use, the absence of data about recurrent fatal accidents does not necessarily imply the absence of potential risks, as reported in the following paragraphs.

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Fig. 1.
Interchange Geometry Before and after the Recent Intervention With Indication of the Main Accidents

3. Methodology of Analysis

To simplify the junction safety performance analysis, the interchange was divided (Fig. 2) into individual components (Torbic *et al.,* 2009).

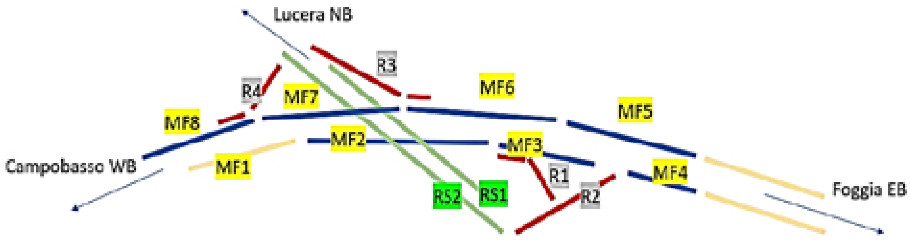


Fig. 2.
Individual Components of the Interchange

As reported above, the first stage of the safety analysis regarded the geometry features, in the light of the *Italian Design Standards*, established in April 2006.
The geometric inconsistencies are basically due to the incorrect design of the road segments unmodified by the recent intervention.
The main inconsistencies detected by the geometric analysis consist in:

- sharp curvature of the inner loop ramp (RS-2 – R-2, R-1- RS-1);
- exit ramp to Lucera (R-3) in correspondence to a left-hand curve of the main road;
- inadequate length of the taper exit lane to Foggia (R-1).

About the ramp R-1, it must be highlighted that he Italian Standards do not admit, in case of interchanges along single carriageway main roads (dual lane), entrance ramps with acceleration lanes.
The second stage of analysis consisted in a driver behaviour investigation, accomplished through electronic devices installed on a standard car driven by five different drivers randomly selected, healthy, with normal response and normal (or corrected to normal) vision, with more than 10 years of driving experience.
This kind of investigation not only confirmed the results of the geometric analysis, but also allowed the identification of further critical elements of the present layout of the road interchange.
In detail, the second level of analysis was aimed at the evaluation of the effects of the driver perception of the road geometry at the exit and entrance ramps of the mainline segment and, in general, in proximity to the merging areas of the interchange.
A final review of the drivers' expectancies and actual visual perception of each segment of the junction was accomplished through a brief questionnaire completed by each tester at the end of every single driving session.

4. Objectives and Methods for the Driver Behaviour Analysis

As reported above, the human behaviour assessment combined with the geometric analysis proved to be useful to identify how the interchange layout affects the driver manoeuvres due to well-known limitations, sensorimotor and cognitive principles of spatial-perception.
It is well known that road features influence the driver performance and contribute to operational mistakes originating accidents.
The most modern approach to road design is based upon some basic rules about the drivers' relationship with the road and the way in which the road is perceived (Birth *et al.,* 2013):

- drivers need enough time;
- the road leads to appropriate speed and stabilizes line tracking (field of view rule);
- drivers must be allowed to pre-programme their actions correctly.

With regard to road junctions, the mental workload of the drivers navigating an intersection is heavier than on continuous roads and the driver performance can be altered in case of incoherent or incorrect expectations (FHWA, 2013).
With respect to interchanges, despite the beneficial effects of the separation of the traffic flows, the human factors analysis reveals, in general, that many drivers have problems in the merging and diversion areas because of insufficient perception and judgement allowance affecting the expectancies relative to speed, path and direction.
With regard to the junction under inspection, beyond the geometric rules, the results of the driver behaviour assessment allowed the identification of some layout elements originating misperceptions, wrong expectations and, in general, wrong manoeuvres essentially due to the inadequacy of the visual field.
Most of the results of the behavioural data were coherent with the geometric analysis. Furthermore, the driver perception scrutiny allowed the identification of a set of measures to improve the optical guidance, to set the drivers' expectations and to better manage the field of view along the most critical sections.
The driver behaviour was recorded by equipping the test-car with common electronic devices consisting in a standard *I-Phone* uploaded with a dynamic GPS software enabled to save data about speed, acceleration and lateral position and to save a movie of each driver performance.
During the tests, the *I-phone* device with its *Dash Camera* was positioned in correspondence to the central axis of the vehicle to record a movie of each driver performance. To better assess the test vehicle position in proximity to the diversion and merging areas an *action camera* was also located inside the car at the right side of the front windshield. A further camera was put inside the vehicle.
In addition, an external camera was placed over the bridge overpassing the mainline upon the sidewalk of the crossroad segment.
The navigation application (*Sygic Navigation System*) allowed the recording of the main kinematic data of each route (speed estimated margin of error of almost 1% - Fazeen et al. 2012). The related diagrams (*distance vs speed, speed vs time, acceleration vs distance, acceleration vs time, etc.),* were memorised in a "cloud" directory before being processed.
Each driver was asked to drive along a well-defined route and all the tests were performed over the same route from the same starting point to the same ending point. The elements of the route (Fig. 2) were ran according to the following sequence: MF-5, MF-6, R-3, RS-2, R-2, Mf-4, MF-5, Mf-6, R-3, R-4, MF-8, MF-1, MF-2, MF-3, R-3, RS-1.
Before starting each test, the selected drivers were carefully instructed about the route, the tasks and the safety warnings. Through the described GPS and video devices it was possible to assess the driver behaviour with specific reference to speed, acceleration-deceleration manoeuvres, delay or anticipation of entrance and exit manoeuvres, transversal lane displacements (Fig. 3).
The tests were performed during off-peak hours in low-volume traffic conditions, to reduce the effects of the vehicle mutual interference.

Fig. 3.
Test Car and Dash Camera Shot

5. Results of the Dual Analysis

At the end of the second stage of analysis, five more critical sections were definitely identified (Fig 4).

Fig. 4.
Interchange More Critical Sections

Section n. 1:	entrance ramp from Lucera to Foggia (R-2, MF-4);
Section n. 2:	deceleration lane - ramp from Campobasso to Lucera (MF-2, R-1);
Section n. 3:	deceleration lane - ramp from Foggia to Lucera (new construction – MF-6, R-3);
Section n. 4:	merging area between the traffic from the Foggia to Lucera ramp and the traffic from the Campobasso to Lucera connector ramp (RS-1, R-3);
Section n. 5:	inner loop following the bridge overpassing the main carriageway (traffic from Lucera to Foggia – RS-2, R-2).

5.1. Section n. 1 – Analysis Results

The geometry of the ramp terminal was not modified by the 2015 intervention. The entrance ramp has no acceleration lane, according to the Italian Standards (DM 19/04/06).
In correspondence to this section, a geometric and visual analysis was conducted (Fig. 5).

Fig. 5.
Section n. 1 Views

As a result of the dual analysis, some critical features were detected.
The most perilous aspect depends on the intersection angle between the ramp and the mainlaine (42°-43°). In absence of the acceleration lane, the field of view is largely compromised. Morever, the horizontal STOP strip is wrongly drawn (the correct position should be alligned to the mainlane axis). The vertical STOP signal is positioned at a consistent distance from the marginal line of rhe main road (16.50 m), while the exceedindly wide cross section of the entrance lane (4.25 m up to 5.20 m) allows wrong overtaking manouvres in correspondence to the STOP strip.
With reference to the driver perception, the videos recorded by the external camera, combined with the internal camera view, confirmed the effects of the geometry inconstencies, through the identification of the wrong driver behaviour due to both the intersection angle and to the absence of the acceleration lane. As shown in Fig. 6, the position of the front end of the car depends on the driver scarce visual perception of the vehicular flow along the main road. The visibility is strongly affected not only by the car A-pillar blind spot, but also by the car lateral pillar which impairs the peripheral field of view (Wade M.G. et. al., 2002).
Under these circumstances, the reduced visibility is a potential cause of accidents. Along the main road, at the speed of 80-90 km/h, the available sight distance of the lateral intersection is insufficient.

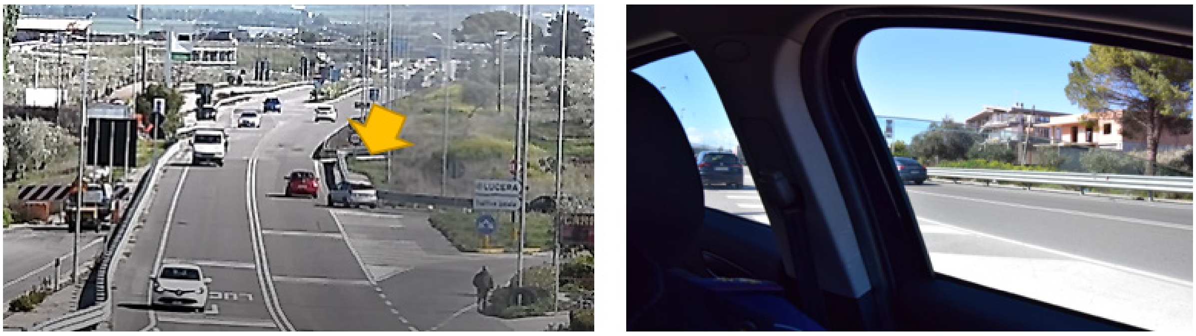


Fig. 6.
Section n. 1 - Effects of the Wrong Intersection Angle

5.2. Section n. 2 – Analysis Results

The geometry of the exit ramp at this section consists in a taper exit which was not modified by the 2015 intervention (Fig. 7).
Although at the existing speed limit of 50 km/h, the length of the exit lane is geometrically correct, there is no transition curve to access the ramp.
The *distance-speed* diagram (Fig. 9a) reporting the driver behaviour approaching the exit lane allows the identification of the following inconsistencies:

- the wrong position of the exit lane, which follows a right-hand curve of the main road (MF-2), does not allow a correct visual perception of the upcoming intersection;
- the backward position of the channelizing island is incorrect and the signalling group upon its nose is too late visible by the vehicles exiting the main road;
- there is a secondary private road access in proximity to the beginning of the exit lane;
- because of the reduced visual distance, drivers tend to delay the exit from the main road and abruptly stop their vehicles close to the nose of the channelizing island.

Fig. 7.
Section n. 2 – Lack of Visibility of the Exit Ramp

5.3. Section n. 3 – Analysis Results

At the section n. 3, the detected critical aspects depend (again) both on the position and on the layout of the deceleration lane of the exit ramp to Lucera (R-3). The length of the ramp, built in 2015, is correct with reference to the speed limit of 50 km/h (Fig. 8).

Fig. 8.
Section 3 – Wrong Use of the Exit Lane

However, the assessment of the driver behaviour through the *distance-speed* (Fig. 9b) and *lateral position-distance* diagrams, allows the detection of some layout features which significantly affect the regularity of the exit manoeuvres.
In detail, the speed and acceleration diagrams and the analysis of the transversal position confirm that:

- the left-hand curvature of the main road axis and, in part, of the adjacent deceleration lane, tends to delay the diversion maneuver in proximity to the nose of the exit lane;
- the main roadway left-hand curve superelevation favors this behavior, making the preventive channeling maneuver rather counterintuitive.

Fig. 9a, b.
Distance-Speed Diagrams (Sections n. 2 and n. 3)

5.4. Section n. 4 – Analysis Results

At this section, wrong technical choices were detected both because of the geometric layout and because of the lack of a logical sequence of the road elements. The previously recalled "pre-programme driver's actions" rule and the "field of view" rule are both violated (Fig. 10).
In more detail, the geometric analysis, the diagrams and the videos about the driver behaviour reveal that:

- the ramp (R-3) from Foggia (B) has priority over the curvilinear ramp (RS-3) from the overpass (A). Vehicles which overpass the main road must STOP at the end of the ramp RS-3 giving way to the traffic from their right side, contrarily to their expectations;
- the inadequate length and width of the taper acceleration lane (ramp R-3) do not allow the vehicles from Foggia (vehicular current B) to spot the vehicles coming from the RS-3 ramp (vehicular current A): in other words, at this section, the vehicular currents have difficulties in mutual sighting, especially at high speed;
- for the traffic from the RS-3 ramp, the horizontal STOP stripe and the vertical STOP signal are wrongly positioned, and drivers tend to abruptly stop their vehicle;
- the exit ramp R-4 to Campobasso is not correctly perceivable because of the limitations of the visual field.

Fig. 10.
Section 4 – Geometric Inconsistencies

5.5. Section n. 5 – Analysis Results

The section of the junction n. 5 is the one overpassing the SS 17 from Lucera to Foggia (RS-2 ramp). In 2015, the geometric layout of this segment of the intersection was not modified.
Along the RS-2 ramp, a critical coordination of vertical and horizontal alignments was detected. The crest in correspondence to the bridge overpassing the SS 17 is followed by a steep descent towards the entrance on the main road and it does not allow the pre-perception of the sharp left-hand curve which follows.

Fig. 11.
Section 5 – Poor Coordination of Horizontal and Vertical Alignments

The horizontal alignment following the crest is a 122 m straight followed by a 55 m radius left-hand curve. The horizontal curve, with modest superelevation, is geometrically inadequate even at the speed limit of 40 km/h and is inevitably run at higher speed because of the preceding descent (Fig. 11).
The records and the speed diagrams deducted by the driving tests (Fig. 12), confirm, in detail, that:

- the curvature of the ramp is exceedingly sharp;
- when running along the curve, towards the end of the ramp, drivers tend to occupy the opposite lane, with the risk of frontal impacts (the recorded driver displacements to the left are up to 0.35-0,37 m);
- the radius of the entrance ramp R-1 from Campobasso is about 25 m: the vehicles directed to Lucera have insufficient space to perceive the vehicles in the opposite direction and to reduce their speed.

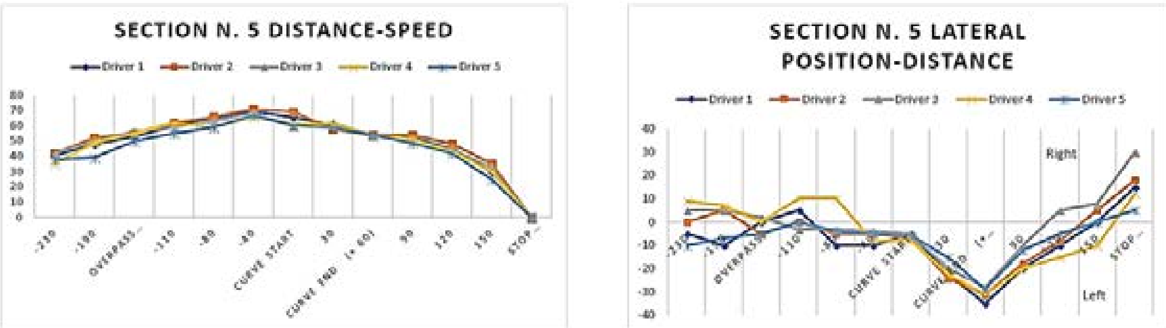


Fig. 12.
Distance-Speed and Lateral Position-Distance Diagrams Ramp R-2 (Foggia Direction)

6. Road Safety Performance Review

The review form of the final questionnaire which the drivers were asked to complete at the end of each test, consisted in two fields: "General data of the driver", "Driver Expectation Elements" referring to the roadway environment and the relationship with the driver expectations with regard to control, guidance, navigation.
Each driver had to assign a performance score (0-5) to each of the 5 sections about signal perception, pre-programming of manoeuvres, perceived road guidance and field of view, adequacy of the speed limit (Fig. 13).
The single answers of the questionnaire matched the driver behaviour as deducted by the control devices.
The section perceived as most dangerous is the n. 5.

	Section 1	Section 2	Section 3	Section 4	Section 5
Total Score (compared to 100)	44	39,2	56	47,6	36,4

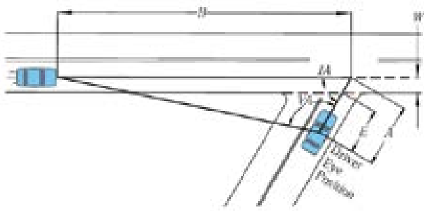
Fig. 13.
Results of the Driver's Final Review

7. Suggested Improvements

The aim of the dual analysis conducted is the identification of immediate and low-cost technical solutions which can improve the safety performance of the interchange through modest adjustments of the segments of the merging and diversion zones and the use of specific signalling systems to support driving guidance and navigation.

7.1. Section n. 1

A safety measure to improve the geometry of the right skewed intersection and the available sight distance for the drivers from the R-2 ramp consists in increasing the intersection angle between the R-2 profile and the main road axis (MF-2-MF-3). To prevent the effects of the viewing limitations due to the car black spots, the vision angle (VA) for the drivers of the oncoming vehicles should be not less than 95° (Campbell J. *et al.*, 2012). The present intersection angle (IA) should rise at least to 70-75° (Fig. 14). This value is compliant with the Italian Standards.



A	Subject Vehicle (SV) Collision Distance
E	Setback Distance
B	Available Sight Distance
IA	Intersection Skew Angle
VA	Subject Vehicle Vision Angle
W	Distance from Principal Other Vehicle (POV) to Intersection Tangent Line

Fig. 14.
Relationship Between the Intersection Angle and the Vision Angle
Source: (Campbell et al., 2012)

Further improvements consist in revising the backward position of the traffic island and in reviewing and repositioning the horizontal and vertical STOP signals.

7.2. Section n. 2

The suggested adjustments consist in redefining the exit ramp geometry and allow a sufficient sight distance for appropriate manoeuvres by creating a parallel change lane preceded by a taper area along the curvilinear alignment of the main road. The existing wide paved shoulder can be exploited to improve the lane length.
Further improvements consist in eliminating the private access, positioning an APL signal before the beginning of the taper lane and correctly re-building the divisional island to improve the visibility of its nose with the vertical directional signals upon it.

7.3. Section n. 3

With regard to the driver behaviour detected at this section, the possible improvements regard the correct pre-perception of the exit lane to better support the driver navigation when approaching the diversion point between the left-hand curve of the main road and the R-3 ramp. To allow drivers to pre-programme their diversion manoeuvres from the mainline traffic, the installation of an APL signal over the nose of the channelizing island is suggested. The destination information and the relative signs and (horizontal and vertical) arrows must be clearly paired with every individual destination travel lane (Campobasso-*left lane*, Lucera-*right lane*).

7.4. Section n. 4

The suggested adjustments consist in:
- redefining the geometry of the entrance ramp R-3 from Foggia, through an appropriately designed parallel acceleration lane to allow drivers to find a gap to merge with the traffic from the RS-3 ramp. The consequent length adjustment of the entrance lane can be achieved by exploiting the existing wide paved shoulder;
- redefining the precedence rules, by giving priority to the traffic from the RS-3 ramp;
- reviewing the geometry of both the noses of the R-3 and R-4 ramps, to allow a better optical guidance.

7.5. Section n. 5

Because of the difficulties to re-shape the ramp and the interchange geometry, the possible improvements consist in the installation of signalling systems to allow drivers to pre-programme their manoeuvres along the rapid descent towards the left-hand curve leading to the main road (Foggia direction).
A possible intervention consists in the installation of a danger signal over the carriageway and in the use of flashing lights over the (existing) signals indicating the left-hand curve following the descent.
To recall the driver attention, horizontal rumble strips are useful. Moreover, to avoid drivers to overpass the central lane, noisy longitudinal strips can improve the lane-keeping control.

8. Conclusions

The analysis reported in this study shed a light upon the effective safety performance of the junction. Despite the lack of data about significant accidents, the geometric and behavioural analysis brings to a rather analytical identification of the most critical sections of the interchange and to the proposal of pertinent and immediate safety measures.
The most significant results of the dual analysis conducted confirm the substantial coherence between the geometric design rules and the expected driver performance, although the driver performance assessment and the driver final judgment proved to be rather useful to identify the set of measures to improve the field of view, to reduce misperceptions and wrong expectations and to improve the road guidance by decreasing the risk of wrong manoeuvres.

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INCREASING TRAFFIC SAFETY AWARENESS IN CZECH KINDERGARTENS THROUGH A SAFETY EDUCATION PROGRAMME

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Abstract: In the Czech Republic, about 600 people die in traffic accidents each year, of which approximately 5% are children and young people up to 18 years of age. The death of a child is always a huge loss for the family and society. To reduce the number of these traffic accidents, trying to protect children by education from the earliest age, we developed a methodology of traffic safety education programme for preschool children (three to six years) and tested it in practice. Ten kindergartens took part in verification of the methodology. Five traffic education topics were used. A questionnaire survey was conducted two months after the end of the children's education. Children were divided into two groups: 235 children in the experimental group who were educated in road safety, and 235 control children in the control group without this education. The aim of this study was to find out if the knowledge and experience of children who have undergone safety education programme in kindergarten are greater than those who did not have education in this topic. For comparison of knowledge among individual children groups, a two-sample t-test was used. Furthermore, it was intended to identify areas where children have the least knowledge. The results showed that children who had undergone safety education programme had higher traffic safety awareness than children in the control group. It can be assumed that if the methodology is applied across kindergartens and children will be educated in road safety, it will contribute to changing the behaviour of children and increasing the safety of children in road traffic.

Keywords: traffic education, preschool children, kindergarten, road safety.

1. Introduction

On Czech roads every year more than 20,000 traffic accidents occur, of which approx. 2,000 involve children under 15 years of age and approx. 800 pre-school children (up to 6 years of age). Of the total number of traffic accidents, roughly one quarter result in tragic deaths. In European comparison, the Czech Republic is on rank 15 with number of acidents per one million inhabitants. Preschool children are involved in three road traffic roles – as pedestrians, passengers and cyclists. Accidents involving preschool children usually happen when crossing the road outside of marked pedestrian crossing. Siegler et al. (2017) confirm that preschool children often overestimate their abilities, since at their age they still cannot fully comprehend reality. Therefore, sudden entering the road is typical for this age.

Given the seriousness of the topic and the high number of accidents on Czech roads, the prevention of child safety in transport was implemented into preschool education system in Czech kindergartens. The influence of the environment occurs in pre-school age, when children gradually socialize and mature all the psychical components. At this age, children begin to realize their position in the group, responsibility for their actions, and gain the ability to self-regulate. Speech is developing, as well as thinking (Vágnerová, 2017). Koláriková and Pupala (2010) also stated that the advantage of an early age is also a great ability to accept new stimuli and learn. They even point to the fact that the child learns more in the first 4 years of life than any other four years in his/her life, including a college period. Therefore, it is important to start with traffic education at the earliest age.

Traffic education in pre-school age exists in most developed countries of the world. Many effectiveness studies confirmed that children, who attended pre-school traffic education, have changed attitudes and behaviour in certain situations related to the safety of children in road traffic in favor of safety (Luria et al. 2000; Thomson et al., 1997; Nishioka et al., 1991; Renaud et al, 1989; Downing et al., 1981; Limbourf et al., 1981). Although these studies illustrate the influence of traffic education on the change in behavior and attitudes of pre-school children, they could not clearl demonstrate that traffic education in kindergartens had a direct impact on the reduction of road accidents involving pre-school children (OECD, 1986; Duperrex et al. 2002; Dragutinovic and Twisk, 2006; Elvik et al., 2009). Moreover, the existing programmes are very diverse, and their objective evaluation is rather an exception. Since the education system in the Czech Republic indicates the obligation to include traffic education only generally, a methodology has been developed at the CDV – Transport Research Centre, which fully complies with this curriculum document and allows teachers to use a wide range of games and activities related to safety of children in road traffic. In addition to games relating to the direct safety of children in road traffic, it offers games that cultivate prosocial behavior and the ability to self-regulate and self-conceive. In addition, the methodology targets children not only as pedestrians, but also as cyclists and future car drivers. The methodology provides teachers with five integrated themes to five weeks a year. Compared to current practices (according to Dragutinovic and Twisk, 2006), this study fills in the following gaps:

1. While the existing programmes mostly focused on children only in the role of a pedestrian, our methodology looks at children in more roles (pedestrian, cyclist, future driver).
2. Most of the programmes were implemented in Western Europe and the conclusions may not be transferable – our study will complement the information on functioning in the conditions of the Czech Republic
3. Only few programmes were subject to objective evaluation – our study tries to fill this gap.

The methodology has been tested in practice in 40 kindergartens. Ten of them were visited afterwards, in order to collect data to answer the following hypotheses:

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1. Does weekly traffic education in kindergarten lead to a change in behavior and attitudes in the assessment of safe and dangerous situations in road traffic?
2. Do the children keep information in their memory and use them in safer decision-making?

The conclusions will provide the background for further traffic-preventive education in the kindergarten practice.

2. Data and Methods

2.1. Education in Kindergartens

In 10 kindergartens (South Moravia region, Czech Republic), traffic education led by a teacher from CDV – Transport Research Centre took place. This training took place for five days, with a total of ten hours of direct work with children. Various kindergartens were involved in the experiment, with the number of children enrolled from 36 to 125. Kindergartens were both private and state-owned. A total of 5 programme types were taught, and each programme was repeated in two kindergartens. In each kindergarten, one class attended, with an average of 23 children aged 3 to 6 years. Weekly programmes were based on the newly developed Traffic Education Methodology for Kindergartens (CDV – Transport Research Centre). The topics of the individual weeks are shown in Table 1, including the contents of traffic education. The training programme took place both in the classroom and outside. Children were taught through experiential and experimental teaching, working both individually and in groups. Discussion circles were included, where children were presented with situations in the pictures and commented on by the teacher. Children had the opportunity to express themselves and share their experience with each other. The programme was complemented by physical learning activities. Once in a week, children were also on a walk around the school where they watched real-world traffic and tried crossing the road.

2.2. Questionnaire Survey

Two months after the end of the traffic education programme in kindergartens, a questionnaire survey was conducted. In total, 470 children from 10 kindergartens were tested. The experimental group consisted of 235 children undergoing traffic education, and the control group included 235 children who did not have traffic education. This design was also used in a number of previous studies focusing on the educational programmes (e.g., Boele-Vos and de Craen, 2015; Ivers et al., 2016; Kurečková et al., 2017). The experimental and control groups were divided into 5 subgroups, according to themes that were presented to them during the traffic education. There were between 18 and 25 children in each subgroup. Each subgroup was tested by another questionnaire. The topics of the questionnaires are detailed in Table 1. In addition to test questions, the age of the children and their gender was recorded in the questionnaires. The children completed the questionnaire individually, the correct answers were recorded by the teacher. The children were provided a calm environment in a separate room and enough time to answer the questions.

2.3. Analysis

The obtained answers allowed comparison between experimental and control group in terms of percentages. In addition, statistical testing was conducted, as described in the following steps:
In order to investigate differences between experimental and control groups, individual questions were given weights (1 to 3 points), which reflect the relative importance of topics. For example, regarding reduced visibility:
- 1 point = a child understands the sense of reflective band
- 2 points = a child understands the sense of reduced visibility
- 3 points = a child knows which colour is the most visible in darkness

The answers (0 = incorrect, 1 = correct) were then multiplied by the weights (number of points) and summed per each education topic. To compare the knowledge between the groups, a two-sample t-test was used. Based on achieved level of statistical significance (p-value), null hypothesis (no difference) was then retained or rejected.

Table 1
Topics and range of traffic education

No.	Education topic	Range of traffic education	Focus of the questionnaire
1	Transport and transport means	The child: - understands the concepts of traffic and transport - knows the means of transport in the immediate surroundings of the kindergarten - knows the sounds of transport - understands that transport may be dangerous - understands that it must respect safety rules - identifies a safe playing place	Does the child know the transport means? Can the child name street sounds? Does the child distinguish between pictures of safe and dangerous situation?

No.	Education topic	Range of traffic education	Focus of the questionnaire
2	Traffic signs	The child: - understands the concepts of transport and traffic - knows that traffic is governed by traffic rules - understands the sense of their observance - knows the importance of traffic signs, recognizes their shape and colour, understands simple pictograms	Does the child understand the concept of road sign? Can the child explain the meaning of simple pictograms? Does the child know what the colours are on the traffic lights and understands their significance?
3	Walk along the street	The child: - knows the rules of safe movement on the street - correctly applies the rules of walking along the sidewalk and crossing the road - understands the concept of reduced visibility, recognizes reflective elements, and can use them - knows which colour is more visible in the dark	Does the child: - know the left and right sides? - know how to cross the road and can show it? - understand the concept of reduced visibility? - recognize reflective elements? - understand the use of reflective elements? - know which colour is best seen in the dark?
4	Watch out, I'm driving!	The child: - knows the rules of safe travel by urban transport - knows how to get in and out of the car - uses helmet while cycling	Does the child: - know it has to be belted? - know who is a cyclist and whether he needs to use a cycling helmet?
5	Child Rescuer	The child: - understands that the movement in traffic can be dangerous - can recognize safe and dangerous situations - recognizes a safe place to play - knows how to call for help in case of injury - knows emergency telephone number and can report its name and address - can identify the location of injury	Does the child: - know its name? - know its home address - know the part of the human body? - know the safe and dangerous situation according to the pictures? - know the numbers and can select a number from emergency numbers? - sort pictures by sequence of events (call of emergency)?

3. Results

3.1. Assessment of Knowledge on "Transport and Transport Means" (Questionnaire 1)

The results showed that 96% of the interviewed children are aware of the means of transport, and 90% of the children can tell more than 5 sounds that can be heard on the street. However, the difference in knowledge between experimental and control groups was not statistically significant.
With pictures of safe and dangerous situations, the children of the experimental group showed a statistically significant difference in recognizing the hazard compared to the children in the control group (p-value = 0.016). Children most often missed the risk of playing on pavement. 21% of children referred to this activity as being mistakenly safe. 15% of children referred to cycling without cycling helmet as unnecessary. Interestingly, when we asked children without the visual support of the direct question, "Do we have to have a helmet while cycling?", 95% of them answered yes (Questionnaire 4).

3.2. Assessment of Knowledge on "Traffic Signs" (Questionnaire 2)

The survey showed that 98% of children are able to recognize the importance of selected traffic signs and pictograms. These were the following traffic signs: pedestrian crossings, car parks, children, traffic lights, roadworks and pictograms: open fire, wheelchair, hospital, toilet, shower, ban on food entry. 97% of children knew which colours are on the traffic light and could explain their importance. The difference between experimental and control groups was not statistically significant.

3.3. Assessment of Knowledge on "Walk Along the Street" (Questionnaire 3)

48% of all respondents knew how to safely cross the road and only 39% could demonstrate it practically. Only 55% of tested children had steady laterality and repeatedly managed to identify the right and left sides. As shown in Figure 1, the knowledge of the road crossing was significantly higher with children from experimental group. Yet, it is only a theoretical knowledge. The practical test, where the child demonstrated looking behaviour, was statistically insignificant when comparing the experimental and control groups. The safety of children in road traffic also increased passive protection and use of reflective elements. Differences between the groups in the knowledge of reflective elements and their usage were statistically insignificant. Only 3% of the tested children understood the concept of reduced visibility. 55% of children knew that the colour of clothing played an important role in increasing the visibility of pedestrians in fog or darkness, and correctly determined that the reflective colour is best seen in the dark, then white and yellow, worst blue and black. The children in the experimental group in this knowledge showed higher success rate than the children in the control group (Figure 2).

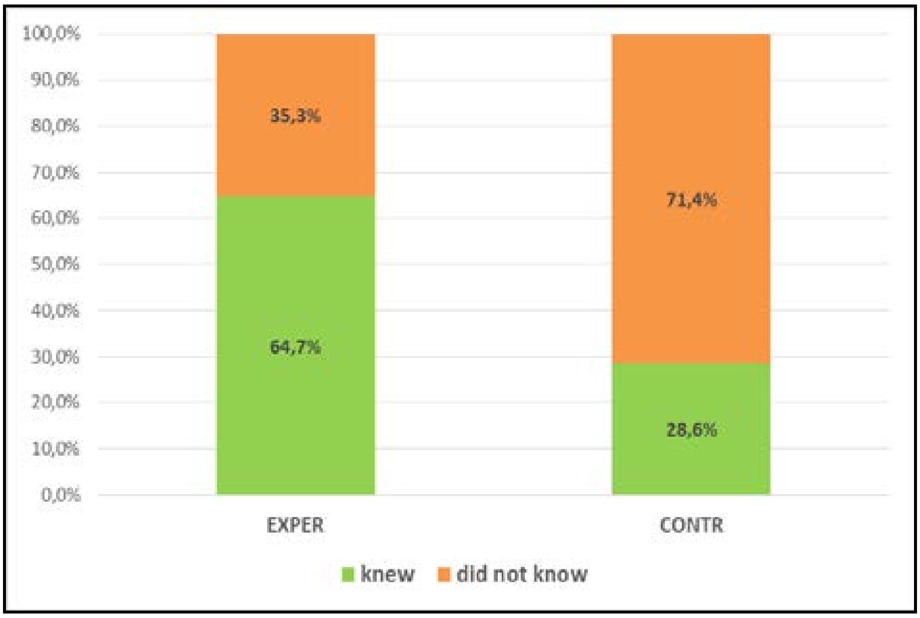

Fig. 1.
The child knows how to cross the road
EXPER = experimental group, CONTR = control group

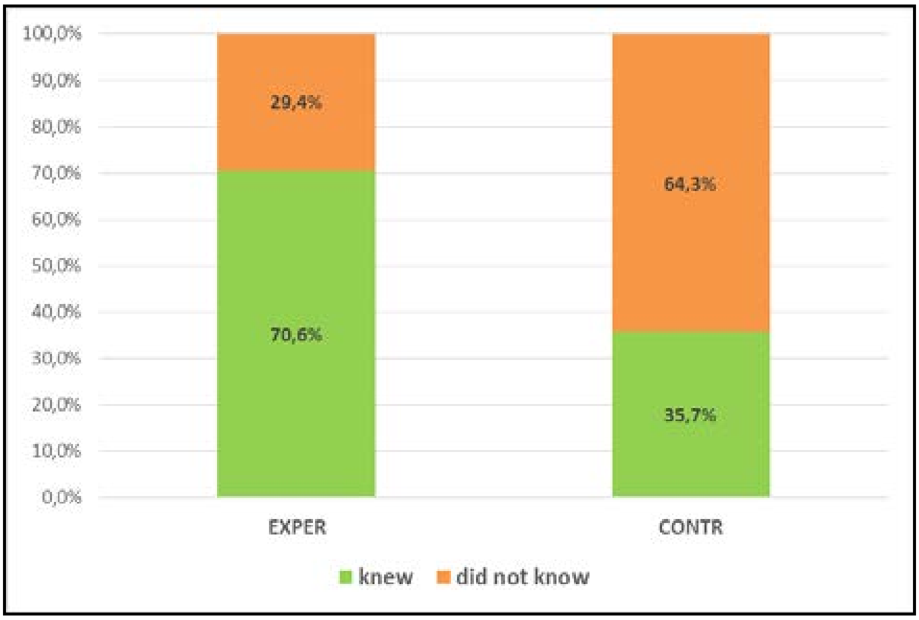

Fig. 2.
The child knows which colour is visible under reduced visibility
EXPER = experimental group, CONTR = control group

3.4. Assessment of Knowledge on "Watch Out, I'm Driving!" (Questionnaire 4)

While 20% of pre-school children did not know who the cyclist is, 95% of all respondents considered it necessary to use a cycling helmet while cycling. In questions about safe travel by car, 93% of children referred to the use of a child car seat as a necessity. The difference between experimental and control group knowledge was not statistically significant.

3.5. Assessment of Knowledge on "Child RESCUER" (Questionnaire 5)

We investigated how children could respond in case of crisis situations and whether they can call emergency. As Figure 3 shows, traffic education on "Child Rescuer" had significant effect in three areas. The children of experimental group were able to easily recognize individual numbers, which involved the ability to identify an emergency phone number. Only 16% of preschool children could dial emergency number on the mobile phone. The children in the experimental group were significantly better in proper sorting of the sequence of events necessary to rescue a person in danger. We found that children in the experimental group were statistically significantly better equipped with knowledge and abilities to call emergency than control group (p-value = 0.002). However, the questionnaire encountered a gap in the knowledge of pre-school children, which was the same for the two groups surveyed. Children often did not know the address of their residence, which is critical in case of being lost and needing emergency. 67% of pre-school children knew the name of the city where they live, but only 50% knew their street, and only 30% of children knew their house number.

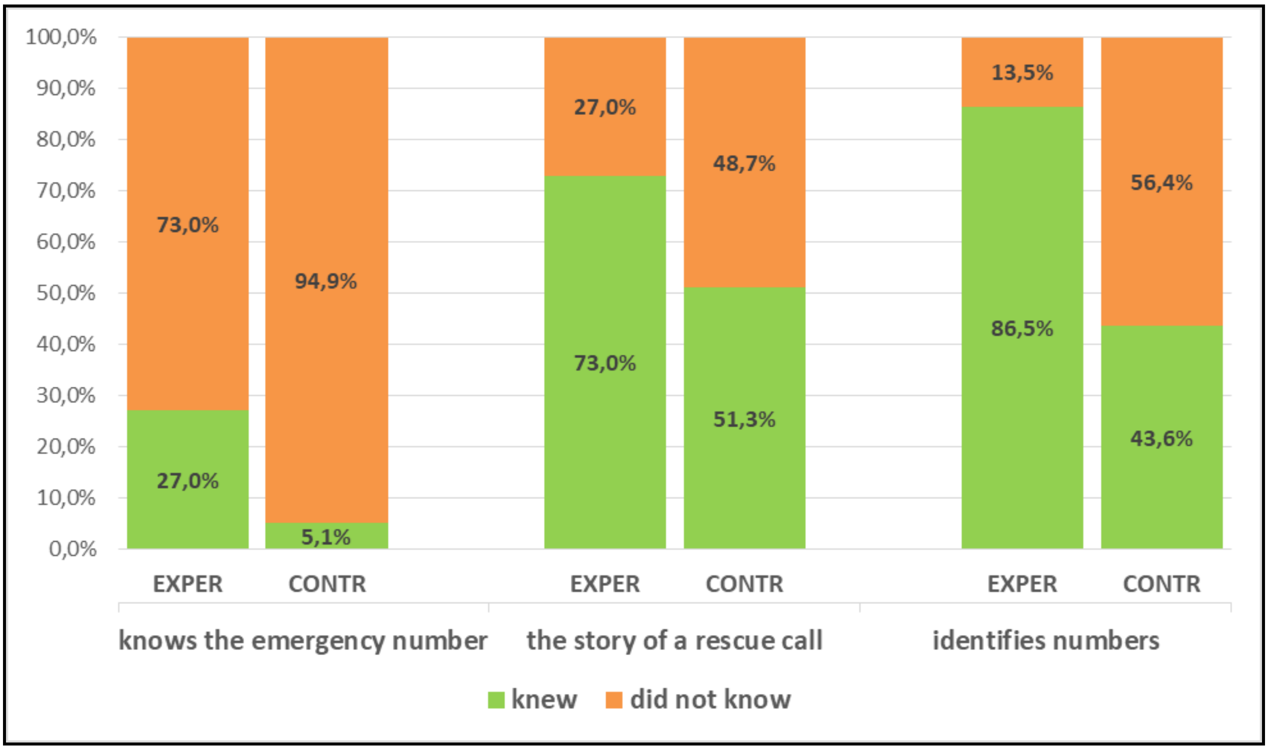

Fig. 3.
The effect of preschool children traffic education on the ability to call emergency
EXPER = experimental group, CONTR = control group

4. Discussion and conclusions

Results showed that only in two cases, the differences of the comparison of experimental and control groups were statistically significant. This may be due to a number of inputs that affect the children more than traffic education in kindergarten. It can involve the influence of the family and its environment, as well as the influence of the age, respectively child's maturity.

Regarding remaining topics, following may be concluded:

- As shown by the survey of Questionnaires 1 and 2, it is clear that knowledge of the means of transport and traffic signs and pictograms is primarily mediated by the family, which is why the influence of traffic education was not significant here. Direct practice in kindergartens has shown that the recognition of traffic signs is very attractive for children, although their knowledge is less important to children than, for example, correct decision-making when they cross the road. Due to the attractiveness of the symbols and their colouring, the children themselves ask about signs names and their importance and they want to learn it.
- Reflective elements are also very attractive for children. Here, too, the influence of parents on their knowledge and use is evident. Parents often protect their children by reflective elements, even if they do not use them and explain their function to children. In addition, reflective tapes are an attractive form of deployment and thus also serve as a children's game. This was reflected in game activities where children used them in kindergartens. The influence of traffic education has been recorded (but not significant) in the knowledge of children of different visibility of individual colours under reduced visibility. It can be seen that this knowledge of the parent population does not pass on to the children.
- Of great importance would be the finding that children in the experimental group have a safer behavior when they cross the road. However, this has not been confirmed in our research. The children in the experimental group had a

better knowledge of the right way to look at before road crossing, but they did the same practice with the same success as the children in the control group. The reason is mainly the unspoken laterality of pre-school children. As stated by Bednářová and Šmardová (2015), the laterality is established between the 7th and 11th year in children. Therefore, it is quite normal that only half of the tested children have repeatedly identified the left and right sides. Children from the experimental group who correctly determined that we were first looking left, then right, and then turning left once more, then practically exchanged the left for the right. A similar issue was dealt with by Limbourg and Gerber (1981) who tested 5–6 year old children 5 months after traffic education. They found that the probability of looking around was greater than in children who did not have traffic education. They also found that probability of looking around would be multiplied if children were scattered.

We believe that the success of traffic education has been statistically significant, and that it has to be done regularly, at least once a week, during walks around the kindergarten. Moreover, practice in kidergantens showed that teachers have found it preferable to have children in the garden before walking, for reasons of safety and greater comfort in childcare. Traffic education methodology also focuses on the children ability to call emergency. Significantly better results were achieved by children from the experimental group. This fact can be justified by the fact that teaching children to the emergency telephone number and only a introduction of children with possible crisis situations and the ways to properly preserve them can keep the child in their memory for quite a long time. Compared to the ability of safe road crossing, this is not a matter of long-term learning. This is also reflected in the role of parents who may perceive their child as being indifferent to familiarizing themselves with them at home. This is why the results show that children learned this information in the traffic education programme. Our results have also shown that the gender role in any of the tested questionnaires did not play any role.
To sum up, it can be said that traffic education in kindergartens makes sense. Children who have this kind of education in the kindergarten had greater knowledge of road safety. Unfortunately, it did not hold that traffic education is directly reflected in the reduction of the risk of children involvement in collisions. Pedestrian safety is strongly based on its psychomotor development, and traffic education in kindergartens is only a supportive tool in its faster development. It is assumed that the safety of preschool children would be increased only if there was a regular involvement of the traffic education in the kindergarten programme and practical training in the streets, which, unfortunately, rarely happens in kindergartens. Finally, these programmes should be evaluated professionally by both kindergartens and researchers (Raftery and Wundersitz, 2011).

Acknowledgements

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IMPACT OF VARIABLE WEATHER CONDITIONS ON DRIVERS' BEHAVIOR

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Abstract: Many previous studies have confirmed the impact of weather conditions on the drivers' behavior, including the speed selection and headways. Both speed reduction and changes in headways were linked to worsening weather conditions. Often as a reason for reducing speed during rain or snow the limitation of visibility caused by these precipitation was indicated. There are few studies aimed at evaluating drivers' decisions to reduce speed in connection with their subjective assessment of the increase of road safety hazards and information from signs, included VMS (variable message sign). The aim of the study is to evaluate whether the reduction of speed or the increase of headways sufficiently compensate for the increased hazard of accidents caused by the deterioration of road conditions. Therefore, the quantitative assessment of the relationship between the road surface condition, vehicles' speed and headways is necessary. The study was conducted based on traffic data from section of road with and without of VMS, which inform about worsening conditions. Results of paper can improve the traffic management and road safety. Results confirms that the speed reduction during bad weather conditions does not compensate for increasing hazard of road safety. Nevertheless, the analyses of road safety do not indicate significant changes in the number of accidents.

Keywords: drivers' behavior, road safety, weather conditions, odds ratio.

1. Introduction

Weather conditions are an important factor affecting the behaviour of road users. This impact may include various aspects of behaviour, including, among others, decisions regarding: the choice of the means of transport, travel time or travel cancellation, selection of a route, driving style (aggressive, relaxed), the selection of speed, headways, etc. Directly and indirectly, those decisions influence traffic performance and safety. Therefore, a deep insight into the scope and scale of the impact of weather conditions on the decision-making process of road users and the effects of these decisions is likely to improve the design process and the road infrastructure and traffic management.
Analyses of meteorological data from recent years suggest that:

- in some years, average temperatures in winter months remain above 0°C, while lower temperatures occur very rarely,
- frequent temperatures close to 0°C may cause a wide range of effects in terms of road surface condition (friction),
- during the winter season there often occur weather conditions that are more typical of autumn, including rainfall.;
- short-term extreme weather phenomena are becoming more and more frequent (heavy rainfall, intense snowfall, storms) following long periods of favourable weather conditions.

The above-listed constraints pose a high potential risk in relation to road safety and traffic performance, which has been confirmed by a large number of studies (*Ellinghaus et al., 2004*), (*Fu et al., 2017*), (*Holldorb et al., 2016*). The past and current research leads to the conclusion that it is possible to reduce the negative impact of changing weather conditions on road safety if drivers identify an actual influence of bad weather conditions on the traffic flow and take proper decisions which would compensate for the increased hazard. This identification and decision making process depends heavily on systems for the collection of data on road conditions and for warning road users (*Hong et al., 2015*), (*Kim et al., 2015*). It is also important to ensure a good technical condition of roads regardless of changing weather conditions. This condition should be adjusted to the road function and to the expectations of its users. Another group of measures to be taken, albeit falling beyond the scope of this paper, includes the development of vehicle construction and equipping them with active safety systems.
Considering the above-mentioned hazards related to changeable weather conditions, the authors made an attempt to assess the influence of these conditions on drivers' compensatory actions such as speed reduction and the change of the headways. Both speed and headways may be treated as surrogate measures of road safety. By reducing the speed, the driver can compensate disadvantages related to the change in the road surface condition. However, the question remains whether the driver reduces the speed sufficiently, i.e. to reach the value at which the length of the braking distance on the surface with a decreased friction is similar to that observed in good surface conditions. In addition, direct measurements were used when carrying out the research on drivers' behaviour, i.e. data on road accidents.

2. The Influence of Weather Conditions on Traffic Flow

The influence of weather conditions on traffic flow, especially the impact of winter conditions and the influence of road maintenance standards, has already been the subject of many studies. A good introduction to the complex issues of this problem can be found in (*Ellinghaus et al., 2004*), (*Fu et al., 2017*), (*Pisano et al., 2008*). Selected effects of variable

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weather conditions on the road surface, traffic flow and driver behaviour are listed in Table 1 (*Pisano et al., 2008*). The research described in (*Pisano et al., 2008*) brings us to an important conclusion, namely that main human errors leading to increased risk on roads are linked to drivers' poor ability to recognise slipperiness and to adapt their behaviour to adverse weather conditions. In terms of speed, average speeds on a slippery road surface are roughly 4 km/h lower than in good conditions. Reducing speed is not sufficient to compensate for the effect of inclement weather nor for the reduced friction. Research results show that adverse weather conditions increase the risk of accidents, suggesting that drivers' adaptation to weather is not sufficient to completely minimise the hazards associated with reduced road friction and poor visibility.

Table 1
Weather impacts on roads, traffic and the driver/vehicle

Weather Variables	Road Impacts	Traffic Flow Impacts	Driver/Vehicle Impacts
Precipitation/Rain	Visibility distance, Road friction, Road obstruction	Road capacity, Traffic speed, Speed variance, Time delay, Crash risk	Vehicle performance (e.g. traction), Driver capabilities, Driver behavior,
Thunderstorms (Lightning)	Visibility distance, Road friction, Road obstruction, Infrastructure damage, Loss of power, e.g. traffic signals	Road capacity, Traffic speed, Time delay, Crash risk	Vehicle performance (e.g. traction), Driver capabilities, Driver behaviour
Cyclonic Conditions/Floods	Visibility distance, Road friction, Road obstruction, Infrastructure damage, Lane/road submersion, Road buckling	Road closures, Travel delays, Crash Risk	Vehicle performance (e.g. traction), Driver capabilities, Driver behaviour
Wind Speed	Visibility distance (due to blowing dust & debris), Lane obstruction	Traffic speed, Time delay, Crash risk	Vehicle performance (e.g. movement), Driver capabilities, Driver behaviour
Snow/Ice	Visibility distance, Road friction, Road obstruction	Traffic speed, Time delay, Crash risk	Vehicle performance (e.g. traction), Driver capabilities, Driver behaviour
Fog	Visibility distance	Traffic speed, Speed variance, Crash risk	Driver behaviour
Temperature/ Humidity	Road surface softening & rutting, Road surface, buckling, Bleeding of asphalt	Traffic speed, Speed variance, Time delay, Crash Risk	Vehicle performance (e.g. traction), Vehicle damage, Driver capabilities, Driver behaviour

Source: Pisano et al., 2008

The importance of drivers' adaptation to changing weather conditions was also discussed in (*Ellinghaus et al., 2004*) and (*Kim et al., 2015*). In (*Ellinghaus et al., 2004*) a hypothesis was formulated that one of the reasons behind accidents in winter conditions is drivers' delayed response to worsening weather conditions (inappropriate identification of the actual condition of the surface). It was also concluded that long-term periods of adverse weather conditions improve drivers' adaptation to these conditions (decreasing the level of accident risk).

The main reason behind deteriorating driving conditions is the change of the value of the friction coefficient. Therefore, maintaining the required value of the coefficient in winter is one of the most important tasks of winter road maintenance (*NCHRP, 2013*), (*Rowland et al., 2007*). This means that, for example, the braking distance at the speed of 70 km/h on dry ice (friction coefficient equal to 0.2) is 3.5 times longer than on a dry surface (friction coefficient equal to 0.7). A full compensation for the deterioration of the surface in the example given would require the reduction of speed from 70 km/h to 38 km/h. Drivers often find it difficult to understand the necessity to reduce their speed so significantly.

Speed as the primary traffic parameter dependent on weather conditions was discussed in (*Ruess and Holldorb, 2007*), (*Thordarson and Olafsson, 2008*), (*Walsh, 2008*). Paper (*Thordarson and Olafsson, 2008*) provides a description of the use of the travel speed parameter in the assessment of the quality of winter road maintenance in Sapporo, Japan. The speed in winter is about 10 km/h lower than in autumn. According to the results, both the temperature and temperature squared value correlated positively with the travel speed. This means that the relationship between the temperature and the travel speed are U-shaped in the above study.

In (*Walsh, 2008*) the impact of snow intensity on speed reduction was described. It was concluded that the average speed reduction increases slightly as the snow intensity increases to 7 mm/h, but the speed reduction tends to increase abruptly after the snowfall exceeds 8 mm/h. Paper (*Ruess and Holldorb, 2007*) demonstrates that the average speed during winter weather events can be estimated based on a linear relationship with the following explanatory variables: average temperature during the event, average wind speed during the event (km/h), average visibility during the event (km), average precipitation intensity (cm/h), road surface index represented by the road condition, volume/capacity ratio, posted speed limit. The influence of winter conditions on road safety was analysed in (*Ellinghaus et al., 2004*), (*Holldorb et al., 2016*), (*NCHRP, 2013*). In (*Holldorb et al., 2016*) it was concluded that weather has a significant impact on road safety. In terms of crash frequency, rate, and severity, wet weather is far more dangerous than winter. Most weather-related crashes happen during rainfall and on a wet surface of a road. Drivers reduce speed slightly on a wet surface. During rainfall, people drive more cautiously and keep on reducing speed. Authors in (*Hong et al., 2015*), (*Kim et al., 2015*), (*NCHRP, 2013*), (*Ruess and Holldorb, 2007*), prove that weather monitoring systems have a significant impact on traffic safety. The results from the study on accidents due to slippery winter road surface suggest that if the road condition surveillance were more frequent, the accuracy of the published information on driving conditions could improve. This is especially true of the night time.

3. Data and Methods

In order to assess the impact of variable weather conditions on drivers' behavior, the authors carried out research on the speed reduction and change of headways as surrogate measures of road safety, and on changes in the number of accidents for roads of different winter maintenance classes.

Speed measurements were carried out on national roads: two lane road – 1x2R (speed limit of 90 km/h), two roadways – 2x2 (speed limit of 70 km/h due to pedestrian crossings) and on two lane road passing through small town – 1x2S suburban section (speed limit of 50 km/h). All the road sections were located in the vicinity of meteorological stations equipped with variable message signs (VMS) informing drivers of risks related to the change in road surface. VMS displayed information in the case of slipperiness or the possibility of it occurring. The assessment of the condition of the road surface was carried out based on the value of the conductivity of the surface and was classified as dry, damp or wet. Studies were carried out in winter months in good natural lighting at a temperature close to 0°C for wet and dry surfaces and for the interim state (damp surface). The variability of the vehicles' speed was assessed based on the value of the average speed *Va* and *V85* speed quantile. This allowed the estimation of the operating speed change (85 speed quantile) in vehicles. To this purpose, data from two-day measurements were used. The measurements were carried out in 3 locations on roads of I (snowdrifts and slush ice are not allowed) and II (a roadway can be covered by a thin coat of slush ice if this does not impede traffic) winter maintenance class. During the measuring period, consecutive timespans were selected with dry, damp and wet carriageway.

One of the elements of the study was to evaluate the impact of the road surface condition (dry, wet) on the share of unsafe headways as a surrogate measure of road safety. The analysis of headways was conducted on the basis of empirical data. These values were determined with the assumption of variable speed of subsequent vehicles and fixed values of deceleration depending on the type of vehicle. An unsafe headways was defined as the time interval between the fronts of two consecutive vehicles *Δtn* meeting the following inequality (*Gaca and Kiec, 2011*):

$$\Delta t_n \leq \frac{V_2^2}{7.2 \cdot V_1 \cdot (a_2 \pm g \cdot i)} - \frac{V_1}{7.2 \cdot (a_1 \pm g \cdot i)} + \frac{V_2}{V_1} \cdot t_r + \frac{3.6 \cdot l_p}{V_1} \qquad \text{[s]} \tag{1}$$

where

Δtn – critical time headway between analysed vehicles [s],
V1 – speed of leading vehicle [km/h],
V2 – speed of following vehicle [km/h],
a1 – deceleration of leading vehicle [m/s2],
a2 – deceleration of following vehicle [m/s2],
g – earth gravity [m/s2]
i – road grade [-],
tr – reaction time of the driver of following vehicle [s],
lp – length of leading vehicle [m].

The analysis of the results included several-day measurements of traffic in 3 localities with different types of cross sections (1x2 with paved shoulders, 1x2 with ground shoulders, 1x2 with sidewalks). The measurements taken made it possible to estimate the value of the share of unsafe headways depending on the weather condition of the road.

In addition to surrogate measures, changes in the number of accidents were analysed on road sections belonging to different winter road maintenance classes (from I to III) and for roads with and without stations monitoring weather conditions equipped with VMS. Based on the accident data, the influence of winter road maintenance class was assessed together with the impact of warning systems (monitoring weather conditions and road condition) on road safety. This assessment can be equated with the assessment of drivers' adaptation to changing weather conditions. Traffic safety was compared between the winter period (November to March) and the non-winter period (April to October). An analysis of the changes in the road safety was carried out with the odds ratio method (*Elvik et al., 2009*) based on the relative measures of changes in the number of accidents. The analyses took into account the period of three years during which accident data was collected, i.e. 2013-2015. The odds ratio method determines the relation between the chance of occurring of a given event (in a given group) and the occurring of such an event in a different control group. Using the odds ratio (*OR*) (equation 2), one can specify how much larger (*OR*>1), or smaller (*OR*<1) chances are for this event to occur. A value close to 1 indicates a lack of influence of the analysed factor (introduced change) on the chance of a given event occurring.

$$OR = \frac{A/B}{C/D} \qquad [-] \tag{2}$$

where:
A – the number of events in the treated group after changes,
B – the number of events in the treated group before changes,
C – the number of events in the control group after changes,
D – the number of events in the control group before changes.

Roads with the monitoring of weather conditions using VMS and roads belonging to the I class of maintenance in winter were adopted as the treated group. The control group consisted of roads of II and III (roads should be cleared of snow, no time indicate) winter road maintenance class without weather monitoring stations. The analysis was carried out for the following 8 sections of national roads:

- I class of winter road maintenance (2 sections), II class (4 sections) and III class (2 sections)
- with stations monitoring weather conditions equipped with VMS (5 sections) and without (3 sections).

For the before and after period, summer and winter months were adopted respectively. In addition, in order to conduct an assessment of the statistical significance of the estimated influence, confidence intervals with 95% probability were determined. The confidence interval for the estimated influence is determined using the following formula:

$$PU = exp(ln(OR) \pm 1{,}96 * SEln(OR)) \ [-] \tag{3}$$

where:
ln(OR) – natural logarithm of the estimated influence (odds ratio)
SEln(OR) – standard error of the logarithm of the odds ratio determined according to the formula:

$$SEln(OR) = \sqrt{\frac{1}{A} + \frac{1}{B} + \frac{1}{C} + \frac{1}{D}} \qquad [-] \tag{4}$$

The applied method allows to estimate the road safety in a simplified way, avoiding the significant limitations of an assessment required when using accident prediction models. The change in the road safety in the treated road sections was determined based on absolute measures, i.e. on the number of accidents.

4. Results and Discussion

4.1. Speed Study

The analysis of speed results consisted in the assessment of the change of speed for road sections with dry, damp and wet road surface, and with and without VMS. Table 2 presents the scope of the treated group and the value of average speed and quantile *V85* vehicle speed and their dispersion between analysed conditions of traffic (delta V) with respect to dry surface and no VMS.

The results indicate the variability of speed for the analysed weather conditions as well as various location of test sites (suburban, urban) and cross-sections (single or two roadway roads). Greater speed changes occur with an average speed more often than in the case of *V85* speed quantile. As was expected, the highest values of speed occur for dry surface. There is a reduction of average speed by ca. 5% (for two-lane roads) and by 7.5% (for two roadway roads) on a wet surface. In the case of *V85* speed quantile the reduction does not exceed 2.1%. For damp surfaces slight changes can be observed, both increases and a decrease in the value of the average speed (from -1.5% to 0.2%) and *V85* speed quantile (change from 0.5% to 1.6%). The results obtained are consistent with what was expected, but their value indicates that the speed reduction is insufficient in relation to the requirements resulting from the actual condition of the road. The compensatory measures taken by drivers, related to the change of speed, indicate the possibility of changing the friction coefficient on wet surface by ca. 0.05. In actual conditions for wet road surfaces this decrease could be several times higher.

One of the measures aiming at improving traffic safety is the use of additional VMS. In all cases, a greater speed reduction was observed when drivers were informed about slippery surfaces via VMS than in situations without such signs. The value of the reduction of average speed ranged from 7.6% to 16.3% and speed quantile from 0.3% to 12.4%. The results indicate that VMS are highly effective, causing much greater compensatory interaction (more than double), compared to the activities arising solely from drivers' perception of the road surface.

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Table 2
Changing the speed of the vehicle depending on the road surface and displayed warnings

Road	**Surface condition**	***No. of veh.***	***Va* [km/h]**	***V85* [km/h]**	***ΔVa* [km/h]**	***ΔV85* [km/h]**
Two-lane suburban (1x2S)	Dry	1697	57.20	59.11		
	Damp	887	56.33	59.43	-0.87	0.32
	Wet	859	53.93	58.81	-3.27	-0,3
	No warning	833	57.17	59.71		
	Warning	480	51.70	59.55	-5.47	-0,16
Two-lane rural (1x2R)	Dry	568	79.50	97.42		
	Damp	359	79.56	98.96	0.06	sty.54
	Wet	268	75.21	96.17	-4.29	-1.25
	No warning	626	84.81	103.04		
	Warning	601	72.57	91.14	-12.25	-11.90
Two roadways (2x2)	Dry	6095	74.20	98.33		
	Damp	3377	74.32	99.32	0.11	0.99
	Wet	4583	68.67	96.26	-5.54	-2.07
	No warning	5614	75.58	98.97		
	Warning	8441	70.33	97.09	-5.25	-1.89

Source: own source

4.2. Headways Study

The aim of the study was to evaluate changes in the behaviour of drivers in platoon when traffic conditions deteriorated. The extension of the braking distance is of less importance here, in view of the fact that for the adopted method of assessing unsafe headways the extended braking distance concerns the leading vehicle just as well as the following one. Drivers were expected to keep a larger distance between vehicles due to a subjective sense of increased risk in road traffic resulting from the rainfall in winter. The results are summarized in Table 3.
All the analysed cases showed a decrease in the share of unsafe headways during rainfall, which confirmed the hypothesis about the influence of rainfall on a subjective sense of the increased risk of road accidents and on making manoeuvres aiming at compensating for this increase (keeping greater distance between vehicles). Due to the size of the sample it is difficult to determine whether this type of cross-section has such a great impact on the change of drivers' behaviour.

Table 3
Share of distances between vehicles classified as unsafe depending on the carriageway condition

Cross-section of the road	**Road condition**		**Difference "Dry - wet"**
	Dry	**Wet**	
1x2 with paved shoulders	44.4%	40.5%	3.9%
1x2 with ground shoulders	52.5%	45.5%	7.0%
1x2 with sidewalks	52.7%	43.3%	9.4%

Source: own source

4.3. Accidents Study

The odds ratio analysis conducted according to the methodology described above makes it possible to estimate the relative change in the number of accidents based the equation 2 resulting from:

- standards of winter road maintenance: an evaluation of class II versus I (I-II) and III versus I (I-II);
- providing roads with stations monitoring weather conditions.

These changes were evaluated using the values of odds ratio along with the scope of confidence intervals table for the probability of 95%.

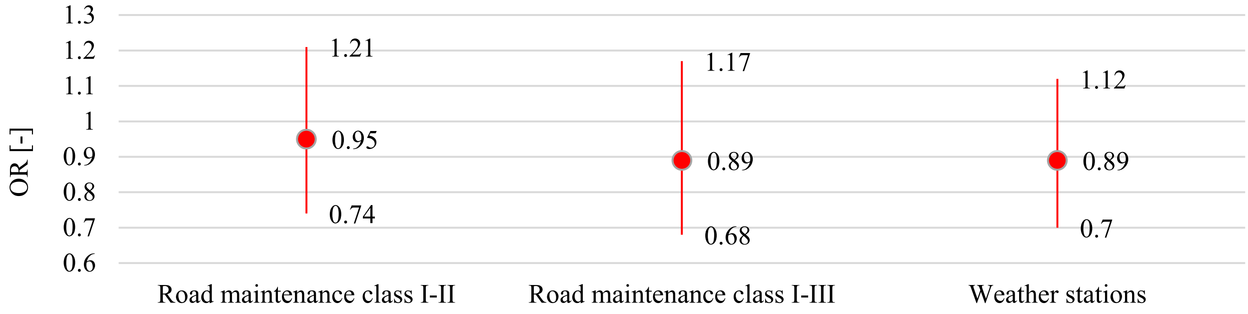

Fig. 1.
The relative change in the number of accidents for different road maintenance classes
Source: own source

Figure1 presents the results of the evaluation of the relative changes in the number of accidents together with the statistical significance. Equipping roads with weather monitoring stations and VMS can reduce the number of accidents approximately by 11%. A similar level can be obtained when changing road maintenance class from III to I. Change in the class by one level causes a change in the number of accidents by around 5%. The analysis shows that drivers are likely to take measures aiming at compensating for worse traffic conditions during winter. Unfortunately, the assessment of the statistical significance of OR values indicates no statistically significant evaluation of changes in road safety (the range contains value of 1.0). Despite this, the presented actions should be considered as improving road safety.

5. Conclusion

The research conducted has confirmed the result of the previous studies on the insufficient compensation of risk on the roads in winter and allow a reliable quantified measure of direct and surrogate road safety. Based on the analyses carried out, the following conclusions can be drawn:

- Drivers insufficiently reduce the speed in order to make up for the changing traffic conditions due to weather conditions arising from the change in the friction coefficient of the road surface. The reduction of average speed equals up to 7.5% which corresponds to the decrease in the friction coefficient by approximately 0.05, when it should be approximately four times greater.
- On a wet road the reduction in the share of unsafe headways decreases to around 10%.
- In winter, number of accidents is relatively less on the road of higher winter maintenance class (approximately 5% for each class) and on the road with weather stations with VMS (about 11%). This suggests that drivers undertake other compensation actions in adverse weather conditions despite relatively insufficient reduction of speed (e.g. better attention and focus, changing distances between vehicles).

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CONTROL MEASUREMENTS OF ROAD MARKINGS RETROREFLECTION AS A QUALITY INCREASING TOOL

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Abstract: The quality and quantity of drivers' visual guidance in road traffic depends on the visibility and the reflective properties of road markings. Using the latest methods and procedures for testing the road markings, a high and consistent level of visibility can be achieved, and thus the safety level of individual roads may be raised. This paper analyses how the systematic retroreflection measurements of road marking can ultimately increase their quality. For that purpose road markings retroreflection has been continuously measured on six single carriageway state roads in Croatia over ten-year period using static measuring method. Between 2003 and 2010, measurements were conducted according to the Kentucky methodology and since 2010, according to the German regulation ZTV M02. The results of measurements in the ten-year period show an overall average increase in night-time visibility of road markings by 48.96% and 23.08% in their daytime visibility. Obtained results prove that the constant and systematic retroreflection testing of road markings can contribute to the enhancements in their quality.

Keywords: retroreflection; road markings; visibility; road safety.

1. Introduction

Horizontal road markings are one of the safety features on modern roads. Generally, they can be defined as a set of longitudinal and transversal lines, signs and symbols on the road surface which inform and guide traffic participants as well as manage and regulate traffic. As such, they represent important road safety element whose presence may reduce occurrence of accidents by 20% (Miller, 1992). Their influence on driver's behaviour and overall road safety is especially prominent at night and in adverse weather conditions (Migletz et al., 1994).

Both road users and the road authorities require efficient and durable road markings. Selection of the type of road markings material by road authority depends on many factors, including the desired durability, required visibility, price, and local considerations. From the users' point of view, road markings provide an optical path by means of contrast of colour during the day and luminous contrast (retroreflection) during the night or under low visibility conditions (Babić et al, 2017). In order to ensure a clear visual path to the driver's both of these properties should be maximized (Horberry et al., 2006).

The retroreflective effect of road markings is possible due to the use of glass beads which are added on the markings surface during the application. The retroreflection process in the glass beads occurs in three steps. As the light ray enters the bead, it gets refracted or bent. Once inside, light gets reflected from the material in which the bead is embedded, and then gets refracted a second time while leaving the bead surface. Retroreflected luminance, R_L (usually referred to as retroreflection or night-time visibility) is an important characteristic of road markings which determines their overall quality. Generally, markings with higher retroreflection are assumed to provide higher levels of visibility during night-time conditions.

EN 1436 (Road marking materials - Road marking performance for road users) defines a standard for retroreflection measurements of road markings using a static and dynamic method. The Norm is adapted from standards originally set by the European Committee for Normalization (CEN) and provides the requirements of the measuring devices (retroreflectometers) to simulate daytime and night-time visibility for an average driver in a passenger car.

The main purpose of these measurements is to control the quality of contractors and to optimize the maintenance activities. Namely, after the contractors finish their job, road markings visibility is measured in order to check whether markings meet the minimum prescribed values. Once in exploitation, markings should be periodically measured (usually after winter season) for the control purposes which enable the road authority to plan and optimize their maintenance costs while maintaining the satisfactory level of visibility needed for the drivers.

This paper presents an analysis of retroreflection measurements on six state roads in Croatia conducted by the Department for Traffic Signalling at the Faculty of Transport and Traffic Sciences, University of Zagreb in the period between 2003 – 2013 using static measuring method. The main goal of the study is to investigate how continuous measurements of road markings visibility influence the quality of contractors and thus the visibility of the markings. Although, due to the complexity of the traffic accidents, it is challenging to precisely determine the impact of road markings retroreflection on safety, the prevailing opinion is that the retroreflection of markings has a positive effect on road safety (Carlson et al., 2013; Avelar et al., 2014; Aldemir-Bektas et al., 2016). Therefore, the quality of road markings must be recognized and their retroreflection performance should also be examined.

2. Static Methods for Testing the Quality of Road Markings

The evaluation of road markings performance was introduced in the European Union through the standard EN 1436 in August 1997. In particular, EN 1436 specifies the performance of white and yellow road markings, based on luminance factor (colour), day-time and night-time visibility and skid resistance. The standard also introduces the importance of wet-night visibility of road markings, describes the methods of measuring the various performance characteristics and defines different classes of performance for road markings. Based on these classes, road authorities may introduce a certain class of performance in their public tenders, depending on the compromise between the road users' needs and the available budget. Main quality characteristics of road markings are in relation with their visibility which can be expressed as reflection in daylight or under road lighting (Q_d) and reflection under the headlights luminance (R_L). Q_d is the property of the markings which describes the brightness of its colour. Q_d measures, true to scale, the luminance (daytime visibility) of a road marking. The observation angle of 2.29° corresponds to the viewing distance of a motor car driver of 30 m under normal conditions. The illumination is diffused light. Reflection in daylight or under road lighting Q_d is measured using a retroreflectometer and this value is expressed and measured in $mcd \bullet m^{-2} \bullet lx^{-1}$. In dry conditions, Q_d of white road markings on asphaltic surfaces shall conform to Table 1.

Table 1
Minimum values of Q_d for white dry road markings on asphaltic surfaces

Road marking colour	Road surface type	Class	Minimum values of Q_d ($mcd \bullet m^{-2} \bullet lx^{-1}$)
White	Asphaltic	Q0	No performance determined
		Q2	$Q_d \geq 100$
		Q3	$Q_d \geq 130$
		Q4	$Q_d \geq 160$

Source: European Norm EN 1436

Reflection under vehicle headlamp illumination R_L (commonly named retroreflection) is the ability of a road marking to reflect light from vehicle headlights back to the driving position of a vehicle. R_L measures, true to scale, the retroreflection of road markings using the same geometry as daytime visibility which implies the illumination angle of 1.24°, the observation angle of 2.29° and viewing distance of a motor car driver of 30 m under normal conditions. The measured value is expressed in $mcd \bullet m^{-2} \bullet lx^{-1}$. Reflection under vehicle headlamp illumination R_L should be measured in dry, wet and rainy conditions with a retroreflectometer. White road markings on asphaltic surfaces in the dry condition shall conform to Table 2.

Table 2
Minimum values of RL for white dry road markings on asphaltic surfaces

Road marking colour	Road surface type	Class	Minimum values of R_L ($mcd \bullet m^{-2} \bullet lx^{-1}$)
White	Asphaltic	R0	No performance determined
		R2	$R_L \geq 100$
		R3	$R_L \geq 150$
		R4	$R_L \geq 200$
		R5	$R_L \geq 300$

Source: European Norm EN 1436

As mentioned in the introduction, the visibility of road markings can be measured using static and dynamic method. Static measurements (daytime and night-time visibility) can be done using the handheld retroreflectometer (Figure 1.) which simulates the geometries mentioned above, i.e. visual distance of the marking on the pavement 30 meters from the driver's eyes, with an eye height of 1.2 m and 0.65 m height of the lights from the road surface.

Fig. 1.
Device for measuring retroreflection of road markings

In the Republic of Croatia, the static measurements were conducted according to the "Kentucky" method from 2003 until 2010. From 2010 the measurements are done according to the guidelines and technical requirements of German regulation ZTV M 02.

2.1. Kentucky Method

In the Kentucky method, measurements are performed in the first third of the length of the road section on which road markings were applied by one application team in one day. In that first third of the section, a single zone of 500 m is evaluated with 10 measurements at distances of 50 m. On each of these 10 micro-locations, three measurements are taken, and an average is calculated. The main disadvantage of this method is that the measurements are performed only in the first third of the measurement section and the other two sections are not taken into account, leading to potential misrepresentation of the retroreflection of the road markings in these sections of the road (Babić *et al.,* 2016).

2.2. Method in accordance with the German guidelines ZTV M 02

ZTV M 02 includes measuring the thickness of dry paint film, day and night-time visibility in dry conditions, night-time visibility in wet conditions and the skid resistance. According to Croatian regulations, measurements are carried not earlier than 30 and no later than 60 days after road markings are applied (Technical Terms of Company Croatian Roads Ltd., 2010). The number of measuring sections of longitudinal markings depends on the length of the road markings which were applied by one application team in one day (Table 3.).

Table 3
Number of measurement sequences

The length of longitudinal markings done in one day (km)	The length of the other markings done in one day (m^2)	Number of measuring sections
< 1	< 120	1
1 - 5	120 - 600	2
>5 - 10	> 600 - 1200	3
> 10	> 1200	4

Source: ZTV M02

Measurement sections are selected according to the principle of randomness. In each measuring section five measuring points are selected. For continuous road markings, every measurement section is 100 m long and measurements are performed at the beginning, then at 25 m, 50 m, 75 m and at the end of the section. For discontinuous (dashed) longitudinal markings, length of 10 dashed lines represents a measuring section and measurements are allocated in the middle point of every second line in that section. In relation to the Kentucky method, the randomness of measurement section selection helps to create a more representative picture of retroreflection for the entire road length.

2.3. Road Markings Visibility Requirements in Republic of Croatia

The required quality of road markings in Croatia depends on the type of the road. Since in this paper only state roads are analysed, the visibility requirements, depending on the state of the marking (restored or existing) and their type (type I and type II) are shown in the Table 4. Restored markings are measured between 30 and 60 days from the application, while existing are normally measured after winter (around one year after the application). A type I line is made from standard paint (solventborne or waterborne), while a type II line is made of thicker material such as plastic materials, industrial tapes, special rain paint, etc. with higher index glass beads.
Minimum values of R_L and Q_d, regardless of the utilized measuring method, are defined in technical terms by Croatian Roads Ltd. and shown in Table 4. which presents minimum values for various lines (restored, existing, type). If the average measured value of R_L and Q_d on one measuring section meets the defined intervals in Table 4, additional measurements must be performed in order to prove whether the marking meets or does not meet defined minimum value.

Table 4
Minimum values of retroreflection for restored and existing lines type I and II

Visibility and state of pavement	Minimum value	Interval ($mcd \cdot m^{-2} \cdot lx^{-1}$)
Restored lines type I		
Night-time visibility, dry pavement	$R_L \geq 200$	$180 \leq R_L \leq 220$
Daytime visibility, dry pavement	$Q_d \geq 130$	$110 \leq Q_d \leq 150$
Restored lines Type II		

Night time visibility, dry pavement	$R_L \geq 300$	$270 \leq R_L \leq 330$
Daytime visibility, dry pavement	$Q_d \geq 160$	$140 \leq Q_d \leq 180$
Existing lines Type I		
Night time visibility, dry pavement	$R_L \geq 100$	$90 \leq R_L \leq 110$
Daytime visibility, dry pavement	$Q_d \geq 100$	$90 \leq Q_d \leq 110$
Existing lines Type II		
Night time visibility, dry pavement	$R_L \geq 150$	$130 \leq R_L \leq 170$
Daytime visibility, dry pavement	$Q_d \geq 130$	$110 \leq Q_d \leq 150$

Source: Guidelines and technical requirements for the works on renewing road markings, Croatian Roads Ltd., 2010

4. Result Analysis

As mentioned before, retroreflection measurements on six state roads in Croatia were conducted continuously each year using static measuring method from 2003 until 2013. The retroreflection was measured between 2003 and 2010 according to the "Kentucky" and from 2010 until 2013 using ZTVM 02 methodology. Each retroreflection measurement each year was measured at the same location.

The average measuring results of night-time and daytime visibility of road markings are presented in Tables 5 and 6 in which, except the daytime and night-time visibility, road classification and number (according Croatian laws) and type of line (ML – middle line, SLR – side line right, SLL – side line left) are shown. The last column (TG) represent the total growth of night-time and daytime visibility for each line in the analysed period (2003-2013).

Table 5

Average night-time visibility (R_L) on selected roads in Republic of Croatia per each year (2003. – 2013.)

Night visibility - R_L – each year ($mcd \cdot m^{-2} \cdot lx^{-1}$)												
Road	**Line**	**2003.**	**2004.**	**2005.**	**2006.**	**2007.**	**2008.**	**2009.**	**2010.**	**2011.**	**2012.**	**2013.**	**TG (R_L)**
D36	ML	142,03	222,94	242,26	252,32	260,66	271,45	272,35	285,15	290,18	305,12	308,07	**116,90%**
	SLR	189,00	204,30	236,63	246,53	253,15	260,37	263,68	268,40	286,40	288,07	290,43	**53,67%**
	SLL	164,00	234,93	241,46	248,43	250,55	259,64	262,00	266,69	281,00	287,64	289,03	**76,24%**
D30	ML	198,28	251,54	262,35	265,56	277,70	286,12	285,35	296,48	311,11	324,56	325,67	**64,25%**
	SLR	256,20	257,80	262,47	266,33	268,74	261,80	283,60	297,33	297,50	301,13	301,56	**17,70%**
	SLL	207,85	215,90	224,61	238,35	255,61	267,40	265,88	276,00	321,25	312,34	322,17	**55,00%**
D37	ML	187,95	198,05	248,40	293,84	209,88	287,63	270,33	251,25	311,83	308,12	315,18	**67,69%**
	SLR	215,50	230,36	235,25	240,55	250,30	219,00	267,70	270,75	255,50	267,45	271,98	**26,21%**
	SLL	240,32	256,10	252,13	255,81	264,12	266,25	282,35	293,75	291,50	288,43	292,01	**21,51%**
D7	ML	188,51	219,06	227,60	288,80	290,40	294,55	299,54	307,35	313,29	309,56	317,87	**68,62%**
	SLR	220,15	262,30	279,83	262,76	266,54	249,77	271,24	278,65	285,11	288,04	289,77	**31,62%**
	SLL	238,67	255,03	263,60	306,35	272,45	232,06	278,31	285,41	293,11	290,17	293,78	**23,09%**
D2	ML	190,47	220,76	247,15	292,75	278,69	269,61	280,57	287,44	269,15	293,07	298,43	**56,68%**
	SLR	211,20	257,30	270,73	272,07	278,23	245,07	261,77	266,51	265,73	280,13	282,79	**33,90%**
	SLL	189,80	226,00	290,38	273,18	272,67	260,94	268,90	271,14	273,07	275,56	277,01	**45,95%**
D55	ML	201,30	243,54	250,20	254,65	260,55	261,05	285,35	282,12	271,30	291,45	288,84	**43,49%**
	SLR	186,63	206,63	236,10	235,13	247,67	223,80	254,41	261,63	266,63	265,45	267,13	**43,13%**
	SLL	176,10	194,56	230,71	233,40	240,58	243,56	238,89	243,78	246,10	248,31	238,99	**35,71%**

Table 6

Average daytime visibility (Q_d) on selected roads in Republic of Croatia per each year (2003. – 2013.)

Daily visibility – Q_d – each year ($mcd \cdot m^{-2} \cdot lx^{-1}$)												
Road	**Line**	**2003.**	**2004.**	**2005.**	**2006.**	**2007.**	**2008.**	**2009.**	**2010.**	**2011.**	**2012.**	**2013.**	**TG (Q_d)**
D36	ML	154,76	157,12	159,4	162,83	166,76	170,7	171,4	175,77	168,76	169,45	166,56	**7,62%**
	SLR	149	153,64	148,83	158,42	160,56	166,12	167,2	169,2	180,1	178,34	180,77	**21,32%**
	SLL	153,6	162,93	144,4	150,22	155,43	161,18	168,65	173,46	169	176,22	178,12	**15,96%**

D30	ML	149,23	154,35	152,96	160,25	166,55	168,9	170	162,1	160,26	175,78	176,04	**17,97%**
	SLR	138	152,7	154,23	156,55	153,25	145,4	155,8	168	172,25	170,23	174,9	**26,74%**
	SLL	139,45	162,2	164,16	166,82	169,55	149,78	157,55	158,75	168	165,89	168,36	**20,73%**
D37	ML	156,1	147,8	139,67	167	169,35	172,13	140,5	168,17	167,08	169,05	170,35	**9,13%**
	SLR	137,3	145,2	115,8	143,6	145,65	119,7	150,24	153	175,18	170,67	174,31	**26,96%**
	SLL	110,21	119,1	129,47	143,4	148,54	152,25	155,34	152,38	169,67	177,69	180,13	**63,44%**
D7	ML	137,51	138,54	139,17	157,87	162,32	178,07	169,45	170,25	171,54	170,8	174,21	**26,69%**
	SLR	143,57	194,55	155,16	145,81	153,23	166,27	164,25	166,35	167,38	169,07	180,81	**25,94%**
	SLL	167,53	156,7	145,85	161,1	167,88	180,83	174,1	178,36	179,33	177,45	180,31	**7,63%**
D2	ML	139,93	140,67	134,1	154,41	168,98	165,27	167,89	165,47	162,25	167,98	169,34	**21,02%**
	SLR	135,45	185,3	141,47	140,76	155,76	166,62	164,67	169,21	178,09	175,45	172,67	**27,48%**
	SLL	134,3	161,2	147,75	146,91	160,45	168,56	170,13	164,41	172,57	170,55	174,21	**29,72%**
D55	ML	156,5	161,9	162,15	165,42	171	181,05	186,9	194,35	202,5	189,56	196,34	**25,46%**
	SLR	137,42	146,9	151,58	159,2	163,66	165	179,72	184,61	188,25	177,56	182,33	**32,68%**
	SLL	164,3	179,91	162,09	144	158,22	168,98	179,5	177,17	186,5	172,77	179,14	**9,03%**

From the collected data it can be concluded that the middle line has the highest growth of night-time visibility and the lowest growth of daytime visibility. As the middle line is the most important to the driver's orientation, the growth of almost 70% is satisfying. Relatively low growth of daytime visibility can be explained with the fact that daytime visibility depends more on external factors such as dust and dirt on the line.
The average values are presented also in the Figure 2 and 3.

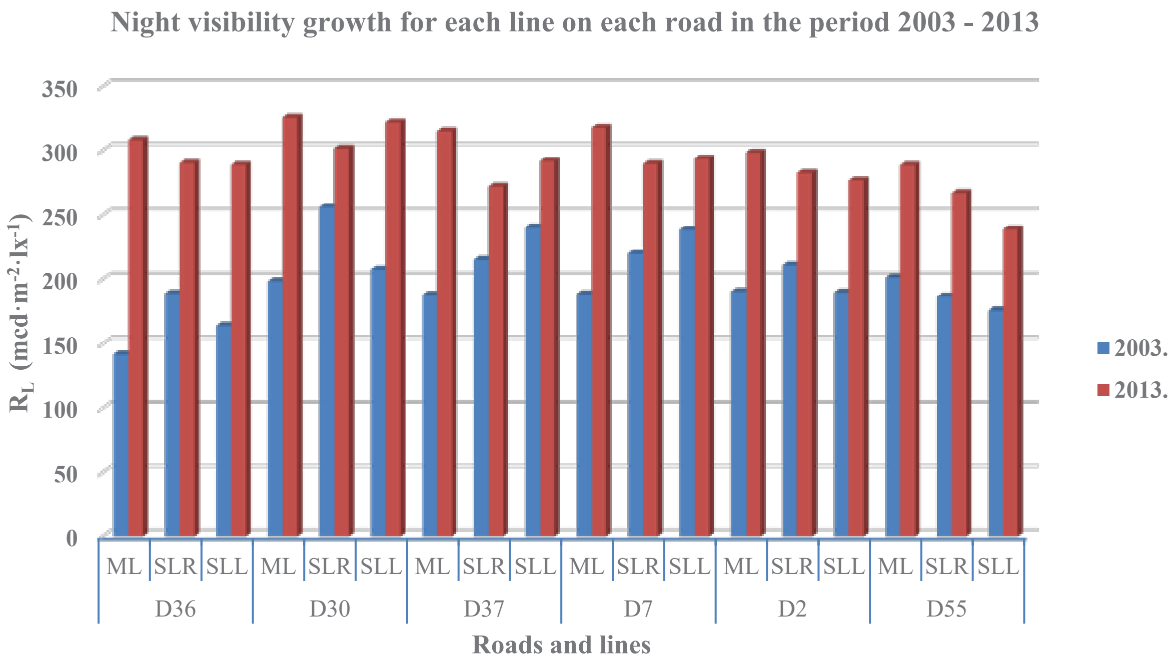

Fig. 2.
Night-time visibility growth for each line on each road in the period 2003 - 2013

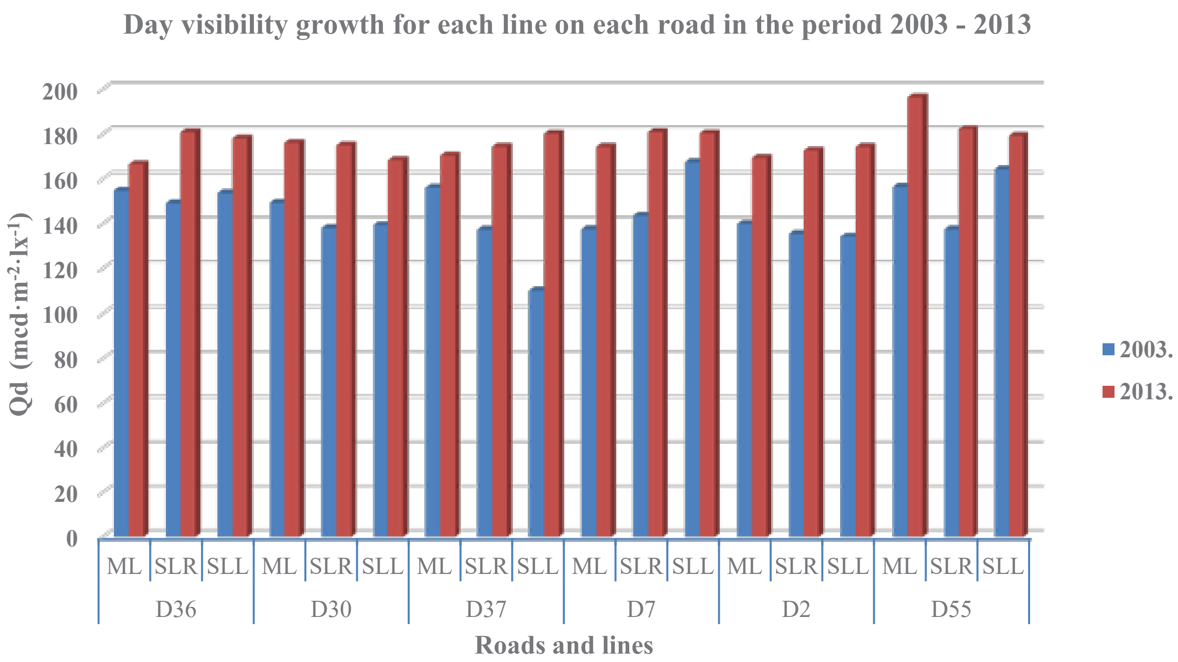

Fig. 3.
Daytime visibility growth for each line on each road in the period 2003 - 2013

The presented results show that the measured values of R_L and Q_d in 2013 at all locations are higher than in 2003. The greater variability in the increase in Q_d values over the decade compared to the R_L values, as mentioned, is due to the influence of external factors such as dust and dirt on the line, while the value of R_L depends primarily on the amount of embedded retroreflective elements (glass beads) and the quality of road markings.
In 2003, road marking contractors were confronted with the poor performance of their work (retroreflection values) and most of the lines needed to be renewed (repainted). In 2004 and 2005, contractors invested more effort and care for their work resulting in less need for repainting. After these initial years of testing, the whole system has become accustomed to the fact that there is quality control of road markings retroreflection. Moreover, these results show that the value of retroreflection is constantly increasing all thanks to systematic testing of road markings.

5. Conclusion

The quality of road markings depends on many factors and one of the most important is the level of quality and knowledge of the contractor. For this reason, it is very important to evaluate the road markings after application in order to determine whether the contractors met all requirements. In addition, measurements must be periodically conducted to gain insight into the state of road markings and, by implementing specific measures, ensuring a certain level of quality.
The purpose of this study was to investigate how quality control influenced the increase in the road markings visibility on six state roads in Croatia. For these purposes, daytime and night-time visibility was measured, between 2003 and 2013, each year in the same location using handheld retroreflectometer.
The results show that the measured values of R_L and Q_d on each road in 2013 are higher than the values in 2003. For example, the middle line on road D36 has a growth of night-time visibility of 116.90% while the minimum growth (17.70%) was recorded on D30. Day-time visibility increased also with extremes of 63.44% on D37 left-side lane and 7.6 on D36 middle line. Overall average growth of night-time visibility on all roads and lines was 48.96% and 23.08% for daytime visibility. These results clearly show that constant control and testing of road markings affects the quality and durability of road markings.
Satisfying the minimum values may compel contractors to invest in technology and training of its employees in order to be able to meet these requirements. Moreover, since the absence or poor maintenance of road markings is directly related to the driver's behaviour and workload, i.e. drivers comfort and perceptibility, the satisfactory levels of road markings visibility ultimately may increase the overall road safety ensuring clear trajectories of the driving path, removing a substantial workload off the driver and providing the anticipatory stimuli of the road environment. This is especially important during low visibility conditions, in which drivers tend to maintain a vehicle's lateral position based on the road markings and their detection distances of road markings are shown to correlate (logarithmically) to retroreflection (Aktan *et al.,* 2004, Finley *et al.,* 2002).
In addition, the lack of proper maintenance effectively cancels the safety benefits that can be gained through new vehicle technologies like Lane Departure Warning Systems (LDWS). Also, it is estimated that by 2025 at least half of the vehicles on Europe's roads will have some ability to "read" the road ahead. These vehicles will not work properly if the road markings and lines upon which they rely are not maintained to a high standard.

From all above it can be concluded that the constant control and testing of road markings may help road authorities to increase road markings quality and determine the proper implementation techniques and technologies for specific roads based on their geographic, traffic and climate conditions. Proper technology (materials) may extend the lifespan of road markings, reduce the activities related to the renewal of the markings resulting in financial savings while maintaining the desired level of road safety.

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QUANTITATIVE ASSESSMENT OF THE TRANSPORT DISADVANTAGE LEVEL

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Abstract: Although transport disadvantage is very widespread phenomenon which could influence various social groups, transport disadvantaged individuals are not affected by the same level of transport disadvantage. The aim of this paper is to determine numerical value, i.e. grade which will present the level of transport disadvantage. The research was conducted on secondary school students of the City of Zagreb. Young people are often considered as transport disadvantaged group. The level of transport disadvantage was estimated within the three segments of their everyday life (school activities, extracurricular activities and evening outings). Data were obtained through questionnaire of 826 secondary school students of the City of Zagreb. The level of transport disadvantage was determined based on the transport mode and travel time to certain activity. Based on the obtained numerical value (grade) students were differentiated as below-average and above-average transport disadvantaged students. In the segment of school activities, below-average transport disadvantaged students were mostly distributed in the city centre and around the city centre, while above-average transport disadvantaged students were mostly distributed in the peripheral part of the city. This kind of spatial distribution obtained for evening outings was somewhat less pronounced. Considering extracurricular activities spatial distribution of below-average and above-average transport disadvantaged students was not pronounced.

Keywords: transport disadvantage, level, grade, quantitative assessment, students, City of Zagreb.

1. Introduction

Transport disadvantage is a widespread phenomenon that can affect all social groups (Gašparović, 2017b). However, some social groups are in geater risk of being transport disadvantaged, including vulnerable groups such as children, older people, disabled, pregnant women, etc. (Murray and Davis, 2001; Stanley and Stanley, 2004; Dodson, et al., 2004; Hurni, 2006; Hurni, 2007). However, it can be assumed that not all transport disadvantaged individuals are affected by the same level of transport disadvantage. In spite of the mobility and accessibility problems, people differ in their living location, public transport provided being more or less frequent, the length of travel, the quality of the roads they travel on, the car ownership, financial status, etc. (Winter, 1994; Gašparović, 2016; Gašparović, Jakovčić, 2014).
The aim of this paper is to develop a method of calculating the numerical value of transport disadvantage. The method proposed is calculation of the grade that represents the level of transport disadvantage. The research was conducted on secondary school students of the City of Zagreb. Transport disadvantage is more pronounced at secondary school children compared to young children and primary school children. Small children and elementary school children do not have such a need for mobility as secondary school students, which is connected with distance from school, extracurricular activities, and leisure time (especially evening outings) (Hopkins 2010, Horton et al., 2011). The vast majority of secondary school students do not have the ability to drive a car, therefore, they depend on the organization and use of public transport, parents, friends, and taxi, or they will walk or use a bicycle (Gašparović, 2017a).
Method of grade determination is supported by several researches, especially by those concerned of children and young people. Thus, for example, Fyhri and Hjorthol (2009) determine indexes, i.e. grades in studying the influence of different parameters on child mobility for school activities, socializing with friends and leisure. Casas et al. (2009) also use grading to investigate the impact of transport based exclusion on the availability of life opportunities for children. D'Haese et al. (2011) use the method of determining grade of the impact of distance and environment criterias on the active journey of children to schools.

2. Methodology

The level of transport disadvantage of each individual was determined based on the transport mode and travel time to activity. The quantitative assesment of transport disadvantage level was carried out within three segments of students' life (school activities, extracurricular activities and evening outings outside their neighbourhood). The parameter of evening outing is processed in two sub-segments (travel to the evening outing location and return from the evening outing location). In case of students who attended more then one extracurricular activity, only one extracurricular activity was taken into consideration in the analysis. Also, some students attended evening outings outside their neighbourhood with multiple destinations, therefore, the most common destination they attended was taken into consideration.
Data required for this research were collected by survey questionnaire. It was performed in seven high schools in the City of Zagreb on 826 students (only students living in the City of Zagreb and without a driver's license were taken into consideration) of which 429 females (51.9 %) and 397 males (48.1 %). Survey included, among other issues the transport mode used by students and estimated time (in minutes) required to travel from home to the location of certain activity. The research was in line with the Code of Ethics of Research with Children (2003). A permission for the research was obtained from the Ministry of Science, Education and Sport of the Republic of Croatia and from the

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principal of each school. The survey questionnaire was anonymous and voluntary. Spatial analysis was performed using the ArcInfo 10 software. As a basis for spatial analysis, data from the questionnaire was used, most preferably the address of the student. Spatial coordinates of student addresses were taken from the "Digital Orthophoto Layer 2012" (DOF 2012) of the GeoPortal of the "Zagreb Spatial Data Infrastructure" (City of Zagreb, 2012).
Quantitative assessment of the transport disadvantage level can be determined by following formulas:

$$TDs = \frac{(m+b+f)+t}{2}$$

$$TDex = \frac{(m+b+f)+t}{2}$$

$$TDeo = \frac{TDeot + TDeor}{2} = \frac{\frac{(m+b+f)+t}{2} + \frac{(m+b)+t}{2}}{2}$$

Where TDs: Transport disadvantage level for school activites, TDex: Transport disadvantage level for extracurricular activites, TDeo: Transport disadvantage level for evening outings, TDeot: Transport disadvantage level for evening outings (travel to the evening outing location), TDeor: Transport disadvantage level for evening outings (return from the evening outing location), m: Transport mode, b: Buffer 400 meters / 800 meters, f: Public transport frequency, t: Travel time to certain activity
For each parameter a grade was assigned to each student depending on which category they belong to. Thus, they were asigned a grade based on the transport mode used to travel to school, extracurricular activites and evening outings (according to data from the survey) as shown in Table 1. The grades are assigned in a manner that the best grade (1) was given to students travelling to the activity on foot, or by bicycle, in-line skates, skateboard and the like. Such a form of mobility is the healthiest, i.e. the most acceptable, and it is more likely that students live closer to a particular activity. If pupils had an option of using public transport or could be driven by another person and did not want to use it, but rather use a taxi instead, they were asigned grade 2. The assumption is that an individual had no financial problems to finance this type of mobility, meaning that transport disadvantage was not so pronounced in this case. Grade 3 was given to students driven by someone else, even though they had an option of public transport. This kind of mobility is not as expensive as a taxi, but requires a person with financial and time opportunities to drive a child. The next grade (4) was assigned to a student using public transport to get to the activity. The worst grade (5) was assigned to a student who had to travel by car or taxi because there was no possibility of public transport (lack of it or it was too far). In the end, if a student could not access activity due to transport, one was received a grade 6.

Table 1
Transport mode grades

Grade	Transport mode
1	On foot, by bicycle, by in-line skates, by skateboard
2	Taxi due to comfort and simplicity
3	Car, though student has the possibility of using public transport
4	Public transport (tram, bus, train)
5	Car or taxi because they had no possibility of using public transport
6	Can not access activity due to transport

Source: Survey

For research purposes, and especially for students using public transport to access activities, GIS was used to determine buffers of 400 meters around each public transport station for daily public transport and of 800 meters for night public transport. In this case, the relationship between students' living location and its position inside or outside the buffer was determined.
As public transport operates according to the timetable, it was necessary to define the public transport operation time frame, i.e. time frame for its stations. For each public transport station, the average number of departures per hour was calculated, to differentiate the stations according to average numbers of departures (below or above) in relation to the students' activity. Calculations were made according to the official timetables of the Zagreb Electric Tramway and the Croatian Railways. As the frequency of departures of the tram transport was considerably higher in relation to bus and railway transport, for this mode the average number of departures in one hour was not calculated, but was rather assumed that all tram public transport stations had above average number of departures.
In order to calculate the public transport frequency for school activities, all the values of departures at the particular bus or train station were summed up from Monday to Friday (school days) from 06:00 to 07:59, from 11:00 to 15:59 and from 19:00 to 21:59. These periods were determined according to the survey on the basis of students' information about traveling to school and return home. It should be noted that some secondary schools of the City of Zagreb have the possibility of organizing early class in the morning shift (from 07:10) and in the afternoon shift (from 13:10). Also, some regular school classes in the afternoon shift start at 13:10 so the early class in these schools begins at 12:25. For both, bus and rail transport, values were divided by 10 (number of hours in period of traveling to school and return from school).

Extracurricular activities take place all days of the week, and therefore, the values of all departures of bus or railway transport on a particular public transport station were summed, and the values obtained were divided by 7 and then by 21. As it was obtained by the survey that some extracurricular activities began even at 7:00 am and some late in the evening, the traveling time frame for the extracurricular activities was taken to be between 05:00 am until 01:59 am (i.e. until the end of daily public transport). Due to the size of the City of Zagreb and its transport system, and the time spent on extracurricular activities, the average number of departures was taken in a slightly more extensive form.

The evening outings outside the neighborhood (e.g. in a disco club, cafe bar and such) was divided into two sub-segments. The average number of departures values for a particular bus or train public transport station were considered separately: travel to the location of evening outing and return to home from the location of evening outing. Since students were engaged in evening outings on every day of the week, the total value of all departures of the bus or railway transport on certain station was divided by 7 and then by 6 (number of hours pertaining to the journey from home to the place of the evening departure). The survey found that students travel from home to the location of evening outing between 18:00 and midnight. In order to evluate the night transport of the City of Zagreb, it was assumed that students who use public transport return from evening outingsin the ime when only night public transport operated. Therefore, for the bus and train public transport stations, the average number of departures on a particular station was not calculated, but stations were differentiated according to (non)operation of night public transport.

The grading were performed as follows: for student who used one of the public transport mode for a particular activity, the value of 0.5 was added if student lived outside the buffer around the public transport station and if public transport frequency at the station was below the average. As stated before, for the returns home from evening outing, public transport frequencies were not taken into consideration, but only data on (non)operating of public transport on a particular station were taken into account; therefore, for the students who returned by public transport, and it did not operate on their station, the value of 0.5 was added to their score. If the student declared that one was unable to access any activity because of transport, one was directly assigned by the highest grade (6). It should be noted that nearest public transport station was considered while not doing the differentiation in regards to the direction of lines of public transport. This procedure was used by Hurni (2006).

In addition, students were also assigned a grade based on the time distance between living location and the activity. The advantage was given to time distance in relation to the spatial distance. The reason for this is the assumption that such a measure was more suitable for this research because of the organization of public transport of the City of Zagreb, and the entire transport system, as well as some physicalgeographical factors that may affect the travel within the city (primarily relief). It should be noted that travel time values were taken directly from the student's statement in the surveys and represent the total time needed to travel from home to certain activity. For students using public transport to access an activity, this represent total time including waiting time at the station as well as walking from home to the station and from station to activity. For students who travelled by car or taxi, this included time spent in the traffic jam or waiting for taxis to arrive. Consequently, grades were given on the basis of the following classes as shown in Table 2. The UNESCO publication "Education for all" (Module A4) was used when defining the classes.

Table 2
Travel time grades

Grade	Travel time (in minutes)
1	od 0 do 15
2	od 16 do 30
3	od 31 do 45
4	od 46 do 60
5	> 60

Source: Survey

At the end, the values were summed and divided by two because two parameters were present: transport mode and travel time. This provided a grade (quantitative value) of transport disadvantage for a particular activity.

3. Results and discussion

Arithmetic mean of the final grades of transport disadvantage was calculated to further analyze the problem. In this regard, students were classified in the categories of above- and below- the average transport disadvantaged students, depending on the activity they attended (school activity, extracurricular activity and evening outing).

The arithmetic mean of transport disadvantage grade for achool activities was 3.431. Out of 826 pupils attending school, 287 students were classified as below the average transport disadvantaged (grades between 1.000 and 3.250), while 539 students were above the average transport disadvantaged (grades between 3.500 and 5.000). Their spatial distribution is shown in Figure 1.

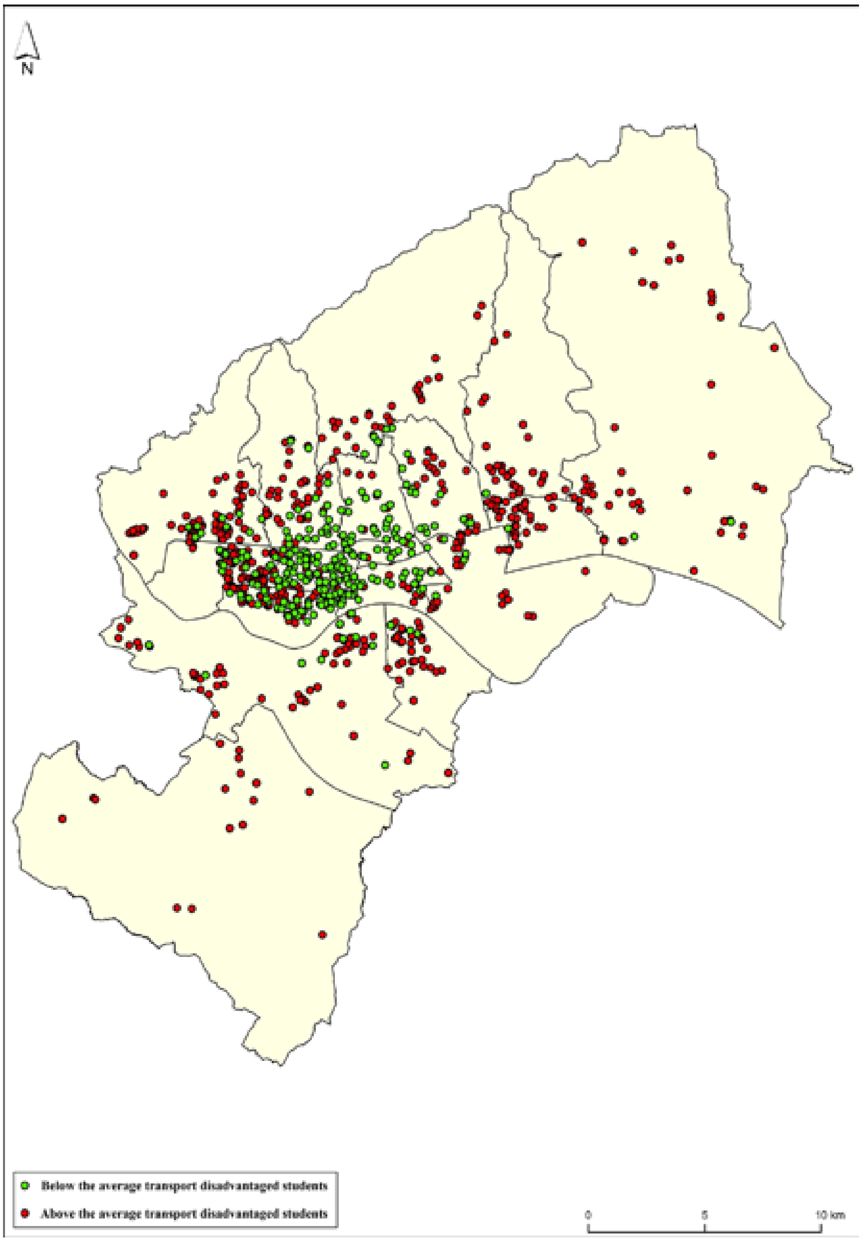

Fig. 1.
Spatial distribution of transport disadvantaged students (school activities)
Source: Survey

Analysis of Figure 1 showed a significant polarization of students with regard to the level of transport disadvantage. Below the average transport disadvantaged students were largely grouped in the wider city center and partly in the western part of the city. Above the average transport disadvantaged students were concentrated in the areas of the city periphery, especially in southern, eastern and northern parts of the city.

These are more peripheral areas of a city where public transport is less developed (fewer lines, less frequent), and the overall transport infrastructure is not sufficiently developed (Gašparović, 2017a). Students living in these areas will had more problems with school activities such as school trips (late to school, significant travel time loss) and academic success (which can be lower compared to students living closer to the city center or in areas with better developed public transport) (Gašparović, 2014).

According to the survey, 380 students were engaged in extracurricular activities. The arithmetic mean of the grade of transport disadvantage was 2.473. Based on the arithemetic mean, 144 students were classified as below the average transport disadvantaged (grades between 1.000 and 2.000), and 236 students belonged to above the average transport disadvantaged (grades between 2.500 and 4.750). Attending extracurricular activities depends on a whole set of objective and subjective factors (e.g. child motivation, financial status, etc.). The offer of extracurricular activities is large and the locations of extracurricular activities are highly scattered throughout the city. Therefore, some students traveled shortly to the location of extracurricular activities in relation to the school. Spatial distribution of the mentioned students is shown in Figure 2. There was no noticeable spatial concentration of students as in the case of school activities, which is expected result due to the factors mentioned above.

However, it could be noticed that fewer students were engaged in extracurricular activities living in the southern parts of the city, which was heavily transport disadvantaged space itself (Gašparović, 2017a). Transport was certainly a factor that impacts students from that part of the city to participate in less extracurricular activities. (Gašparović, 2017c).

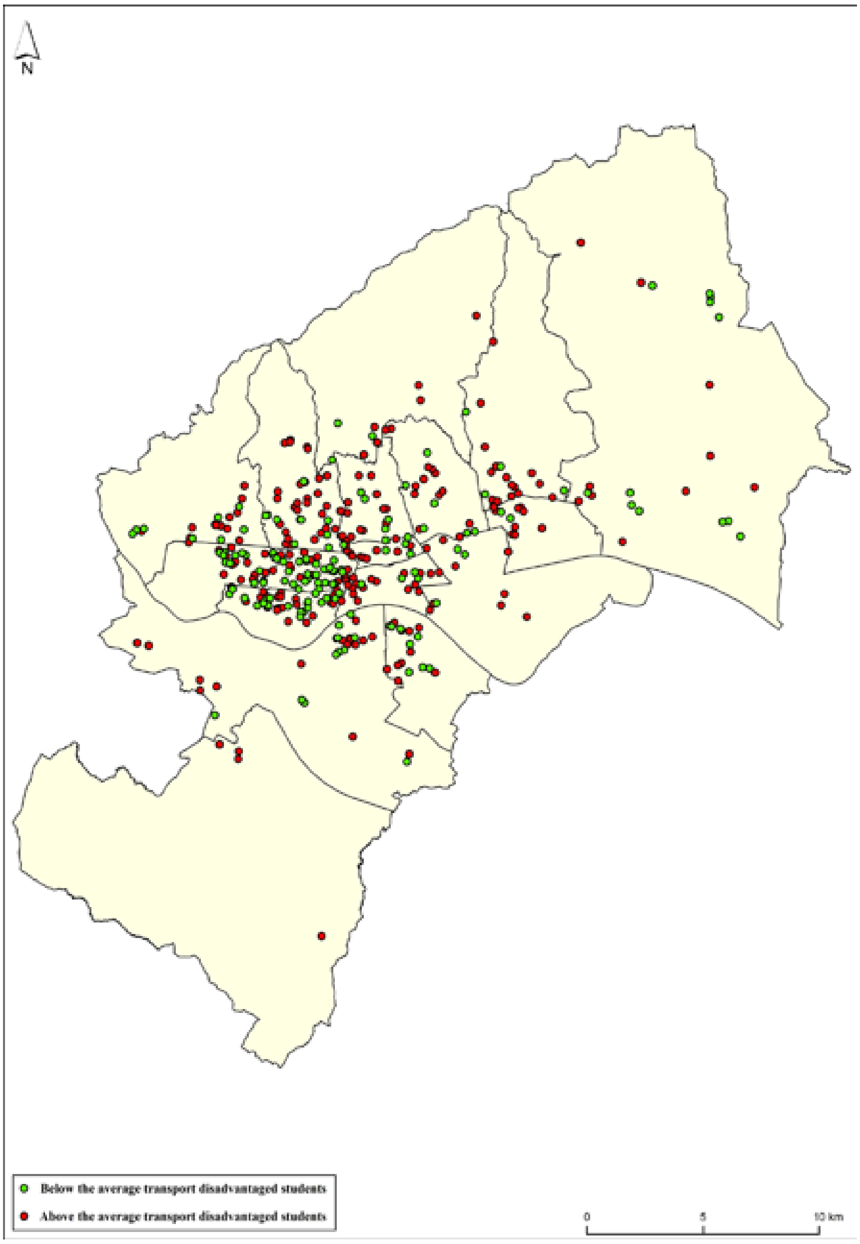

Fig. 2.
Spatial distribution of transport disadvantaged students (extracurricular activities)
Source: Survey

The arithmetic mean of the grade of transport disadvantage for evening outings was 3.056. Out of 714 students who were engaged in evening outings, 344 were classified as below the average transport disadvantaged (grades between 1.000 and 3.000), while 370 students belonged to above the average transport disadvantaged (grades between 3.125 and 4.875). Their spatial distribution is shown in Figure 3. Similarly to the extracurricular activities, not all students participated in the evening outings. Engagement in evening outing depended on various objective and subjective factors. However, although the locations of evening outings were dispersed all over the city, unlike extracurricular activities, a certain concentration of below the average transport disadvantaged students can be observed in the wider city center. Also, above the average transport disadvantaged students can be observed in peripheral parts of the city (southern and eastern part).

Students living in these peripheral parts of the city faced the problem of lack of public transport, later arrival to the home, with the need for early departure from the evening outing and of ensuring transportation (friends, parents, taxi...). (Gašparović, 2017b).

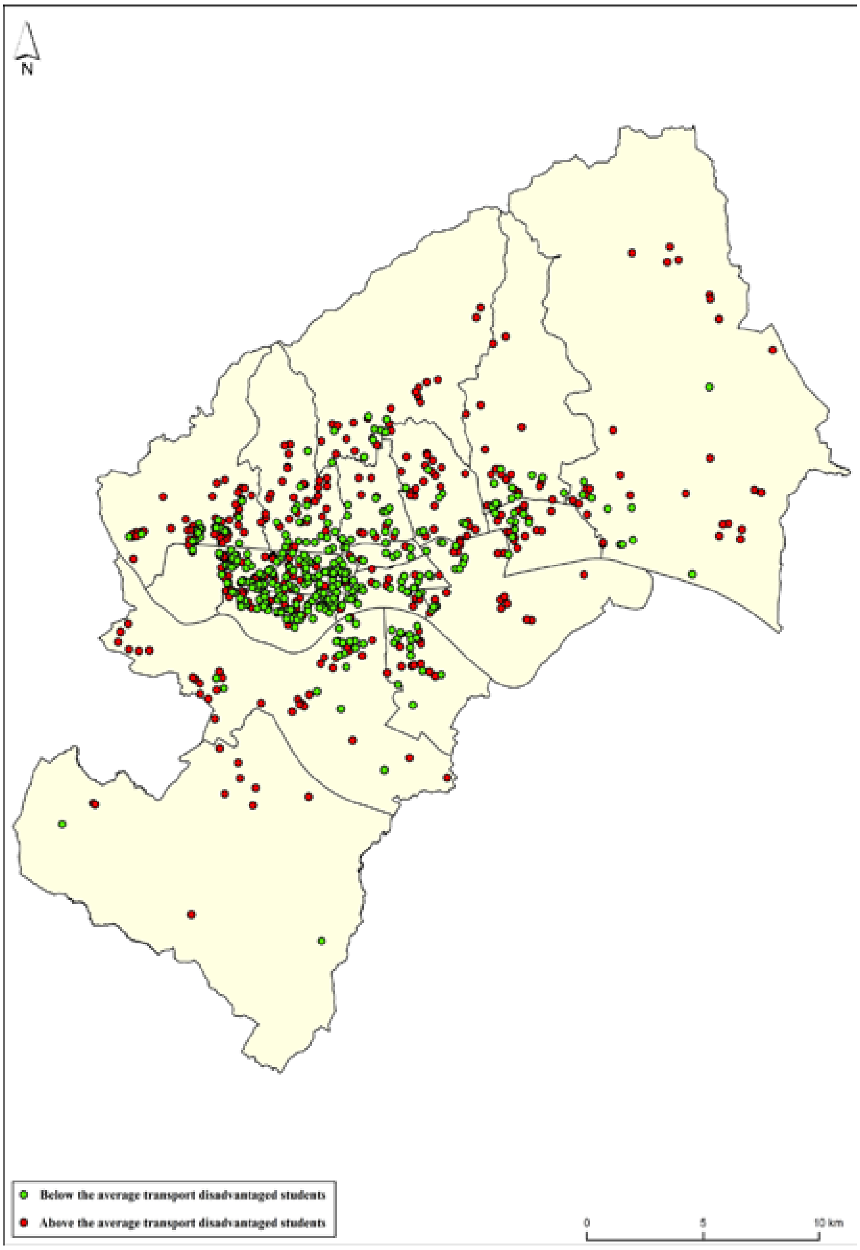

Fig. 3.
Spatial distribution of transport disadvantaged students (evening outings)
Source: Survey

4. Conclusion

Transport disadvantage affects many social groups and is present in everyday life. However, transport disadvantage does not affect equally all individuals from a particular social group. These results showed that transport disadvantage did not affect equally all students, and depended on their activity. This paper attempted to quantitatively calculate the level of transport disadvantage for certain student activities. The paper itself opens up a series of questions and possibilities of research: should it include some other activity in calculating the quantitative level of transport disadvantage, how to calculate a common grade of transport disadvantage, can the same methodology be applied to other disadvantaged social groups (e.g. older people, disabled, etc.). These issues should include a multidisciplinary approach to research that should, as a result, reduce transport disadvantage and improve the quality of life of an individual and achieve transport and social justice.

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DETERMINING THE EXTENT OF USABILITY OF TACTILE WALKING SURFACE INDICATORS

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Abstract: The paper focuses on usability of guiding lines and tactile features which enable the visually impaired to move safely and independently in facilities designed for transport. On a transport terminal example, the authors, with the help of Fuzzy logic, model the degree of these modifications usability for all passengers. In the mathematical model, the input information takes advantage of Fuzzy sets which do not include sharp edges and are influenced by the real fragmentation of the given terminal´s space and the intensity of transport streams. When creating the model, firstly, input and output variables, including the values which can increase, are specified. Then, a set of rules is formulated, based on individual user groups´ specific experience. The users are divided into six basic groups: fully mobile persons, persons with reduced mobility using compensatory aids, visually impaired persons, persons with hearing impairment, persons with mild mental disabilities, and non-native speakers. The resulting outputs of the Fuzzy model are various degrees of usability of tactile features specified for the defined user groups.

Keywords: public transport passengers, disabilities, Fuzzy logic, tactile walking surface indicators (TWSIs).

1. Introduction

Passengers using public transport move in real environments of transport terminals, departure halls and arrival halls. These facilities are perceived by them through their sense priorities, this perception is dominantly visual, acoustic or tactile. A large percentage of the whole amount of passengers is persons with limited mobility or orientation. Severely visually impaired persons cannot drive cars, and therefore they are frequent users of public passenger transport. Despite all modern supplements, their mobility is still dominantly dependent on the "long white cane" technique, which is helpful for their independent mobility and spatial orientation. The accessibility of transport infrastructure should be logically in compliance with the two-sense rule for information systems. For persons with visual impairment, the visual information is transformed into audio and tactile information (Matuška, 2014), (Loeschcke *et al.*, 2011), (Boenke and Girnau, 2012). In case of waiting rooms of transport terminals´ departure halls, visually impaired persons´ mobility is affected mainly by the disposition complexity, distribution of obstacles along natural guiding lines (Košťálová and Matuška, 2016), convenient lighting, acoustic elements of the information and guiding system, spaces without undesired flaring surfaces and without mirroring. All these also depend on the intensity of the transport streams and noise burden in the given space. In case of existing transport facilities, which are often included in the system of the cultural heritage preservation, it is not easy to additionally install aesthetic and functional tactile elements convenient for visually impaired persons. Moreover, the usability and sustainability of these additional adjustments and their financial demands are the essential factors for owners of and investors into the facilities.

The authors of this paper decided to apply Fuzzy logic to evaluate the rate of usability of specific adjustments aimed at safe and independent mobility of all persons. There is a qualitative gap between the knowledge obtained through the natural cognitive process and the knowledge obtained through the exact science method. Fuzzy logic helps to overcome this gap (Křemen, 2007). This advanced method of managerial decision-making is used by the authors for evaluation of the real usability of "tactile indicators on a walkable area" in relation to all passengers. The tactile indicators concerned were specifically designed for visually impaired persons´ independent and safe mobility. The elements individually perceived in a given space are exactly evaluated when using practical experience and knowledge.

The set theory defines a set as a group of elements of certain properties. The given element either belongs or does not belong to a particular set. This means that only these two conditions can develop. L. Zadeh created the theory of fuzzy sets and fuzzy logic, in which it is determined how much such an element belongs to a set, and the element is defined within the range of <0,1>; where 0 means the complete non-membership and 1 means the complete membership. Fuzzy logic thus measures the certainty or uncertainty of the elements´ membership in a set. This is similar to the process of people´s decision making in the sphere of mental and physical activities which are not fully algorithmic (Dostál *et al.,* 2005). The processing in Fuzzy systems requires three basic steps – fuzzification, inference and defuzzification.

- *Fuzzification*: conversion of real variables into linguistic variables and their application into fuzzy sets with the determination of the degree of membership, determination of the membership function shape, transformation of the input data into the predetermined range <0,1>.
- *Inference:* inferential mechanism and creation of the rule basis < IF >, < THEN > on the linguistic basis, determination of the support degree, that means the weight of the rules.
- *Defuzzification*: conversion into real values, resp. conversion of fuzzy sets into the sharp output value which specifies the membership in the set in the best possible way (Dostál, 2008).

2. Usability of Tactile Indicators (TWSIs)

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The amount of the offered information and distribution of its sources must be logical. The excessive amount of information (e.g. of an acoustic kind) results in excessive psychical stress imposed on a visually impaired person. On the contrary, the absence of important information, e.g. in a large departure hall or on a platform, devalues the whole system of adjustments (Matuška, 2014). If there are too many tactile elements close to each other in a small space, a contrary situation develops. A person with severe visual impairment is not able to distinguish one individual element from the other individual elements, and a smaller waiting room turns into a critical space (see Fig.1). Then, such a kind of adjustment of the floor (quite frequently a historic one) does not work in case of visually impaired persons. Moreover, it is not safe for people with reduced mobility and quite often it is even not aesthetically matching the original architectural style (see Fig. 2).

Fig. 1.
TWSI in passenger hall, bus terminal Kanazawa (Japan)
Source: (Nakagoshi, 2017)

Fig. 2.
TWSI before stairs, railway station Agui (Japan)
Source: (Nakagoshi, 2017)

2.1. Research into Perception of Space

The authors of the paper applied Fuzzy logic with the aim to provide a mathematical expression of the rate of usability of tactile indicators on a walkable area. The input data needed for the mathematical model were obtained from the research survey based on the questionnaire specially designed by the authors (Košťálová, 2018). The survey was carried out in the time period from June 20th to June 21st 2018 in selected railway stations during the assumed afternoon rush hour. 162 respondents participated in the survey, our priority efforts were made to address as many age groups as possible. The results were used for dividing the passengers into fuzzy sets and determining the degree of the membership, and the priority type of the spatial perception applied by the individual groups of users. To make the real situation simplified, two types of the assessed space´s size were considered. One type was represented by departure halls with the size over 8 × 8 m, the other type was represented by waiting rooms of light dimensions up to 8 × 8 m. The authors applied the standard systems of load bearing structure of transport facilities in the Czech Republic and, simultaneously, they considered testing of blind persons' ability of walking in the straight line. The distance of 8 metres is the limit distance within which a blind person keeps his/her moving direction in a straight line with a minimum desired deviation, (Zdařilová, 2011). The results of practical measurements on road crossings and in the public space are used for making the walk of persons with severe visual impairment safe (Suzuki *et al.*, 2010).

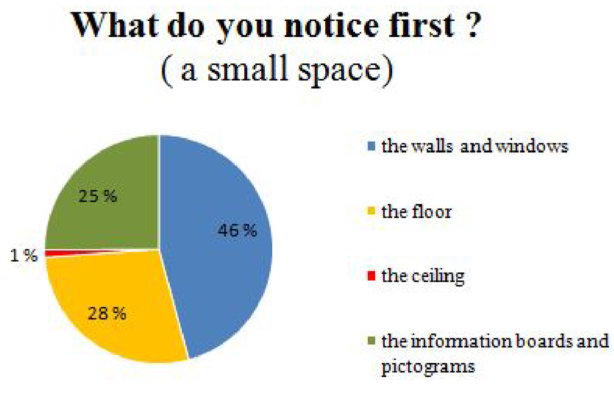

Fig. 3.
Perception of small space within a small space
Source: (Košťálová, 2018)

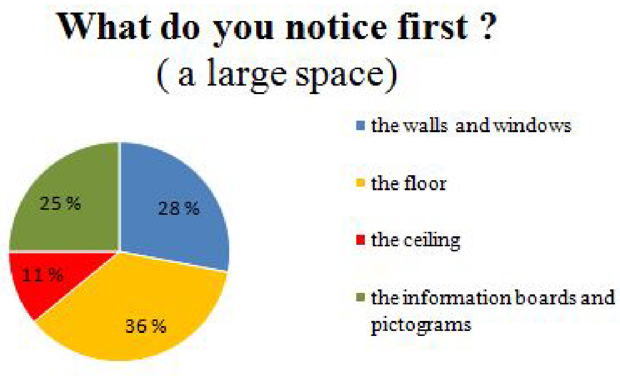

Fig. 4.
Perception of small space within a large space
Source: (Košťálová, 2018)

Selected outputs from the aforementioned research are presented below for illustration (Košťálová, 2018; Fig. 3, Fig. 4).

Types of passengers *(given in percentage):* Persons without moving restrictions (79 %), person using compensatory aids (7 %), persons with baby strollers (4 %), persons in wheelchairs (3 %), persons with hearing impairment (3 %), persons with severe visual impairment (2 %), persons non-familiar with the language or written characters (1 %), persons with mild intellectual disabilities (1 %).
Age of the passengers *(given in percentage):* From 6 to 12 (1 %), from 13 to 17 (17 %), from 18 to 26 (26 %), from 27 to 45 (13 %), from 46 to 65 (22 %), from 66 to 80 (20 %), over 80 (1 %).

2.2. Classification of Passengers

Processing in the MathWorksMATLAB program was carried out with the support given by the Fuzzy LogicToolbox and Mamdani´s regulator (MATLAB: License No: 40 62 77 67, e-mail domains: tul.cz, release: 2018a, Technical Univerzity of Liberec, The Faculty of Art and Architecture, Department of Buildings, J. Košťálová). When creating the model, we first specified the input variables including the range of their values. Users of the transport infrastructure and facilities can be divided into several groups (Boenke, Girnau, 2012), (Matuška, 2014). However, every person is unique and has a differently long reaction time when a stimulus appears. Physical maturity and psychical maturity are also important. Dividing the passengers into strictly given categories based on the existing norms and decrees can never fully correspond with reality (Zdařilová, 2011), (ISO 2011), (Loeschcke *et al.*, 2011). Every person can be defined through a mathematical combination of individual limitations. To make the calculation process realizable, the authors applied a simplified model of an assessed person. To make the situation better understandable, we can give an example of a person who suffers from Diabetes of the 2nd type. The primary disease is further complicated by secondary issues; these complications have an impact on the primary disease development. A relatively healthy person is gradually changing and is showing a bigger number of potential disabilities. In case of the worst complications, the person is gradually becoming blind, and very often his / her limb amputation is necessary (see Tabs. 1, 2).
Concerning the behaviour of passengers in transport facilities, some groups logically merged during processing of the model, individual limitations were simplified and the transport streams´ intensity was neglected in the considered size of the space. In the FIS Editor, four input variables were chosen: PD (mobility impaired passengers), VP (visually impaired passengers), HP (hearing impaired passengers, deaf and dumb passengers), MP (mentally impaired persons and persons not familiar with the language and written characters), and then one output variable: UVL (artificial guiding lines in Czech Republic) = TWSI (evaluation of the usability of a tactile indicator) – was chosen (Tabs. 1 – 5).

Table 1
Classification based on mobility limitations and disabilities

MOBILITY /PD/		Classification according to function
Mild mobility disabilities and temporary limitations	- persons accompanying infants up to the age of 3 in baby strollers, - pregnant persons - heart diseases, venous diseases, etc.	**0 – 0.3**
Moderate disabilities	- canes, crutches, walking sticks	**0.2 – 0.5**
	- rollators, walkers	**0.5 – 0.75**
Severe disabilities	- mechanic wheelchair, three-wheel electric scooters - electric wheelchair, hand-bike	**0.75 – 1.0**

Source: (Košťálová, 2018)

Table 2
Classification based on visual limitations and disabilities

VISION /VP/		Classification according to function
Dioptric **eye-glasses**	- defects corrected with diopters	**0 – 0.3**
Persons with low vision *Classification according to the World Health Organization*	- moderate low vision	**0.2 – 0.5**
	- severe low vision	**0.5 – 0.6**
	- severely severe low vision	**0.6 – 0.7**
Blind persons	- practical blindness	**0.7 – 0.8**
	- complete blindness	**0.8 – 1.0**

Source: (Košťálová, 2018)

Table 3
Classification based on hearing limitations and disabilities

HEARING AND SPEECH (impact on spatial orientation) /**HP**/		Classification according to function
Minor **hearing and speech**	- correction with hearing aids	**0 – 0.3**

defects		
Remnants of hearing	*Classification according to the WHO*	**0.15 – 0.75**
The deaf	*Classification according to the WHO*	**0.75 – 1.0**

Source: (Košťálová, 2018)

Table 4
Classification based on mental and cultural orientation

MENTAL AND CULTURAL ORIENTATION influencing the spatial orientation /**MP**/		Classification according to function
Non-familiar with the culture, mild retardation	without the knowledge of the language and written characters, IQ 50 – 69 / feeble mind, senility	**0 – 0,3**
Medium retardation	IQ 35 – 49 / debility, oligophrenia, imbecility	**0.3 – 0.75**
Severe retardation	IQ 21 – 34; IQ < 21 is not considered Sub-normality, idiocy	**0.75 – 1.0**

Source: (Košťálová, 2018)

Table 5
Usability of tactile indicators

TACTILE INDICATOR (TWSI) = UVL	Classification according to function
Unused	**0 – 0.2**
Partly used: intuitive	**0.2 – 0.525**
Fully used	**0.525 – 1.0**

Source: (Košťálová, 2018)

2.3. Fuzzy System

Variables and membership functions were set in a detailed way in the Membership Function Editor.

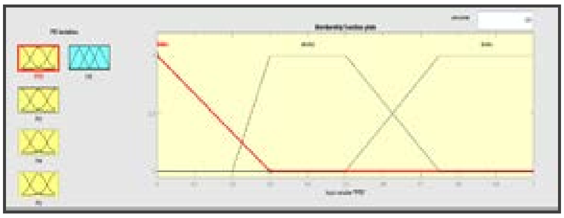

Fig. 5.
Mobility limitations and disabilities
Source: Membership Function Editor

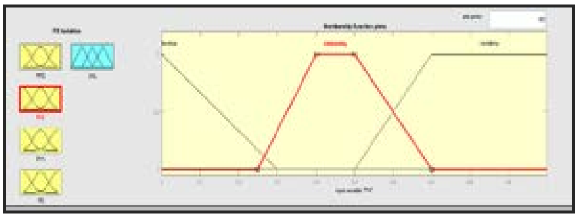

Fig. 6.
Visual limitations and disabilities
Source: Membership Function Editor

The decided range was in ten parts in the interval <0,1>. See Tabs. 1 – 5. In case of each group, the triangle and trapezoid shapes of the functions *L* and *Z* were used, depending on the limitations and disabilities. See Figs. 7 – 9.

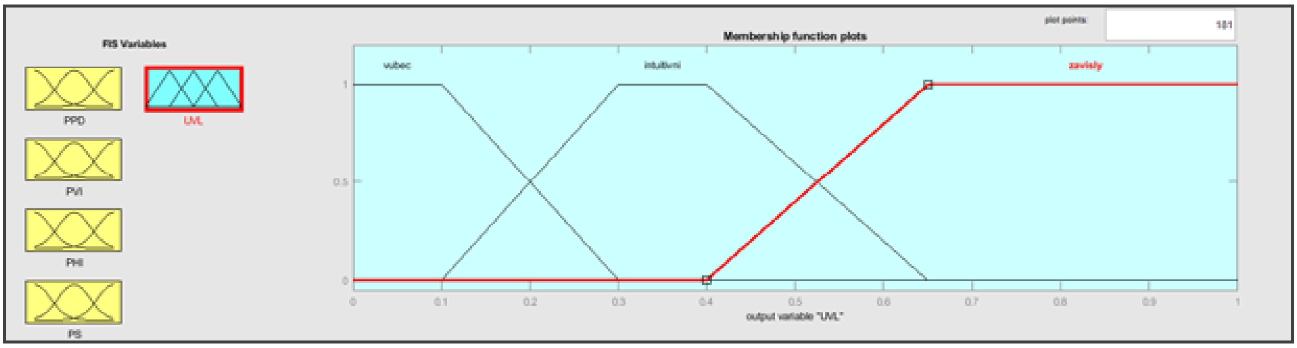

Fig. 7.
Usability of a tactile indicator
Source: Membership Function Editor

The next step was to formulate the basis of rules resulting from the specific user groups´ experience and from the aforementioned research results. The inferential rules based on real situations and potential combinations of various disabilities were set into the Rule Editor. Our model involves 25 rules which are most frequently applicable in the real environment (see Fig. 8).

***Rule basis** as the output:*

1. *If (PD is mild) and (VP is blind) and (HP is correction) then (UVL is fully used) (1)*
2. *If (PD is moderate) and (VP is correction) and (HP is correction) and (MP is mild) then (UVL is partly) (0.35)*
3. *If (PD is severe) and (VP is correction) and (HP is correction) and (MP is mild) then (UVL is partly) (0.75)*
4. *If (PD is moderate) and (VP is low) and (HP is non)and (MP is medium)then (UVL is used)(1)*
5. *If (PD is mild) and (VP is correction) and (HP is deaf)(MP is mild) then (UVL is used) (1)*

   ....

25. *If (PD is non) and (VP is correction) and (HP is correction) and (MP is non)then (UVL is unused)(0.25).*

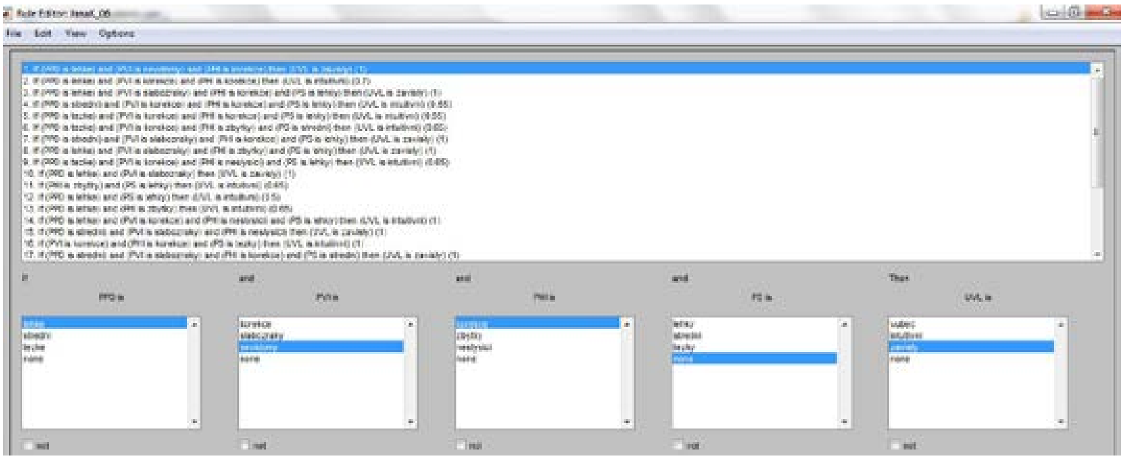

Fig. 8.
Rule basis as the output
Source: Rule Editor

The most frequently used method of the Center of Area was used for defuzzification, when a sharp value is determined by the coordinates of the area of the unified output fuzzy sets (Jura, 2003). *Rule Viewer* is a control tool in the Fuzzy Logic Toolbox; it shows all inferential rules applied in the model. The result is visible in the graphic part and it is simultaneously displayed numerically at the output variable. See Fig. 9. On the basis of combinations of specific limitations, the authors of the text modelled eight real persons, and the result of the set determines the usability of a tactile indicator in a smaller space.

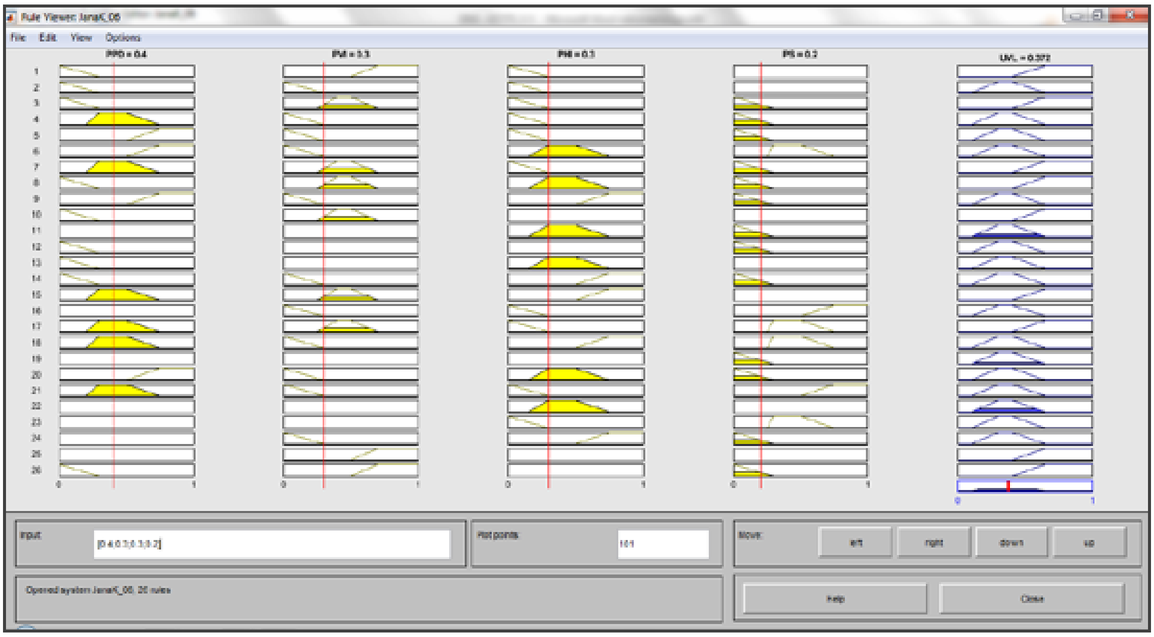

Fig. 9.
Passenger No. I
Source: Rule Viewer

Surface Viewer is the second control tool in the Fuzzy Logic Toolbox. The illustrated surface shows the progress of two chosen input variables from the X axis and Y axis on one output variable Z axis. The user No. III defined by

⟨0,4|0,3|0,3|0,2⟩ is illustrated in the Fig. 10. More specifically, a person aged 62 is concerned. This person uses one walking stick and a hearing aid in one ear. Due to Diabetes of the 2nd type, the person suffers from the beginning diabetic retinopathy, which is still only a very mildly limiting factor in his / her spatial orientation but does not cause any serious problems. The result brought by the calculation points to such a reality in which the tactile indicator in the given space will be perceived intuitively, and the person is likely not to use it. See Tab. 6.

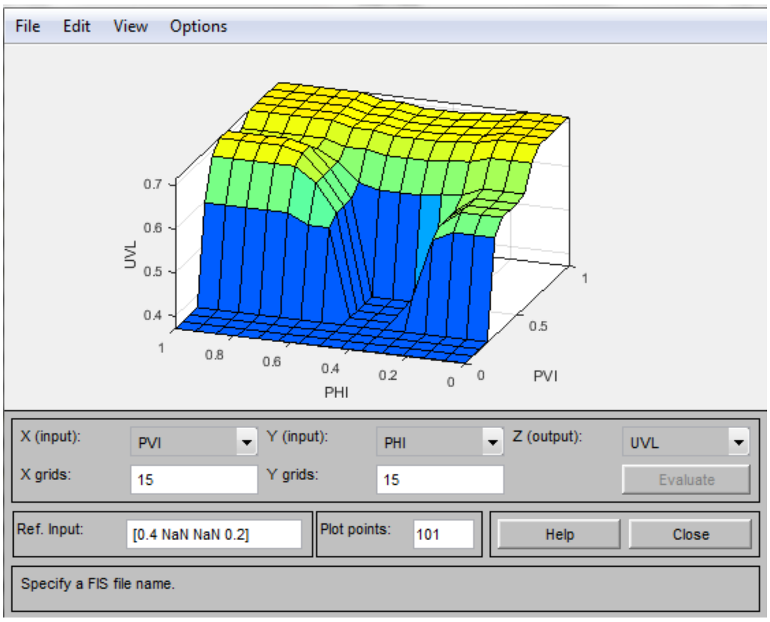

Fig. 10.
Spatial illustration of function progress of user No. III
Source: Surface Viewer

3. Conclusion

The model outputs and the research results point to the usability of tactile elements (TWSIs) in waiting rooms and departure halls of the ground plan dimension up to 8 × 8m. See Table 6.

Table 6
Evaluation of the TWSI usability related to specified persons

Evaluation of usability of tactile indicators related to the specified types of persons					
User	**PD / mobility**	**VD / vision**	**HD / hearing**	**MD / orientation**	**Use of TWSI**
I.	0.2	0.2	0.3	0.7	**0.37**
II.	0.2	0.2	0.3	0.7	**0.37**
III.	**0.4**	**0.3**	**0.3**	**0.2**	**0.37**
IV.	0.7	0.3	0.5	0.4	**0.37**
V.	0.9	0.3	0.2	0.3	**0.37**
VI.	0.3	0.5	0.1	0.3	**0.61**
VII.	0.3	0.7	0.1	0.3	**0.65**
VIII.	0.1	0.9	0.3	0.3	**0.66**

Source: Rule Viewer

The mathematical model created with the support by the Fuzzy Logic Toolbox confirmed our assumption – in case of all users (except for blind persons or persons with low vision) the usability will be in the medium area of intuitive utilization. That means that neither “rather yes” nor “rather no” can be used as the resulting evaluation. The worse the vision comfort, resp. light conditions in the given space is, the more important the usability will be. However, the research results have revealed that this can be claimed dominantly for spaces in which one of the dimensions excesses the length of 8 m.
Every user´s independent and safe mobility inside a transport facility should be ensured by the following:

- access to the main entrance from a public transport stop (or a wheelchair access),
- the shortest possible route between the entrance and the information office or the ticket office (a possibility of assistance service),
- a route to public toilets and vertical link (elevator, staircase, escalator),
- a route to platforms (access to departures) – see Tomandl *et al* (2017).

Availability of TWSIs is of a great help for the visually impaired because thanks to it they can walk independently and safely. However, like in case of every safety element, their usability must be ensured for all user groups (passengers). TWSIs must not create barriers for the others and they must be safe and functional (distinguishable) during all the existence of the facility (Mizuno *et al.*, 2008). Inside transport facilities where the length without a guiding line in the walk direction does not exceed the distance of 8 metres (in waiting rooms and departure halls), acoustic guiding beacons with a voice phrase should be preferably designed (Guideline, 2017).
The data processing which was carried out within the framework of the aforementioned research applying the Fuzzy system confirmed that tactile elements installed additionally in a small space in which the guiding line is not interrupted are a kind of redundant information. These elements will not be perceived by other users except for severely visually impaired persons for whom a correctly installed acoustic guiding beacon is a more convenient item of information about the space. In a guidance and information system, an acoustic guiding beacon with a voice phrase installed over the entrance door is a safety element for everybody. Excessive designing of tactile indicators causes an irreversible degradation of historic surfaces (not only in case of buildings within the system of cultural heritage preservation) and, simultaneously, it is an unnecessary barrier for persons with limited mobility.

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COMPARISON OF MODERN AND CONVENTIONAL METHODS AT THE ENTRANCE AND EXIT OF TUNNELS

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Abstract: Turkey has gained importance especially highway transport since 1950. For this reason, the number of vehicles on the highways has rapidly increased and this increase has brought many problems. The most important problem is traffic accidents which cause material and spiritual loss. The winter conditions that are effective in some regions of the country occur disruptions in highway transportation. Particularly in winter when the temperatures are below 0 ºC accidents happen due to the snow and icing. Although millions of dollars are spent every year to struggle against snow and icing, existing methods are insufficient. Conventional methods used in the struggle against snow and ice damage to pavements, metal parts, environment, human health and economy of the country. Tunnels are often used because of Turkey's geographical situation. Traffic accidents are often seen at the entrance and exit of tunnels, especially during the winter seasons because of snow and icing. In these areas, the ice detection and prevention systems as an application of intelligent transportation system can be used instead of conventional methods to reduce the number of traffic accidents. In this study, it is compared that conventional method with the ice detection and prevention system in terms of advantages and disadvantages.

Keywords: tunnel, ice detection and prevention system, traffic safety.

1. Introduction

After the Second World War, highways transportation becoming important in the 20th century quickly tended to increase and became competitive with other systems of transportation. After the energy crisis in the 1970s was surpassed, in the 1980s the highways transport tendency continued to increase. This increase tendency was also observed in Turkey. In the 2000s, highways transport became a dominant system in many developed and developing countries. From the Ottoman Empire to Republic of Turkey in the 1923, 4,000 km is in good condition, it took over 18,000 km long road. From the promulgation of the Republic until 1948, the railway policy was important in the transport. However, in the 1948 this situation changed and a very important turning point came on the highways. In this period, significant developments were experienced in highways transport with the increase of resources. But the greatest improvement is happened with the help of the Marshall plan, in the 1948. Marshall plan is still being debated, although it has caused a major improvement in highways transport. In addition, in the 1950 the General Directorate of Highways (GDH), responsible for the maintenance and construction of roads, was established. At the end of the 1960s with modern transportation vehicles in all seasons transport could be made to almost every part of Turkey. From 1980's to the day, necessary importance is given to highways transport. Road length under the responsibility of GDH is 67,119 km by January 2018 (GDH, 2018). The number of vehicles on the road naturally increased considerably over time. Figure 1 shows the number of vehicles on yearly basis. The increase in the number of vehicles has brought both positive and negative issues to the agenda. Positive issues include ease of access and transport, short travel times, etc. Negative issues are traffic accidents, material and spiritual loss, environmental pollution, etc.

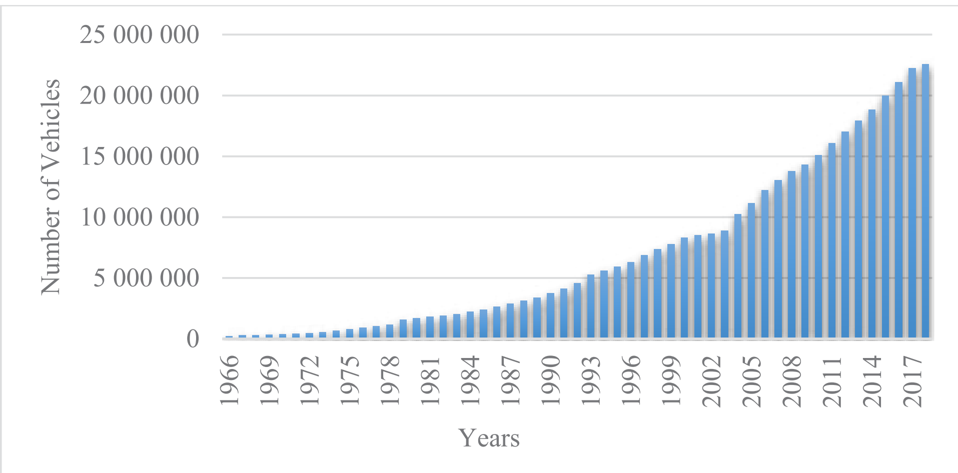

Fig. 1.
Number of vehicles
Source: Turkish Statistical Institute, 2018a

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This paper was carried out by taking into account the negative consequences of the increase of vehicle numbers. There is no doubt that one of these negativities is traffic accidents as mentioned before. Traffic accidents cause millions of people to die and are injured each year. Apart from that, billions of dollars are causing material loss. Because of these losses, statistics about traffic accidents have vital importance data. Some sections of annual statistics kept around the world:

- Nearly 1.3 million people die in road crashers each year, on average 3,287 deaths a day.
- An additional 20-50 million are injured or disabled.
- More than half of all road traffic deaths occur among young adults ages 15-44.
- Road traffic crashes rank as the 9th leading cause of death and account for 2,2% of all deaths globally.
- Road crashes are the leading cause of death among young people ages 15-29, and the second leading cause of death worldwide among young people 5-14.
- Each year nearly 400,000 people under 25 die on the world's roads, on average over 1000 a day.
- Over 90% of all road fatalities occur in low and middle-income countries, which have less than half of the world's vehicles.
- Road crashes cost USD $518 billion globally, costing individual countries from 1-2% of their annual GDP.
- Road crashes cost low and middle-income countries USD $65 billion annually, exceeding the total amount received in developmental assistance.
- Unless action is taken, road traffic injuries are predicted to become to fifth leading cause of death by 2030 (WHO, 2015).

The situation in Turkey is not different from the World. Thousands of people die every day. The statistical data of accidents in Turkey are given in Table 1.

Table 1
The Number of Traffic Accidents

	2009	2010	2011	2012	2013	2014	2015	2016
Number of Traffic Accidents	1,053,346	1,106,201	1,228,928	1,296,634	1,207,354	1,199,010	1,313,359	1,182,491
Number of Death	4,324	4,045	3,835	3,750	3,685	3,524	7,530	7,300
Number of Injuries	201,380	211,496	238,074	268,079	274,829	285,059	304,421	303,812

Source: Turkish Statistical Institute, 2018b

As seen in statistics, traffic accidents are a major threat to humanity all over the World. The most important issue to investigate in order to prevent or reduce the number of traffic accidents are the causes of the accidents. While investigating the causes for these accidents, some changes are seen from the country to the country. The statistics of causes of traffic accidents in Turkey are:

- Driver Faults;
- Passenger's Faults;
- Pedestrian Faults;
- Road Defects;
- Vehicle Defects (*Turkish Statistical Institute,2018c).*

However, it is not enough that causes of traffic accidents are merely collected under these headings. Therefore, it cannot be said that the traffic accidents statistics are kept perfectly healthy. For example, traffic accidents due to seasonal and weather conditions are not considered as a cause of traffic accidents. Air temperature, ice formation on the road, severe winter conditions etc. should be considered as a causes of traffic accidents. If the country is considered, the winter conditions, which are more intense in the eastern part of the country, undoubtedly increase the traffic accident rates. In these regions, the temperature of the winter season is below 0º C.
According to GDH data, there are a total of 242 tunnels in Turkey as of January 2018. The total length of these tunnels is 196.675 km. As mentioned, the winter effect in the country is mostly seen in eastern part. The Erzurum province in the Eastern Anatolia is a transit point. There is a continuous transition between this region and the Black Sea region. Therefore, there are many tunnels connecting the Eastern Anatolia Region and the Black Sea Region of the country. A part of this transition is carried out by these tunnels. In addition, the tunnels are not limited to just this region. Figure 2 is given map of tunnels in these regions. There are totally 162 tunnels in Black Sea and Eastern Anatolia Region. The total length of these tunnels is 67.416 km. Also in June, Ovit Tunnel was opened between Rize – Erzurum. This tunnel, which is at 2,640m altitude, is the world's 3rd longest double tube tunnel and its total length is 14km. Due to both severe winter conditions and high altitudes of the places where the tunnels are located, especially in the winter months,

there are many accidents in the entrance and exit of the tunnels. One of the main cause of traffic accidents is seasonal conditions in the tunnels found in the regions shown in Figure 2. For this reason, special precautions should be taken especially for the entrance and exit of tunnels where sudden passage is experienced. Particularly in the winter season, the formation of icing can be seen in the entrances and exits of the tunnel due to the effect of low temperature, drizzling and slope. Special precautions should be taken in these areas in the struggle against snow and ice.
According to GDH statistics in 2016, 660 traffic accidents occurred in the tunnels. In order to reduce the number of these traffic accidents, the most effective method in the struggle against snow and ice should be used. Due to responsibility of the tunnels belongs to GDH, the struggle against snow and ice in these regions is carried out by GDH.

Fig. 2.
Map of Tunnels
Source: Generate of Directorate Highways, 2018

The fact that the air temperature is so low brings with it a lot of problems. At the beginning of these problems snow accumulation and icing on the road can be shown. Various methods have been developed to reduce the effects of snow and ice. These methods are divided into conventional and modern methods. The first conventional method of fight against snow and ice is plowing. Then, one of the first methods that comes to mind in the fight against snow and ice is salting. Although the salt is thought to be advantageous in terms of cost, the damage in the environment and the road infrastructure are being discussed. Due to these negative aspects of salt, different conventional methods have been developed. Some of them sanding, wetted sanding and warm wetted sanding. A kind of modern method are electrically conductive asphalt coating (snow free) systems, spraying systems and detecting and preventing systems are used in addition to conventional methods. Many studies have been conducted on these methods. Some of these studies are listed below;
The initial studies regarding ensuring road safety and fighting against icing traces to the 1970s. In one of the initial samples of these studies performed in order to investigate the effect of hardness of aggregate on friction; Furbush (1972) revealed with tests performed on the roads without snow and ice that hard materials yield more sliding resistance than soft materials do. In a study performed for detection how long an aggregate with better sliding resistance can exist on road; Gray and Male (1981) emphasized that sands, widely being used in winter maintenance work are easily thrown off the road platform and passage of ten and twelve vehicles is enough for sand drift.
Regarding the studies for detection of environmental effect of sand; According to American Society of Testing Materials and Wisconsin Transportation Center (1996-1989) suggested that friction provider materials can obstruct rain water flow holes and sewages and abrasive material can be splatted under the wheel loads. Hallberg and Henrysson (1999) applied heated sanding and warm wetted sanding methods together with conventional methods on four different types of materials in their studies. In both methods applied for the first time, friction could be efficient on the road surface for a few days. Nixon (2001) stated in his study that abrasive materials are more expensive than salt and as well as the lack of their contribution to traffic safety, it has been failed in recollecting, cleaning and retrieval of them and he concluded that "abrasive use in winter maintenance work must be reduced".
Investigations have been performed on environmental harmful effects of salt rather than on its implementation, in the studies regarding salt. Mangold (2000), In Vaa's (2004) study, he applied warm wetted sanding method on intercity roads and other roads in Norway and revealed that warm wetted sanding method yields approximately desired friction value in terms of traffic safety. In the study of Vaa, friction coefficient of the method between the road surface and vehicle wheel was observed at certain intervals in the adverse winter conditions, on a road platform where Annual Average Daily Traffic (AADT) volume is 1200. During this observation, the first measurements were performed at the certain times of the day and 5 days later a final measurement was made for sand and effectiveness of sand on the

surface. It was seen in the last measurement that despite most of the sand got away from the road, there were sands on the road platform enough to increase coefficient of friction. It was proven in this study that wetted sanding method is much better than other methods in terms of durability.

Kuloglu and Kok (2005) experimentally investigated the effects of salt for asphalt coating. It was explored that salt, which has been used to reduce and prevent the frost effect in winters, forms a solution, melting on the road platform and causes serious damage, leaking through concrete asphalt pavement.

Compared with conventional methods for snow and ice control (e.g. deicing and sanding), anti-icing (if applied appropriately) can lead to decreased applications of chemicals and abrasives, decreased maintenance costs, improved level of service, and lower accident rates (O'Keefe and Shi, 2005).

Anti-icing, a proactive snow and ice control strategy that is sometimes practiced as the first line of defense in a winter maintenance operation, came into practice during the 1990s. As anti-icing is most commonly conducted, a small amount of liquid chemical is applied to the roadway or bridge deck prior to a storm to prevent ice from forming a bond with the surface. The benefits of anti-icing are well documented in national studies, manuals and in field tests conducted by various state departments of transportation (Minnesota Department of Transportation Office of Policy Analysis, 2009).

Çodur and Tortum (2015) emphasized the importance of traffic accidents in their study. In addition, they have identified some parameters that cause traffic accidents. By adding a different interpretation to the traffic accidents, the traffic accidents due to the geometrical features of the roads were discussed.

Wright et al. (2016) examined the influence that the chemical modifications have on the durability of the pavement surface course. The study has demonstrated that specific low surface energy materials (sodium format and sodium silicate) can be incorporated into pavement surface course to reduce the adhesion between ice and the pavement surface, thereby allowing the ice to be easily removed.

Alemdar et al. (2018) evaluated that the detecting and preventing icing for Erzurum province and found various suggestions. It is proposed that the implementation for a critical junction in Erzurum province will be good for traffic safety.

Kaya et al. (2018) carried out a study on the traffic accidents in Turkey. The study is proposed example of an application of intelligent transport system to reduce traffic accidents and ratio of deaths. A system has been suggested that can be used to detect the locations of vehicles under snow, particularly in avalanche accidents that occur east of the country.

The aim of this study is to make a short comparison of the modern methods with the conventional methods and then make suggestions about the methods that can be used in the tunnels. Information on an application of the detecting and preventing icing system has been given.

2. Materials and Methods

In this paper, the regions where these methods are frequently applied are examined in order that comparison can be made. Therefore, Turkey is taken into consideration. Notably Eastern Anatolia Region in Turkey stands out with harsh climate and snowfall in winters. In this context, it is a region where heavily been struggled with snow. In terms of having information related to the winter conditions in Turkey can be analyzed Figure 3. As seen from Figure 3, especially Erzurum, Ağrı and Kars are living the most severe winter effects. These cities covered with snow for 95 to 125 days a year have adverse climatic conditions prevalence due to the high altitude. For example, some temperature values of Erzurum province are given in Table 2 and Table 3.

Table 2

Erzurum Temperature Measurements

Erzurum	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MEASUREMENT PERIOD (1929-2017)													
Highest Temperature (°C)	8.0	10.6	21.4	26.5	29.8	32.2	35.6	36.5	33.3	27.0	20.7	14.0	36.5
Lowest Temperature (°C)	-36.0	-37.0	-33.2	-22.4	-7.1	-5.6	-1.8	-1.1	-6.8	-14.1	-34.3	-37.2	-37.2

Source: Turkish Meteorological Service, 2018a

Table 3

Erzurum Maximum Measurements

Daily total Highest Precipitation		Fastest Wind Daily		Highest Snow	
23.02.2004	59.6 mm	16.04.1974	110.2 km/h	24.02.2004	110.00 cm

Source: Turkish Meteorological Service, 2018a

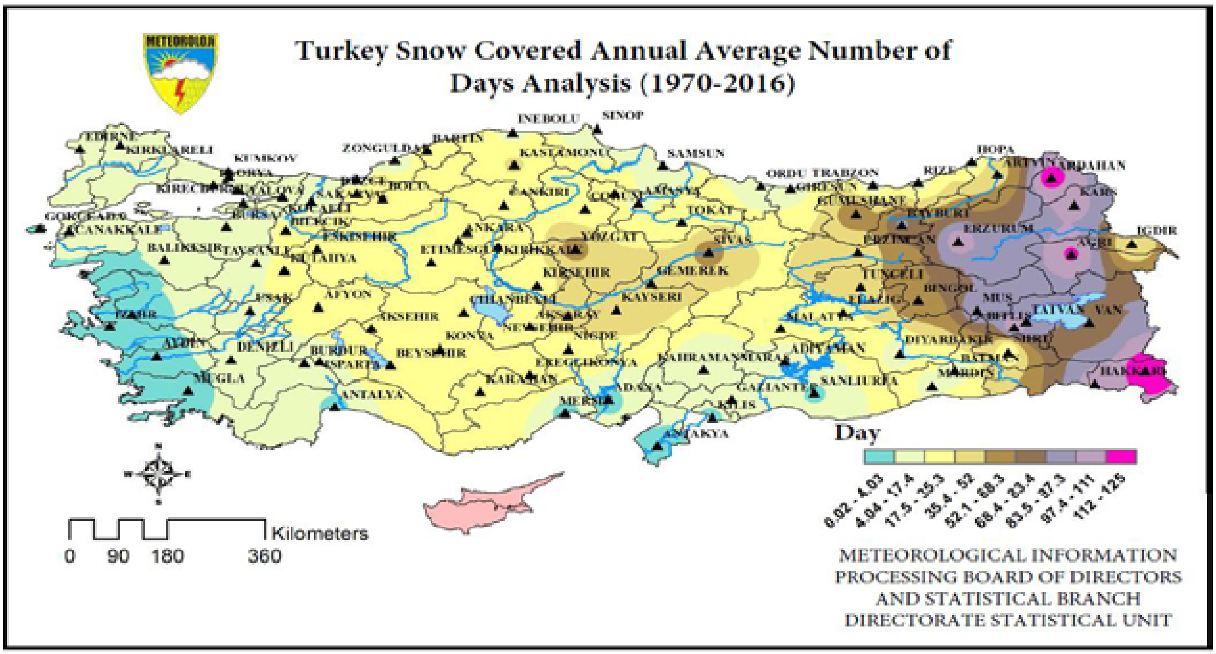

Fig. 3.
Turkey Snow Annual Average Number of Days Analysis (1970-2016)
Source: Turkish Meteorological Service, 2018b

Many methods have been used in the World to ensure traffic safety fighting against icing. These methods are conventional methods such as plowing, salt, sand, wetted sanding and warm wetted sanding method. In addition, warm wetted sanding, a special application of conventional methods. A kind of modern method are electrically conductive asphalt coating (snow free) systems, spraying systems and detecting and preventing systems are used in addition to conventional methods. The conventional methods have been used for elimination of the negative effects of winter conditions in the most cities where snowfall and icing frequently occur. Snow and ice fighting methods are mentioned in Table 4.

Table 4
Methods used in the struggle against snow and ice

Methods		**Information**
CONVENTIONAL METHODS	**Plowing**	Plowing is the process of scraping and cleaning on the road using human power, tools and vehicles to remove the snow and ice effect on the road. To ensure traffic safety on highways, snow and ice should be cleaned from the road surface immediately after snowfall. Reduced friction coefficient due to the effect of snowfall, it can be recovered to acceptable levels by removing snow and ice from the road surface. Plowing is generally accepted as the most effective technique for snow and ice control (Performance Evaluation of Snow and Ice Plows, 2015). A variety of road cleaning vehicles are used in the plowing methods. For example, Figure 4.
	Salting	Removal of snow on road and prevention of icing by spreading chemicals on road are primary works that have to be performed for struggling against snow and icing. To prevent icing, chemicals lowering freezing point should be spread on road immediately after the start of precipitation or before the start of precipitation. Thus, formation of a connection between snows or ice surface is prevented. Due to being low cost, it is generally used in solid state as a defroster and icing preventer. Because of salt is effective until certain temperatures, icing is prevented more quickly using some liquid chemicals. A salting operation is given in Figure 5.
	Sanding	Regarding struggling with snow and icing; Some substances have been applied on road surface as anti-skid in case of the road roughness decreases rapidly; very low temperatures at which effect of the chemical decreases; snow on road steadying. The abrasive substances such as sand, coal dust and ballasts prevent vehicles from slipping on the road platform and getting out of lane, increasing the roughness of the surface layer of snow stuck. But, this method is allowing coefficient of friction to increase, scatter around by the effect of traffic and provide short-term solution since abrasive substances cannot stick on road steadying (Varış, 2007).

Methods		Information
	Wetted Sanding and Warm Wetted Sanding	The warm sanding method called Hot Stone is a process of spreading of aggregate particles of 2-5 mm in diameter on road after being heated up to 180 degrees. The aim of this method using diesel fuel in heating of abrasive materials is to increase the coefficient of friction by fixing sand (abrasive material) to snow or ice on the road pavement thereby providing a safe driving. In the conventional sanding method, abrasive substance scatters out of the road through passing of a certain number of the vehicle on road pavement or its impact lasting only for a few hours after being applied. The warm wetted sanding method is the process of spreading of aggregate particles of 0-4 mm in diameter on road platform by mixing with hot water in a scrambler at 90-95 degrees. The purpose of this method is to increase friction on pavement providing abrasive substance scattering around quickly by traffic impact to stick on road by means of water. This method bases on the principle of addition of hot water to sand and covering water particles with sand particles. It has been found that the effectiveness of the friction force decreases with the passage of less than 50 vehicles from a road where the sandblasting method is applied. However, on a road with warm wetted sanding, it is seen that the method is effective despite the fact that 2000 vehicles have been passed through and that the road surface has a friction force above the standards. When it is compared with other methods, it is seen that its effect on pavement lasts between 3-7 days in appropriate weather conditions (Dahlen, 2003). The view after application of warm wetted sanding method to the icy road surface is given in Figure 6.
	Chemicals	This method much uses fight against snow and ice like other methods. Chemical substances can be applied in solid or liquid state. The type and amount of chemicals to be applied varies depending on the amount of snow or ice, the ambient temperature and the application area. Because they are cheap and effective, the most used chemicals are; sodium chloride (NaCl), magnesium chloride ($MgCl_2$), calcium chloride ($CaCl_2$), calcium magnesium acetate (CMA) and potassium acetate (KAc) (Daji-Ajvazi et al., 2018).
MODERN METHODS	Electrically Conductive Pavement	The system is a layout to prevent snow and ice accumulation by using the automation related to the heating cable. Heating cables are used as a precaution in places where icing threatens life and property safety. With the heating cables applied to the pavement, the heat rises upwards evenly from every point of the furnace and a homogeneous heat distribution occurs in the spaces. Examples of the implementation and applied of this system are given in Figure 7. and 8. Electric heating cables can be applied on almost all underground roads. Electric heating cables are used in the areas where snow and ice exist and traffic environment is prepared in terms of traffic safety.
	Anti-icing Spray Method	Frost, ice formation and adhesion of the snow to the surface of the road are prevented by the anti-icing and solvent solution. This solution is able to prevent and solve frost on the snowy and icy surface. It is applied to the surface of the coating before snowing, so that the thin film layer formed by the solution prevents adhesion of the snow to the road surface. This solution is environmentally friendly, it is a general advantage that it is applied very quickly and saving labor and time. It is also the most important advantage that this solution is not corrosive and does not damage the asphalt and concrete roads. Figure 9. shows the application of an anti-icing spray method.
	Detecting and Preventing Icing System	This system is also called auto-icing spraying method and this system is developed by combining the anti-icing spraying system with technology. The components of this system are the nozzles, the sensor, the tank and the control unit. The nozzles are located on the road surface and are used to spray the chemicals onto the road surface. The sensor unit is used in weather forecasting, which includes detectors for air temperature and humidity and the sensors are used to be informed about snowfall and icing on the road surface. Also Road and Weather Information System (RWIS) can be used as a sensor in this system. Chemicals are stored in the tank unit and chemical pumping to the nozzles is carried out from this tank unit. The task of the control unit is to activate the system actively. As mentioned, this system is fully automatic. In other words, it is not a system based on human power. Only if there is a technical problem, an external intervention may be necessary. Chemical spraying of the pavement and control unit is given in Figure 10. and 11.

Fig. 4.
Example of Plowing
Source: General Services, Concord, 2018

Fig. 5.
A salting operation
Source: Municipality of Eskişehir Tepebaşı, 2012

Fig. 6.
The view after application of warm wetted sanding method
Source: Nova Scotia Report, 2010

Fig. 7.
Electrically Conductive Pavement implementation
Source: Samm Technology Communications Industry and Trade Inc., 2014

Fig. 8.
Electrically Conductive Pavement applied on the bridge
Source: National Public Radio, 2017

Fig. 9.
Manuel Solution by Trucks
Source: Snow & Ice Practices, 2011

Fig. 10.
Spray Nozzle of Detecting and Preventing System
Source: Rock to Road, 2015

Fig. 11.
Control Unit of Detecting and Preventing System at entrance of the Bolu Tunnel
Source: General Directorate Highways, 2011

3. Result and Discussion

Traffic accidents are increasing day by day. To prevent traffic accident, the causes must first be thoroughly investigated. As mentioned before, the seasonal conditions in traffic accident statistics in Turkey is not considered as a cause of a traffic accident. Therefore, evaluations made in this area are not accurate enough. First of all, the causes of traffic accidents must be investigated thoroughly. Thus, traffic accident statistics can give more accurate results. In this study, the winter conditions that should be considered as the cause of traffic accidents and the struggle against snow and ice are discussed. While struggling with winter conditions, many factors can be restrictive. The first of these is environmental pollution. One of the world's most talked-about topics in the 21st century is environmental pollution. Therefore, environmental pollution should be considered to the maximum extent in the struggle against winter conditions.

The struggle against winter conditions is more important for the eastern part of the country. The most preferred method of struggle in these regions is plowing. In fact, to apply some of the other conventional methods, the plowing method is applied first. The most commonly used method after plowing is salt. The salt affecting under certain conditions has many negative effects for pavement layer and environment. Saltwater leaking from pavement edges or micro cracks in the road surface can damage to the pavement by causing freezing-melting interaction depending on temperatures varying within a day and it may also lead to aging of the coating with bitumen oxidation (Varış, 2007). In addition, these salts increase salt concentration of rivers and streams over time and they adversely affect drinking water, irrigation and aquatic life (Transportation Association of Canada, 2013). Despite the low cost of salting, due to damage to the environment and the pavement there has been a tendency towards alternative methods.

One of these methods is sanding, which is the same as the application of salting. It is an improved method to remove harmful effects of salting. In the salting method, the freezing point is lowered and the roughness of the road is increased. Sanding method does not much affect the freezing point. It only increases the roughness of the road. In addition, the damage of the salting method cannot be completely removed. In the sanding method, remaining sand on the road surface causes environmental and visual pollution. Because of these reasons, sanding is not a preferred method.

Another method used is wetted sanding and warm wetted sanding. As mentioned before from the technical section, the heating and wetting process in this method are applied. If the heating process is considered first, the heated sand (warm sand) has a significant effect on freezing point, unlike the conventional sanding method. However, in this method, as in the classic sanding method, occurs environmental and visual pollution. Another process in this method is wetting. The main purpose of this process is to make adhere better to surface by wetting sand. In addition, warm wetted sand provides a little melted when it adheres to the snow or ice surface. This method, which is highly developed compared to the classic sanding method, is regarded as the most developed of the conventional methods. Other implementation type of conventional methods is chemical usage. The productivity of chemical usage varies depending on the type of chemical used. It can also damage the chemical environment. Nevertheless, it is shown effective substance for struggle against snow and icing. Although it is the most advanced conventional method, even in this method, occurs environmental and visual pollution.

New methods called modern methods have been developed due to the disadvantages of conventional methods. One of these methods is electrically conductive pavement. In this method, no substance is used in the struggle against snow and ice. Therefore, anything pollution does not occur. In this method is tried to melt snow and ice by using heat energy. Heat energy is spread homogeneous throughout the application area. The heat energy is supplied by electricity in the system. But as it is known, the cost of electricity is high. Another method is the automatic spraying system or anti-icing system. In this method, road and weather information is taken before snowfall and chemical is applied to the road. The negativities existing in the use of chemicals are valid in this method. The last method is detecting and preventing system, which is the most developed of the modern methods. In this method, any human power isn't used except for service and maintenance. So the system is expressed fully automatically. Two sensors are used in the system. One of these sensors is temperature information sensor. The other is humidity information sensor. After the information received from the sensors is interpreted by the system, if there is a possibility of snowfall or icing, the system starts to work. Then, chemicals where in the tank unit are pumped to nozzles and they are sprayed to the road at the required intervals from nozzles.

4. Conclusion

All methods are discussed. The advantages and disadvantages are clearly demonstrated. Although, low the cost of salt, it isn't preferred due to the damage to the environment and the pavement. Also, the use of human power and vehicles in conventional methods may interfere with the struggle against snow and ice in some situation. The situation is the same in Anti-Icing Spray Method, which is found in modern methods. Because the use of vehicles and human power, the same situation like conventional methods is valid in this implementation. In the electrically conductive pavement method, the use of electricity may be expensive. The last method examined is detecting and preventing system. Full automatic generation of the system is a big advantage over other methods. As long as service and maintenance are done regularly, it can work well for many years. However, in this method, like electrically conductive pavement, can also have high electricity cost. If an alternative energy source is found, this method can also work more economically.

If all methods are considered for tunnel application, it can be said that the most effective methods are modern methods. However, the plowing method is often used to prevent snow accumulation. Excessive roughness on the road or unevenly distributed roughness can cause traffic accidents in tunnel exits. Therefore, applying the method of salting or sanding may cause problems. Despite it has advantages, the situation is the same for wetted sanding and warm wetted sanding method, which is the most advanced implementation of conventional methods. Therefore, it may be a better solution to use modern methods at such critical methods. Since method A is a method based on human power and vehicles, there cannot be a continuous intervention. Electrically conductive pavement method may not be a reasonable option because the cost is high. However, it can be a reasonable option if an energy source that is less costly than electricity can be used. It can only be applied to the entrance and exit areas of the tunnels. Conventional methods can be used in the remaining areas. Thus, the cost can be reduced and traffic safety can be provided. The detecting and preventing icing system has some drawbacks in use. This method was applied in Bolu Tunnel. But this method cannot work well together with the plowing method which is used to prevent snow accumulation. For this system to work first of all the snow on the road should be cleaned. During the cleaning work at the entrance of the Bolu Tunnel, the snow accumulations are swept to the roadside by vehicles. During this sweep, snow accumulations cover the sensors of the detecting and preventing system. So the system has not worked for days. If these troubles can be resolved, this method may become a logical option.

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SIMULATION OF CRISIS SITUATION IN ROAD TRANSPORT

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Abstract: In road transport, a sudden crisis situation can occur, but also a crisis with gradual development that can be predicted and subsequently addressed by traffic modeling. The aim of the paper was to create a real road intersection model based on a traffic survey. The model created in the PTV VISSIM program was the basis for simulating crisis events at peak hours. The simulation model was used to analyze the crisis situation associated with a light-signaling failure across the intersection. The parameters studied for traffic fluency were a vehicle crossing time and the length of the car queue. The results of the simulation experiments revealed the negative impact of this situation associated with the disrupted traffic flow on the secondary roads. The simulation model was created for the needs of city logistics solutions in the city of Košice.

Keywords: simulation, city logistics, crisis situation, road transport.

1. Introduction

The current trend in road transport is that its volume is increasing, which also leads to a higher incidence of crisis situations and, in general, has a negative impact on society. This fact is not avoided even by the Slovak Republic. Most roads in Slovakia are obsolete and do not suit such vehicles, as they are more and more exposed, so it is necessary to look for ways to improve their quality and therefore the safety of transport. One of the ways to achieve this is transport modeling, which is currently at the stage of its greatest development. Transport modeling can bring answers to many questions that could help improve the overall situation on the road. Using computer simulation tools, it is possible to study, for example, how transport behave in the section where a crisis occurs in the form of a lane closure or light signal shutdown and the like. Traffic modeling, however, does not only provide solutions to crises but also helps avoid them by better explore a particular stretch of traffic, thus suggesting immediate improvements. Traffic modeling, in combination with computer simulation, is a powerful tool to tackle various problems, including traffic congestions (Degong et al., 2018). We can actively use already verified models such as Car following model (Chen et al., 2018), Cellular automata model (Regragui and Moussa, 2018) or various adapted and modified models. Traffic congestion, along with various crisis situations, represent a very important area of research in road transport (Guenther et al., 2018). Their impact is manifested not only in the area of transport means movement but also in the pedestrian movement (Feliciani and Nishinari, 2018). Computer simulation is also appropriate to address the impact of traffic situations on the traffic flow of passengers in the means of transport (Miristice et al., 2018). It follows that simulation as a research method has a tremendous potential in road transport. For this reason, it can also be used for research due to the different types of crisis situations and their consequences (Kristoffersson and Engelson, 2018).

2. Crisis Situations in road transport

The term "crisis" has its origin in medieval Greece, in the word "krino", which meant final decisions without the possibility of appealing or preventing unhappiness or seeking rescue. Roots can also be found in the Latin language, where the word "crisis" was a critical culmination point. At present, the concept of the crisis has taken hold and has begun to be used throughout the world in the context of transport, economy, military, culture, social, natural and technical sciences, and so on. Therefore, it is not possible to define the crisis in general for all types of areas. However, it can be said that the crisis is such a moment that the situation turns to worse. In other words, it is a state of peak tension identifying the phenomena of social life. Crises also occur independently of the will of a person in the form of events that bring about negative impacts, reduce security and prevent the smooth running of different processes.

The occurrence of crises in road transport may be related to any action that occurs in nature and in society, and in specific circumstances may become uncontrollable and cause damage or loss. If one does not understand the nature of these undesirable changes, he cannot eliminate the causes that have led to their creation, respectively reduce them or prevent them from arising in the future. In connection with road transport, the above-mentioned facts apply in particular. Therefore, this issue cannot be addressed without continuous monitoring of factors that could influence the situation on the road and their detailed analysis.

For the analysis needs, a whole range of methods can be considered, among which computer simulation methods dominate.

2.1. Simulation in Road Transport

Simulation in road transport represents a huge contribution to the solution and optimization of traffic situations in real conditions. Its further application can be seen in the solution and evaluation of recurring problems and questions. This is, for example, the question of whether a roundabout or normal junction is more advantageous in a given location.

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Simulation can be used to analyze realistic but also fictitious traffic situations and suggest changes to improve the traffic situation. When looking for optimal solutions for areas affected by frequent crises, it is best to model the exact crossroads or other critical locations and to observe the impact of concrete simulated changes on traffic and thus to identify the ideal changes that could prevent the crises in that section.
However, in order for the real-time simulation to be performed, it is necessary to first perform a detailed analysis in which the traffic survey plays a dominant role. The traffic survey gives the necessary information that helps simulate the section at a specific time.
Traffic survey is a necessity without which it is not possible to simulate the real situation on the roads and to find solutions for them. If the simulation is not relevant to reality, its results cannot be used in the real system.
Simulation has also brought great benefits for transport as such. Whereas in the past computer simulation has been a demanding mathematical activity designed only for specialized people, today computer simulation is also available to the general public. This is thanks to the simple processing of simulation programs that contain a graphical environment, which helps to better orientate in the model and creates a realistic picture of simulating. Developers of such programs have also implemented complex math functions or algorithms into pre-configured functions on task pane, by which different conditions in a simulation can be created. This step avoids the sophistication of programming and making computerized simulation easy to access, fast, clear and reliable.

3. Analysis of the Current Traffic Situation in the Selected Area

The Slovak Republic is currently undergoing a several-year phase of the road infrastructure construction in the form of highways and the speed roads network. This necessitates the realization of a large number of analyses and surveys associated with individual urban agglomerations. Among the largest and most significant agglomerations in Slovakia is the city of Košice.
The city of Košice is the second largest in Slovakia. It is the metropolis of the East with a population of 239 thousand. It is situated in the Košice Basin, where the Hornád River flows, which divides it into two parts. In the west and northwest, it is bounded by Slovak Rudohorí, from the east by the hills Slanské vrchy. Kosice has located only 20 km from the border with Hungary and about 80 km from the border with Ukraine. The city's territory also crosses major international transport routes. There are several major traffic nodes in the city. These include the crossroads of the streets - the Juzna trieda Street, the Jantarova Street, and the Rastislavova Street.
As part of the analysis of the traffic situation at this intersection, a traffic survey was carried out. The survey was performed in October 2017 for two weeks, three days a week for two hours. More precisely, in these days and hours:

- every Monday from 9:00 to 11:00,
- every Saturday from 11:00 to 12:00,
- every Friday from 14:00 to 16:00.

The task was to find out if the maximum rush hour would appear in the early, midday or afternoon hours and then use this information in the simulation. The intersection is located in the city of Kosice - South (Fig. 1). It connects the city centre in three directions, from the Jantarova Street, through the Juzna trieda Street, and from the Rastislavova Street.

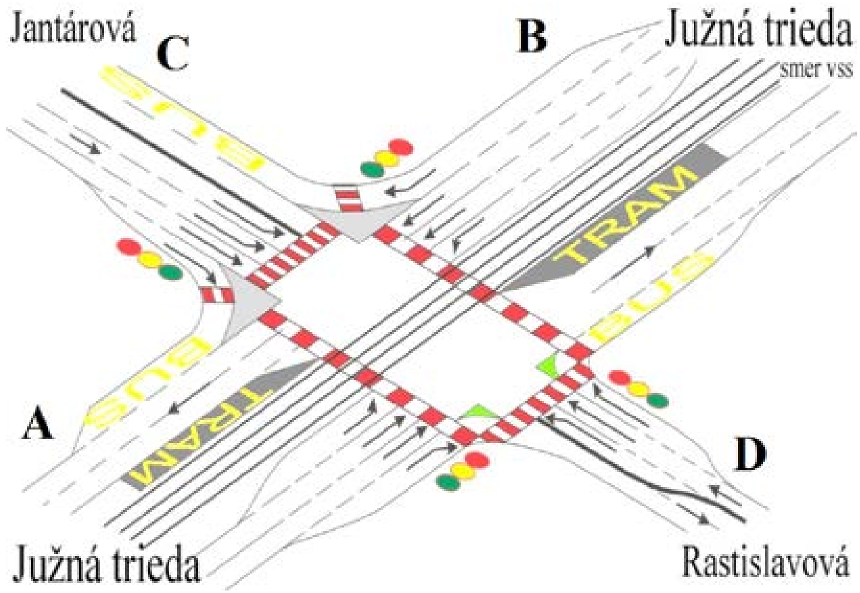

Fig. 1.
Diagram of intersection Južná trieda Street, Jantarova Street, and Rastislavova Street
Source: Authors

This intersection is among the busiest crossroads. There is a corporate zone between this junction and the next junction (called VSS) where many companies, offices and production halls are housed, which reflects on transport as well. Transportation here is mostly provided by passenger cars, but also various vans, lorries, trucks, and suburban buses and public transport buses. The Juzna trieda Street forms the main thoroughfare from the city centre out of the city and in the opposite direction. The second most used traffic lane is from the Jantarova Street to the Juzna trieda Street towards the bridge on the VSS crossroads in both directions. This connection is mainly used by suburban buses. Another fact is that trams run through this crossroad, what is also the reason a crisis situation can occur - whether for collision with another vehicle or for the reconstruction of tracks or crossing over the tracks. Interestingly, there is a lack of an induction coil at the junction that would prefer trams. There are no pedestrian traffic lights with signal buttons or dedicated bus lanes. Traffic at this intersection was explored if it came to a crisis situation. Fig. 2 shows the real picture of the surveyed crossroad where crises situations were simulated in the PTV VISSIM program.
The road to the Juzna trieda Street is the main two-lane road, before the junction, it subdivides into four lanes - two lanes continue in the direct direction, one lane for turning left in the direction Jantarova Street, and one lane for turning right in the direction Rastislavova Street. In the opposite direction, it is the same. The Jantarova Street is a secondary road with exit marked by a sign give way. It also has four lanes - two to turn left in the direction of the Juzna trieda Street toward the VSS Bridge, one lane in the direction of Rastislavova Street and one to turn right in the direction of the Juzna trieda Street towards Liberation Square. The exit from Rastislavova Street is also a secondary road with traffic signage give way. It has three lanes - one lane turning in the direction of the Juzna trieda Street toward the VSS Bridge, one straight lane in the direction of Jantarova Street and one for turning left in the direction of the Juzna trieda Street towards the Liberation Square.

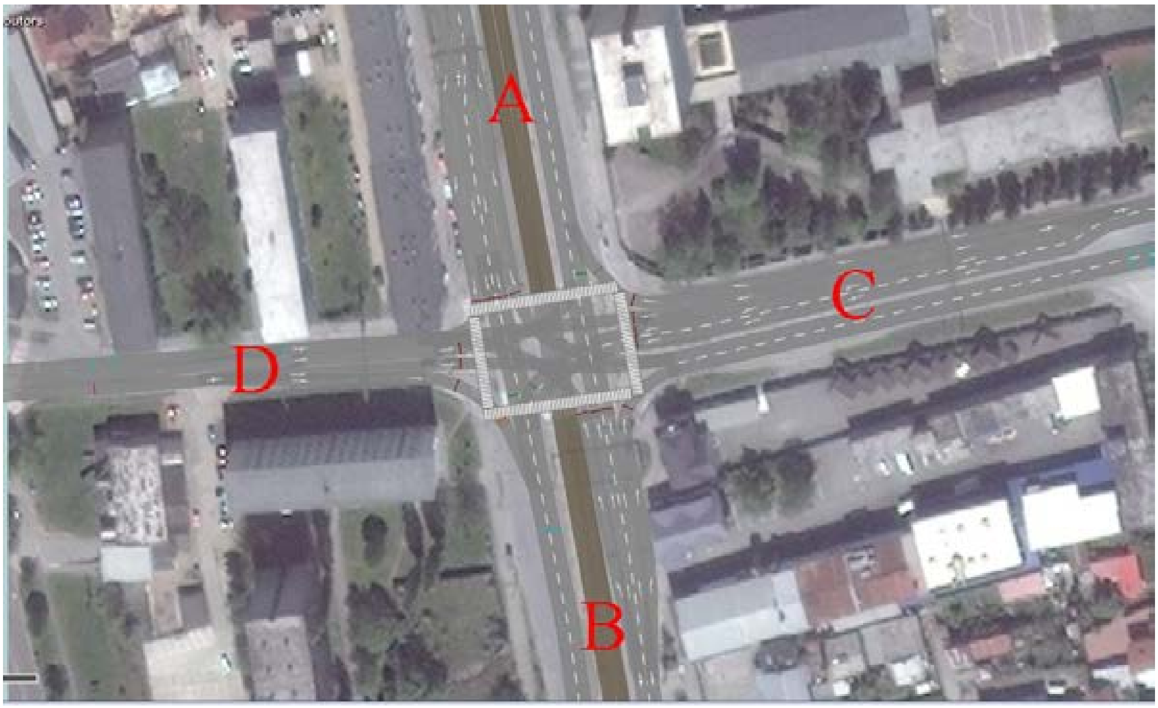

Fig. 2.
A real view of the monitored intersection
Source: Authors

Entrance and exit of the same street were identified with these capital letters.

- A = Južná trieda Street from/towards the Liberation Square;
- B = Južná trieda Street from/towards the VSS Bridge;
- C = Jantarova Street from/towards;
- D = Rastislavova Street from/towards.

Authenticity was followed by traffic signs on the roadways for individual lanes and also for pedestrian crossings.

3.1. Structure of Vehicles at the Monitored Intersection

Based on the traffic survey, it was possible to determine the exact composition of the vehicles at the rush hour. It was based on the sums of specific types of vehicles at 15-minute intervals in rush hour for each exit. Percentage evaluation is shown in Fig. 3. Passenger cars with over 98% participation were the largest in this segment. The remaining 1.5% belonged to other types of vehicles. At the time of the rush hour, there were no lorries with a trailer or articulated buses.

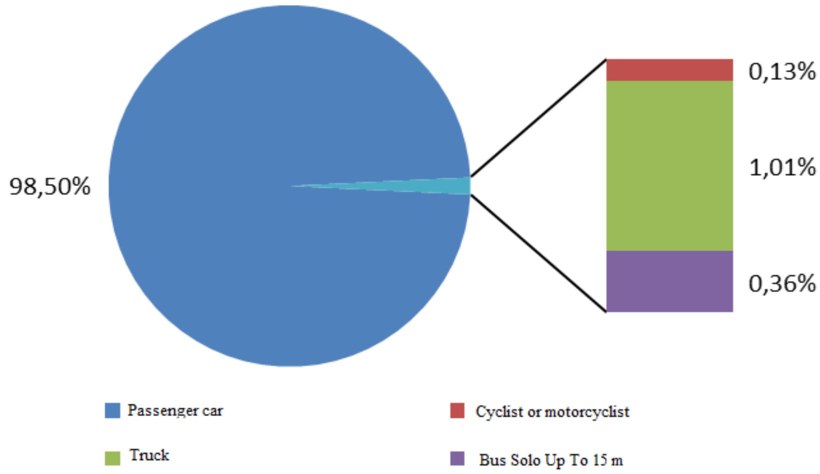

Fig. 3.
Structure of vehicles during rush hour
Source: Authors

The number of turning vehicles from each exit is the sum of all types of motor vehicles drove through the intersection in 15 minutes interval of rush hours from each exit (A, B, C, D) to all possible entrances. Specific values are depicted in Fig. 4. As can be deduced, Jantarova Street towards the Juzna trieda Street was the busiest road during the rush hour in the direction of the VSS Bridge, with a share of more than 16% from all vehicles crossing the junction. The second busiest road was from Jantarova Street to Rastislavova Street, with a share of 14.16%, and the third one was the road in direction Juzna trieda Street towards Rastislavova Street with 13.79%. The least busy was the direction from the Jantarova Street to the Juzna trieda Street towards the center, where the number of vehicles accounted for only 0.52% of the total number of vehicles.

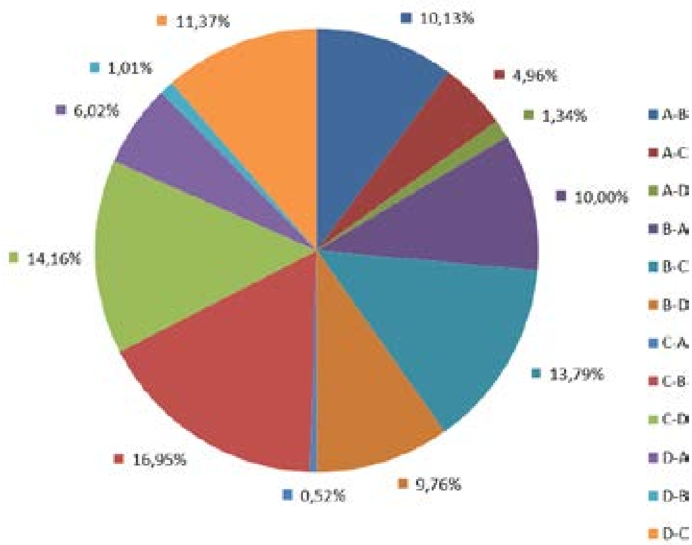

Fig. 4.
The number of vehicles turning from each direction during the rush hour
Source: Authors

4. Simulation Model

The simulation of the real process was carried out in the computer program PTV VISSIM 7.00-13, that was the most appropriate for the given issue. The program is specialized for transport, strategic planning, traffic engineering and traffic management.
The selected intersection was controlled by traffic lights in all directions for vehicles, pedestrians and tram traffic. Light signaling setting is depicted in Fig. 5. To simplify, each driving direction has been marked with letters A through D. These letters are compatible with the direction markings in the previous steps. Single letters mean crossroad entrances and exits.

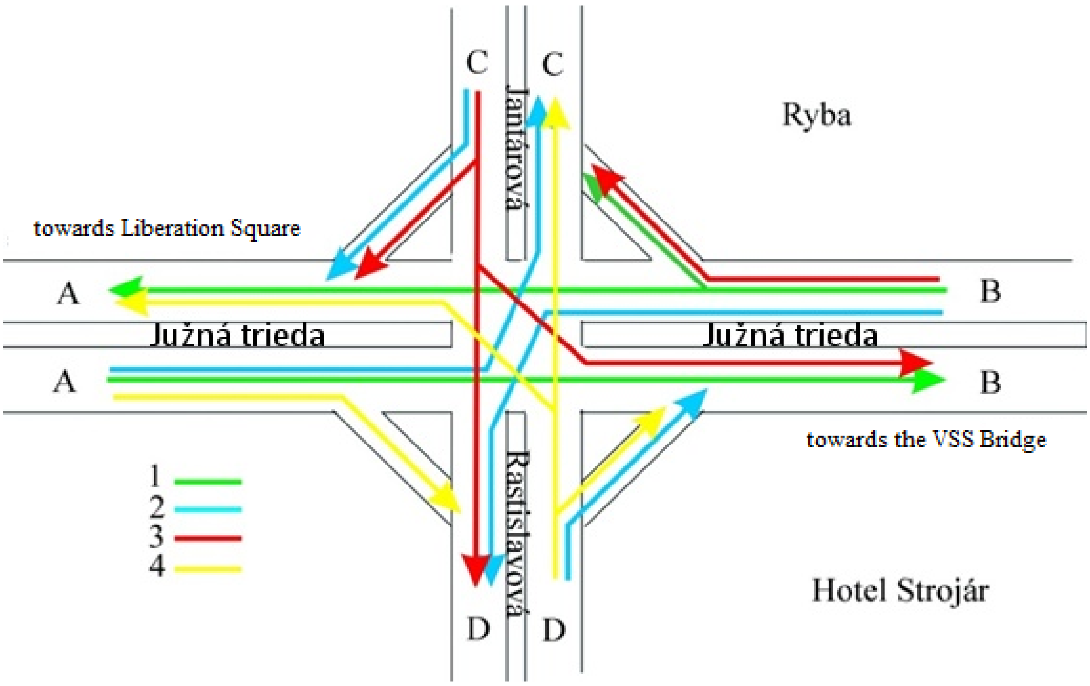

Fig. 5.
Traffic control scheme by light signaling at the selected intersection
Source: Authors

Each direction has been marked in a different color to illustrate the synchronized traffic lights courses at the intersection and their durations have been measured. The results are recorded in Table 1.
After summarizing the synchronized light course times and the intervals between them, it was found that the entire signalling traffic lights cycle is repeated every 80 seconds. The "signal controls" menu was used to set the light signalling in the simulation program. The group has been defined in the simulation program and the necessary number of subgroups called "signal program", which represents traffic lights for specific directions, has been created. These are marked from A to D depending on where they are going from. The composition of the light signalization consisted of red - yellow - green. The length of the green light signal also took into account the duration of the yellow light signal, which turned on after the green light signal and lasted 3 seconds.

Table 1
Synchronized traffic lights courses duration in intersection directions

	Exit from the direction	Entrance into the direction	Duration
1.Concurrently	A	B	15 s
	B	A, C	15 s
2.Concurrently	A	C	10 s
	B	D	20 s
3. Concurrently	C	B, D	20 s
	B	C	20 s
4.Concurrently	D	A, C	20 s
	A	D	20 s
5. Anytime	C	A	-
	D	B	-
6. Total			**80 s**

Source: Authors

There were two directions at the intersection during the survey, which were not controlled by the traffic lights. Specifically, it was the exit from the Jantarova Street to the Juzna trieda Street (C-A) and the exit from Rastislavova Street to the Juzna trieda Street in the direction of the VSS Bridge (D-B). The low number of vehicles driving these directions assumes that road users are able to drive themselves by road traffic labelling (give way line). Switching off the traffic lights in these places is not an obstacle for fluent traffic.

5. Simulation Experiments

When creating simulation models for experiments, the basic model of the peak time was used and was supplemented by specific features describing a given crisis situation. The task was to create crisis situations that could actually occur for subsequent comparison of values and to find out how the unfavorable situation will affect traffic on a particular stretch of a road. The aim was to gather information and make it easier to avoid a negative impact on real traffic.
The experiment was set with the switched off traffic lights in all directions of the intersection. The original light signal setting has changed to permanent yellow for all driving directions via the "signal heads" option. Traffic management was secured by traffic signs according to the valid rules for this junction.
The main route consists of the traffic flows in both directions on the Juzna trieda Street (A-B, B-A). Jantarova Street and Rastislavova Street are secondary roads, with road users obliged to give priority to vehicles going on the main road. As a result, conflicting zones were set up using the "conflict area" option - all crossing points on the junction were highlighted in yellow, the red and green colors were assigned depending on driving priority at a particular conflicting zone.
The average time of vehicle passing the junction to the Juzna trieda Street exit in the direction of the VSS Bridge (A) can be seen in Fig. 6. The longest passage time from part A during the switched off traffic lights was in the section Juzna trieda Street - Jantarova Street (AC) between 9:00 and 9:15 and lasted 25.46 seconds in average per vehicle. The passage time for connection the Juzna trieda Street - Rastislavova Street (AD) was 18.58 seconds in time from 9:15 to 9:30. The Juzna trieda Street - direction (A - B) was the slowest at 9:45 to 10:00 with 18.34 seconds.

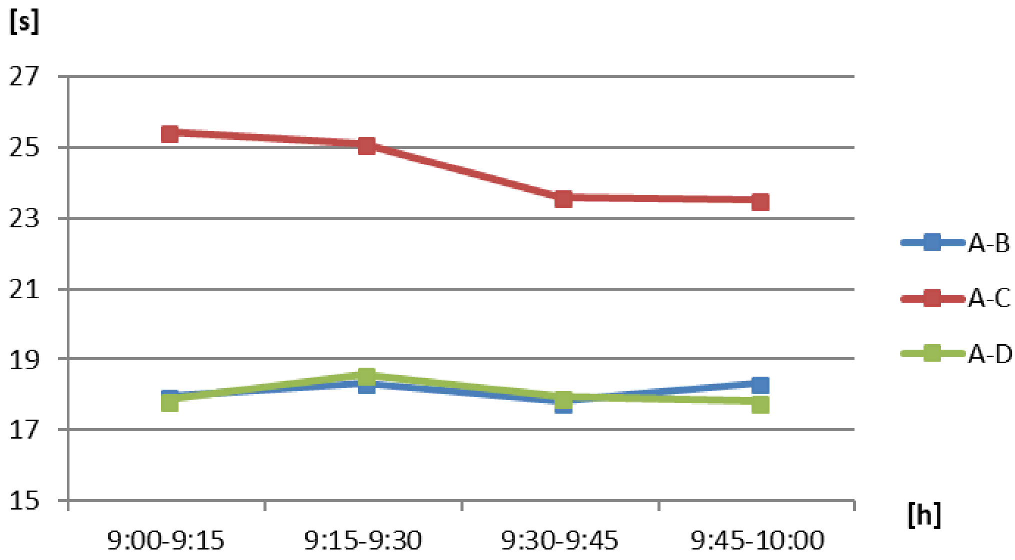

Fig. 6.
The average time for the vehicle passing from point A to B, C, D when the traffic lights are off
Source: Authors

As further the car column lengths were analyzed that have started to emerge as a result of switching off traffic lights. The average and maximum lengths of the column caused by stopping the car on red light signal for each time interval were measured. The exit from A to B is the main traffic stream, so the delay from this exit is minimal. The longest column has created in conjunction with the Jantarova Street (A-C) at 9:15 am to 9:30 am with an average length of 0.06 meter and a maximum length of 6.44 meters.
The values of the columns for the Jantarova Street (C) are shown in Fig. 7. The longest column was created in conjunction with the Rastislavova Street (C-D) from 9:00 am to 9:15 am with an average length of 45.26 meters, which corresponded to the longest passage through this section. The maximum length of 170.86 meters was set at 9:15 to 9:30 am.

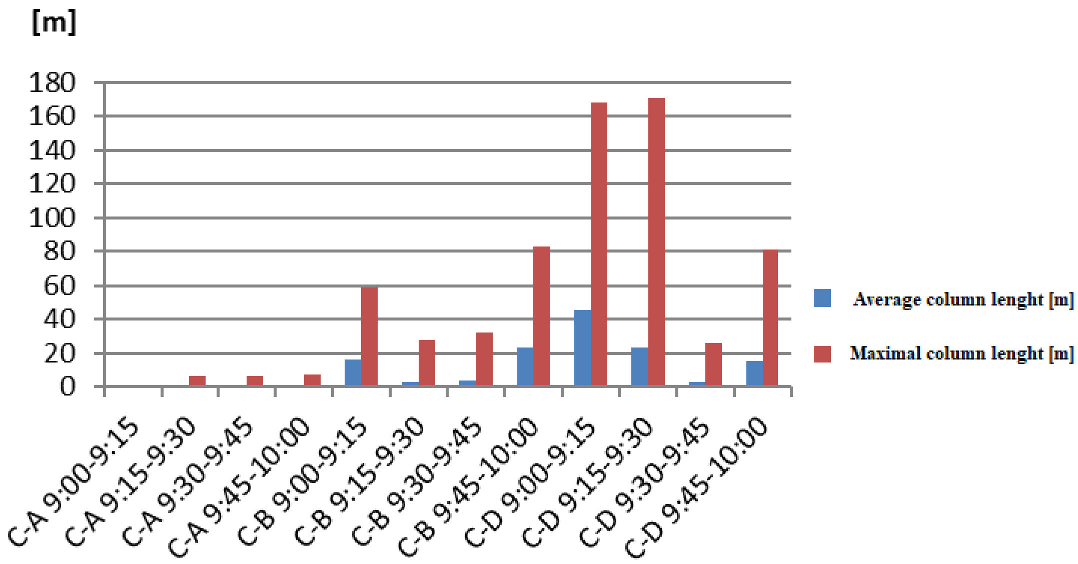

Fig. 7.
Column length from exit C when the traffic lights are off
Source: Authors

The simulation experiment, in which traffic lights were switched off, found that switching off traffic lights was the most disadvantageous for drivers involved in a traffic jam coming from the Jantarova Street, which belonged to the secondary roads. The longest average passage of the vehicle, in connection with the Jantarova - Rastislavova Street (C-D), lasted 81.14 seconds, but there was being 60.35 seconds in the base model. For the connection from the Jantarova Street to the Juzna trieda Street towards the VSS Bridge (C-B) was the longest average passage time 65.48 seconds per vehicle. In the case of the basic model, the vehicle passed the stretch by 18.16 seconds faster. The passage through the other connections has improved significantly compared to the basic model, even in the case of the secondary exits from the Rastislavova Street, where the reason for the improvement was probably only a less use of the road.

6. Conclusion

The presented application of the computer simulation method has provided a wide range of different information, which only the selected sample was presented in the contribution. Overall, however, it can be said that this method is highly efficient and provides valuable information for prediction of crisis situations in the road transport sector, which can be used to take effective maintenance of traffic, redevelopment and security measures.

Acknowledgements

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DRIVERS' GAZES AT HORIZONTAL ROAD MARKINGS AHEAD OF INTERSECTIONS

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Abstract: Eye movements of young drivers travelling along a dual-carriageway city street were analysed, with focus at their gazes at horizontal road markings ahead of eight intersections, at two preview distances: 35-70 m and 70-180 m. The visual region was divided into three sections: centre, horizontal line markings, and other areas. The number of observers (on average 5-6, out of 32 participants, i.e. 18-24%) and the number of gazes at the horizontal signalisation (on average 27-37 gazes, i.e. about 41-53% of all gazes) were quite low, which may suggest that the markings are used as a confirmation of other visual cues allowing for positioning of the vehicle within a travel path. On average, no meaningful differences between the two preview distances were measured. However, there were very significant dissimilarities between different intersections: whereas at intersections with broad road the gazes from farther prevailed, it was the opposite in case of smaller crossings.

Keywords: Eye tracking, city driving, road intersection, horizontal road marking**.**

1. Introduction

1.1. Road Safety and Horizontal Road Markings

Road safety is one of the key contemporary issues in all of the countries. According to a report from World Health Organisation (2016), over 3400 people die every day in road accidents and road fatalities are the main cause of death amongst people 15-29 years old. Furthermore, the same report estimates that financial expenses associated with vehicular accidents reach an enormous 3% of World's Gross Domestic Product. Therefore, increase in road safety should be of profound importance for all countries and a way to improve standard of life for all people (Makarova *et al.,* 2018). European Commission (2010) adopted an ambitious plan to reduce the number of fatalities by 50% within a decade. In spite of meaningful lowering the death toll, the target is not quite being met. Therefore, research into various issues regarding driving, driver focus, and infrastructure is of utmost importance, because it is necessary to understand which parameters truly control road safety.

Driving a vehicle belongs to cognitive processes based mostly on visual input, which can be measured by the movements of driver's eyes, as was described by Rockwell (1972). In the system driver-vehicle-road, the failure of scanning the road by the driver is deemed as responsible for majority of accidents, as was documented by Lee (2008) in his review. Particular role in supporting drivers in their task of keeping the vehicle on the desired travel path play horizontal road markings (Steyvers and De Waard, 2000). Markings importance was proven by Miller (1992) who performed statistical analysis, which demonstrated that the presence and proper quality of horizontal signalisation can bring safety benefits sixtyfold exceeding the expense of its installation and maintenance. The advantage is mostly due to lowering the number of accidents, which were calculated to be the controlling parameter in all financial analyses regarding road maintenance, as was shown by Abboud and Bowman (2002).

1.2. Eye Tracking as a Tool for Driving Research

Eye tracking started to be used as a research technique for studies of drivers in the early 1970s (Mourant and Rockwell, 1970). Presently, it is a broadly used tool for analysis of drivers' behaviour in response to various stimuli, mostly visual (Taylor *et al.,* 2013). Despite the multitude of published reports regarding both eye movements by drivers and the perception of horizontal road markings, field analyses, on a busy multi-lane city road, with the plethora of distractions, to which drivers are constantly exposed, are effectively absent. The advantage of such experimental procedure is the possibility of recording the real-world scenarios, but the disadvantageous is impossibility of recording responses to rare events, which can be conveniently simulated in laboratory. Whereas gazes, fixations and fixation durations were recorded, in this analysis we are concentrating on gazes at horizontal road markings delimiting travel path ahead of intersections. First results, concentrating on the view from a distance between 125 and 175 m ahead of the intersection were already presented by us (2018). In this work, we present additional data.

2. Experimental

2.1. Participants and Test Area

Participants of the experiment were volunteers, not compensated for their work, recruited amongst final-year Krakow University of Technology students. After filling a simple questionnaire regarding general health, vision, driving

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experience, and basic demographic data, selected were 32 drivers holding valid category B licence and having corrected or uncorrected 6/6 vision, all aged 20–28. Most of the drivers reported to be moderately familiar with the region where the test was to take place. Ethical guidelines related to work with human subjects, set by Krakow University of Technology, were followed at all stages of the experiment. Information about the participants is shown in Table 1.

Table 1
Test participants

Participants	Number	Age	Average driven distances per month		
			Below 200 km	**200-1000 km**	**Over 1000 km**
All	32	24.1 (1.72)	23 (72%)	6 (19%)	3 (9%)
Male	21 (65%)	24.4 (2.01)	14 (67%)	4 (19%)	3 (14%)
Female	11 (35%)	24.2 (0.98)	9 (82%)	2 (18%)	–

Source: Authors

The study was done within city limits of Kraków, Poland, in an area designed in the 1960s for moderate-density high-rise residential blocks of low-end flats. The quarters are separated by broad streets forming barriers for pedestrians who can cross only at very limited places. The route, taken on roads with two lanes of traffic in each direction, with increases at most of intersections approaches to as much as five lanes, has numerous interchanges and roundabouts, turnarounds, pedestrian crossings controlled and not controlled by traffic lights, and contains public transport infrastructure for buses and trams. Map with the route and analysed intersections marked is shown in Figure 1.

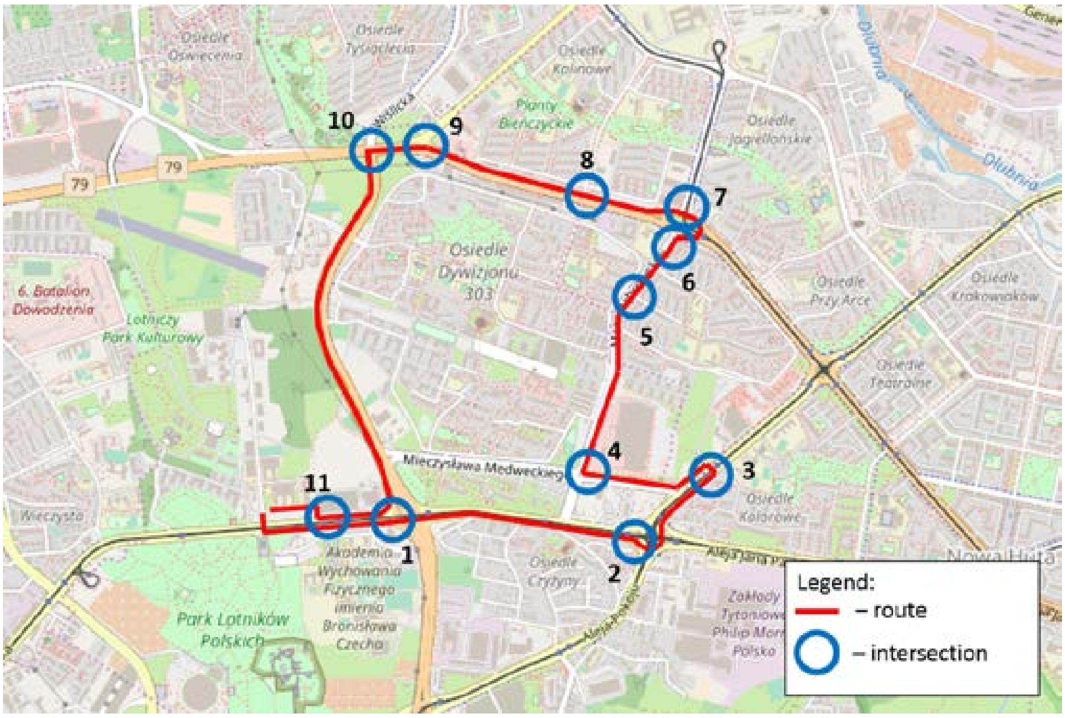

Fig. 1.
Map of the test route with the eleven analysed intersections marked
Source: Open Street Maps (2017), route overlay by authors

2.2. Experiment

The eye tracking device FOVIO (Seeing Machines; Canberra, Australia) was mounted on the steering column of a 2014 compact car powered by 1.25 dm³ petrol engine and equipped with a 5-speed manual transmission. One has to note a significant deficiency of the utilised method: unlike wearable eye tracking devices, the used stationary equipment was not able to record eye movements when the driver moves head sideways. Participants were given a brief time to familiarize themselves with the vehicle, during which time the performance of eyetracker device was verified. Drivers who knew the area were not informed earlier about the planned travel path; all participants were instructed to obey the rules of the road. Verbal instructions regarding the travel path, with appropriately advance information, were given by the research coordinator present in the passenger seat. Tests were run in late summer, with weather conditions varying from sunny to cloudy. Driving was done during off-peak hours on work days.
EyeWorks™ (EyeTracking Inc.; Solana Beach, California, U.S.A.) was used to process the collected data. Despite quite significant data voids caused by the use of a stationary eyetracker, the quantity and quality of the obtained raw data was sufficient for processing and in our opinion the stationary equipment gives different perspective than the wearable and

also is less intrusive on the driver. For analysis of the collected data, visual field ahead of each intersection was divided into three regions: centre, horizontal signalisation, and all other fields. Similarly to our previous report (Pashkevich *et al.,* 2018), we have discarded data for three of the analysed 11 intersections due to their specific configuration, which would make comparative analyses difficult and uncertain.

3. Results and Discussion

Firstly, we tried analysis of an average responses at the far and the near visual fields. As shown in Table 2, on average only approximately 21% of drivers were recorded to glance at the road markings; however, on average 47% of gazes were given to them. This discrepancy might suggest that once the horizontal road markings became important for guiding at a particular intersection, confirmation glances were necessary, but different interpretations might be equally probable. However, due to the aforementioned dissimilarities between intersections, we cannot state a positive conclusion. Relatively large standard deviations, given in parentheses in Table 2, are a proof of high uncertainty.

Table 2

Average number of observers with recorded glances at far and near distances

	Far distance (70-180 m)		**Near distance (35-70 m)**		**Difference between number of gazes (far vs. close)**
	Observers	**Gazes**	**Observers**	**Gazes**	
All gazes	25.4 (1.9)	70 (49.7)	25.1 (1.7)	66 (50.0)	106%
Gazes at road markings	6.0 (3.3)	37 (39.4)	4.6 (2.5)	27 (29.4)	137%
Percentage gazes at road markings	24%	53%	18%	41%	–

Source: Authors

Because calculating averages did not appear to be a proper analysis method, individual intersections had to be examined. The results for gazes at the near and far visual fields of the analysed intersections are provided in Table 3. Three types of responses were noticed: at intersections 1, 2, and 6 the far field (70-180 m) gained more glances, at intersections 4 and 5 it was the near field (35-70 m), and at intersections 8, 9, and 11 the responses were relatively equal. The responses we can relate to the number of traffic lanes at the intersection. Thus, we may hypothesise that the larger number of glances at horizontal signalisation ahead of broad, multi-lane intersections 1, 2, and 6 are search for confirmation of location on the road. Particularly, intersections 2 and 6, where very low focus was reported (Pashkevich *et al.,* 2018), are the locations where overwhelming other visual information was leading to marginalising the horizontal markings. Contrariwise, intersections 4 and 5 are relatively small and the drivers had to more watch for pedestrians than search for visual cues to find their position within the roadway. Additional research is required to analyse the effect of the number of traffic lanes and their arrangement on drivers' focus and glances.

Generally, glances at centre field and at other regions were following the same pattern as gazes at the road markings. Therefore, we suspect that other environmental signals were also controlling factors. Nonetheless, expectedly, there were approximately twice more gazes at the centre region than on the road markings. Whether that was the case would have to be verified both under laboratory and field conditions.

Table 3

Gazes at various regions from 70-180 m and 35-70 m

No.	**Visual region**	**Far region (70-180 m)**		**Close region (35-70 m)**		**Difference in number of gazes per observer (far vs. close regions)**
		Observers	**Gazes per observer(a)**	**Observers**	**Gazes per observer(a)**	
1	Centre	22	73	22	80	91%
	Road markings	10	49 (15%)	9	21 (7.8%)	233%
	Other areas	20	83	15	58	143%
2	Centre	17	101	23	91	111%
	Road markings	8	50 (14%)	3	7 (0.5%)	714%
	Other areas	15	100	19	87	115%
4	Centre	23	84	20	78	108%
	Road markings	3	11 (1.3%)	1	29 (1.1%)	38%
	Other areas	14	48	16	70	69%
5	Centre	21	121	22	100	121%
	Road markings	2	31 (2.1%)	5	45 (6.9%)	69%
	Other areas	9	49	16	65	75%
6	Centre	20	84	23	69	122%
	Road markings	3	15 (1.5%)	4	7 (1.1%)	214%
	Other areas	20	72	23	61	117%
7	Centre	16	84	16	69	121%

	Road markings	10	31 (10.7%)	5	37 (7.8%)	84%
	Other areas	19	81	17	74	110%
8	Centre	18	55	16	71	77%
	Road markings	4	17 (2.3%)	3	25 (3.2%)	68%
	Other areas	26	74	22	86	86%
9	Centre	17	79	18	55	145%
	Road markings	8	49 (13.4%)	7	40 (9.0%)	123%
	Other areas	20	78	24	89	87%
(*a) In parentheses are given percentages of gazes at road markings in relation to all of the gazes by all of the test drivers whose gazes were recorded ahead of particular intersection region.*						

Source: Authors

4. Conclusions and Future Research

The presented results demonstrate that drivers utilise horizontal road marking at the level of gazes, which is beneficial for road safety. Thus, those signals should always be maintained in an unequivocal and easy to recognise manner, so drivers could use them without extensive mental load.
However, this small exploratory study has shown that significant additional research in this field is needed and that there are more questions than answers. Whereas a person not familiar with the importance of road marking documented by numerous scientific publications could discount or omit their importance due to low number of observers (on average only 21%) and observations (on average only 47% of gazes at horizontal signalisation), the same data can and ought to be treated as a proof that the markings are critical only as confirmation signals. We cannot assess whether such rare gazes were sufficient for perception and for locating of the vehicle within the road width by all kinds of drivers or were an evidence of lack of experience, because all the test participants were young and Underwood (2007) has demonstrated that the visual search pattern for older and more experienced drivers can frequently be different. Similarly, it was not possible to verify with the stationary eye tracking device, if maybe the drivers were gazing at the horizontal road markings while they were moving their heads right or left. Furthermore, it is quite possible that the drivers' responses would be different depending on their familiarity with the test route, because Charlton and Starkey (2011) reported that route familiarity breeds general inattention, but that new road safety features are noticed, nonetheless.
We recognise the need to perform additional experiments during daytime, with both experienced drivers and elderly population, because their experience and compensation might possibly lead to different outcome. Similar analysis, but outside of the lit city area, should be performed during night time driving, because of the increased danger and specificity of driving in darkness (Plainis *et al.,* 2006). For night time driving, retroreflectivity of road markings is of critical importance and in this field there are novel developments that have a potential of also influencing the outcome. It is reported (Burghardt, 2018; Burghardt *et al.,* 2018) that the use of a new technology for glass beads can provide retroreflectivity reaching 1000 mcd/m²/lx, whereas the standard technology furnishes road markings with only third of that retroreflectivity. Additional eyetracker work related to the perception of retroreflectivity is important in light of the recent reports that people driving at night do see and appreciate high retroreflection (Pashkevich *et al.,* 2017; Burghardt *et al.,* 2017).
Finally, it must be added that the presence and clarity of horizontal road markings is critical not only for human drivers, but also for machine vision and the emerging technology of autonomous vehicles that rely on it. While Calrson and Poorsartep (2017) reported that high quality of road marking is absolutely necessary for autonomous vehicles, Mosböck and Burghardt (2018) claim that the same features are needed for safety of drivers of traditional cars. Field analysis done simultaneously on machine vision equipment and human drivers could be of profound importance.

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CHANGING THE TRACE - BELGRADE "TRAFFIC SNAKE GAME" EXPERIENCE

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Abstract: Sustainable transportation modes should take a dominant role and become more represented in urban transportation systems. Behaviour change initiatives could be important and useful tool for encouraging users to make changes in usual mobility patterns and switch from motorized to non-motorized transportation options. One of the excellent example is the Traffic Snake Game (TSG) campaign which originates from Belgium and was created by Mobiel 21. The objective of the campaign is to promote sustainable transport to school for primary school pupils (age 4 to 12), their parents, and their teachers. In general, TSG aims at +20% more sustainable trips during the campaign compared to the baseline. Traffic Snake Game currently runs in more than 1,700 schools across 19 EU countries. Within the project TRACE H2020 traditional version of the TSG initiative is enhanced with tracking campaign which should expand the knowledge on how tracking can support behaviour change initiatives and urban planning activities. Thanks to TRACE project, Belgrade - Serbian capital, got the opportunity for participating in this " TSG 2.0" behavioural changing campaign under the coordination of M21. This paper will present experience and results from Belgrade TSG pilot. Also, assessing the potential and conditions for applications in this behaviour change initiative are analysed and discussed.

Key words: sustainable transportation modes, behaviour change, tracking, TSG.

1. Introduction – Traffic Snake Game in Brief

The aim of the Traffic Snake Game is to encourage primary school children to travel more sustainably to school. The campaign originates from Belgium and is developed by Mobiel 21. Traffic Snake Game currently runs in more than 1,700 schools across 19 EU countries and is typically played for one or two weeks. During the campaign week(s), children that travel sustainably to school receive a small sticker in the form of a dot. All children that receive a sticker paste it onto a large green rectangular sticker and all rectangular stickers are pasted onto the school banner. At the end of the campaign period, the children are rewarded for their efforts to travel sustainably to school. Within the project TRACE H2020 this traditional version of the TSG initiative is enhanced with tracking campaign which should expand the knowledge on how tracking can support behaviour change initiatives and urban planning activities. Based on an extensive stakeholder investigation, Mobiel 21 developed tracking hardware that was suitable for tracking primary school children. The trackers were carried by the children and measured the home-school travels. The receiver was used to read out the data from the trackers and get the data on a server on which a travel mode was added to the GPS tracks. The tracking data were presented on a website trace.trafficsnakegame.eu and each participating school had a login to consult their data, which consisted of a heat map and a model split for the school and for each class.
Traffic snake game, in its original version, represents the behavioural change campaign and the following chapter present more information about travel behaviour changes as well as tracking potentials and importance for using modern technologies in these initiatives.

2. Behaviour Change and Tracking Campaign

Travel behaviour changes in response to a wide range of policy measures, such as infrastructural changes, changes in prices (e.g., prices of public transport and fuel), improvements in public transport, reallocation of road capacity, and ‘soft’ measures (Goodwin, 2003; Geels & Schot, 2007). As Goodwin (2003) points out, travel choices are made by millions of individuals and companies in function of their own well-being and profit. Changing this complex set of behaviours requires a coherent policy in which the individual elements strengthen each other. For changing travel behaviour, campaigners have traditionally relied on Theory of Planned Behaviour, Norm-activation Theory, and Stages of Change models (Bamberg, Fujii, Friman, & Gärling, 2011; Transport & Travel Research Ltd, 2003; Fujii & Taniguchi, 2006). In recent campaigns, Self-determination Theory and Cialdini’s six principles of influence have been used as a theoretical framework (Buningh, Martijnse-Hartikka, & Christiaens, 2014; Kennisinstituut voor Mobiliteitsbeleid, 2011). To date, there are no strong empirical findings showing that one of the presented theories is superior to others for changing travel behaviour (MAX, 2007).
Learning psychology has a long history (Pavlov, 1927; Thorndike, 1911; Skinner, 1938; Tolman, 1938) and its basic principles have been replicated in countless studies (for reviews see De Houwer & Beckers, 2002; De Houwer, Thomas, & Baeyens, 2001; O’Leary & Drabman, 1971). Learning psychologists explain changes in behaviour (or the intensity of behaviour) via mere exposure, classical conditioning, operant conditioning, and observational learning. Traditional Traffic snake game campaign use operant conditioning form for its initiatives. Pairing a behaviour with a consequence (the administration or withholding of a positive or negative stimulus) can increase or decrease that behaviour, what is called operant conditioning. Many behavioural change campaigns use some form of operant conditioning, mostly

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positive reinforcement (i.e., administering a reward) and often in the form of ‘gamified’ designs. The rewarding stimulus may vary from giving money to presenting a smiley face or positive feedback on the health benefits of cycling and walking.

TRACE H2020 project promotes new version of the existing behavioural change campaign - Traffic snake game, adding the tracking campaign. Tracking has a long history. For years, police forces, fire departments and medical units have tracked their vehicles by painting numbers on the roofs and citizen movements have been tracked using diaries and manual traffic counts (Flamm & Kaufmann, 2007). Besides these laborious forms of tracking, automated tracking is becoming increasingly prevalent. In recent years, the rise of technological applications and devices has yielded a vast new range of opportunities for tracking (Vandenberghe, Vanhauwaert, & Carels, 2011). The new technologies offer numerous and novel opportunities for data collection on travel behaviour (Flamm & Kaufmann, 2007).

It is clear that tracking data allows to map the movements of individuals in different ways that may be used in transport and mobility planning (Stopher, FitzGerald & Zhang, 2008; Yue, et al., 2014). But the question is: *How tracking can support behaviour change?* Tracking can be used to optimize behaviour change initiatives in different ways. By providing detailed information on the movement of people through space, tracking data have the potential of providing key information to predict and influence travel behaviour. First, tracking data can be used to describe and analyse the target audience and their current travel behaviour. Second, when tracking data is mapped onto information on the environment, it allows to gain insight in the association between travel behaviour and the environment. Third, tracking data can be used to evaluate the success of behavioural change measures and any other policy measure that aims to increase the modal share of cycling and walking. Finally, tracking data can be used to actively influence users by feeding the tracked information back to the users.

Within **TRACE H2020** project, tracking is defined as the ***automated gathering of digital information on human travel movements, with a spatial frequency of at least two location points per trip***. Tracking thus requires minimal route information (i.e., the same individual recorded on at least two locations) that only some automatic recording systems can offer (Bossuyt et al, 2016).

It is clear that tracking data offer campaigner’s insight in the current mobility choices of a target audience (e.g., inhabitants of a city, employers of a company, pupils of a school). This allows to fine-tune campaigns in a more precise and accurate manner than with traditional self-report measures. To investigate whether tracking of such a young target group was possible and delivered interesting results for the school, additional measurements were added to the TSG tracking campaign: (a) to check whether automatic travel mode detection was possible, the teacher measured the travel mode of the children carrying a tracker by asking the child how he/she came to school, (b) to check whether the home-school route was accurately tracked, the parent received an email with the route of their child and indicated on a short questionnaire whether the route was accurate, and (c) to check whether the obtained data were useful to the school and whether the workload of a tracking campaign was not too high, interviews with the school were conducted.

3. TSG Pilot in Belgrade

Traffic Snake Game Pilot took place in four Belgrade schools and it was based on two parallel campaigns:

- The **“Behaviour change campaign”**, based on the traditional modality of the Traffic Snake Game, with the support of the play snake-banner and stickers.
- The **“Tracking campaign”**, with the use of trackers.

Participating schools are differently positioned in the city area. Two schools are centrally located, and two others are on the urban and suburban periphery, which was important to notice differences in the using and changing of transportation modes.

Fig. 1.
Belgrade TSG school's location and basic facts

3.1. Pilot Step by Step

The local approach was initiated through the first Focus group meeting (TSG pilot). The Focus group allowed the dissemination of the project, as well as a brief explanation of the TSG campaign and the pilot. Some useful feedbacks from Focus group attendees were collected. The schools were selected based on some mobility criteria (location, existing infrastructure, traffic volumes in nearby area, school attractiveness – existence of pupils from far away etc.).
The weeks before the campaign, many contacts were taken with the schools and several meetings (face-to-face) took place within that period, which discussed the following topics: detail explanation of TSG campaign (paper-based campaign and a web-based version - TSG 2.0); providing further information and clarifications on the Tracking campaign; selection of classes to involve and class/school coordinators; definition of final action plan for pilot implementation; setting rewards and prizes to be given to participants during the TSG pilot.
Moreover, few weeks before the pilot started, a consent letter was delivered to the parents of the involved classes explaining both the two Traffic Snake Game campaigns (Behaviour change and Tracking), to inform them about the initiative in which their children would have been involved.
Particular attention was paid to the issues related to privacy, considering also the involvement and tracking of underage people in the Tracking campaign. Indeed, further documents (based on the model provided by M21 adapted to fit the requirements emerged by the schools) were draft and delivered to parents, to let them inform about the functioning of the trackers and related data collection, and to collect a signed consent form by them.
The **Behaviour change campaign** took place in the two weeks in November 2017. Before the campaign, in each school was measured its baseline mobility profile. According to the results collected, Faculty of Traffic and Transport Engineering (FTTE) in collaboration with schools set the target, based on the current number of sustainable trips. Generally, relative increase of 20% sustainable trips was planned because the number of sustainable trips was already very high and the absolute increase of 20% (according with the general rule of the TSG) target was not realistic. Every day during the two weeks of the duration of the Behaviour change campaign, local coordinator together with teachers registered the data collected by pupils, filled in the class measurement forms. All pupils that travelled sustainably received a dot sticker. There were different dots (by colour) for each travel mode. Pupils pasted their dots onto the green round class sticker (Fig. 3). When one green sticker become full, the remaining dots were pasted onto a new green sticker. Full green class stickers were pasted onto the traffic snake banner (Fig. 2). Some days after the Behaviour change campaign another hands up survey were carried out by teachers with their pupils. The aim was to assess the long term effects of the initiative, as possibly showed by data recorded on the class measurement forms.

Fig. 2.
Snake banner

Fig. 3.
Sticker filling in the class

The **Tracking campaign** took place only in one week in November 2017. Trackers were delivered to the classes in 3 schools that decided to test them in the Tracking campaign. With the assistance of FTTE coordinator, the trackers were distributed to pupils, and coordinator together with teachers took note in the dedicated template of the ID number of trackers associated with the pupils. The trackers were supposed to track, register and send to the receivers the movements between h. 06:00 to h. 10:00: this way, only the trip from home to school should have been registered. After the campaign FTTE got back trackers and receivers from schools and process of the transmission of data then started.
During the two weeks of campaign children in every participating class were rewarded several times with symbolic prizes. After the campaign, some celebrations took place in all participating schools. Final ceremony of the completion of the campaign was held in School Danilo Kiš, with attendance of the headmasters and teachers from participating schools and pupils. Schools were thanked for their participation, results of the initiative were presented and discussed with them, and participation certificates were distributed to each school, class and personally was given to teachers.

3.1.1. Parents Questionnaire

After the end of the campaign a questionnaire was sent to parents of the pupils participating to the TSG Tracking campaign pilot. Based on the example provided by M21, the six questions of the questionnaire asked feedback to parents about the clarity and understandability of the documents related to the Tracking campaign, and their perception about the road safety level nearby the area of the schools and along the home-school paths. The feedback received by parents through the questionnaires filled in was modest, about the 37% of total number of involved pupils in tracking campaign.
Despite the questionnaire's modest response compared to the total number of participants in the pilot, the obtained results could provide interesting findings. The respondents considered worthwhile providing their remarks about the traffic safety around the (way to) schools, which means that the topic is perceived as a significant issue. In the two open-answer questions the participants gave their opinions about safety problems in the particular school zones and provide some useful suggestions for improving the traffic safety around the school or on the way to school. Considering the school locations safety problems are different and the most important are listed below: parking, lack of infrastructure or bad condition of pedestrian infrastructure, non-existence of bicycle paths, signalization (signs and marks) are in poor condition or not exist at all (particularly on pedestrian crossings), non-permitted signal time for pedestrians (RTOR) or insufficient pedestrian time on signalized intersections, locations of public transport stops. In order to overcome these problems with the aim of improving pupils' safety in the school zones, the participants of the survey proposed the following: improving signalization in school zones, presence of police in the school surrounding, punishing of drivers, setting barriers and pedestrian fences near schools and pedestrian crossings, reconsider locations of public transport stops, providing school bus (for suburban school). When it comes to suggestions for improving the project, participants pointed to the problem of lack of information about the results (for tracking campaign). Also, they believe that involvement of the police in the project could be useful. Generally, parents are satisfied and gave the support for this kind of initiatives.

4. Pilot Results

The main purpose of the Traffic Snake Game, in its traditional Behaviour change campaign, is to encourage children (and their parents) to use sustainable means of transport on their way to school, rather than the most polluting and dangerous cars or motorcycles. In the Trace version, trackers have also been tested within the Tracking campaigns to track the paths done by children every morning.
In the schools that participated in the pilot, pupils (and teachers) were generally engaged by the initiative. The Behaviour change campaign, the traditional game with the dots to be attached on the snake banner, was explicitly appreciated by them even after the pilot's end. The Tracking campaign was accepted as well as a traditional version of

the TSG campaign, after initial problems were overcome. Unfortunately, there have been some problems in receiving paths tracked by the trackers in a reasonable time, which affected on the usability of the tracking results.

Table 1
Percentage of the sustainable trips (before, target and after campaign)

SCHOOL	SUSTAINABLE TRIPS BEFORE CAMPAIGN	SUSTAINABLE TRIPS TSG TARGET*	SUSTAINABLE TRIPS AFTER CAMPAIGN
OŠ "Danilo Kiš"	**71%** III (71%); IV (93%)	**84%** III (71%); IV (93%)	**90%**
OŠ "Vlada Aksentijević"	**56%**	**72%**	**67%**
OŠ "Kraljica Marija"	**68%**	**82%**	**98%**
OŠ "Jovan Dučić"	**81%**	**92%**	**96%**

Considering the schools all together, data shows clearly the benefits that could be obtained by the Traffic Snake Game (Table 1):

- Sustainable modalities (walking, cycling, bus/train, car-pooling) all together increased by 18%, passing from the 69% registered before the campaign to the 88% during the campaign. That means that the goal usually set up when a Traffic Snake Game is implemented (relative +20% of the sustainable modalities) has been exceeded.
- Very significant differences were noticed between grades in some schools. Older pupils mostly are mostly walk to school comparing to younger kids. This could be explained by school location (in the middle of the residential block) and pupils age (older pupils have more mobility independence). This was also observed in other schools, but in smaller percentage, mainly because of the school position.
- Walking modality increased most significantly in all schools during and after the campaign.
- Car use registered before the campaign decreased in all schools during the campaign and after the campaign.
- Splitting the sustainable modalities, data shows that the heavier reduction of cars was largely captured by the walking modality.
- Significant use of public transport mode was noticed in suburban school (33%), but during and after the campaign percent of user of PT decreased in favour to walking modality. Also, larger percent of bus users (18% during campaign) are detected at city centre school. Two other schools are located centrally in the blocks of buildings, so the number of PT users among pupils is smaller and relatively stable in the campaign phases.
- Cycling is registered in very low percentage only in one school in the residential block (about 7%), while in other schools there is negligible participation of these movements (below 1%). This is expected due to infrastructure characteristics and safety reasons.
- Car-pooling share differ from 2% - 13% depending on school (position). School in the very city center and suburban school have bigger participation of this mode (11-13%), which also decreased during and after the campaign.
- In a short-term scenario, the positive results obtained during the campaign were substantially confirmed by the survey made after the campaign.

Splitting results by schools, data change considering the different scenarios and environments around each one of them. As predictable, sustainable modalities (walking in particular) were more relevant in schools located within the centre of blocks of building, and where car parking is more difficult, even in the baseline: in these cases, the improvement registered during the campaign were less significant. That is reasonable, considering that the baseline was already remarkable in terms of sustainability. Anyway, in all cases the reduction of the use of cars and motorbikes has been registered and measured by data collected.

5. Conclusion

The implementation of the Traffic Snake Game pilot in Belgrade, in its Behaviour change campaign modality, was a very successful. Kids and teachers very well accepted traditional TSG campaign. After some initial difficulties, the pupils and the teachers welcomed and carried on the initiative with enthusiasm. And many of them even asked to repeat it during the next school year. It could be concluded that there is a high potential for continuing with the Behaviour change campaign in the future.
The results obtained in terms of behaviour change were remarkable. Based on data collected at schools by the teachers, the modal split changed during the implementation of the campaign in all schools concerned, dramatically in some of

them, in favour of less polluting modes of transport. And the positive results were maintained even after the end of the game. This could be interpreted as a sign that children and their families felt responsible with their travel to school choices.
It should be noticed that TSG website is not able to show in real time (or even after a short while) the results achieved at school level. On the TSG website, it was expected to have additional features compared to the previous campaigns, such as a gamification scoring tool or some data stats page, instead of having it reduced.
The Tracking campaign, where it took place, was appreciated by children as well. Unfortunately, at this moment it is not possible to give a reasonable evaluation of such a campaign so far because there were problems with receiving received data from trackers. Tracking TSG in Belgrade has very low response (33%) by parents and one school has dropped out according to staff recommendations. Despite of very detail explanation of Tracking campaign to teachers and parents (in the formal letter delivered before the campaign) they remained suspicious regarding privacy issues and was not willing to give permission for their children to participate in this campaign. At this moment there is no clear picture about perspectives of TSG tracking campaign, they are still unknown and depends on the data usability.
One important remark concerning the implementation is the potential incompatibility between the two TSG versions, as they have different objectives. The objective of the Behaviour change campaign is to induce a modal shift towards more sustainable travelling modes for the house-school trips. On the other hand, objective of the tracking campaign is to collect information (GPS location, speed and mode) on the usual trip of the pupils.
Generaly, the pilots showed that integrating a tracking service into a campaign design aimed at behaviour change should be done with caution. Whenever campaigners are thinking about integrating tracking, they should give thought to the following observations:

- The complexity of combining the technical and practical implementation with a behaviour change campaign would be too much workload for the school.
- Local authorities, schools and companies are very much interested in measuring the regular users' travels, in order to use the tracking data for planning purposes. Therefore, combining the tracking with behaviour change does not ensure a proper detection of the state of the art in terms of real trips.

Tracking (the technical act of keeping records of travel patterns) itself does not directly provoke behaviour change. Tracking can, in turn, support incentive schemes, nudging campaigns and other kind of initiatives. Tracking is useful to collect data and, if the sample is accurate enough, to measure or evaluate behaviour change or to have some insights on mobility in the pilot site. Also, it is neccesery to mention that the collected data are of high value to the stakeholders and can be used to facilitate the communication between schools/companies and the city about sustainable mobility needs.

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Abstract: The non-motorized movements, especially bikes, being a part of a transport system that provides sustainable mobility, play an important role in the strategy that the interdisciplinary commissions from local administration adopt and promote. The increase in the non-motorized trips attractiveness depends on the push/pull methods used by local authorities in the general urban mobility policy. The main concern of the decision makers is to identify the itineraries that attract a larger number of users and to prioritize the streets that form these itineraries, to be able to develop a bike dedicated network. The paper presents the development of an infrastructure network dedicated to the bike movements in two cities from Romania (Oradea and Dej) of different sizes, which allows the access from the main residential areas with high population density to the educational centers and to the recreational areas.
The results of the case study presented in the paper reveal that although the same methodology for developing bicycle infrastructure networks is being applied, the main characteristics (population, age, jobs, road network length, population density, street density, geographic location) of both cities will influence both the design of the network, the type of the streets and the typology of the bicycle users.

Keywords: urban mobility, bicycle networks, emission consumption.

1. Introduction

Economic, social and environment pressure carried out by society as well as shifts in standards of living due to urban development led to proliferation of non – motorized movements and new forms of urban development appropriate to lower emissions and resources consumes, a better air quality, an improved health level, enhanced and rational land use, overall welfare and urban life quality.
In 2007 European Union engaged to reduce greenhouse gas emissions (GES) with 20% until year 2020 relative to year 1990 emission level. Later, in 2009 the legislative package " Romania national strategy regarding climate changes 2013 – 2020" was promoted and concrete tools and procedures were developed in order to achieve intended goals (NR-SC Strategy, 2012) and taking in consideration that „Green Paper: Towards a new culture for urban mobility" elaborated by European Commission (Green Paper, 2007) stipulates that, in order to enhance attractiveness of cycling and walking, local and regional authorities should integrate as well as possible this types of non-motorized movements in their development and monitoring policies regarding urban sustainable mobility and therefore it is absolutely necessary to show more consideration regarding this kind of specific infrastructure development.
Paris statement „Transport, Health and Environment Pan-European Programme" (THE PEP) stipulates the necessity of an European Master Plan for urban areas set up and latest actions of European Parliament and underline the compulsion of dedicated infrastructure for non-motorized movements (primarily cycling infrastructure)as part of multimodal transport policies. Common to all recommended policies is the inter - sectorial nature of the endeavor mainly because the expected impact goes beyond transport field and interacts to health, education, environment field.
The progress of latest studies regarding the sustainable mobility impact awareness in growing life quality for residents of urban areas lead to implementation of Sustainable Urban Mobility Plans, intended to promote equilibrium between all relevant transport modes and, in the same time, to encourage a shift to more viable transport modes, such as un – motorized transport. Concurrently, this type of infrastructure development occurs in the context of European Union requirement that all local administrations willing to access European development funds should elaborate Sustainable Urban Mobility Plans.
Thus, is impossible to independently study mobility in relation to physical-spatial planning, given that the needs, volume and travel possibilities are to a great extent determined by the latter, and that mobility makes planning of urban form conditional the considerable influence that its characteristics have on the quality of urban life, on the attractiveness and consequently on the economic development of the urban areas.

2. Literature Review

Analyzing the movement of residents relative to the means of transport used, motorized and un-motorized types are identified. In the case of motorized movements, a number of attributes such as static and dynamic space consumption are defined (Héran & Ravalet, 2008). In the case of non-motorized journeys, it is necessary to identify their role and effects on urban mobility (Kenworthy & Laube, 2001), (Stead, 2008), (Popa *et al*., 2006), (Dekoster & Schollaert, 1999). The need for mobility through non-motorized journeys is described in the field studies in relation to the existence of a certain means of movement. Thus, there can be identified studies for which the bicycle or its derivatives (tricycle, tandem bicycle, etc.) (Epperson, 1996), (Landis, 1996), (CROW, 2007), (HCM, 2000), (PREDIT, 2008) (Soren, 2000).
At present, there is a particular interest from local administrations in studying, developing and implementing Sustainable Urban Mobility Plans at local and regional level, plans where bicycle trips play an essential role, as

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presented in specific works such as (SPYCICLES, 2007), (PRESTO, 2010), (MOBILE 2020, 2012) leading to an improvement of the national standard applied in Romania.
At the current level of traffic modeling in urban areas, several cycling planning and estimation techniques, that adapt the standard four-step model, can be identified in the literature. They can be classified into three subcategories: the first subcategory - aggregate or simplified travel forecasts (Epperson, 1996), using statistical data obtained from questionnaires applied to residents of urban areas, studied and found to be suitable for identifying areas of interest for the use of the bicycle; the second subcategory - models for the location of bicycle facilities (Landis, 1996) starting from the assumption that the cycling infrastructure facilities are trip generators and the third subcategory - sequential traffic patterns, very similar to the standard four-step model (Ridgway, 1995), (Stein, 1996) and adapts the modeling steps for the non-motorized environment.

3. Methodology

3.1 Standard Four-Step Modeling of Macroscopic Traffic

Present paper aims to develop a four-stage version of the classic model, which corresponds to the specificity of cycling, which can subsequently be used in urban planning and in the integration of cycling with other modes of transport.
Choices that determine transport demand, with its specificities, are multiple. In the case of an individual user, demand is determined by the "*choice to travel for a particular reason, on a particular itinerary and at a certain time of the day*" when dependent on the car, and for those non - dependent on the car, their choice will also contain the transport mode selection step.
Transport demand models describe the user's choices for carrying out a transport or movement for a particular reason or purpose, (s), destination, (d) mode of transport, (m) and itinerary, (k) in a predetermined reference time interval, h.
The sequence of the most used sub - modules is as follows(Ridgway, 1995):

$$\mathrm{d}_{sodmkh} = \mathrm{d}_{soh}[SA, ST] \cdot P_{soh}(d)[SA, ST] \cdot P_{sodh}(m)[SA, ST] \cdot P_{sodmh}(k)[SA, ST] \tag{1}$$

In this sequence you can use a simplified notation that implies the arguments [SA, ST] and h, the default range.
In the previous relationship, the demand flow is expressed as the product between the movements generated for a certain purpose *s* in the origin area *o*, during the period considered - d_{so} and probabilities of choice:
- Of a particular destination, *d* for a given reason, $s - P_{so}(d)$,
- A particular mode of transport, *m* to reach destination *d* and purpose $s - P_{sod}(m)$,
- Of itinerary *k* relative to mode *m*, for destination *d* and purpose $s - P_{sodm}(k)$.

The model with this structure is known as the "*partly choice model or the four-step model* ". The formulation and specification of the model corresponds to a predetermined order assumption in which the choices related to each dimension lead to actual use, at which time they also influence each other. The specification used in relation (1) corresponding to the structure represented in Figure 1 implies, for example, that the choice of mode is conditional upon the choice of destination and the outcome of this step determines the choice of the itinerary.
Often, in order to obtain models with greater precision, the demand function is differentiated by user categories or market segments of users; in this case, the demand determination sequence, the relation (1), will carry an index of the analyzed user category.

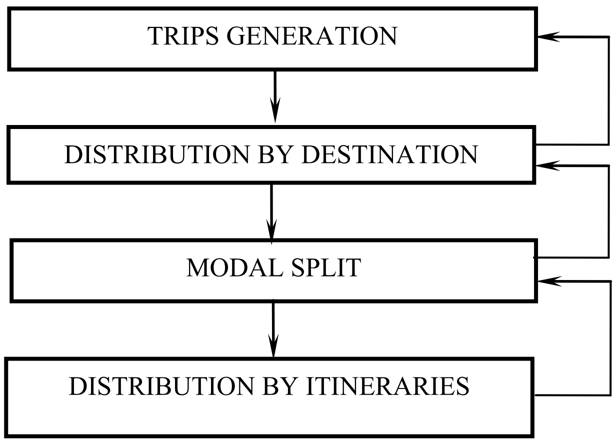


Fig. 1.
The Four-Step Model
Source: (Ridgway, 1995)

The sub - models in relation (1) are called patterns of generation, distribution by destination, modal choice, or route choice, and together they lead to the flow evaluation for each link. Patterns used in practice can be categorized based on the type of attributes used and the behavioral hypotheses from which they are derived.

3.2 Modeling Adapted to the Specificity of Bicycle Movements

The methodology of designing and developing a bicycle track network underlying the proposals made in this paper is intended to be used by local authorities in Romania with the necessary adjustments specific to the structure of the street network in each urban area (Fig. 2.).
The modeling adapted to the specificity of cycling follows the standard sequence of the four-step models (generation, distribution, modal split and itineraries (routes) affectation, but without taking into account modal degradation, selected mode of travel is already known - cycling.
Urban mobility should be determined from a transport network and zoning of the study area, as well as general spatial data and socio-economic data collected through home surveys.

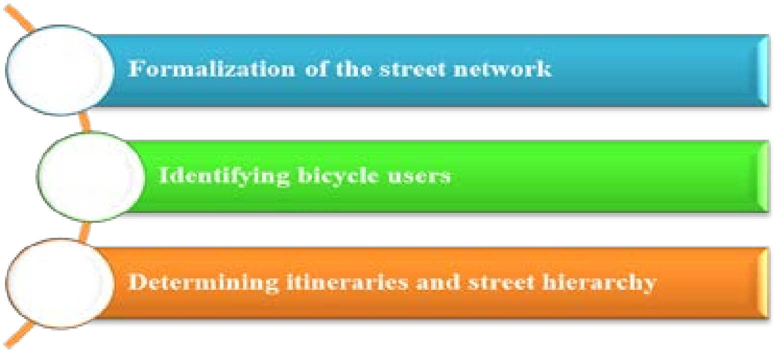


Fig. 2.
Stages of Development of the Bicycle Infrastructure Network

Four demographic groups are considered: kindergarten children, middle school students, high school students, employees and retirees, as well as a range of activities: education, service, shopping, others (recreation, health needs, etc.).
Bicycle trips can be analyzed taking into account two categories of travel purposes: the first category refers to workplace, school, shopping, healthcare, etc., and the second category refers to trips to recreational purposes. Recreational trips can be considered as cycling trips just for entertaining, sports training, and so on. The demand for transport is modeled on several layers of demand consisting of the amalgamation between demographic groups modeled and the classes of activities envisaged.
Trip generation stage - The first step is to start from a multimodal transport network, a division into areas of the study area, the existence of general spatial use data, and socio-economic characteristics gathered for a later calibration and model validation. This is the stage that asses the number of trips generated and attracted by each area. Data on resident population in analyzed areas are taken into account and, in order to do that, it is fragmented down in demographic groups and modeled activities (education, service, shopping, others);
Trip distribution stage - the most commonly used model is the gravitational model, in this case having a utility function calibrated according to the data obtained in the survey. Generally, the gravity model can be written as follows:

$$t_{ij} = g_i \cdot a_j f(d_{ij}) \tag{2}$$

Where:
$g_i = \sum_j t_{ij}$ represents demand generated in *i* analyzed zone,
$a_j = \sum_i t_{ij}$ - demand attracted by *j* analyzed zone
$f(d_{ij})$ - function describing the difficulties encountered when traveling between the zones *i* and *j* (also called "travel impedance"). For the "travel impedance" function the distance was used.

Mode choice stage does not apply to this model.
Route assignment stage - affecting the demand on itineraries is the last step in the "four-stage" demand model. The objectives of the stage, in addition to estimate the routes used for each relationship in the "Origin –Destination (O-D) modal matrix", are mainly the analysis of the O-D pairs that require a particular link and the identification of the most solicited links.

The input data required for route assignment stage are:

- ✓ the selected transport network, with nodes, links and the attributes set for each one,
- ✓ The O-D modal matrix for the considered reference time frame (it contains the results of the three previous steps of regarding transport demand),
- ✓ Route selection principles, considered relevant to the problem.

The route assignment modelling, adapted here to the specificity of bicycle trips, consists of simplifying the route selection by reducing it to the minimum distance involved. Using Dijkstra's algorithm on ArcGIS software package, minimal paths for non-motorized movements were determined, resulting in connection graphs between the selected nodes.

4. Case study: Developing Bicycle Network Infrastructure in Small and Medium Sized Cities

Taking into account the proposed methodology, the three stages of earlier described four step model were applied on two urban structures differentiated by population size. Thus, the development of a network of cycling facilities in Oradea and Dej (urban areas in west region of Romania), whose main features can be seen in Table 1, was pursued.

Table 1

The Main Features of the Chosen Urban Areas

Main features	Oradea	Dej
Urban area [km^2]	115.56	109
Population [inhabitants number]	223718	38393
Population density [inhabitants/km^2]	1747.86	307.31
Street network length [km]	396	150
Public transport network length [km]	57.76	42
Street network density [km / km^2]	3.426	1.376
Population by age category [%]	29% - 0-19 years 56% - 20 – 64 years 15% over 65 years	20% - 0-19 years 41% - 20-44 years 25% - 45 – 65 years 14% over 65 years
Average income [euro]	400	300
Average number of employees	98000	12000

Source: (PUG Oradea, 2016),(PUG Dej, 2009)

A computer support was used to carry out the case study, namely the ArcGIS software package. Thus, it was necessary to customize a vector map of Oradea and Dej provided on open Internet (Open Street Maps) according to the characteristics that a map used in modeling specific to the domain of Transport Engineering must fulfill (Fig. 3, Fig. 4). When designing the infrastructure dedicated to non-motorized trips, it is important to associate the attributes specific to this type of modeling, such as: the number of lanes per sense, the possibility of placing facilities specific to this type of travel on the adjacent sidewalk or directly on the street tram, parking on the boundary between road and pedestrian area, vehicle speeds (for reasons related to the safety of users of non-motorized vehicles) as well as the car traffic flow at peak hours (for the same reasons).

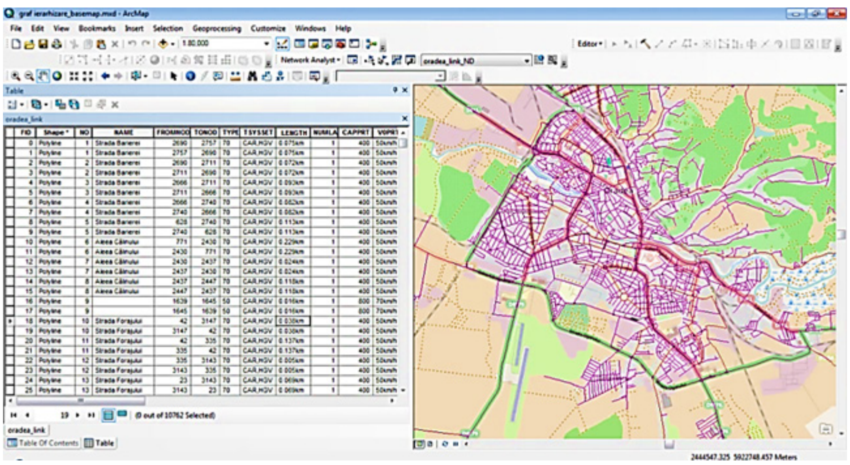


Fig. 3.

The Street Network of Oradea, Represented on the ArcGIS Computer Support

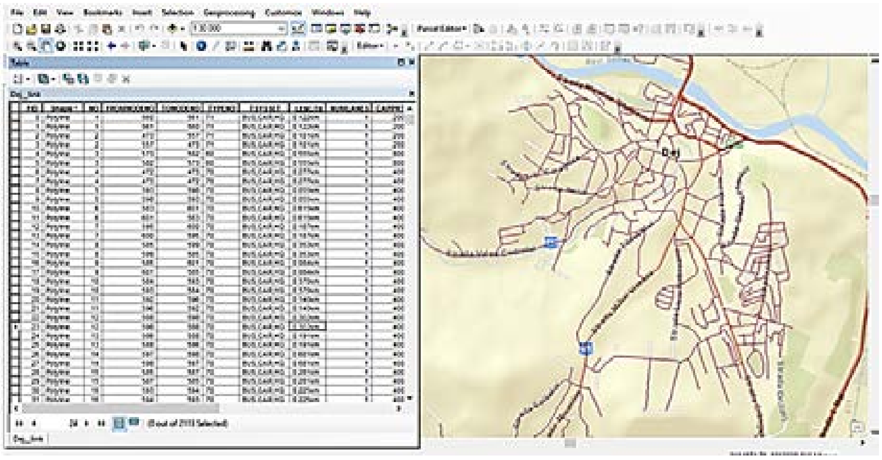


Fig. 4.
The Street Network of Dej, Represented on the ArcGIS Computer Support

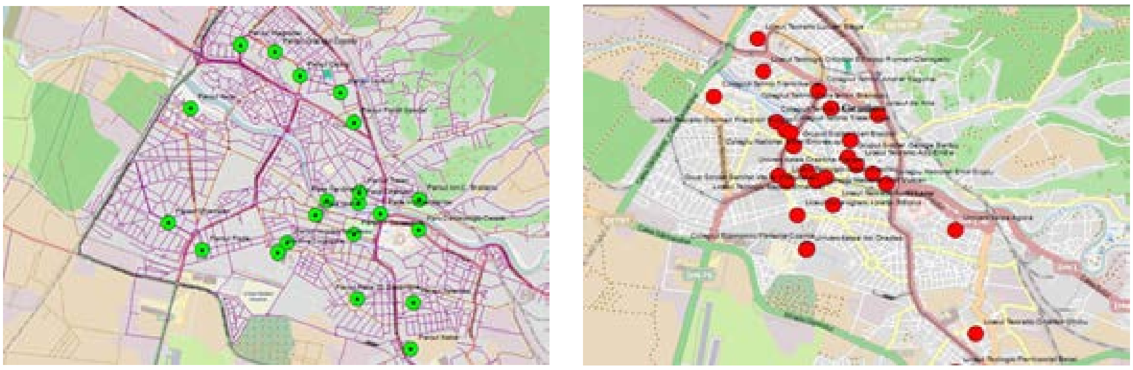
In the case of bicycle trips, the specificity and exposure of possible categories of users to the whims of the weather represent a real problem, leading to their decrease. The young and active persons account for a high percentage of the user's category. Determining the type of user representative of non-motorized journeys, and especially those who use the bicycle as a mode of transport, needs to be done in relation to the specific characteristics of residents in each urban agglomeration, in part by surveying the population's preferences in the area under consideration.
For the target population category between 15 and 24 years old, in 2012, the City Hall of Oradea started a campaign to promote the use of the bicycle as mean of travel from home to and from the main activities in personal interest, such as outdoor recreation activities. This promotion consisted of two steps: the first step was to raise awareness among young people and individuals about the benefits and importance of using the bicycle for daily travel, and the second stage of the project consisted in conducting a survey based on a significant number of questionnaires, namely 1519, survey carried out within the city's educational establishments, targeting young people residing in Oradea.
Similarly, in 2015 Dej City Hall started a survey based on 660 questionnaires, conducted to identify the main needs and problems facing the Dej city population using the bicycle as a means of daily travel.
Thus, survey results for the two cities of different sizes can be seen in Table 2.

Table 2
Results for the Two Cities of Different Sizes

	Oradea	Dej
Percentage of bicycle owners	67%	35%
Percentage of bicycle users in adverse weather conditions	40%	37%
The percentage of those who do not use the bicycle because they lack dedicated infrastructure	58%	12%
The percentage of those who do not use the bicycle due to the lack of bicycle parking	25%	20%
Percentage of bicycle users differentiated on the purpose of the movement	90% - recreational 10% for other purposes (shopping, personal interest, work, school)	71% - recreational 29% for other purposes (shopping, personal interest, work, school)

Source: (SUMP Dej, 2016), (ZMO, 2014)

For the present situation, the next step was to identify recreational areas and educational establishments in the two cities chosen. Thus for Oradea there were identified 21 recreation areas (Fig.5.a.) and 28 educational units (high schools and universities) (Fig. 5. b.) and for Dej were identified 4 lyceums and 3 zones recreation (Fig. 6.a., Fig. 6.b.).



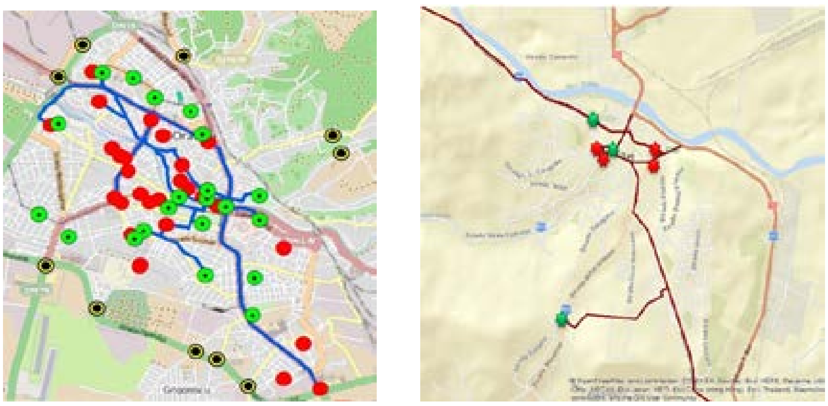
a. b.

Fig. 5.
Setting of Recreation Areas (a) and Educational Units (b) on the map of Oradea

a. b.

Fig. 6.
Setting of Recreation Areas (a) and Educational Units (b) on the map of Dej

Compared to the city of Oradea, which is located in a depression area, with streets whose slopes do not exceed 4% (the maximum recommended for cycling), most of the streets in Dej have a high gradient (about 15%), so as a result of the study it is proposed to place bicycle paths only in certain arteries, connecting the city center and its adjacent areas, between the city center and the high school, and between the city center and its leisure areas.
Using Dijkstra's algorithm on the ArcGIS computer support, minimal paths for non-motorized trips were determined for the two urban areas, resulting in graphical links between the selected nodes. The next step was to make a hierarchy of the graphs links, resulted from the number of itineraries that are going through them.
In the case of non-compulsory mobility considered in our case to be between schools in the city and outdoor recreation areas, the local authorities may raise some objections to the usefulness of investing in a large-scale infrastructure network dedicated to non-motorized journeys by bicycle. For this reason, a small network is proposed for development in the case study, which ensures the movement between different points of interest of the same type.
Thus, for the city of Oradea, the main network is made up of 24 streets, streets mainly of the second category (connectors) and the third category (collectors) (Fig. 7.a.) while for developed network for the city of Dej, is made up of 10 streets of category III and category IV (for local use) (Fig. 7.b.).



a. b.

Fig. 7.
Bicycle Infrastructure Networks Proposed for Oradea (a) and Dej (b) Municipalities

Once it has been identified how decision makers can choose the structure and size of bicycle network in order to attract users in as large a number as possible, with beneficial effects on motorized traffic and implicitly on the budget allocated to the healthcare system in that city, it was proposed that the types of bicycle tracks be placed on the road, also taking into account the speed regime.

5. Conclusion

As a result of the study of the two cities, the following conclusions can be drawn:

- ✓ The model can be applied to all public administrations, managing to deliver a network of cycling infrastructure, starting from a network of the most widely used arteries and then providing indications for its development so that designing and investment in building as well as the location of these infrastructures is done in stages, finally unifying all the points of interest between them. Planned network will ultimately satisfy both the needs of the users of bicycle trips and the interests of the decision makers in the city.
- ✓ From the point of view of the demographic component, it can be noticed that in a city with a population of approximately 200,000 inhabitants, such as Oradea, the number of educational units, the number of recreation places and green spaces is much higher than the one from a small town of about 40000 inhabitants. It can be said that the higher the number of points of interest, the larger the network will build and will cover a larger area of the city, and it is also used by other types of users. This can also be seen from the results of the questionnaires, in a large city where there is a large number of young people, as they are the main users of the bicycle; instead, in small towns such as Dej, bicycles are used in most cases by mature people, as a mean of moving from home to the workplace. In these types of cities, the cycle track network is much smaller.
- ✓ Another difference between the two types of cities was their geographical location, Oradea being in a depression area and Dej being placed in a hilly area. This has prevented the design team from using certain types of streets, due to the high tilt, the impossibility of bicycle climbing in many areas of Dej, so the resulting network is much more restricted.

In conclusion, we can say that the practical valorization of the proposed solutions for the provision of adequate cycling infrastructure proposed for Oradea and Dej, as well as other cities, where the theoretical arguments. The proposed methodology could serve for similar actions but is conditioned by the difficulty to achieve the adhesion of the urban population and political decision-makers to promote non-motorized journeys. This involves a joint effort of teams with diverse formations specialists, rigorous solutions, coherence and perseverance for completion and implementation.

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EXPLORING THE IMPACT OF PERSONAL AND HOUSEHOLD CHARACTERISTICS AND TRAVEL RELATED FACTORS ON TRAVEL MODE CHOICE BEHAVIOR IN MEDIUM-SIZED RUSSIAN CITIES

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Abstract: Growth in motorization level in Russian cities last decades leads to a gradual shift in individual's travel behaviour - from usage of public transport to private car driving. As a result road networks of the Russian cities are heavily congested especially in the morning and evening peak hours. This paper describes the results of investigation of factors influencing individual's travel mode choice decisions and development of appropriate mode choice models to support decision-making process and assist in forming of policies which are needed to move towards more sustainable urban mobility patterns. The empirical data are based on Yuzhno-Sakhalinsk travel survey conducted in 2016 including empirical data on the individual's mode choice, individual`s characteristics (age, sex, driver's license etc.), household characteristics (household size, number of cars etc.) and travel related characteristics (travel time, travel cost, number of transfers etc.). Based on empirical data and discrete choice models theory the travel mode choice model parameters were defined. The results of investigation provide helpful information for decision makers to ensure better understand individual's travel mode choices and test urban transport policies promoting sustainable travel behavior.

Keywords: Travel behaviour, mode choice, multinomial logit model.

1. Introduction

Russia is a highly urbanized country. At present about 75% people are living in cities and towns. Growth of urban population was accompanied by a quick growth of motorization: the level of motorization has increased for 25 years by 3 times. Motorization of society gave the people real alternative to the use of public transport. In XX century Russian cities were projected and developed mainly with the orientation on the use of public transport. Car ownership was restricted by high prices, by special quotas on car purchasing by Government till the beginning of 90th.
Accessibility and comfort of cars gave a real advantage to this mode of transport in competition with old-fashioned public transport systems. But growth of motorization of society took place in conditions of old urban infrastructure projected in the assumption of motorization level less than 150 cars per 1000 people. Town-planning structure, capacity of urban road infrastructure collided with growing volumes of car traffic which resulted in significant increase of congestions, reduction of traffic flows speed and common worsening of urban transportation systems functioning. In these conditions it became obvious the necessity of improvement urban transport systems.
Sustainable urban transport policies in Russian cities need to be based on the understanding of influencing individual's travel mode choice decisions and appropriate mode choice models to support decision-making process.

2. Mode Choice Behavior in Medium-Sized Russian Cities

Medium-sized Russian cities are defined as cities with populations ranging from 100 000 to 1 000 000 residents (table 1). At present there are 155 medium-sized cities with population more than 42 million people in Russia (table 1) This is 41% of the total population of Russia. So this is a reason why a special attention has to be paid to problems of transport systems functioning in these cities.

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Table 1
Classification of Russian cities by population

Cities	City population	Number of cities	Examples	Population	Share of population
Mega cities	≥ 5 000 000	2	Moscow, Saint Petersburg	17 662 243	17.3%
Core cities	1 000 000 – 5 000 000	13	Novosibirsk, Kazan, Samara etc.	15 526 125	15.2%
Medium-sized cities	500 000 – 1 000 000	22	Saratov, Penza, Astrakhan etc.	13 515 719	13.2%
	250 000 – 500 000	41	Kaliningrad, Kursk, Sochi etc.	14 480 597	14.2%
	100 000 – 250 000	92	Pskov, Yuzhno-Sakhalinsk, Norilsk etc.	14 154 911	13.9%
	Total	155	-	42 151 227	41.3%
Small cities	< 100 000	942	Tobolsk, Elabuga, Sarov etc.	26 704 791	26.2%
Total		1112	-	102 044 386	100.0%

Source: Rosstat

Medium-sized Russian cities have a comparable urban density with the large Russian cities. But as a rule in medium-sized cities in contrast with the large cities there are no public transport systems with segregated ways such as metro/subway, light rail or bus rapid transit. Medium-sized Russian cities are characterized by conventional old-fashioned public transport services with direct tram, bus and trolleybus lines duplicating each other on a considerable extent. Public transport vehicles in most cases operate in the mixed traffic. As a result, in conditions of road congestion, the commercial speeds of public transport and regularity of services are significantly reduced.

The mass public transport systems with segregated ways can be an effective alternative to the use of private cars, since they provide high level of services in terms of travel time, reliability and comfort. Such systems operate in many medium-sized Western European cities (WB, 2013). The development of such transport systems in medium-sized Russian cities can significantly improve the quality and attractiveness of their public transport services and move the cities towards more sustainable urban mobility patterns.

The medium-sized Russian cities, in contrast to Western European cities, has the extremely low share of trips made on a bicycle. In Russian cities, as a rule, there is no developed separated bicycle infrastructure. The experience of Western European cities shows that cycling can be a real alternative to traveling by private cars, especially for short distances, as well as being a convenient mode to access to public transport services. The total share of non-motorized travel modes in the considered medium-sized cities of Western Europe is approximately 35-45% (table 3), while in Russian cities (such as for example Yuzhno-Sakhalinsk and Krasnoyarsk), it is just over 20% (table 2).

Table 2
Modal choice in some Post-soviet medium-sized cities

City	Statistical context*	Population, in thousands (2017)	Year of survey	Mode choice in percent				
				walking	bicycle	car as driver	car as passenger	public transport
from 100 000 to 250 000 residents								
Yuhzno-Sakhalinsk	CP	194.9	2016	22	<1	48	10	19
from 250 000 to 500 000 residents								
Sevastopol	CP	428.8	2017	28	<1	25	4	41
Tallinn	CP	448.1	2009	30	4	26		40
from 500 000 to 1 000 000 residents								
Vilnius	CP	574.2	2011	36	1	38		25
Riga	CP	641.4	2008	19	2	45		34
Lviv	CP	728.4	2010	34	1	26		39
Krasnoyarsk	CP	1 082.9	2018	20	<1	42	5	30
	UA	1 340.0	2018	21	<1	43	8	26

Sources: NIIAT, EPOMM, GIZ
** CP – "city proper"; UA –"urban agglomeration"; MA – "metropolitan area" (UN, 2016)*

The share of public transport in Russian medium-sized cities is comparable to Western European cities. But this is not so much related to the level of public transport services, but rather to the relatively low current motorization level of the population.

Table 3
Modal choice in some Western European medium-sized cities

City	Statistical context*	Population, in thousands (2017)	Year of survey	Mode choice in percent				
				walking	bicycle	car as driver	car as passenger	public transport
from 100 000 to 250 000 residents								
Salzburg	CP	150.9	2012	20	20	37	8	15
Groningen	CP	202.6	2008	15	31	30	14	10
from 250 000 to 500 000 residents								
Verona	CP	257.3	2008	18	9	55		8
Augsburg	CP	289.6	2014	23	14	35	12	16
Malmö	CP	324.9	2013	15	22	42		21
Strasbourg	UA	456.6	2009	33	8	36	11	12
from 500 000 to 1 000 000 residents								
Nurnberg	CP	511.6	2014	23	12	33	10	22
Antwerp	CP	520.5	2010	20	23	41		16
Leipzig	CP	571.1	2008	27	14	40		19
Nantes	UA	612.8	2012	27	5	52		16
Düsseldorf	CP	613.3	2008	27	11	40		22
Rotterdam	CP	623.5	2008	18	16	34	15	17
Stuttgart	CP	623.7	2009	27	5	44		24
Oslo	CP	673.5	2014	32	5	31	6	26
Frankfurt	CP	736.4	2008	31	11	27	11	20
Valencia	CP	790.2	2012	41	4	32		23
Sevilla	CP	703.0	2011	37	6	35		22
	MA	1 519.6	2007	31	2	53		14

Sources: EPOMM, SocialData
** CP – "city proper"; UA –"urban agglomeration"; MA – "metropolitan area" (UN, 2016)*

Currently parking for cars even in the central parts of medium-sized Russian cities, as a rule, is free. As a result using a private car is often even cheaper than using of public transport. The lack of an effective parking policy in medium-sized Russian cities has resulted in the high share of trips made in private cars. This share is more than 50% in Yuzhno-Sakhalinsk and Krasnoyarsk. It is significantly more than in the cities of Western Europe under consideration. The introduction of parking fees and the restriction of the number of parking spaces is an important policy to improve the sustainability of urban transport systems.

3. Methodology

Development of sustainable urban transport plans and policies requires collection data on urban travel demand and development of appropriate tools (models) for transport assessment and forecasting as a part of decision making process. The general approach to modeling the travel mode choice is presented in fig.3.

The approach to travel mode choice model development involves identification individual and household preferences in choosing the travel mode, determining the travel times and costs for the actual and alternative modes, developing a model specification, and estimation of model parameters.

The identification of the preferences in choosing the travel mode is carried out by interviewing the residents of the city. The survey data can include data on the actual travel mode choice - revealed preference data (RP) and / or data on the hypothetical travel mode choice - stated preference data (SP). Urban transport plans and policies can include not only existing but also alternative travel modes and their characteristics. Cycling, bus rapid transit and light rail transport can be considered as alternative travel modes in medium-sized Russian cities. Stated Preference surveys allow to explore the travel mode choice with the unavailable alternatives in the current context (for example, bus rapid transit), and consider the characteristics currently not represented (for example, cost of car parking) (Cascetta, 2011).

Travel times and costs data are available often only for the chosen travel mode in the case of RP data use. Travel times and costs data can be prepared with using network models. Many alternatives of routes with different service characteristics in terms of travel times, costs, number of transfers, etc. can be identified for each travel mode. The choice of the route from the set within each travel mode is carried out based on the expert opinion or minimization of the generalized costs considering the restrictions (for example, by the number of transfers, the maximum walking distance, etc.). In the case of the availability of detailed data on the choice of routes for trips, more detailed models can be built.

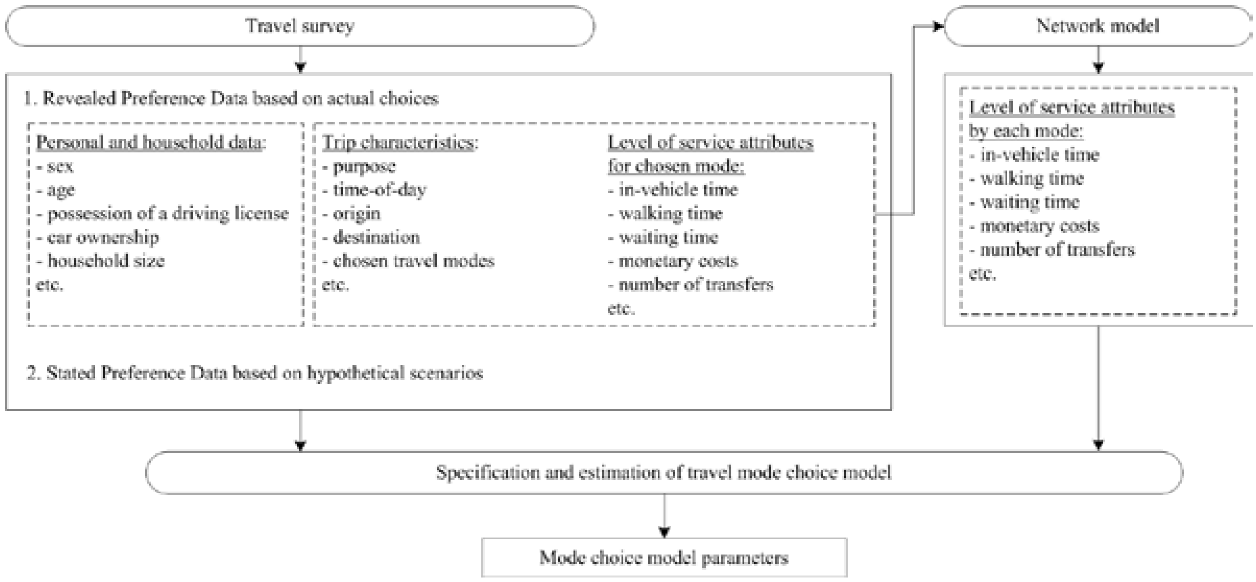


Fig. 3.
Approach to travel mode choice modelling

The factors influencing mode choice are presented in table 4. The list of factors considered in the models may vary in different cities, depending on the preferences identified in the survey, available data for building the model and urban transport policies which can be assessed with the model. It is advisable to include the availability and cost of car parking in the list of factors considered in mode choice models to implement a sustainable urban transport policy in medium-sized Russian cities.

Table 4
Factors influencing mode choice

Characteristics of the traveler	Characteristics of the journey	Characteristics of the transport facility
- household structure; - possession of a driving license; - car ownership / availability; - income; - the need to use a car at work, take children to school etc.	- trip purpose; - time of day; - whether the trip is undertaken alone or with others.	- travel times: in vehicle, waiting and walking times by each mode; - monetary costs (fares, tolls, fuel and other operating costs); - availability and cost of parking; - reliability of travel time and regularity of service; - comfort and convenience; - safety and security; - the demands of the driving task; - opportunities to undertake other activities during travel (use the phone, read, etc.)

Source: Ortúzar and Willumsen, 2013

The probability P_i of choosing travel mode *i* is determined by the logit function where:

$$P_i = \frac{e^{V(X_i)}}{\sum_z e^{V(X_i)}},$$

P_i – the probability of choosing alternative *i*;
$V(X_i)$ – measurable part of utility;
X_i – the characteristic of alternative *i*, e.g. travelling time and cost;
z – all the alternatives that the individual may choose between.

The logit model says that the probability that an individual will choose a certain alternative is dependent on its utility in relation to the utility of all the other alternatives. The coefficients of the utility function are determined by maximizing the likelihood function (Domencich and McFadden, 1975).
Both trips and trip-chains (tours) can be considered. The approach based on trip chains where trips are considered as the components of trip chains is preferable. If one chooses the car for the first leg of a tour this is likely to remain the choice for the other legs (Ortúzar and Willumsen, 2013).
The use of travel mode choice models for decision making process allows to assess wide range of scenarios such as introduction of a new mode of transport, introduction of parking fees, etc.

4. Case Study

The described methodology was applied for the city of Yuzhno-Sakhalinsk, a Russian medium-sized city located in the Far East on Sakhalin Island (fig. 4). The study area includes the territory of the city of Yuzhno-Sakhalinsk and two small settlements Dal'neye and Novaya Derevnya having a common border with the city. The total population in the study area is about 200 thousand people.

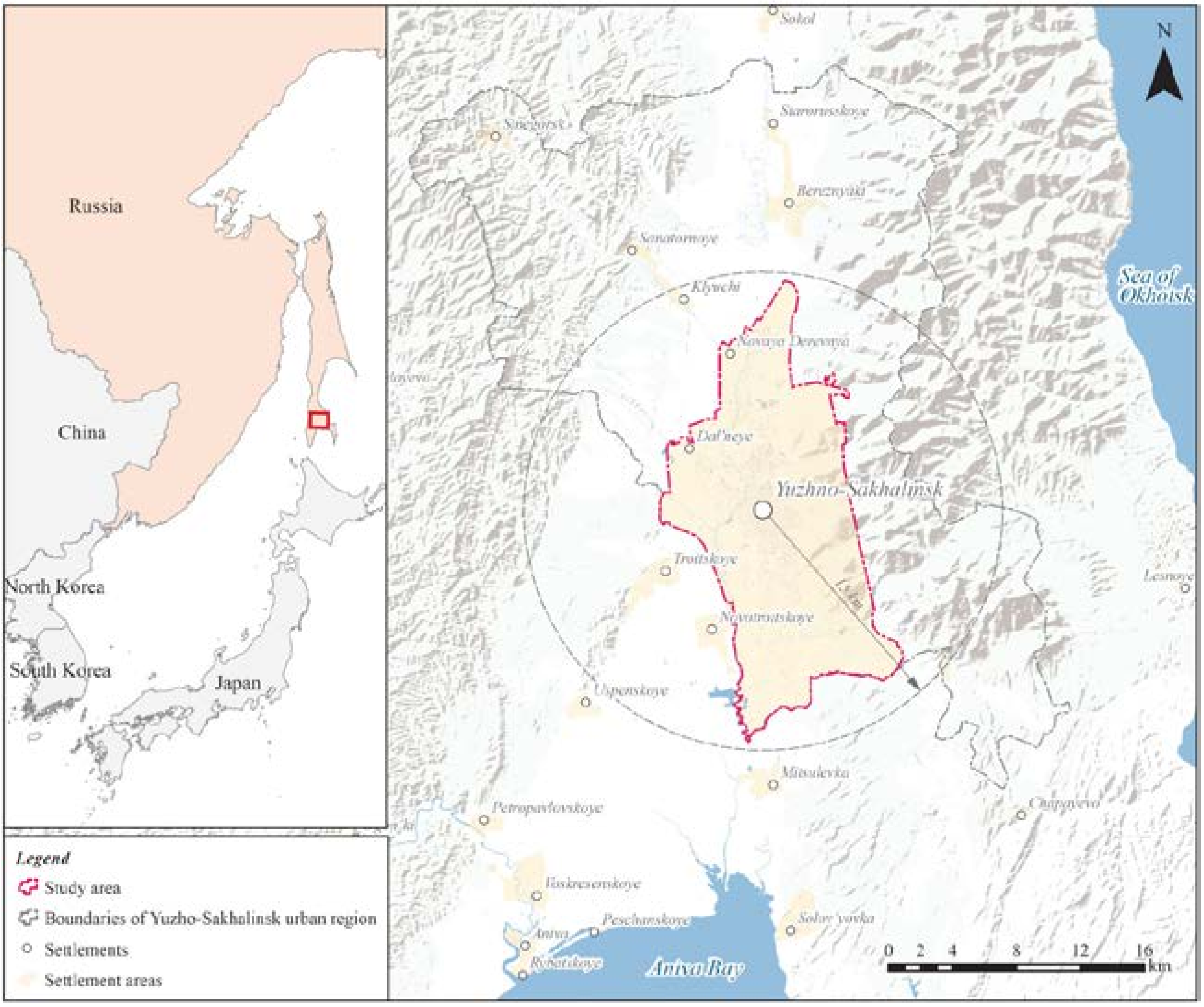


Fig.4.
Study area of the city of Yuzhno-Sakhalinsk

The main sources of information for this study were a travel survey of residents of Yuzhno-Sakhalinsk and data on the transport network of the city of Yuzhno-Sakhalinsk. The survey was conducted by phone in March-April 2016 and covered more than 1500 people not younger than 16 years. The sample is representative of sex, age and geographical location. The survey questionnaire includes questions for obtaining detailed information on the socioeconomic characteristics of the respondent and the movements made for the previous day. Movements for distances of less than 400 meters were not considered. The survey was conducted from Tuesday to Saturday, so the sample includes information on the movements made only for weekdays.

Travel times and costs data for the actually chosen and alternative travel modes were prepared for each movement, with network model taking into account the location of the starting and ending points and the actual time of the day. The data on the transport network include detailed graphs of the road and bus networks, as well as the associated detailed graph of the walking network. The cycling network was absent at the time of the survey. Data on speeds and delays on sections of the road network were used, as well as data from bus monitoring system obtained by GPS to obtain accurate travel time data at various time periods of the day for each mode. Monetary costs for travel by each mode were determined on the basis of fares on the bus and operating costs for car movements.

The study uses the approach based on trip chains. Trips chains beginning and ending at home (tours) were considered (table 5).

Table 5

% of total round trips from home in Yuzhno-Sakhalinsk

Purpose	Single-mode							Multi-mode total	Total
	Bus	Car driver	Car passenger	Taxi	Walk	Other	Total		
Single purpose total	**12,3%**	**20,4%**	**4,4%**	**0,6%**	**16,2%**	**0,3%**	**54,2%**	**5,1%**	**59,3%**
Work	6,2%	10,4%	1,8%	0,4%	4,9%	0,2%	23,8%	3,3%	27,1%
Shop	1,1%	1,7%	0,6%	0,0%	5,0%	0,0%	8,4%	0,2%	8,6%
Accompaning someone	0,5%	3,9%	0,3%	0,0%	1,6%	0,0%	6,2%	0,1%	6,3%
Clinic / Health	1,2%	1,1%	0,5%	0,1%	1,0%	0,0%	3,8%	0,3%	4,1%
Education	1,7%	0,1%	0,1%	0,0%	1,6%	0,0%	3,5%	0,3%	3,8%
Other	1,8%	3,1%	1,2%	0,2%	2,2%	0,1%	8,5%	1,0%	9,2%
Multipurpose total	**2,2%**	**20,9%**	**2,2%**	**0,0%**	**3,3%**	**0,1%**	**28,7%**	**11,9%**	**40,7%**
Dual-purpose	1,6%	9,1%	1,3%	0,0%	2,0%	0,0%	14,0%	5,4%	19,4%
Tri-purpose	0,5%	5,5%	0,3%	0,0%	0,9%	0,0%	7,2%	3,7%	10,9%
Four or more purposes	0,1%	6,3%	0,6%	0,0%	0,4%	0,1%	7,5%	2,9%	10,4%
Total	**14,5%**	**41,3%**	**6,6%**	**0,6%**	**19,6%**	**0,3%**	**82,9%**	**17,1%**	**100,0%**

The focus in this investigation was done on the study of round home-to-work trips since they have a large share in the total volume of trips and form peak loads on the urban transport network. In addition, data for round home-to-work trips is available in an amount sufficient to perform statistical estimation.

When a car as a driver from home to work is used, the same mode is used in the opposite direction. For other travel modes different combinations of modes within a single tour are possible (table 6).

Table 6

% of total round trips home-work-home in Yuzhno-Sakhalinsk

Purpose	Mode	Work-to-home trips						
		Bus	Car driver	Car passenger	Taxi	Walk	Other	**Total**
Home-to-work trips	Bus	22,9%	0,0%	2,7%	0,5%	1,0%	0,2%	**27,3%**
	Car driver	0,0%	38,4%	0,2%	0,0%	0,2%	0,0%	**38,9%**
	Car passenger	2,2%	0,0%	6,8%	0,0%	2,4%	0,2%	**11,7%**
	Taxi	0,2%	0,0%	0,2%	1,5%	0,0%	0,0%	**1,9%**
	Walk	0,2%	0,7%	1,0%	0,0%	17,5%	0,0%	**19,5%**
	Other	0,0%	0,0%	0,0%	0,0%	0,0%	0,7%	**0,7%**
	Total	**25,5%**	**39,2%**	**10,9%**	**1,9%**	**21,2%**	**1,2%**	**100,0%**

Examples of the influence of individual and household factors on the travel mode choice for round home-to-work trips in the city of Yuzhno-Sakhalinsk are shown in fig 5 and 6.

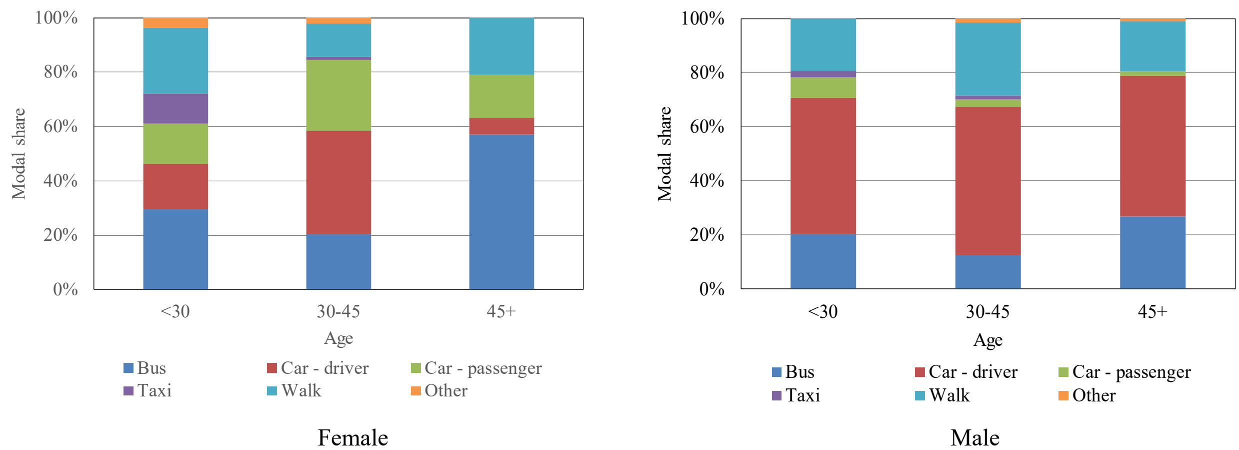
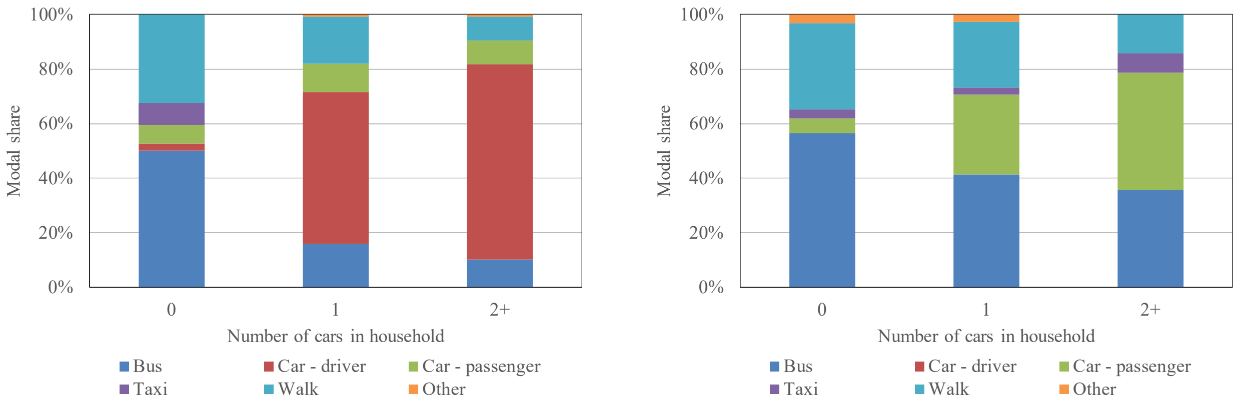


Fig. 5

Modal split by sex and age group for round home-to-work trips



Possession of driving license

Absence of driving license

Fig. 6.
Modal split by possession of a driving license and car ownership for round home-to-work trips

The developed travel mode choice model is based on RP data. Since the initial sample is not very large only the main alternatives and factors influencing the choice of alternatives are considered in the model. The model considers three travel modes: car, bus and walking (table 6). Trips on the car as driver and passenger in the model are combined. Trips on a taxi due to the low actual share in the total volume of trips and the small amount of available data are not considered in the model. In addition to the time and cost characteristics of the alternatives, the model introduces individual and family characteristics, such as the presence of a car in the household, the possession of a driver's license. To consider the expressed preferences of choosing a bus by women over 45 years (fig.5) a corresponding dummy variable is introduced into the model. The number of transfers on public transport is insignificant, therefore the characteristics of transfers are not included in the model. Alternative-specific coefficients are introduced into the model to account for unexamined factors.

All coefficients in the model have expected signs and are statistically highly significant (table 7). According to the obtained coefficients of utility functions walking time and especially the waiting time at the bus stop are more important to the user than in-vehicle time. The presence of a car in the household is one of the most significant factors in choosing the travel mode.

The developed model can be improved and made more sensitive to support decision making by disaggregation the alternatives and variables considered in the model. The model did not consider costs for car parking, as RP data was used, reflecting the fact that parking in Yuzhno-Sakhalinsk is free of charge. In order to take into account this and similar facts the existing RP data can be supplemented with SP data taking into account additional variables and alternatives, including hypothetical. A hypothetical alternative may be, for example, bus rapid transit system or cycling pathes which are currently included in the Transport Strategy of the City of Yuzhno-Sakhalinsk.

Table 7
Alternatives, attributes, and coefficients of logit model for round home-to-work trips in Yuzhno-Sakhalinsk

Mode	Parameter	Name	β	t
Walking	$T_{wl\ Walk}$	Walking time (minutes)	-0.0583	-5.94
	Walk	Alternative specific attribute	4.7477	6.18
Car	$T_{b\ Car}$	In vehicle time (minutes)	-0.0349	-2.22
	Mc_{Car}	Monetary cost (rubles)	-0.0264	-3.62
	CarAvail	Car availability in family (1 if yes, 0 otherwise)	3.1326	5.42
	DL	Driving license possession (1 if yes, 0 otherwise)	0.8547	2.13
Bus	$T_{b\ Bus}$	In vehicle time (minutes)	-0.0349	-2.22
	$T_{wl\ Bus}$	Walking time (minutes)	-0.0583	-5.94
	$T_{wt\ Bus}$	Waiting time (minutes)	-0.0850	-2.37
	Mc_{Bus}	Monetary cost (rubles)	-0.0264	-3.62
	W45	Dummy variable (1 if women and age≥45 years, 0 otherwise)	1.3058	3.43
	Bus	Alternative specific attribute	4.4323	5.81
				Wald Chi2 (7) = 78.80 Prob > chi2 = 0.0000

The introduction of a parking fees system, the development of a cycling network and the implementation of a bus rapid transit system development project can significantly improve the sustainability of the urban transportation system of Yuzhno-Sakhalinsk. At the same time the mode choice model can be an effective tool in assessing the demand for each travel mode, in the formation of a pricing policy on transport and in supporting decision-making process in whole.

5. Conclusion

The used methodology of travel mode choice modeling has shown its efficiency on the example of the transport system of a typical medium-sized Russian city. The obtained results were used by the City Administration when developing the transport strategy of Yuzhno-Sakhalinsk for the period up to 2035.

The directions of further research in this direction:

- development of methods for collecting and processing data on movements of the population (including using GPS tracks);
- consideration of a wider range of alternatives and their characteristics associated with the ongoing changes in the urban mobility (MaaS, car sharing, park & ride and other systems and technologies).
- additional studies of the travel mode choice behavior within the framework of complex trip chains.

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APPRAISAL OF PEDESTRIAN SIDEWALKS AS A NETWORK TO PUBLIC PARKS IN URBAN RESIDENTIAL AREAS IN SOUTH AFRICA

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Abstract: Public parks in residential areas form a crucial part of any community life. It is observed that users of public parks almost always incorporate walking to the parks from their residences as a part of their daily physical activity. Sidewalks form an integral part to facilitate pedestrian access to the public parks, which in turn supports an effective transportation network. However, residential areas in South Africa have experienced a significant decline in public park users and it also has been observed that a similar decline is occurring in pedestrians making use of sidewalks. Studies have proven that a provision of adequate pedestrian networks leading to public parks increases the number of users. Therefore, using the case study of Bloemfontein city of South Africa, this study aims at exploring how sidewalks in residential areas can be improved as a non-motorized transportation platform to provide easy and efficient access to the public parks. This study used the Conjoint Analysis technique as an unbiased method to evaluate the attributes influencing pedestrians to evade sidewalks and in turn avoid going to public parks as a subsequent result. Findings suggest that the physical design attributes of a sidewalk, the perception of safety from using the sidewalk, and the actual pedestrian's safety on sidewalks are the major attributes, which to a varied extent influence the number of pedestrians utilizing the sidewalk to access public parks in residential areas. Increasing the perception and actual safety of residential sidewalks as well as improving the physical design of these sidewalks, will increase the number of public park users in residential areas of South Africa. A wide range of factors can contribute to the lack, inefficiency, and the avoidance of sidewalks in residential areas. It was observed on numerous occasions that the roadway is preferred by pedestrians over using the sidewalk, even with the hazard and dangers of walking in the same space as that of moving vehicles. The lack of pedestrian infrastructure is often due to neglected municipal planning and budgets (Krambeck, 2006). Pedestrians in developing countries are much more likely to be injured or killed by vehicles as compared to developed countries (Krambeck, 2006). In this regard, the pedestrian environment in South Africa is insufficient and contribute to pedestrian fatalities (Albers, Wright and Olwoch, 1998).

Keywords: public parks accessibility, pedestrian infrastructure, pedestrian safety, sidewalk utilization, sidewalk design.

1. Introduction

Physical access to public parks requires proper linkage from neighbouring spaces as well as no barriers preventing pedestrians from entering the space. Not only should it be easy for children and elderly people to make use of physical access to the public parks, but there should also be relatively easy access to the space from houses and residential areas next to the public parks (Sendi and Golicˇnik Marusˇic, 2012). The lack of pedestrian networks imposes a great impact on the mobility of residents in residential areas, and in turn, the overall quality and efficiency of a transport network. The vibrancy and usability of public parks and open spaces are greatly dependent upon the accessibility factors such as pedestrian sidewalks, sufficient lighting, access roads, and pathways (Das and Honiball, 2016). A walkable environment also produces advantages such as property values increase, a decrease in air pollution, and the improvement of social integration (Uysal *et al.*, 2016). South Africa is a developing country which can benefit greatly by improving the walkability in its residential areas.

Most South Africans depends on walking as their major mode of transport (Todes *et al.*, 2010). Pedestrians can be observed not only in the central business districts but also in and around the residential areas (Dempsey, 2012). It has been well observed that pedestrians in residential areas exhibit dangerous walking behaviors such as jaywalking, extended periods of walking in road carriageways, and obstructing the movement of traffic on a regular basis. This kind of pedestrian behavior can be attributed to the lack of pedestrian friendly networks in the residential areas (Brysiewicz, 2001). It is also observed that the sidewalks in the residential areas where present and sufficient in width, equipped with various urban furniture, are mostly overgrown and unmaintained. Built up gardens into the sidewalk areas, building rubble, overgrown trees and utility boxes were found to be frequent obstructions on the sidewalks of residential areas.

Pedestrian's personal safety as well as their perception of safety also encourage residents of residential areas to only use walking as a mode of transport if it is absolutely necessary and essential to their living. This means that residents could be deterred from walking to public parks not only due to the sidewalk conditions but also due to their perception of safety as well as their actual safety. Therefore, this investigation focuses primarily on the assessment of the built environment and safety concerns that influences pedestrians' choice to avoid sidewalks at a neighbourhood level of cities in South Africa. For this purpose, the city of Bloemfontein has been chosen as the study area.

1.2 Study Area

The Universitas neighbourhood of the Bloemfontein city has been identified as a suburb where the identified problem of pedestrians using the roadway for walking is quite prominent. From site observations and surveys it was found that in some instances pedestrian even obstruct the normal flow of motorized traffic. Although, there are sidewalks present, these sidewalks are not pedestrian friendly. To further investigate the issue, other residential suburbs in Bloemfontein were evaluated and compared to Universitas.

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The average travel time for a pedestrian to travel to a public park was calculated by measuring the average travel distance of a commuter to the public parks and then calculating it from the average walking speed of a person. It was estimated that the average person does not take longer than 13 minutes to commute from his residence to any public parks in the neighbourhood with a minimum travel time of about 4 minutes. However, the travel time to most of the public parks varies between 6 to 9 minutes on an average. This shows that there are a sufficient number of public parks in the residential areas of South African cities, specifically in Bloemfontein with an average number of 1.2 public parks per every square kilometre. However, as observed from survey, these parks are not used to their full potentials. There are a number of factors which contribute to their underutilization among which accessibility is a major reason. Residents in the residential areas of Bloemfontein are all within walking distance of public parks in their area, which raises concern as to why there are not as many residents using these public parks, which necessitated this investigation.

It is found that sidewalks are available along the majority of the roads leading to the public parks. However, the major challenge observed is the obstructions affecting walkability on the sidewalks. Ideally, pedestrians are supposed to commute to public parks on the sidewalks instead of on the road reserved for vehicles. However, this is often not the case due to the pavement network being obstructed for various reasons such as home owners building right up against the road or plants and rocks being in the way. Figure 1 shows an example of how the pavement network in the study area is obstructed. The physical survey of the study area found that as much as 17% of the pavement network in a public parks service area is obstructed and unnavigable. It is also found that all the pavement networks leading to public parks in the study areas are 5% or more obstructed, which means that pedestrians commuting to public parks in the study areas are not able to remain on the pavement without having to go into the adjacent road at some stage of their journey. A comparison between the qualitative condition of the sidewalks to the roadways leading to 11 different public parks in the study area were assessed. The average pavement width and road lane width were also measured using GIS software. All the road lane widths (varying between 3.6m and 4.8m) were measured to be sufficient for vehicular movement in both directions, yet they pose danger in situations where the road is shared with vehicles from both direction and pedestrians. The pavement widths in the service areas are also sufficient (varying between 3.0 m and 3.5 m) for pedestrians to commute on, provided that the pavements are not obstructed.

For the purpose of this study, from the 35 neighbourhoods in Bloemfontein, Universitas was found to be ideal for this investigation. Universitas is very diverse in terms of trip generating destinations, it is the largest neighbourhood in the city, and consists of a large number of pedestrians avoiding sidewalks. Universitas also seemingly sufficiently represents other neighbourhoods in Bloemfontein. Universitas has an area of 9.66 square kilometres and is located on the south-western side of Bloemfontein. The suburb holds major sub-arterial roads connecting adjacent neighbourhoods to each other and to the business district. Consequently, Universitas acts a thoroughfare for motorists and pedestrians. Residents mostly stay in stand-alone houses, apartments, and townhouses. The University of the Free State with 37 000 enrolled students is also located in this suburb, and the growing number of students has been a major contributor to the increase in residents over the past few years. Many houses have been converted to student housing to accommodate this increase. Along with students, the overall income level of Universitas is medium to high. Schools within and directly adjacent to the suburb are Universitas Primary school, Greys College Secondary school, Eunice Secondary school, and Dr. Bohmer Secondary school. Other present trip generating destinations making Universitas pedestrian-rich is two retirement villages, five churches, two shopping centres, twelve public parks, and two hospitals.

Fig. 1.
Jacobs Street: Typical sidewalk leading to a public park in the study area

Figure 1 shows typical sidewalk features found within the study area. Some of the more prominent features are:

- Acceptable to bad condition of maintenance;
- Built up gardens over a portion or full width of the sidewalk;

- Various hindrances in pedestrian visibility and sight distance affecting safety and perception of safety spots for A range of obstructions namely trees, signboards, street lighting posts, refusal bins, garden décor, and electrical junction boxes.

2. Methodology

All the public parks in the study area were identified as the trip generating destinations. A physical survey was conducted to measure all the sidewalk networks and its general maintained condition. Also, the service area pedestrian sidewalk network length was measured by using GIS software. It was necessary to measure the sidewalk network length in order to compare the road network with sidewalk network's condition level. Further, a household survey was conducted in the residential areas of the city by using pre tested questionnaire through systematic random sampling process among 319 respondents from which a total number of 284 usable responses were obtained. The SPSS Conjoint Analysis was used to analyses all 284 responses. By using the data obtained Conjoint Analysis Technique was used to understand the preferences of the pedestrians, generation of the sidewalk attributes and construction of Conjoint Profiles were done.

2.1. Conjoint Analysis Technique

Part of this investigation comprised of using the Conjoint Analysis Technique to evaluate the attributes of the pedestrians for using the sidewalks while travelling to the public parks. This is a multivariate technique initially developed for marketing research to understand an individual's preference (Green and Srinivasan, 1978). The Conjoint Analysis Technique is based on the concept that an individual will trade-off between attributes that make up a specific product before making a final decision. The behaviour of pedestrians in the study area with their relation to sidewalk attributes was examined and used as the inputs for applying the Conjoint Analysis Technique. The recent research by Wicramasinghe and Dissanayake (Wicramasinghe and Dissanayake, 2017) is an apt example of the appropriateness of this technique where they applied the Conjoint Analysis Technique as an unbiased method to evaluate the attributes influencing pedestrians to evade sidewalks was used as a point of reference and applied to evaluate sidewalk networks in residential areas instead of in central business districts.

The part-worth utility index was used to calculate the Total Utility Value of the selected sidewalks locations by making use of equation (1). The Conjoint Analysis theory states that the product (in this case, sidewalk profiles leading to public parks) which receives a higher Total Utility Value than the other products will be considered more valuable (Green and Srinivasan, 1978).

$$\text{Total Utility Value } U(Xij) = \text{Constant} + \sum_{i=1}^{m} \sum_{j=1}^{k_i} u_{ij} X_{ij} \tag{1}$$

U(Xij)	=	Total utility of an alternative
m	=	Number of attributes
ki	=	Number of levels in ith attribute
uij	=	Utility associated with jth level of the ith attribute
Xij	=	Dummy variable that takes on 1 if the jth level of the ith attribute is present or 0 other

2.2. Generating Sidewalk Attributes

Appropriate attributes used for evaluation emulated from a comprehensive literature study which identified attributes researched internationally as well as locally. Furthermore, the sidewalk attributes identified from physical surveys in Universitas were also taken into consideration.

From reviewing various tools and methods to measure the attributes of sidewalks leading to public parks, the common attributes found are the sidewalk's maintained condition, pedestrian safety, obstructions hindering movement on the sidewalks, and pedestrians' perception of safety.

The responses from the questionnaire survey in the study area, and coinciding it with all available literature, pedestrian safety, number of obstacles within the sidewalks, pedestrians' perception of safety, and the maintained condition of sidewalks were identified as the primary attributes of pedestrians not utilizing sidewalks. Each of these independent attributes were assigned three different levels of influence as shown in Table 1.

Table 1
Selected Sidewalk Attributes and their Different Assigned Levels of Influence

Sidewalk Attribute	Different Levels		
	Level 1	Level 2	Level 3
Pedestrian Safety	Safe	Relatively Safe	Unsafe
Number of Obstacles in Sidewalks	0	1-5	< 5
Perception of Safety	Perceived Safe	Perceived Relatively Safe	Perceived Unsafe
Maintained Condition of Sidewalks	Good	Acceptable	Bad

2.3. Constructing Conjoint Profiles

When using the Conjoint Analysis Technique, the selected attributes need to be combined into sets of hypothetical profiles. A total of 81 (3x3x3x3=81) attribute combinations exists, yet these combinations can be reduced to only 9 profiles by using a statistical method which is the orthogonal fractural design. The use of the orthogonal fractural design is necessary since the Conjoint Analysis Technique makes use of a ranking response technique which becomes very tedious for respondents if they are to rank 81 profiles instead of 9. The orthogonal fractional design is a method used to reduce profile configurations, while all attributes are arranged to be presented equally and on an uncorrelated basis. The orthogonal fractional design was performed by using SPSS software (version 23). Table 2 shows the 9 profiles generated from performing the orthogonal fractional design to the attribute profiles.

Table 2
Nine hypothetical profiles generated using orthogonal fractional design

Card	Pedestrian Safety	Number of Obstacles in Sidewalks	Perception of Safety	Maintained Condition of Sidewalks
1	Unsafe	1 - 5 Obstacles	Perceived Unsafe	Good
2	Unsafe	> 5 Obstacles	Perceived Safe	Acceptable
3	Relatively Safe	No Obstacles	Perceived Unsafe	Acceptable
4	Relatively Safe	> 5 Obstacles	Perceived Relatively Safe	Good
5	Relatively Safe	1 - 5 Obstacles	Perceived Safe	Bad
6	Safe	> 5 Obstacles	Perceived Unsafe	Bad
7	Safe	No Obstacles	Perceived Safe	Good
8	Unsafe	No Obstacles	Perceived Relatively Safe	Bad
9	Safe	1 - 5 Obstacles	Perceived Relatively Safe	Acceptable

Each hypothetical profile was then captured into illustrations for respondents to rank. Care was taken to ensure uniformity of each profile to minimize any influence other than the attributes being evaluated. Once the 9 representative profiles were constructed into illustrations, it was incorporated in a section of the questionnaire issued for the respondents to rank from 1 (most preferred) to 9 (least preferred).

A model to describe the expected relationship between attributes and ranking scores is required when executing the Conjoint Analysis. For this analysis a discrete relationship between factors and ranking scores is assumed. From Table 3 it is observed that a discrete model indicates the attribute levels are categorical and that no assumption is made about the relationship between the attributes and the ranks.

The relative importance of each attribute is produced by the Conjoint Analysis. Each attribute receives an importance value which indicates its level of importance in comparison to the other attributes. The importance of an attribute is derived from level of difference that each attribute makes in the total utility of a profile considered. The attributes' utility values are formed from the range of the level of differences between attributes. The Level of Importance depends on the particular attribute levels chosen for the evaluation. For example, the larger the range, the more important the attribute would be. The importance measures are ratio-scaled, relative, and study-specific measures. Therefore, an attribute with an importance of 40% is twice as important as an attribute with an importance of 20%. Figure 2 illustrates how the importance of an attribute is determined.

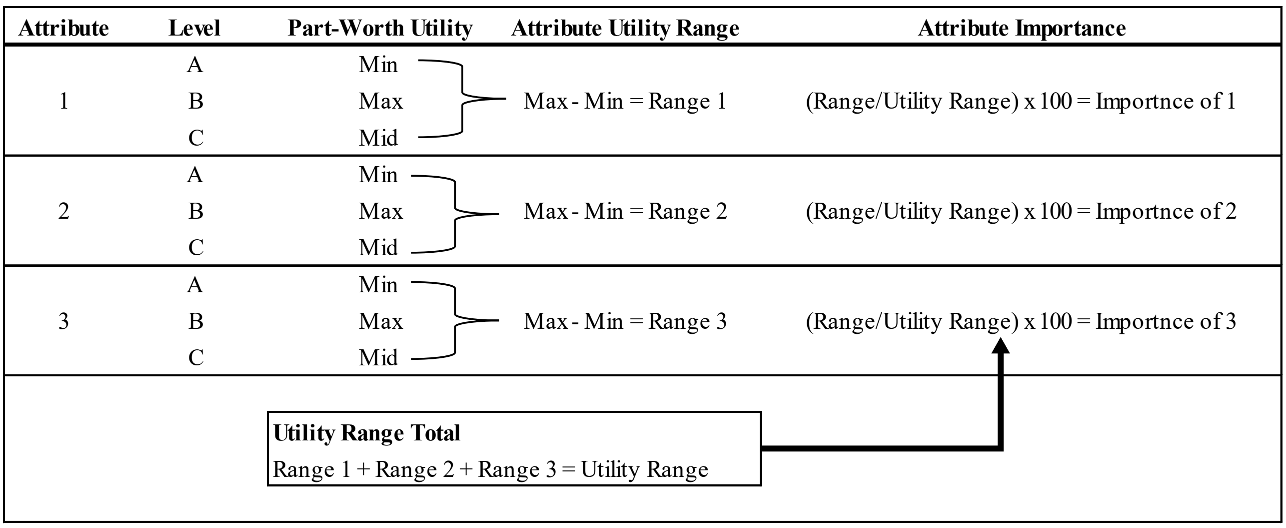

Fig. 2.
Determination of Attribute Importance
Source: (Green and Srinivasan, 1978)

3. Results and Discussion

The evaluation of the selected attributes revealed that the Pedestrian Safety has an importance value of 51.5%, Number of Obstacles had an importance value of 33.5%, the Perception of Safety obtained an importance value of 9.8%, and the Maintained Condition of Sidewalks had a 5.2% value of importance.

Regarding the use of a sidewalks to access public parks, pedestrian safety was found to be the most important attribute. The second most important attribute was found to be the number of obstacles in the sidewalks. The perception of safety was found to be 5 times less important than the actual pedestrian safety, which could be due to the level of awareness residents have about their residential area. The maintained condition of the pavements showed to be the least important attribute.

It is critical, however, to understand the importance of each attribute when evaluating the results of the part-worth utilities. Part-worth utilities allow for a deeper understanding of what specific features within an attribute drives a respondent's choice. Part-worth utilities are numerical values assigned to each attribute level in terms of how much each attribute and level influenced the respondents to make that choice. Attribute levels that are more preferred by customers are assigned higher scores and levels that are less preferred are assigned lower (in comparison) scores.

However, it is important to note that, these part worth's are relative. If an attribute level received a negative utility value is does not mean that the attribute level was unattractive. In fact, an attribute level with a negative value may have been accepted by all respondents. But, all else being equal, a more positive value is better.

Part-worth's in the Conjoint Analysis technique are scaled to an arbitrary additive constant within each attribute and are interval data. Utilities are thus scaled to sum to zero within each attribute. The results for the relative and individual part-worth utilities are summarized in Table 3.

What stands out in Table 3 is the range of the pedestrian safety. Sidewalks that are known to be safe are much more preferred than sidewalks that have an unsafe reputation. This also indicates the importance of the attribute as mentioned before. Another observation is that the pedestrian safety attribute levels seem to have a logical and relative linear relationship.

The number of obstacles in the sidewalk is the attribute with the second highest importance. The attribute levels indicate a logical increase in importance with more than five obstacles being the least important, followed by one to five obstacles, and then of highest importance is the no obstacles. In relation to the other attributes and their attribute levels, no obstacles were found to be the second most important attribute level.

Table 3
Conjoint Analysis Results: Part-Worth Utilities

Part-Worth Utilities		
Attributes	**Attribute Levels**	**Utility Estimate**
Pedestrian Safety	Safe	1.400
	Relatively Safe	-.008
	Unsafe	-1.352
Number of Obstacles	No Obstacles	1.204
	1 - 5 Obstacles	-.434
	> 5 Obstacles	-.780
Perception of Safety	Perceived Safe	-.200
	Perceived Relatively Safe	.345
	Perceived Unsafe	-.165
Maintained Condition	Good	.132
	Acceptable	-.123
	Bad	-.014
(Constant)		5.000

At first, the results of the perception of safety seem to be counter intuitive, with a "relatively safe" perception of safety receiving a higher preference score than a "safe" perception of safety. Similarly, the "unsafe" perception of safety also has a slightly higher value than the "safe" perception of safety. The main reason for this is the nature of the conjoint generated profiles (*The conjoint profiles are generated to equally represent all attribute levels in an uncorrelated manner. Thus, resulting in attribute level combinations that forces the respondent to choose the most preferred attributes while sacrificing other attributes of less importance*).

Similar to the perception of safety, a bad maintained sidewalk condition has a lower preference score than an acceptably maintained sidewalk condition. This is also due to the combination of attributes in the generated conjoint profiles as previously mentioned. The part-worth utilities for the maintained conditions of the sidewalks leading to public parks, is very low and would therefore make little difference in calculating Total Utility Values.

Further, after matching appropriate attribute levels at each location, the Total Utility Value of all eleven locations were calculated (see Table 5). Table 4 shows an example of how the Total Utility Value is calculated at location 8.

Table 4
Example of calculating Total Utility Value at a location

Attribute	Applicable Attribute Level	Part-Worth Utility	Sum	Conjoint Constant	Total Utility Value
Pedestrian Safety	Safe	1.40	2.39	+ 5	= 7.39
Number of Obstacles	None	1.20			
Perception of Safety	Perceived Relatively Safe	-0.20			
Maintained Condition	Good	-0.01			

A summary of the Total Utility Values of each location is shown in Table 5. The TUV Rank column ranks the sidewalks according to Total Utility Value in ascending order. The calculated Total Utility Values of each location is compared and evaluated against the actual number of monthly users of the public parks related to each location.

The total utility value of the 11 locations evaluated revealed that Location 8 had the most preferable attribute conditions, having a TUV value of 7.39. It is clear that pedestrians seek to commute on a safe sidewalk that is also perceived safe, having no obstructions and in a good maintained condition. Location 11, with a TUV value of 2.93, was the least preferred type of sidewalk that pedestrians would want to commute on. Although Location 11 have an acceptable maintained condition, the sidewalk is deemed unsafe as well as perceived unsafe, which is a major detergent for pedestrians.

Table 5
Attribute levels and Total Utility Value of each selected location

Location	Pedestrian Safety		Number of Obstacles		Perception of Safety		Maintained Condition		Constant	Total Utility Value
1	Relatively Safe	-0.01	> 5	-0.78	Perceived Unsafe	-0.16	Acceptable	-0.12	5	3.92
2	Relatively Safe	-0.01	1 – 5	-0.43	Perceived Unsafe	-0.16	Good	-0.01	5	4.38
3	Safe	1.40	> 5	-0.78	Perceived Relatively Safe	0.34	Acceptable	-0.12	5	5.84
4	Safe	1.40	1 – 5	-0.43	Perceived Safe	-0.18	Acceptable	-0.12	5	5.64
5	Safe	1.40	> 5	-0.78	Perceived Unsafe	-0.16	Acceptable	-0.12	5	5.33
6	Relatively Safe	-0.01	> 5	-0.78	Perceived Relatively Safe	0.34	Acceptable	-0.12	5	4.43
7	Unsafe	-1.35	1 - 5	-0.43	30% Perceived Relatively Safe; 70% Perceived Unsafe	-0.02	Good	-0.01	5	3.19
8	Safe	1.40	None	1.20	Perceived Safe	-0.20	Good	-0.01	5	7.39
9	Unsafe	-1.35	1 – 5	-0.43	Perceived Relatively Safe	0.34	Good	-0.01	5	3.55
10	Safe	1.40	1 – 5	-0.43	40% Perceived Safe 60% Perceived Relatively Safe	0.13	Good	-0.01	5	6.08
11	Unsafe	-1.35	1 – 5	-0.43	Perceived Unsafe	-0.16	Acceptable	-0.12	5	2.93

4. Conclusion

The lack of a pavement network in the service area of a public park deters many potential users from commuting to the public parks. Many users are composed of families with children and do not wish to commute on the road due to the pavement not being accessible or in a proper condition. Many residential homes in the study area have developed gardens and driveways on their front pavement, which prevents pedestrians from commuting on them. A pavement network does not belong to the owners of the lots along which the pavement lies and should not be utilized and developed by these owners in such a way that the pavement loses its pedestrian functionality. Therefore, appropriate policy interventions for provision of adequate, well maintained and unobstructed pavements commensurate to the roads leading to the public parks in the residential areas are one of the foremost requirements.

The results of the Conjoint Analysis provide important insight into the use of sidewalks leading to public parks and the avoidance thereof. It is concluded that the most preferred sidewalk to commute to a public park is a sidewalk that is deemed safe as well as being perceived as safe. The sidewalk needs to be in a good maintained order and have no obstacles obstructing a pedestrian's right of way. Open and public spaces are usually safer as well as perceived safer when there are more people visible and walking to the same destinations (Giles-Corti *et al.*, 2005), so by only providing well-designed sidewalks that attracts pedestrians to use for accessing public parks, an improvement in the safety and perception of safety on sidewalks leading to public parks is expected.

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HUMAN FACTOR AND SUSTAINABLE DEVELOPMENT OF TRANSPORT

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Abstract: The transport system of Europe, especially the Western Balkan countries, still has no sustainability attributes. Cities have become a serious problem from the aspect of overcoming the planned paths for their inhabitants, but also for visitors. Tourist trips are on the increasing. Reducing mobility would entail the regression of society and the economy. The increase in mobility must also be accompanied by an increase in the efficiency of the transport system. This paper deals with the impact of human factors on the challenges of modern transport system, with emphasis on possible options of developing transport in the context of sustainable development.

Keywords: transport system, sustainable development, human factor.

1. Introduction

Traffic plays a crucial role in urban development by providing access for people to education, markets, employment, recreation, health care and other key services. Especially in cities of the developing world, enhanced mobility for the poor and vulnerable groups is one of the most important preconditions for achieving Millennium Development Goals. Those cities with transport modes in an integrated system are more likely to evolve and prosper as centers for trade, commerce, industry, education, tourism and services. It is common that cities ranking at the top of surveys measuring urban quality of life have high quality urban transport systems that prioritize public transport and non motorized modes (Pardo et al., 2015). In order to return urban places to people and to create more livable cities, decision makers need to change the direction of urban transport development toward a more sustainable future. Establishing a sustainable urban transport system requires a comprehensive and integrated approach to policymaking and decision making, with the aim of developing affordable, economically viable, people-oriented and environment-friendly transport systems.
Sustainable development has been the topic of many conferences and activities by transportation professionals and international agencies. The concept aims at launching a large-scale political, economic and cultural project, harmoniously linking environmental requirements with those of economic development, from a long-term point of view (Camagni, 1998). The Bruntland Report of the World Commission on Environment and Development called Our Common Future (WCED, 1987) defined sustainable development as a process of change in which the exploitation of resources, the direction of investments, the orientation of technological investment, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. The most important elements being satisfaction of (basic) human needs and at the same time complying with available or affordable resources (e.g. environmental, financial and social) implying intergenerational justice. This means that the human factor is significant for developing of traffic in the context of sustainable development.

2. The Impact of Human Factors on the Sustainability of Modern Transport System

2.1. Uncontrolled Motorization

With rapid urbanization and economic growth, motorization has been accelerating in cities in developing countries. Owning a private car is a major aspiration for people in cities all over the world. City managers in developing countries are following the same car-oriented transport development patterns made by many cities in developed countries in the past. At the same time, many cities in developed countries are now trying to recover from a car-dominated development era by halting the building of more infrastructures for private vehicles and re-allocating road space for public transport and non-motorized transport.
In the developing world, however, the trend is still largely in favor of the expansion of infrastructure for private motor vehicles. Policies for more and more road construction have clearly failed to cope with ever increasing demand from rapid motorization, resulting in a vicious circle as depicted in Fig. 1. This cycle shows how the increase of infrastructure to alleviate travel demand will have apparently positive consequences in the short term, but some months later there will be a much greater congestion than before, thus increasing the problem rather than solving it (Buis, 2009).

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Fig. 1.
Vicious Circle of Car-Oriented Transport Development
Source: (Buis, 2009)

European data suggest that there were 495 cars per 1000 inhabitants on average in the EU-15 countries, with the equivalent EU-25 average being, for example Luxembourg had 659 cars per 1000 inhabitants, while Italy and Portugal had around 575, whereas at the lower end, Hungary and Slovakia had 282 and 225 cars per 1000 inhabitants respectively (Euro found, 2009). Car dependence, therefore, is an undesirable phenomenon for cities, which look at reducing it as much as possible. The policies and strategies used for that purpose are similar to the ones used for tackling congestion and are mainly based on car dissuasion (Zavitsas et al., 2010).

2.2. Urban Air Pollution and Noise

Another major problem for city managers is urban air pollution, which is a widespread environmental hazard. As shown in Table 1, even though the level of different air pollutants in cities of developing cities are generally higher than those of developed ones, still very few cities overall stay below the recommended levels by the World Health Organization (WHO).

Table 1
Air Pollution in Selected Cities

	PM10 (µg/m3)	**SO2 (µg/m3)**	**NO2 (µg/m3)**
WHO Air Quality Guidelines:	**20**	**20**	**40**
Beijing	89	90	122
Delhi	150	24	41
Tokyo	40	18	68
Mexico City	51	74	130
Bangkok	79	11	23
London	21	25	77
New York	21	26	79
Paris	11	14	57
Shanghai	73	53	73
Santiago	61	29	81

Source: (Pardo et al., 2015)

In most cities in the world, the road transport sector is the largest contributor of these urban air pollutants, as well as to high levels of carbon monoxide and hydrocarbons, among other substances. These high levels contribute to various respiratory and cardiovascular illnesses (Pardo et al., 2015).
Looking at noise, this hazard is often underestimated, as its impacts are considered to be less significant than those of air pollution; however, it is still a nuisance that degrades the quality of life of residents and requires to be addressed. Research has shown that many people are exposed to transport noise levels that affect their quality of life and health, notably in large agglomerations. Road traffic is by far the main source of exposure to transport noise, with almost 67 million people in the EU (i.e. 55 % of the population living in agglomerations with more than 250,000 inhabitants) being exposed to daily road noise levels exceeding the EU benchmark for excessive noise of 55 dB (Butcher, 2018). The impact of road traffic noise has, thus, far-reaching and wide-ranging effects, becoming an issue of immediate concern to many authorities (Zavitsas et al., 2010).

2.3. Energy Efficiency and Greenhouse Gas (GHG) Emissions

Transport is the second largest sector contributing to global carbon dioxide (CO_2) emissions from fossil fuel combustion as shown in Fig. 2. Globally, road transport is responsible for about 16% of man-made CO_2 emissions. It is a common misconception that global warming is mainly caused by cars and trucks. It is important to understand that there are other, larger, contributors and ALL sources of CO_2 emission must be addressed if the problem is to be solved.

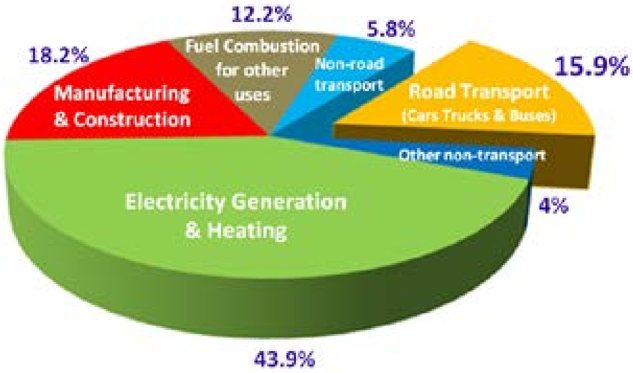

Fig. 2.
Greenhouse gas emissions by sector
Source: International Organization of Motor Vehicle Manufacturers, http://oica.net

Internal combustion engines that are used in cars have been improving with technological advances, becoming more efficient in terms of fuel consumption and contributing less to air pollution. However, fuel efficiency in transport is a multidimensional environmental issue that is not only related to technological advances, but also to travel choices, driving style and network flow. Therefore, to address the issue of fuel efficiency it is required to look at improving both the efficiency of each transport mode and the efficiency of the transport system as a whole. As cars are the main contributors to urban emissions, several studies have investigated the conditions under which cars operate more efficiently, looking into factors such as engine size, speed, etc. The most valuable finding of researchers has been that cars consume fuel more efficiently when travelling at around 65 km/h.
Public transport is considerably more efficient in terms of fuel consumption per traveller than private cars, not only because of its higher passenger occupancy, but also because it keeps large numbers of vehicles off the road, thus relieving the network from congestion and ensuring steadier traffic flow conditions. Similar effects on fuel efficiency has the promotion of walking and cycling, which substitute motorised trips and hence reduce fuel consumption, as well as the endorsement of "clean" vehicle technologies (e.g. electric vehicles, hybrid etc), which are energy efficient but do still contribute to congestion.

2.4. Urban Transport Needs of all Social Groups and Disabled Citizens

Urban transport needs of all social groups are seldom met, especially in cities of developing countries. This may be due to a lack of understanding of such needs, a lack of data on the transport trends of different population groups or simple lack of knowledge about the importance of understanding all these needs and acting upon them.
A more comprehensive approach towards the travel patterns of different groups in society reveals the following:

- There are many more trips being taken by individuals with higher income than by those of lower income, mostly because low-income groups do not have the capacity (in time or money) to travel more. This weighs heavily on their capacity to access jobs, education, health and all other services that a city can provide, reducing their participation in society as a whole (Thynell, 2009),
- There is much less accessibility for lower-income groups (and vulnerable groups in general) due to high/inequitable transport fares, lack of public transport provision to areas where low-income populations live, and lack of safe and high quality infrastructure for these users (including sidewalks, which are often neglected in favour of roads) (World Bank, 2002),
- Transport patterns of citizens vary widely, with low-income women travelling in trip chains (various short trips chained to one another) rather than pendular trips (one trip in the morning and one in the afternoon), and a great use of no motorized transport modes (walking, cycling),
- Negative impacts from unsustainable transport systems affect the poor disproportionately (Badami et al., 2004).

This situation poses a threat to social development and general equity in cities. For instance, non-motorized transit is often an 'orphan' in transport systems and is frequently overlooked and considered as a peripheral issue rather than a core requirement. In most cases, for example, cycling is not well integrated with public transportation, which leads to loss of potential passengers. Also, partly as a result of this circumstance, the majority of victims in traffic accidents are pedestrians and cyclists, many of whom belong to lower income groups (Pardo et al., 2015).

The disabled and the senior citizens are important disadvantaged social groups with special mobility needs which ought to be addressed more effectively. The special needs should be anticipated in the planning and construction of new transport infrastructure. Barrier-free facilities can significantly enhance the mobility for these social groups. In recent years, a growing number of cities have issued municipal regulations on barrier free facility construction, requiring all new instruction projects, including public and residential buildings, roads, bridges, pedestrian overpasses and underpasses, metro and rail stations, as well as tourist sites, to be barrier-free, thus enabling the safe and convenient mobility of the disabled, seniors, injured and other disadvantaged social groups. Barrier-free bus stations and buses, sidewalks for the blind, ramps, elevators, lifting platforms and wheelchair waiting positions are essential elements which can enable barrier-free mobility (Pardo et al., 2015).

2.5 Other Challenges - Political Difficulties, Safety, Economic Prosperity

Although many urban transport problems fall under the categories discussed in the previous sections, there are also further problems, different in nature and smaller in scale that can only be defined at their own context. These mainly include political difficulties, safety and economic prosperity. As in any other discipline, transport is also related with a number of political issues to be addressed for a policy, a scheme or an infrastructure project to be implemented. These can be broadly categorised into two categories: conflicts of interest and communication problems.

Conflicts of interest arise between elected politicians (mayors, ministers, etc.) and the public (voters), as the latter expect to see solutions to the cities' transport problems during the politicians' terms. The characterisation of a politician as "successful" (and his/her reelection) strongly depends on the voters' opinion. As such, politicians often look to satisfy the short-term wishes of the public to ensure the overall happiness of the voters, and therefore tend to support short-term plans of uncertain effectiveness, disregarding long-term impacts and sustainability issues. Considering communication problems, the management of traffic in cities involves several processes such as monitoring, dynamic management and enforcement, and it is very often the case that different authorities are responsible for each one of them. Namely, in most cities at least three or four authorities are involved in traffic management, with the most common being national, local and city authorities and the police, but also being complemented by parent companies, public-private-partnerships and public funding CONDUITS Transport problems in cities Deliverable no 1.1 27 initiatives. Good communication and coordination between those is, as expected, a necessity for any efficient traffic management process (Zavitsas et al., 2010).

The loss of human life has been an important issue since the early development of the transport sector. It is well established that there are several factors affecting the road fatality rate of any country, the most obvious among them being the speed, the level of vehicle ownership, the condition of the infrastructure and the condition of the vehicles. The drivers' attitude is also mentioned as an important factor, though it is very difficult to evaluate (Bester, 2001).

The European Commission set the ambitious target of halving the number of road fatalities by 2010 in its White Paper "European transport policy for 2010: time to decide" of 2001. A new target for 2020 to halve the number of road deaths compared to 2010 was set by the EU in its "Road Safety Programme 2011-2020". Much progress has been made with reducing the number of fatalities. The average annual reduction between 2006 and 2010 was 7,1%. The highest annual decreases occurred in 2009 and 2010, while slight increases occurred during the last two years of the examined period. However, it is estimated that the number of road accident fatalities in the EU fell by 40% between 2006 and 2015 (ERSO, 2017). Fig. 3 shows evolution of the number of fatalities between 2006 and 2015, index base 100=2006.

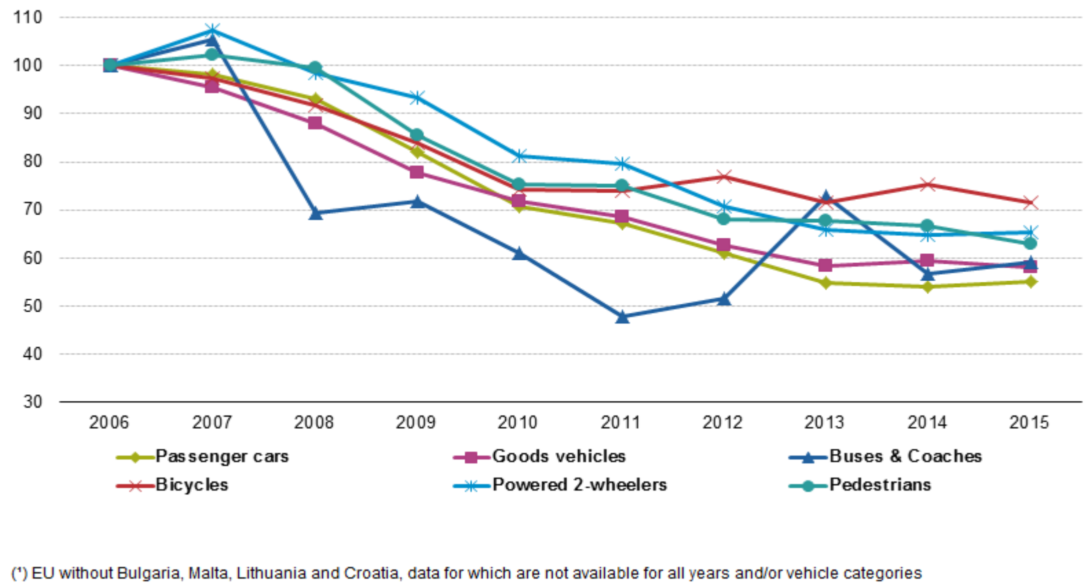

Fig. 3.
Evolution of the number of fatalities between 2006 and 2015

Source: Eurostat, July 2017

Unsurprisingly, most people killed in road traffic accidents were car drivers or their passengers (44.7 % in 2013). The second-largest category was pedestrians (21.9 %), well ahead of victims of motorcycle and moped accidents combined (17.9 %). Cyclists account for 7.8 % of EU road deaths, but in individual countries, this proportion can be as high as 22 %. Moreover, cycling deaths are under-reported: some accidents involving cyclists are not reported to police. While car drivers and passengers represent the largest category of road traffic deaths (44.7 % of all road traffic fatalities in 2013), pedestrians (21.9 %) are the second largest category in the EU, well ahead of drivers and passengers of motorcycles (15.0 %). Cyclists account for 7.8 % of the road traffic deaths, while shares of fewer than 3 % were accounted for by the remaining categories: goods vehicles, buses and coaches and "other" (essentially, agricultural tractors and other motorized vehicles) (Eurostat, 2013).

Over the last decade, the largest drop in the number of fatalities in the EU-28 was among car drivers and their passengers (-52.8 %), followed by occupants of goods vehicles (-43.9 %), and buses and coaches (-42.4 %). This shows that the many measures taken to improve road safety are paying off. The fall in the number of fatalities among cyclists (-33.7 %) and pedestrians (-38.8 %), though, was smaller. The pattern for buses and coaches in stands out from the rest. There were 97 deaths in the EU in this category in 2012, but the number rose to 148 in 2013 (Eurostat, 2013).

One of the fundamental reasons for the existence of cities is proximity, as several economic advantages are related to short trip distances and travel times. Urban transport problems, such as congestion, can increase travel times and affect the efficiency of commerce, counterbalancing the economic advantages of urban proximity. From an economic perspective the existence of nearby urban areas establishes a competitive environment, in which each city tries to provide better transport services to residents, businesses and industries in order to advance, expand and ensure the economic prosperity of the region (Zavitsas et al., 2010).

3. Policy Options for Sustainable Development of Urban Transport

A sustainable urban transport system requires strengthening various features of the system including mobility, accessibility, affordability, social equity, efficiency, safety, security, convenience, low carbon, comfort, and people- and environment-friendliness. In order to achieve all these elements, various challenges need to be addressed in an integrated manner.

These challenges include improving human health through the reduction of urban air pollution, tackling climate change, reducing the number of deaths and injuries from road accidents, controlling excessive motorization, improving public transport services, encouraging more walking and cycling, and recognizing the specific needs of urban poor, women, the elderly, people with disabilities, youth, and children. It is critically important to understand that urban transport (or mobility) is not an isolated issue and is related to many other aspects of urban life in general.

In general, sustainable transport emphasizes the use of public transport, bicycles and walking and discourages the use of individual motorized modes of transport (cars and motorcycles). It also promotes the improvement of institutions, urban development plans, sound policies, appropriate technologies and the development of promotional schemes that persuade users into using sustainable urban transport modes (Pardo et al., 2015).

3.1. Sustainable Urban Transport Plans

"Sustainable mobility is the ability to meet society's need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future" (WBCSD, 2015).

To improve the transport sector from an environmental point of view, long-term strategies are crucial. A Sustainable Urban Transport Plan is a tool for structuring plans within a city or region. Not only cities, but also regions and nations must work according to long-term strategies to curb urban transports. The strategies could include actions to increase the efficiency of transportation and logistics, substitute conventional vehicles and fossil fuels with clean vehicles and renewable fuels, plan and create a society with less need for transport, and influence the demand for transport.

The European Commission has proposed that all cities with more than 100,000 inhabitants should describe the movement of goods and people and its conditioning factors and impacts in a Sustainable Urban Transport Plan (SUTP). The SUTP should apply for 5–10 years, but the actions and budgets should be revised every 1–2 years. The plan should be embedded in an overall development strategy with a long-term perspective of 20 – 30 years. The SUTP should integrate transport and mobility with other key planning, especially for land-use, environment (e.g. Environmental Management Plans), social inclusion, economic development, safety, health and education.

3.2. Push – Pull Approach

One way to view the problem is to analyze it from the standpoint of "where" people should be in transport (where we should "push" them) and from which modes we should "pull" them. This is commonly called the "push - pull" approach (Müller et al., 1992). It emphasizes that urban transport measures must persuade users into using public transport and no motorized transport, while developing strategies to "push them out" of automobiles and similar transport modes.

To achieve the "pull" component, one must provide good quality of service in public transport, develop infrastructure for public transport and non motorized transport and in general develop policies that improve conditions for the use of

these modes. To arrive at a situation where people are "pushed from cars", policies must be in place to discourage their use by eliminating fuel subsidies, creating charges to automobile ownership and use, and in general creating policies that increase the cost of using these modes while using the revenue from those charges to enhance sustainable urban transport modes. This approach is generally used by transport economists as it follows a rationale of "price-driven-behavior" (Pardo et al., 2015).
Figure 4 shows the results of behavioral effects of push and pull measures in an experiment of the Helmholtz Center for Environmental Research (UFZ) (Heck et al., 2015).

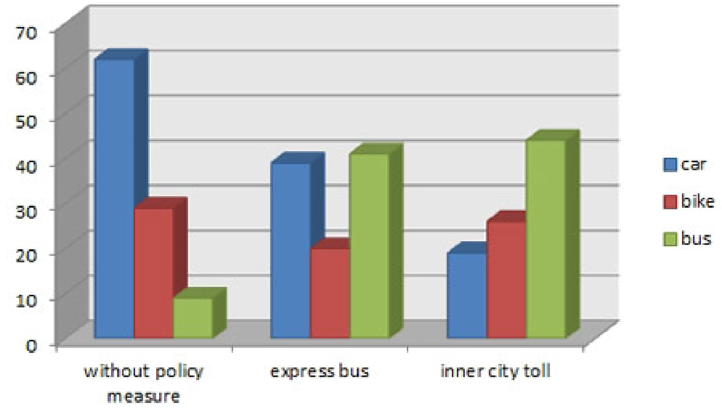

Fig. 4.
Behavioral effects of the introduced push and pull measures
Source: (Modified according Helmholtz Centre for Environmental Research, 2007)

In this experiment the UFZ analyzed the impact of offering an express bus to the inner city as a pull measure and as another option the introduction of an inner city toll. Although this experiment is not representative it could demonstrate that with both measures the behavior could be influenced significantly. The use of public transport increases likely in both scenarios while bike usage is higher with an inner city toll and less when an express bus is offered.

3.3. Avoid, Shift, Improve Approach

The traditional approach applied to deal with increased transport demand has been the provision of additional road space by means of new and expansive road infrastructure. This supply-side oriented approach has, however, not delivered the expected benefits. Increased traffic volume continues to produce excessive levels of congestion, GHG emissions and other externalities. For this reason, the traditional approach adopted in recent years to provide additional infrastructure is considered ineffective and old school. Therefore, a new approach to tackling current transport problems is required.
The new approach, known as A-S-I (from Avoid/Reduce, Shift/ Maintain, Improve), (figure 5) seeks to achieve significant GHG emission reductions, reduced energy consumption, less congestion, with the final objective to create more liveable cities. The objective of the A-S-I approach is to promote alternative mobility solutions and to develop sustainable transport systems. In contrast to the traditional supply-oriented-approach in transport planning, the A-S-I approach is focused on the demand side and offers a more holistic approach for an overall sustainable transport system design.

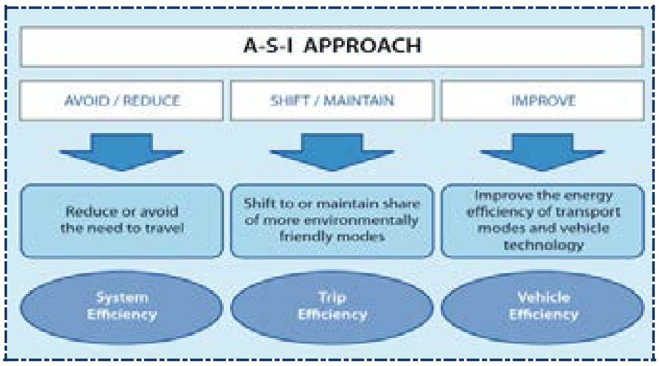

Fig. 5.
A-S-I Approach
Source: (Heck et al., 2015)

Firstly, "avoid" refers to the need to improve the efficiency of the transport system. Through integrated land-use planning and transport demand management the need to travel and the trip length may be reduced

Secondly, the "shift" instruments seek to improve trip efficiency. A modal shift from the most energy consuming urban transport mode (i.e. cars) towards more environmentally friendly modes is highly desirable. In particular, the shift towards the following alternative modes:

- Non-Motorized Transport (NMT): walking and cycling. They represent the most environmentally friendly options.
- Public Transport (PT): bus, rail, etc. Although PT also generates emissions, lower specific energy consumption per pkm and higher occupancy levels imply that the associated CO2 emissions per passenger-km are lower compared to cars.

Thirdly, the "improve" component focuses on vehicle and fuel efficiency as well as on the optimisation of transport infrastructure. It pursues to improve the energy efficiency of transport modes and related vehicle technology. Furthermore, the potential of alternative energy use is acknowledged (Heck et al., 2015).

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3.4. Policy Options and Measures for Road Safety

Every day, road traffic accidents claim more than 3,400 lives worldwide, with a total of 1.25 million deaths annually. The highest majority of victims are young people aged between 15 and 29 years old living in low-income countries. A comprehensive strategy encompasses the safety approaches and systems that contribute to Road Safety as well as the agencies that have a role in contributing to the delivery of the strategy.
Model for a successful road safety strategy, based on good quality data, the 3 E's, the Safer System Approach and a matrix of effective partnerships (the pillar of this model) is shown on figure 6.

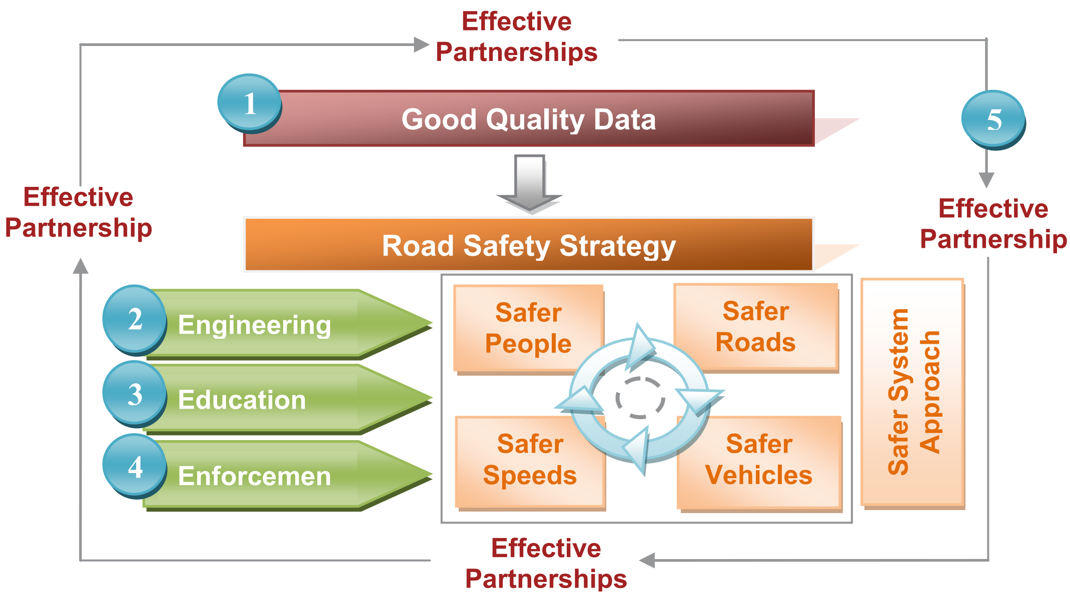

Fig. 6.
Model for a successful road safety strategy
Source: (Morley et al., 2016)

a) Good quality data - any effective strategy needs to be built on reliable data. This ensures that activities are targeted at those factors most contributing to road traffic fatalities. All high performing countries have good quality data systems (with high accuracy and integrity) on which to base policies, regulations, and initiatives. The Safety Net project, a study undertaken by a consortium of key European Road Safety Research Institutes on behalf of the European Commission, found that data should be collected using a consistent, transparent and independent framework with no interference from stakeholders It is also crucial to train investigators on how to investigate traffic collisions and accurately collect reliable data.
b) Engineering for a Safer System - effective engineering plans take into consideration both infrastructure and technology. A well designed infrastructure reduces road hazards and promotes the safety of road users. Moreover, vehicle and infrastructure related technologies increase road and vehicle safety while reducing fatal accidents.
Infrastructure refers to the development of a well-planned infrastructure that contributes to the improvement of road safety, and thereby reduces the number of deaths on roads, for example: improvement of road designs including the strategic allocation of roadside-barriers, creation or improvement of pedestrian walkways and crossings, creation or improvement of bicycle lanes and crossings, well-planned allocation of traffic signals, road and speed limit signs, etc.
Technology comprises of two categories: vehicle-related technologies (vehicle design and installed technology: seatbelts, airbags, advanced braking systems - ABS, alcohol interlock black box device) and infrastructure-related technologies (technology used on the roads: advanced radars and speed cameras, point to point systems, tailgating cameras, Changeable Message Signs - CMS, Variable Speed Limit - VSL signs etc.) (Morley et al., 2016).

c) Education for Safer People - evidence based studies have shown that education is crucial to developing safer people and safer communities; therefore, road safety must be taught in schools as well as through driver trainings and safety campaigns.
d) Enforcing Road Safety Laws - effective enforcement includes written laws and sanctioned schemes that are well thought out and contextualised, but still based on proven leading practice. Enforcement also includes physical enforcement mechanisms both through police and technology (e.g. radars, cameras, etc.). Enforcement is critical in putting education and engineering efforts into effect, in order to achieve a complete Safer System.
e) Effective Partnerships - include a range of expertise relating to the human, vehicle, environment and legal aspects of road accidents, are an extremely positive asset to a road safety strategy. Those partnerships involve a collaboration between different organisations that can leverage a diverse range of skills and work together towards the common goal of casualty reduction. Partnerships are effectively the back-bone for successful road safety achievements. Strategies that empathise on the quality of collision data collection should also recognise the importance of road safety partnerships between the different stakeholders. Those stakeholders can help facilitate the sharing of information as well as the validation of data and statistics, for example, the range of data collected by the Ministry of Health, the Ministry of Transport and the Ministry of Interior.

3.5. Policy Options for Mobility of all Social Groups and Disabled People

Urban transport needs of all social groups are seldom met, especially in cities of developing countries. This may be due to a lack of understanding of such needs, a lack of data on the transport trends of different population groups or simple lack of knowledge about the importance of understanding all these needs and acting upon them.
Unlike developing countries, most economically developed countries are rapidly approaching the point where all buses, coaches and trains must be accessible to disabled people (January 2020) and in many cases these vehicles already meet the requirements. Taxis are also accessible in many parts of the country, though non-metropolitan urban areas and rural areas lag somewhat behind. There are also duties on air travel and sea travel providers to ensure that disabled people can access their services and expect a certain level of accommodation to their needs, though they can be denied travel on safety grounds.
Many day-to-day problems for disabled people stem from confusion over the rules, poor or insufficient communication, inadequate training, and/or a lack of enforcement. Issues where these concerns overlap include the provision of assistance on vehicles and at stations; the carriage of mobility scooters; and buggies and prams using wheelchair spaces on buses.

3.6. Networks and Organizations Promoting Sustainable Urban Transport

Promotion of sustainable transport has become a major issue in cities around the world. Several partnerships have been established to create synergy and leverage resources among different institutions and organizations. For example, the Partnership for Clean Fuels and Vehicles (PCFV), with well over 100 partners has been successfully working on phasing out lead from fuels, establishing standards for low-sulphur fuels and promoting clean vehicle technology. The United Nations Environment Programme (UNEP) acts as the Clearing House for the PCFV and also works in the area of fuel economy (Global Fuel Economy Initiative), public transport and investments in non-motorized transport (Share the Road Initiative) (www.unep.org/transport). The Partnership on Sustainable Low Carbon Transport (SLoCaT), is another example. With over 30 members, it aims to provide options and advice for the establishment of sustainable transport systems. Other initiatives have been established in developing cities, such as the Sustran network (which has chapters in Asia and Latin America and acts primarily as a discussion group of practitioners), the Cities for Mobility network (initially a European Union project and from 2007 a network led by the city of Stuttgart), and in general various electronic debate forums. Other initiatives such as the Sustainable Urban Transport Project from the German Cooperation Agency (GIZ) have concentrated in developing documents and other material to support implementation of sustainable urban transport (Pardo, 2015).
Various non-profit institutions have been crucial to the promotion and implementation of sustainable urban transport. These include the New York-based Institute for Transportation and Development Policy (ITDP), the World Resources Institute's Embarq network, and the above-mentioned Sustainable Urban Transport Project.

4. Conclusion

When it comes to the sustainable development of transport, we can't avoid the fact that the human factor is the focus of all activities that at the same time impact transport as unsustainable and sustainable. The consequences of uncontrolled motorization are felt throughout the planet. Forecasts indicate that the global population will increase by more than two billion in the next 40 years, so it is expected that the situation related to all types of pollution of the environment will worsen. Conscious of these facts, man takes measures to ensure that transport, especially in urban areas, becomes sustainable and acceptable for all citizens. The paper presents the impact of human factors on the sustainability of the modern transport system and the policy options for the sustainable development of urban transport, in order to show the complexity of the issues and the importance of all the activities that influence the building of a sustainable world in which we live.

Building a sustainable world requires that we develop a meaningful systems thinking capability so that we can learn, collectively, how we can promote the common good. It requires an unswerving commitment to the rigorous application of the scientific method, and the inquiry skills we need to expose our hidden assumptions and biases. It requires us to face the ethical issues raised by growth and inequality, to speak, unafraid, of our deepest aspirations for a just, equitable and sustainable world. It requires that we listen with respect and empathy to others. It requires the humility we need to learn and the courage we need to lead, though all our maps are wrong. If we devote ourselves to that work we can move past denial and despair to create the future we truly desire, not just for us, but for our children. Not just for our children, but for all the children (Sterman, 2012).

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OPERATIONAL MODEL AND IMPACTS OF MOBILITY SERVICE BASED ON AUTONOMOUS VEHICLES

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Abstract: Emerging infocommunication and vehicle technologies, especially autonomous vehicles (AVs), imply a significant alteration in urban mobility. Shared, mostly demand-driven mobility services based on small-capacity AVs emerge. The research questions are, how to operate this new transportation system, and what impacts it has. We apply system and process-oriented analytical modeling method. Firstly, the alteration in urban transportation modes is revealed. Then, the mobility service types are identified and characterized. In order to facilitate their integration into the passenger transportation system, the structural model has been developed. The functions and the interrelations between the functions have been revealed to model the operation. Real-time data about current demand, vehicle location, and status significantly affects the operation. Finally, the impacts of this novel mobility service are estimated. The impacts concern the entire transportation system (e.g. shifting in modal share), environmental load, management of traffic and infrastructure as well as passenger habit. The quantitative correspondences are assessed by questionnaire survey applying stated preferences. The calculation method of modal shift has been elaborated. The results can be used as a base to organize and operate the mobility service.

Keywords: alteration in mobility, autonomous vehicle, impacts, operation, functions.

1. Introduction

The technical developments, especially the autonomous road vehicles (AVs) result alteration in mobility services. Shared mobility services based on small capacity AVs emerge, which is called STA - Shared Transportation based on AVs (Földes and Csiszár, 2018). Our aim was to model the operation and impacts of AVs focusing on STA. The research questions were:

- how is the service operated?
- what are the operational functions and how are they interrelated?
- what are the impacts?

The novelty of this work lies in the fact that researches deal primarily with the development of the vehicle and control technology as well as traffic modeling (Szalay *et al.,* 2017), while management of the entire passenger transportation including AVs requires a more complex approach. The results of this paper fill this niche; namely, the technological advancement is placed into a wider context in order to reveal correspondences which are to be tackled in the future. The results can be expeditiously used for development of future mobility systems.

The remainder of the paper is structured as follows. In Section 2, a brief review of the related works is provided. In Section 3, the alteration of the mobility system is described and then the most relevant features of the STA are summarized. The structural and operational model covering the operational functions and their connections are elaborated in Section 4. The impacts are summarized in Section 5; the expectations towards the impacts and the alteration in the modal share are detailed. The paper is completed by the concluding remarks, including further research directions.

2. Literature Review

Several scientific papers study the operational issues and the impacts of AVs. Mobility services based on AVs open new opportunities in terms of demand management. According to Lamotte *et al.,* (2017), implementing demand management strategies into reservation-based services would lead to benefits, such as reduced congestion costs. Kashani *et al.,* (2016) appointed that replacing conventional public transportation with demand responsive services in low demand areas can significantly increase the quality of mobility without any extra operational costs. On the one hand, AVs can be applied in rural areas with low population density as a door-to-door, flexible way of transport. On the other hand, AV-based feeder mobility service can connect high population density areas to public transport (Owczarzak and Zak, 2015). When determining system attributes, it is important to properly assess and forecast future demand towards the mobility system based on AVs. The key to this lies in the investigation of user preferences and expectations. Passenger attitudes were rather positive, especially for services implemented within a major facility (e.g. university) (Christie *et al.,* 2016). Bansal *et al.,* (2016) found that 41% of the respondents would use a shared AV weekly at a competitive price.

Besides survey data collection, novel methods were elaborated to evaluate reliable passenger demand data and to use them for planning purposes. Horváth (2016) developed an OD matrix estimation method to determine the number of departing and arriving passengers between given zones. Atasoy *et al.,* (2015) found, that significant benefit over static allocation of the vehicle can be achieved using dynamic allocation of the vehicles to different service types: taxi,

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shared-taxi, and mini-bus. Schofer *et al.,* (2003) developed a model that estimates the needed number of vehicles in the case of a demand responsive service. The correlation between the size of the service area and trip duration is positive whereas between population density and the size of the fleet is negative.

Benefits of AVs consist of safer roads, travel time reduction, possibilities for older or disabled people and teenagers to use cars, reduction of space required for parking vehicles, increase of efficiency of the transport network (Alessandrini *et al.,* 2015). Chen et al. (2016) found that each 80-mile range shared AV replaces 3.7 privately owned vehicles. However, they highlighted that the efficiency of AVs hinges on automatized recharging. Bischoff et al. (2016) revealed that a fleet of 100 000 AVs could replace the conventionally driven vehicle fleet in Berlin (Germany). Simulation results of Fagnant and Kockelman (2014) indicated that each shared AV replaces 11 private vehicles but generates up to 10% more travel distances. Gruel and Stanford (2016) considered a scenario supposing all vehicles in operation are shared. They found that the number of vehicles in the region reduces, the utilization of cars and thus the trips per AV per day increase. Overall, it can be expected that vehicle kilometers are going to increase.

We conclude from the literature review that all research and development activities should be derived using a system-oriented approach because of the complex and dynamic features of the passenger transportation. Operation of such services requires new information management methods; while several elements of operation of demand-responsive transportation can be adapted.

3. Alteration in Mobility Services

3.1. STA on Mobility 'Palette'

The AVs facilitate the alteration of travel modes. Future transportation modes and the alteration of existing ones are represented according to the number of passengers and flexibility in Fig. 1. The flexibility is a complex indicator depending on, for instance, temporal and spatial availability.

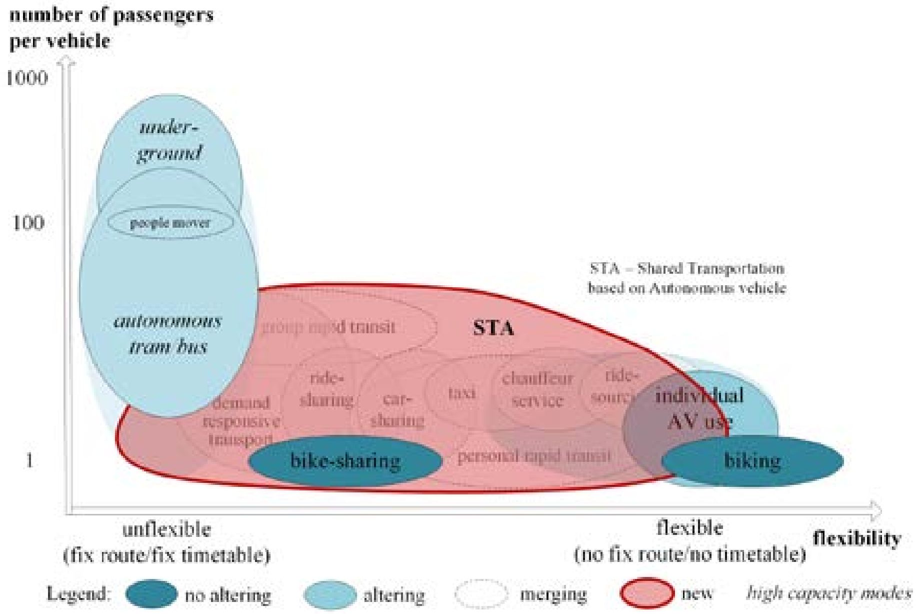

Fig. 1.
Alteration in Mobility Modes

Cycling and bike sharing are mostly unaltered. The individual motorized road transportation modes are used for the most flexible travel purposes. The other transitional modes are merging more-or-less into the new mode. This mode can serve a significant demand which was served by individual car formerly. It provides either direct service or feeder service to the high capacity public transportation lines. Since the large one-directional travel demand cannot be served by any other modes efficiently the arterial lines remain important.

3.2. STA Types

The revealed service types are the following (Földes and Csiszár, 2018):

- s_1 taxi: door-to-door service between any departure and arrival points without capacity sharing.
- s_2 shared taxi: door-to-door service between any departure and arrival points with capacity sharing.
- s_3 feeder pod: feeder service from any departure points in a zone to the stop of a high-capacity line; transfers are guaranteed by the semi-fixed timetable. The operation is symmetric in the opposite direction.
- s_4 fix route pod: mostly feeder service on fix route. The departure and arrival points are fix stops. It is operated according to the fix timetable, but additional departures may be inserted according to the current demand.

The characterization of types is summarized in Fig. 2. Car (max. 4 passengers) and pod (5-15 passengers) are distinguished as a vehicle type. The new mode is highly customized, demand-driven (or demand-responsive), and available via mobile application. Advance ordering is mandatory. A flexible tariff system is to be introduced in order to influence the demand and supply. The rates may depend on the type of service as well as the current demand and capacity. Designated meeting points and so-called smart stops are introduced where the demand is concentrated. Smart stops are equipped with electronic devices which enhance the passenger mental and physical comfort.

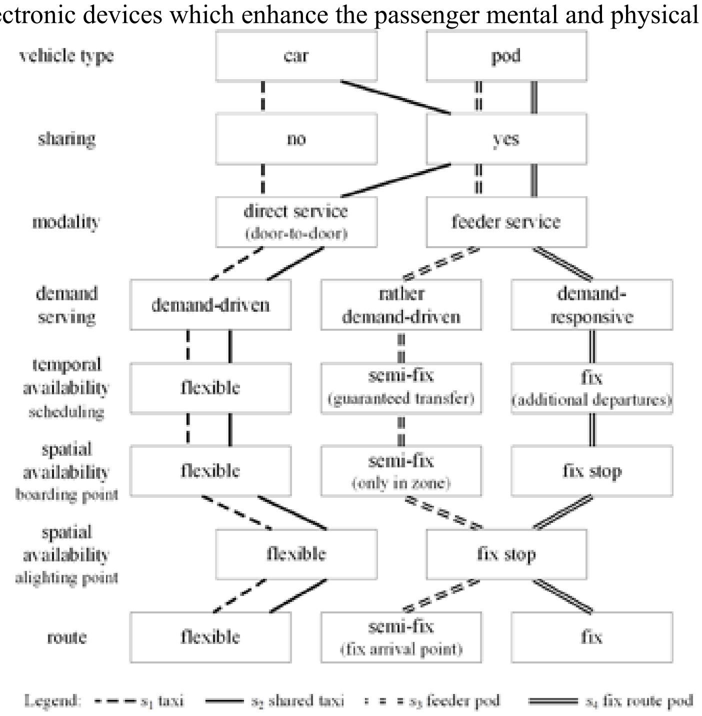

Fig. 2.
Characterization of STA Types

4. Operational Model

During modeling, we applied system engineering principles to envisage the system. Accordingly, both the structure as a framework of processes and the operation were modeled.

4.1. Structural Model

Several methodologies have been developed to address the system engineering issues, but they should be improved as the AVs are to be integrated into the mobility systems. We present the structural model in Fig. 3. The main components are represented by numbers.

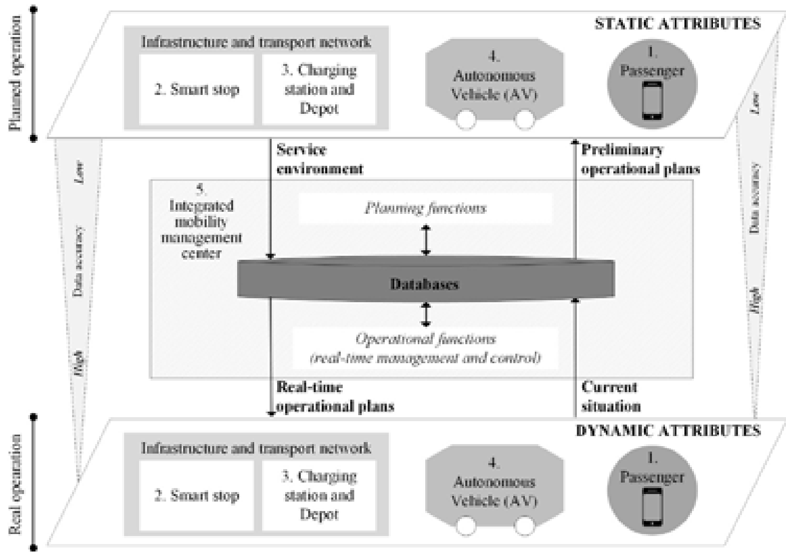

Fig. 3.
Structural Model

The dynamism is one the most significant challenge during the operation. The real-time data should be managed in an integrated manner; they are used not only for operational but for dynamic planning purposes as well. We conclude that the autonomy is a relative concept. Although the AVs are able to make decisions in traffic, the mobility system and services based on them require novel planning, operation, maintenance and traffic control methods.
The model is applicable during data modeling to identify the entities, their attributes, and the connections. The data map both the static and dynamic attributes which correspond to the planned and the real operation. The planned operation is a result of planning functions, whereas the real operation is monitored and influenced by operational functions. As the time of the transport task completion is approaching, the data accuracy is increasing because the current status of the components is getting known due to the monitoring of real-time orders. Accordingly, the dynamism of planning increasingly approximates the dynamism of the operation. The integrated database is primarily managed by the integrated mobility management center.

4.2. Operational Functions

We revealed and categorized the operational functions (Fig. 4.). The categories are represented by different colors. The functions provide data to each other; the output (result) of a function can be an input to another function. The direction of the data flow can be either one- or bi-directional which is represented by the arrows.

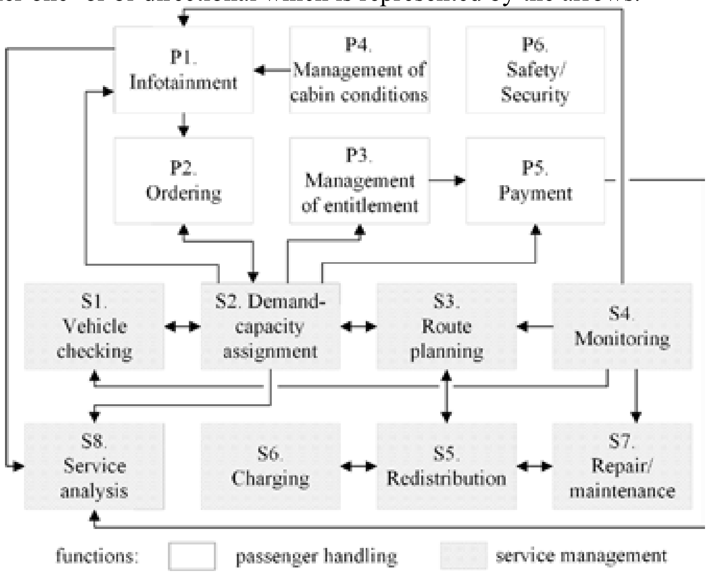

Fig. 4.
Operational Model

Service management functions

S1: the general attributes of the vehicles (e.g. status) are checked to select the serviceable ones. S2: current attributes of travelers and serviceable vehicles are compared (e.g. current direction, number of free seats) and the most appropriate vehicle is assigned to a trip. The ordering and demand-capacity assignment functions are interrelated by an 'iteration', especially in the case of shared services. Finally, information about the planned travel is provided to the passenger. S3: historical, current and forecasted data are used in the route planning function. Furthermore, the dynamic attributes of the route sections are considered. Not only the useful runs (passenger transportation) but the empty runs (approaching charging station or the next passenger) are determined. The demand-capacity assignment and redistribution depend on route planning. S4: the vehicles and the sections of runs are monitored during the travel. The automatic monitoring function provides data for the vehicle checking function (e.g. the failure of a vehicle). S5: completed vehicle runs are followed by redistribution. The vehicle is directed to either a charging point or a parking lot or sent to a zone where the potential demand is high. S6: the charging is automatized and managed by the management center. S7: the repair and maintenance are organized according to diagnostic data. S8: the mobility service is analyzed and evaluated using user feedback, travel or payment data.

Passenger handling functions

P1: the infotainment contains personalized, travel-related real-time information provision (before, during, after the travel) and entertainment functions. The information is mostly provided automatically to the personal or the on-board devices. P2: the ordering with wide-range of customized settings is mandatory, that is executed either in advance or just before the travel (ad-hoc). In this way, the capacity is utilized more efficiently. P3: the vehicles can be opened after an authentication (only the user can use the vehicle who is assigned to it). P4: the cabin condition is monitored and managed automatically or adjusted by the traveler. P5: after arriving at the destination, the price is calculated on the base of current travel, dynamic price factors, passenger discounts, etc. Several payment methods can be applied (e.g.

automatic payment based on location data). P6: the CCTV surveillance and automatized detection (advanced sensor technology) have an important role to prevent and manage safety-critical situations effectively.
Although several functions are automatized, the aid of the personnel is particularly needed in the case of special passenger groups (e.g. technically underdeveloped persons) and situations (e.g. emergency).

5. Impacts

5.1. General Impacts

The impacts of mobility services based on AVs are considerably wide. They concern society, mobility habits, traffic characteristic, management of infrastructure, and the environment of the transportation system. The most relevant qualitative impacts are summarized in Fig. 5.

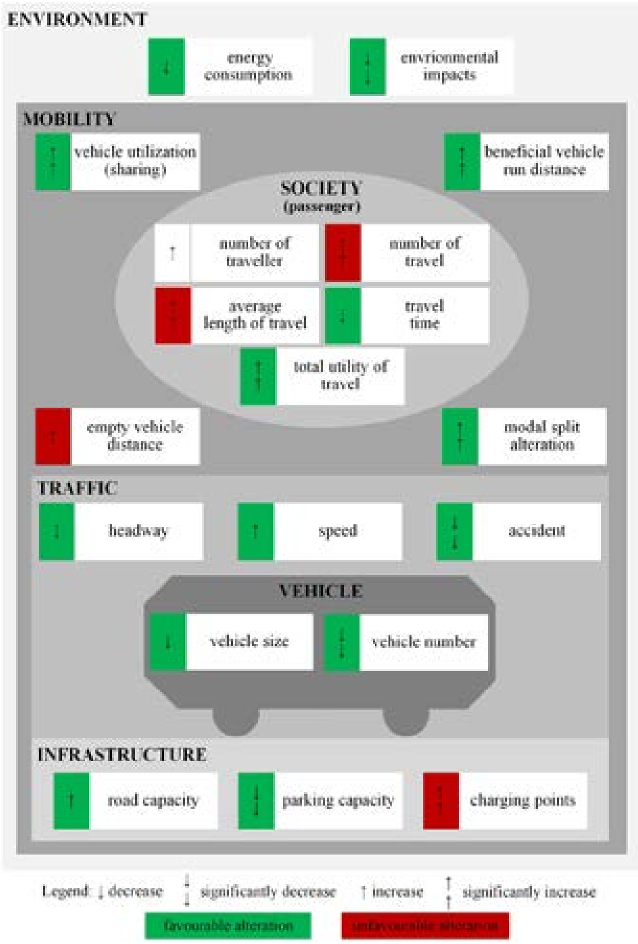

Fig. 5.
Impacts Model

The most striking challenge is to increase the user acceptance toward the AVs. The traffic flow parameters are getting worse at an early stage (Davidson and Spinoulas, 2015). However, with high AV penetration rate, advanced cruise control, and emerging V2V communication technologies, it is expected that traffic flow is getting more fluid. Headway between vehicles certainly falls, because AVs have practically zero reaction time. Significant improvements in traffic parameters (use of limited road capacity) can be achieved with the shared use of AVs as a feeder service. Due to useful (e.g. working during travel) and convenient travel, the travel time is not considered as a wasted time anymore, and thus travelers tend to travel longer distances and more frequently. Moreover, mobility service with more individual features is provided for the population segments who are unable to use private cars. Hence, during the planning STA services, the aim is to service the probably increasing travel demand by fewer vehicle. However, the individual car usage and ownership decrease as the consequence of shared AV service. But, due to vehicle redistribution processes, the length of empty runs rises. Nevertheless, replacement of own cars is rather challenging as people prefer the ownership. Since the required parking capacity corresponds to the number of vehicles and stationary traffic, similar cutdown is expected in this area. These phenomena fairly influence the urban land use. Moreover, energy consumption may be reduced as the consequence of adaptive driving. This also leads to less environmental impact.

5.2. User Expectations

The quantitative system parameters can be determined in several ways (e.g. simulation, analyzing the user expectations). We measured the user expectations by a questionnaire survey. The questions cover the respondents' socio-demographic characteristics, current mode use, willingness to shift to an STA service and expected impacts. The survey was performed via internet in Hungary in February 2018. 510 responses have been received. Most of the respondents were born after 1980, are male, high-educated and live in the capital city (Budapest).
The expectations towards the impacts of AVs are measured by rating questions. The respondents evaluated the impact-related statements using values. For instance: 'Do you agree that the total utility of the travel will increase (without driving the travel time can be spent with useful activities)?'. The 1-3 set of values according to the Likert-scale (Nemoto and Beglar, 2014) was introduced, where the meaning of the values is: 1: I do not agree, 2: I have doubt; 3: I agree. The statements were derived from the Fig. 5. Only the impacts which can be assessed without complex knowledge were considered. The average evaluation values represent the degree of the agreement. The impacts according to these values are presented in Fig. 6. The most agreed impact (energy consumption reduction) can be found on the bottom. The results are to be used to determine the focus areas to be improved. For instance, to make it obvious that the shared use of AVs results in fewer vehicle.

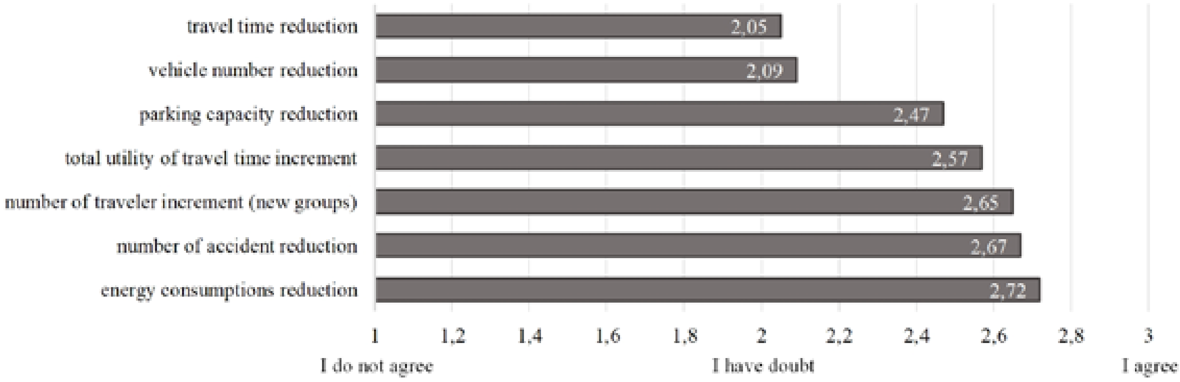

Fig. 6.
Agreement Towards Impacts

5.3. Quantitative Method for Impact Calculation - Alteration in Modal Share

In order to demonstrate the application opportunity of the survey results for determining quantitative impacts, the calculation method of modal share is elaborated and interpreted through an example. The modal share (the percentages of the use of transportation modes) can be calculated in several ways; however, the most appropriate way is to calculate it based on the covered travel distance [passenger-km]. The respondents (r_k) $k = 1..n$, the current transportation modes (m_i) $i = 1..4$ (*1*: walking, *2*: bike, *3*: car, *4*: public transportation) and the STA types (s_j) $j = 1..4$ are considered. The variables are as follows:

$_k^i l$ travel distance of r_k with m_i [km],

$_k^i f$ travel frequency of r_k with m_i in a given time interval (e.g. month) [number of travels/month],

$_k^i a_j$ willingness to shift from m_i to s_j by r_k [%].

The values of the variables come from the survey. The current modal share of m_i is indicated by M_i (1).

$$M_i = \frac{^iL}{\sum_i {^iL}} \tag{1}$$

where ^iL is the current total travel distance with m_i in a given time interval (2). During the total distance calculations, the distances covered by all the respondents are considered.

$$^iL = \sum_k {_k^i l} \cdot {_k^i f} \tag{2}$$

For the determination of future modal share the future total travel distances are calculated. $^iL_j^{'}$ indicates (3) the future total travel distance shifted from m_i mode to s_j type considering the respondent's willingness to shift $({_k^i a_j})$.

$$^iL_j^{'} = \sum_k {_k^i l} \cdot {_k^i f} \cdot {_k^i a_j} \cdot {^ic} \tag{3}$$

where ^ic is a correction factor. It is introduced to consider the proportion of the real (M_i^{real}) and the calculated (M_i) modal shares (4) in order to correct the sample if the survey is not representative. M_i^{real} is available from official data sources.

$$^{i}c = \frac{M_i^{real}}{M_i} \tag{4}$$

$^{i}L^{'}$ means the future total travel distance with m_i which is calculated by (5). It represents the remaining travel distance with m_i mode after the shifting to all the s_j types.

$$^{i}L^{'} = {}^{i}L - \sum_j {}^{i}L_j^{'} \tag{5}$$

$L_j^{'}$ means the total future travel distance with s_j after shifting from all the current transportation modes. It is calculated by (6).

$$L_j^{'} = \sum_i {}^{i}L_j^{'} \tag{6}$$

In this way, $M_i^{'}$ and $M_j^{'}$ indicates the future modal share of m_i and s_j according to (7) and (8).

$$M_i^{'} = \frac{{}^{i}L^{'}}{\sum_i {}^{i}L^{'} + \sum_j L_j^{'}} \tag{7}$$

$$M_j^{'} = \frac{L_j^{'}}{\sum_i {}^{i}L^{'} + \sum_j L_j^{'}} \tag{8}$$

In the case the current m_i mode is shifted to s_3 or s_4 types, the future travel chain contains a feeder distance and a public transportation distance if the length of travel is long enough. This feeder distance is indicated by l_j. The distance covered by the public transportation is calculated as ${}_{k}^{i}l - l_j$. Thus, the additional total travel distance (${}^{i}D_{j=3,4}^{'}$) with public transportation is calculated by (9).

$$^{i}D_{j=3,4}^{'} = \sum_k ({}_{k}^{i}l - l_{j=3,4}) \cdot {}_{k}^{i}f \cdot {}_{k}^{i}a_{j=3,4} \cdot {}^{i}c \tag{9}$$

This additional public transportation distance is added to the future total travel distance with public transportation.
We applied the method to determine the expected modal shift in Budapest. As the 2/3 of the respondents are Budapest residents, a valid (but not representative) sample is available. We 'measured' the working, shopping and leisure motivated travels by the survey. The respondents chose the appropriate categories; the categories were transformed into values.

${}_{k}^{i}l$ <1 km: ${}_{k}^{i}l = 1$, 1-3 km: ${}_{k}^{i}l = 2$, 3-5 km: ${}_{k}^{i}l = 4$, 5-10 km: ${}_{k}^{i}l = 8$, >10 km: ${}_{k}^{i}l = 12$,

${}_{k}^{i}f$ everyday: ${}_{k}^{i}f = 20$, often in a week ${}_{k}^{i}f = 15$, sometimes in a week ${}_{k}^{i}f = 10$, sometimes in a month ${}_{k}^{i}f = 5$,

${}_{k}^{i}a_j$ every time ${}_{k}^{i}a_j = 1$, every second time ${}_{k}^{i}a_j = 0.5$, never ${}_{k}^{i}a_j = 0$.

As the public transportation network in Budapest is quite dense, $l_{j=3,4} = 2$ is considered.

The current and future modal shares are presented in Fig. 7. Only the willingness to shift to STA types were considered; other impacts (e.g. promotion of soft mobility modes) were neglected. However, relevant consequences about the tendencies can be drawn. Current car users' willingness to shift is the highest, as bikers' and pedestrians' willingness to shift are the lowest. According to the stated preferences, the individual car use can be significantly reduced by the introduction of flexible shared services (STA type s_1 and s_2). However, the promotion of soft mobility modes and the shared use of AVs as a feeder service are needed in order to avoid the significant increment of motorized road traffic.

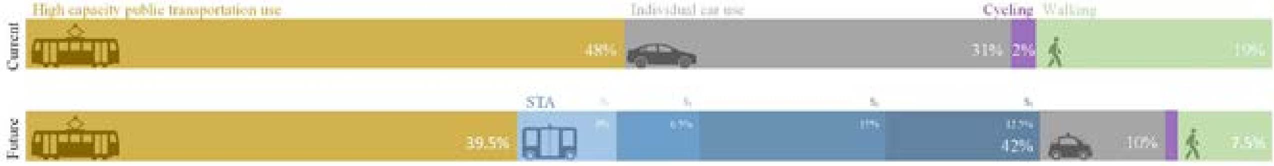

Fig. 7.
Current and Expected Future Modal Share in Budapest
Source: current modal share: Centre for Budapest Transport

6. Conclusion

The AVs and the intensifying passenger expectations require new mobility services. Operation of future passenger transportation system will be rather complex as all constituents have 'intelligence'. The main contributions are the structural, operational and impacts model of a transportation system based on AVs. The user expectations should be considered to enhance the acceptance of AVs.
Key findings include the following:

- although AVs operate in the traffic autonomously, their management requires advanced computer integrated information systems,
- several operational functions (e.g. vehicle-passenger assignment, entitlement checking) alter significantly as the vehicles are unmanned, shared and run according to the current demands,
- energy consumption reduction is expected; whereas travel time and vehicle number reduction are not expected from the spread of AVs by society,
- individual car use decreases with the application of shared AVs as the car users have high willingness to shift.

We faced, as a lesson learned, that only expectations can be measured as the AVs are still barely available. Our further research focuses on the elaboration of the operational functions and the elaboration of additional quantitative methods for impact assessment.

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QUALITY ASSESSMENT METHOD FOR MOBILITY-AS-A-SERVICE BASED ON AUTONOMOUS VEHICLES

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Abstract: The Mobility-as-a-Service (MaaS) concept is proposed to readdress the integration of transportation modes regarding information management, especially customized multimodal journey planning, booking, ticketing and payment. When conventional road vehicles are replaced by autonomous road vehicles (AVs) in the MaaS, the service processes alter significantly. Service quality reflects features of the service in an aggregated, objective way. Service quality assessment is essential for service planning and operation. The research question is how to evaluate the expected quality of this new service (MaaS based on AVs). We have identified the quality criteria, taken both user expectations and operator purposes into consideration. The Analytic Hierarchy Process method (AHP) has been applied to determine the weights. The service quality evaluation index system is established based on the criteria and their corresponding weights, a ten-point scoring method is proposed to score the expected service quality. One example is presented for demonstration purpose. The elaborated new assessment method is applicable to score the expected quality of this new service, to compare the expectations/attitudes of various groups (transportation experts, potential users, service providers, MaaS operators, etc.), in order to support decision making when planning and introducing such a new service.

Keywords: Mobility-as-a-Service, autonomous vehicles, service quality assessment, Analytic Hierarchy Process (AHP) method.

1. Introduction

The Mobility-as-a-Service based on Autonomous Vehicles (MaaS based on AVs) is a data-driven, user-centric, car-usership oriented, integrated public mobility service, which is proposed on hypothesis that high level integration of transportation modes could be realized. The MaaS operator is a new role, it acts as an intermediary between users and transport service providers. The mobility service is booked or purchased directly from the MaaS operator rather than the single service providers. The so called transitional mobility services (e.g. car-sharing, ride-sharing, ride-sourcing) are to be replaced by autonomous pod service in the MaaS based on AVs, to provide the either door-to-door or first/last mile mobility solution. The pod term covers mini, small or medium capacity vehicles. The conventional public transportation service (e.g. bus, tram, metro) remains for large volume passenger transit purpose; however, it becomes more automated or autonomous (Földes and Csiszár, 2016). We consider only one MaaS operator and focus on user-vehicle assignment of passenger transportation in urban area. Other relevant issues (e.g. goods delivery, vehicle charging, parking, reallocation) of the MaaS based on AVs belong to our further research work.
Definition of the proposed new mobility service types, elaboration of the system structure and the operational model, as well as the calculation principle of dynamic pricing, were the most relevant contributions of our previous work (He and Csiszár, 2018). Accordingly, questions of how to design, model and operate such a new mobility service have been studied. However, the service quality issues are to be still explored. Service quality reflects features of the service. Quality assessment is essential for service planning and operation. Therefore, in this paper, our main research question is how to evaluate the expected quality towards this new service. We unfold this main question into three sub-questions as following:

1. which quality assessment criteria are to be introduced?
2. how are the weights of criteria to be determined?
3. what are the application opportunities of this assessment method?

The personal flexible transit (PFT) is a mini pod service with limited capacity; one vehicle serves only one user with private space. Small group rapid transit (SGRT) is used as a shared service (with unknown people) or car-rental purpose (one user books a vehicle and share it with familiar people, e.g. friends, families); the small capacity vehicle serves 2-6 users. The special demand responsive transportation (SDRT) is defined for mobility-impaired users. The small capacity vehicles (2-6 users) are equipped with extra devices (e.g. ramp, voice-based guiding system). The group rapid transit (GRT) is a feeder service to conventional public transportation with medium capacity vehicles (7-12 users), Both, the timetable and the route are determined in advance. All these services are shared types and reservation is required to guarantee a seat. In order to provide a high-quality mobility service, users are not allowed to stand on these vehicles. Furthermore, these on-demand services may replace the conventional public transportation service in the night in case of the lower mobility demand and energy saving purpose.
The remainder of the paper is structured as follows. State of the art is summarized in Section 2. In Section 3, the service quality assessment method is elaborated; namely, establishing, scaling and weighting of quality criteria are presented, respectively. The weights of the criteria, one example to demonstrate the applicability of the assessment method, as well as the further application opportunity are as results and discussed in Section 4. The paper is completed by Section 5 as a conclusion, including further research directions.

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2. State of the Art

From the users' perspective, service quality may involve two aspects, expectation towards and perception of the service (Mugion *et al.*, 2018). Users satisfaction is also derived from the perceived quality. From the service provider's perspective, the relevant aspects are the targeted (planned) and provided quality. In our approach, the quality of the MaaS based on AVs refers to the 'bridge' between the providers' targeted and the users' expected service quality. In order to simplify, it is still called the expected service quality.

Deb and Ahmed (2018) find that both perceptions and expectations of the passengers are important to estimate the service quality. Safety, comfort, accessibility and timely performance are the most relevant factors in this analysis. In another research, waiting time, cleanliness and comfort are found as three main variables of the service quality (dell'Olio *et al.*, 2011). A research review about quality attributes of public transport concludes that service reliability, frequency as well as these attributes connected to individual perceptions, motivations and contexts are relevant ones (Redman *et al.*, 2013). In order to address the importance of service quality attributes, two customer satisfaction survey methods (questionnaires and face-to-face surveys) using the same case study of Madrid (Spain) are compared. The novelty of this study is that a comparison between two quality survey methods is provided. Furthermore, a method to estimate attribute importance directly from a stated preference survey is also elaborated (Guirao *et al.*, 2016). Service quality has a direct effect on the intention to use the public transport service and sustainable means of transportation such as car-sharing and ride-sharing more. Consequently, the use of one's own car is to be less (Mugion *et al.*, 2018).

According to the hypothesis that higher level of mobility integration is more appealing to users, the existing MaaS schemes are evaluated and compared by using several criteria (ticket integration, payment integration, ICT integration and mobility package integration) and the mobility integration index has been introduced (Kamargianni *et al.*, 2016). A compensated multicriteria method is developed to analyze and assess the quality of European carsharing systems. This method takes both the service properties and user expectations into consideration (Csonka and Csiszár, 2016). The pairwise weighting method of AHP is applied to derive priorities for different criteria for shifting urban commuters to the public transport system. Reliability, comfort, safety and cost as 'parent criteria' are identified based on literature review and expert opinion in this study (Jain *et al.*, 2014). Quality criteria of a cargo transportation service are introduced as the price of transportation, safety, reliability, accessibility of the service and duration of delivery. The weights of the criteria are determined based on the mean value of four assessments of experts. The safety criterion is assessed as the most important one regarding of competitiveness of a cargo service (Matijošius *et al.*, 2016). A multicriteria model based on user perceptions to assess urban public transport is developed and implemented in Florianópolis, Brazil. In this study, the pairwise comparison method is applied to scale evaluation descriptors and an evaluation equation is presented to calculate the aggregated value of the service quality (Barbosa *et al.*, 2017).

We conclude from the literature review that transportation service quality assessment requires rather complicated research and 'soft' (subjective) criteria are more focused in recent years. Several studies assess the service quality by applying the existing quality criteria (e.g. in the case of a bus service). Furthermore, the pairwise comparison method of AHP is also applied in several papers but with different weighting approach. Most of the quality assessment methods refer to the conventional public transportation; accordingly, quality related researches regarding the new mobility services based on AVs fill a significant 'research gap'. Our service quality assessment method presented in this paper is a new approach. We have identified the quality criteria for this new service (MaaS based on AVs), the pairwise comparison of 1-9 scaling and weighting method of AHP (Saaty, 1977) are applied to scale and weight the criteria. Then the service quality evaluation index system is established based on the criteria and their corresponding weights, a ten-point scoring method is proposed to score the expected service quality, here the quality criteria are to be graded (scored) as evaluation index. The comparison/analysis of the scored aggregated quality value is the applicable opportunity of the method.

3. Methodology

In the developed quality assessment method, both the operator purposes and user expectations have been taken into consideration. The steps of the method are summarized in Fig. 1.

Step 1: the quality criteria are determined according to the relevant research studies (e.g. mobility service operation), forecasted service properties and user expectations. This step is the real novelty of the assessment method, because this mobility service has specific new characteristics/attributes (e.g. integrated smart phone application, travel fellow selection, PFT service, opportunities of wifi and charging (phones) in vehicles). These new characteristics are highlighted and combined with the existing/old ones.

Step 2, 3, 4: the AHP method is applied to scale, check (and calibrate) and weight the criteria. The 1-9 scaling of pairwise comparison method has been applied. The weights of each level criteria regarding their corresponding upper level criteria are calculated first as local weights, then the aggregated weights of criteria regarding the service quality Q are calculated as global weights.

Step 5: the calculation method (equation) of the aggregated quality value (Q) is introduced. The assessment method is completed with the entire established quality criteria as well as their corresponding global weights.

Application step: the quality criteria are as evaluation index to be scored. The importance of each criterion (index) is ten points. The final (aggregated) value of service quality Q is calculated.

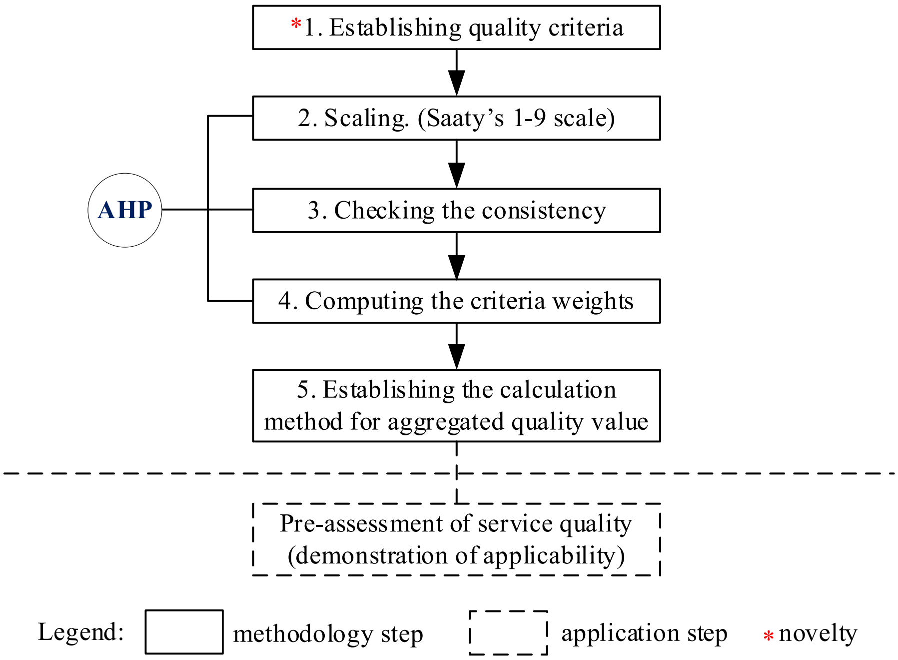

Fig. 1.
Steps of the Method

3.1. Establishing Quality Criteria

The service quality criteria have been identified according to various literature review (e.g. user expectations towards MaaS, acceptance of AVs and shared AVs, integration level of mobility services), MaaS projects (e.g. interface of smartphone application, questions of surveys, impact assessments), operational aspects (e.g. frequency, dynamic pricing, tariff structure) and forecasted service characteristics of our previous work. The hierarchical structure of quality criteria is presented in Fig. 2.

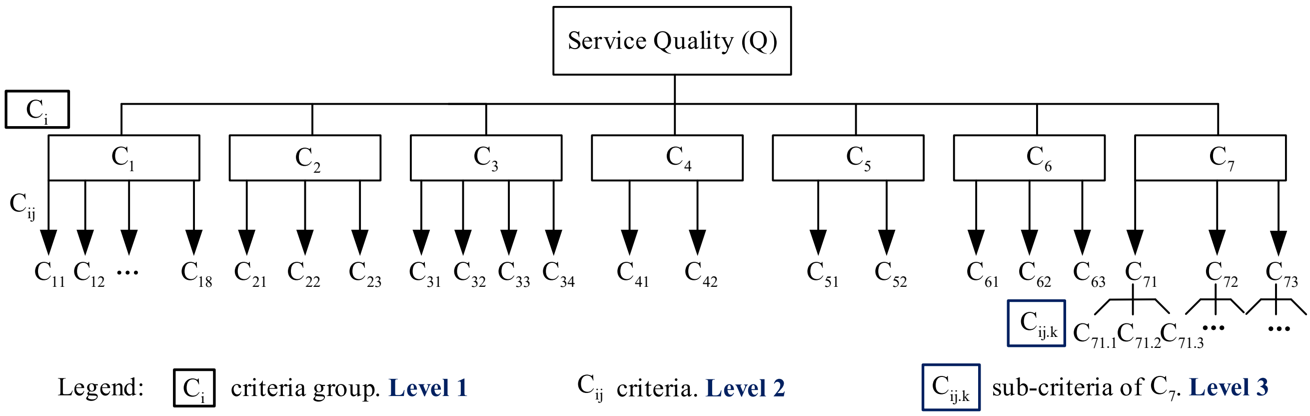

Fig. 2.
The Hierarchical Structure of Quality Criteria

Three levels of criteria are proposed. The first level criteria groups (C_i, C_1 to C_7) mainly refer to public transportation: C_2 Availability, C_3 Accessibility, C_4 Information, C_5 Time, C_6 User care and C_7 Comfort (EN.13816:2002). The C_1 Speciality group is introduced to identify the most relevant characteristics of this new service. The second level criteria (C_{ij}) are put in the focus of the assessment method, the corresponding local and global weights of each criterion is to be calculated (in this paper, weights of C_{ij} regarding C_i and $C_{ij.k}$ regarding C_{ij} are local weights, weights of C_i regarding Q and C_{ij} regarding Q are global weights). The third level sub-criteria ($C_{ij.k}$) are introduced only with the C_7 criteria group. On the one hand, 'comfort' is a quite subjective criteria group, the single criteria are not enough to describe it in detail. On the other hand, users are willing to pay more for the higher comfort service, and comfort can be improved with less effort compared to other criteria related aspects.

The elaborated service quality criteria are presented in Table 1. The other public transportation related criteria groups are eliminated or merged, e.g. security, environmental impact (EN.13816:2002). As the security and safety issues of AVs are still not matured enough (laws, regulations, responsibility, etc.), the pairwise comparison of their importance with importance of other criteria is not possible. The emergency management is considered with criterion C_{61}. Namely, during establishment of the quality criteria Table 1, we assume that the basic requirements of security and safety are met. Environmental impact C_{16} as a criterion belong to C_1 Speciality.

Table 1
Service Quality Criteria

Criteria			Details	
C_i	C_{ij}	name	description/ $C_{ij.k}$	
C_1 Speciality	C_{11}	**integrated smart phone application**	integration of function of planning, booking, ticketing and payment in one application	
	C_{12}	**travel fellow selection**	user can choose (sympathetic) travel fellow	
	C_{13}	seat position selection	for SGRT and SDRT service	
	C_{14}	application reminders	calendar/transfer point reminder, etc.	
	C_{15}	personalization	recommendation of preferred route, trip, combination of transportation modes, etc.	
	C_{16}	environmental impact	battery electricity vehicles, lower pollution	
	C_{17}	**PFT service**	individual mini pod transit	
	C_{18}	dynamic pricing	variable price, similar approach as in the case of Uber	
C_2 Availability	C_{21}	operating hours	24 hour, non-stop	
	C_{22}	frequency/regularity	timetable (GRT) or on-demand service	
	C_{23}	average distance to reach the service	GRT (distance $\leq$ 250m)	
C_3 Accessibility	C_{31}	**ticketing and payment**	electronic ticket, one ticket for an entire journey, etc.	
	C_{32}	ticket validation	QR code scanning or NFC technology	
	C_{33}	booking	instant booking or pre-booking	
	C_{34}	tariff structure	pay per use, monthly package, etc.	
C_4 Information	C_{41}	real-time information	vehicle tracking, current network condition, boarding/alighting points identification, emergency information, etc.	
	C_{42}	feedback	suggestion or complaint	
C_5 Time	C_{51}	estimated time	trip time, transfer time, etc.	
	C_{52}	punctuality	delay $\leq$ 5minute	
C_6 User care	C_{61}	emergency services	E-call, etc.	
	C_{62}	user support service by personnel	24 hours	
	C_{63}	**special care (for impaired)**	wheelchair space, ramp, human assistance, etc.	
C_7 Comfort	C_{71}	supplementary service	$C_{71.1}$	**charging (phones) in vehicles**
			$C_{71.2}$	**wifi in vehicles**
			$C_{71.3}$	**entertainment devices and services**
	C_{72}	vehicle condition	$C_{72.1}$	cleanness of vehicle (both outside vehicle body and inside cleanness, e.g. window, seat.)
			$C_{72.2}$	odour (smell) in vehicle
			$C_{72.3}$	ergonomic design (e.g. seat comfort)
	C_{73}	waiting station (GRT)	$C_{73.1}$	cleanness
			$C_{73.2}$	seating opportunity
			$C_{73.3}$	weather protection

Such an envisaged, integrated, multimodal mobility service is to be realized via a single interface on smartphones, therefore the C_{11} integrated smartphone application is chosen as an important criterion to assess the functionalities of journey planning, booking, ticketing and payment. In the case of SGRT and SDRT services, users may have the opportunity to select the travel fellow (C_{12}) and seat position (C_{13}). Accordingly, travel fellow selection relate feeling of security and comfort. The function of application reminder C_{14} (e.g. calendar reminder, vehicle arrival reminder) is more and more embedded in the existing MaaS smartphone applications; however, this tendency may be clearer in the applications of the MaaS based on AVs. Function of smart recommendations according to users' preferences and behavior is already embedded into other information services, e.g. e-shopping (Amazon), entertainment (Youtube, music player), e-news. Such function (C_{15} personalization) is to be considered also for mobility services, e.g. recommendation of travel time and shortest route according to users' preferred routes/combination of transportation modes. PFT service C_{17} is listed individually, because the size of vehicle may be an advantage of parking space. The similar approach is as in the case of Uber service, price is charged according to real-time demand. C_{18} dynamic pricing is applied to better conciliate the demand and capacity (e.g. lower price is charged by pre-booking, because the time is enough to coordinate tasks and optimize the vehicle run).

3.2 AHP: Scaling and Weighting

The multicriteria analysis method is widely used to support decision making (San Cristobal, 2012). The AHP method is one method of multiple criteria decision analysis (Bhushan and Rai, 2004). In our work, the elaborated hierarchical structure of the criteria is the base of AHP method, then the Saaty's 1-9 scale method (Saaty, 1977) is applied to scale pairwise comparisons. The numerical values towards pairwise comparisons are presented in Table 2. The 'element(s)' word in Table 2 refer to the criteria (criterion) in this paper.

Table 2
Saaty's 1-9 Scale

Numerical values	Option (verbal scale)	Explanation
1	**equal** importance of two elements	two elements contribute equally
3	**marginally strong** importance of one element over another	experience and judgement favor one element over another
5	**strong** importance of one element over another	one element is strongly favored
7	**very strong** importance of one element over other	one element is very strongly dominant
9	**extremely strong** importance of one element over another	one element is favored by at least an order of magnitude
2, 4, 6, 8	**intermediate values** to reflect **fuzzy inputs**	used to compromise between two judgments
reciprocals	reflecting dominance of second alternative compared with the first	relative comparison

Source: (Saaty, 1977), (Bhushan and Rai, 2004)

Considering the hierarchy levels, the criteria groups (C_i), criteria (C_{ij}) and sub-criteria ($C_{ij.k}$) are all scaled by pairwise comparisons within each level. The scaling results are square matrices (the comparison matrices). The comparison matrix of second level criteria M_i are as examples and presented as following:

$$M_i = \begin{bmatrix} 1 & x_{12} & \cdots & x_{1j} \\ x_{21} & 1 & \cdots & x_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ x_{j1} & x_{j2} & \cdots & 1 \end{bmatrix}$$

Where i is the index number of criteria group C_i, M_i is the comparison matrix of criteria C_{ij} regarding C_i. j is the index number of criteria. For example, M_1 is the comparison matrix of C_{11} to C_{18} within criteria group C_1. x_{12} is the scale value of the importance of C_{11} and C_{12}. All values on the primary diagonal are 1. Because of pairwise comparison and according to Table 2 (reciprocals), $/x_{j1}=1/x_{1j}/$. From matrix M_1 to M_7, together with M_{71}, M_{72}, M_{73}, as well as the matrix M^* contained C_1 to C_7, totally 11 matrices are established at first. We use the comparison matrix M_3 of criteria C_{31} to C_{34} to demonstrate in detail.

$$M_3 = \begin{bmatrix} 1 & 1 & 2 & 2 \\ 1 & 1 & 3 & 1 \\ 1/2 & 1/3 & 1 & 1/2 \\ 1/2 & 1 & 2 & 1 \end{bmatrix}$$

x is used to represent the scaling value. For example, $/x_{21}=1/$ is the scale value of criterion C_{32} compared with C_{31}, namely, the ticket purchase method (electronic ticket) has equal importance of the ticket validation method (QR code scanning or NFC technology). $/x_{23}=3/$ is the scale of criterion C_{32} compared with C_{33}, namely, the favor of criterion ticket validation method is marginally stronger than the booking method (instant booking or pre-booking), and $/x_{32}=1/3/$ represent the importance of C_{33} is marginally weaker than the C_{32} (Table 2, reciprocals). There is no strict rule towards how to scale the value of 'importance', according to the fuzzy approach (Table 2) of Saaty's method, value depends on the individual 'favor' (or according to experience) which criterion. In the presented example M_3, the ticket validation method is more important by assuming that users prefer the quicker ticket checking process in general. Several users may prefer the booking method and opposite scaling value may occur. The AHP is a kind of open method, but the relatively subjective scaling process are controlled by the further consistency checking step. All the scaled matrices are checked by Saaty's method, the consistency of those matrices is ensured at a mathematical theory level. The other criteria are pairwise compared in the similar way. The scaling of the criteria is according to the general experience, literature review, comparison of existing MaaS models, etc. In our work, 1-6 scale is applied for all the matrices (the introduced criteria are with similar importance, without wide gap towards importance between two criteria), except M_4 matrix, where 1-8 scale is introduced (compared C_{42} feedback, the importance of C_{41} real-time information is quite stronger, the scale 8 is assigned).

The next step is to check the consistency of the comparison matrices by Saaty's Consistency Index (CI) and Consistency Ratio (CR). The checking requirement is $/CR < 0.1/$ (Saaty, 1977). If $/CR > 0.1/$, then the examined matrix has to be adjusted or redone (re-examined). CI is calculated by equation (1).

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{1}$$

$\lambda_{\max}$ is the maximum and principal eigenvalue of matrix M_i, and n is the rank of matrix M_i, M_i is square matrix with $n \times n$. W is the eigenvector of matrix M_i. $\lambda_{\max}$ and W are to be calculated by equation (2).

$$\left(M_i - \lambda_{\max} \cdot I\right) \cdot W = 0 \tag{2}$$

Replace CI with the equation (1), CR is to be calculated by equation (3)

$$CR = \frac{CI}{RI} = \frac{\lambda_{\max} - n}{RI \cdot (n-1)} \tag{3}$$

Where RI is the random consistency index to determine whether M_i is a consistency matrix or not. The value of RI is presented in Table 3.

Table 3

Values of the Random Index (RI)

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

Source: (Saaty, 1977), (Bhushan and Rai, 2004)

The calculation processes of consistency checking (as well as the further weighting/calculation steps) of comparison matrices are done in Matlab. The value of $\lambda_{\max}$ and checking results of CR are listed in Table 4. The values are round to two decimals.

Table 4

$\lambda_{\max}$ and Value of CR of Each Comparison Matrix

matrix	M^*	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_{71}	M_{72}	M_{73}
$\lambda_{\max}$	7.74	8.92	3.09	4.08	2	2	3.09	3.07	3.09	3.05	3.07
CR	0.09	0.09	0.08	0.03	0	0	0.07	0.06	0.08	0.05	0.06

By adjustment and calibration, all the checked $/\ CR < 0.1\ /$, consistency of established comparison matrices are acceptable. Then the corresponding normalized right eigenvector regarding the principal eigenvalue $\lambda_{\max}$ of comparison matrix are calculated as local weight of each criterion. First step is to normalize the corresponding eigenvector W_i of the principal eigenvalue $\lambda_{\max}$. The principal eigenvalue $\lambda_{\max}$ and the corresponding normalized right eigenvector W_i of the comparison matrix present the relative importance of the various criteria being compared. The elements of the normalized eigenvector (each $/\ w_{ij} / \sum_{j=1}^{i} w_{ij}\ /$) are local weights with respect to the criteria or sub-criteria. The corresponding global weight (aggregated weight) of each criterion is multiplication of the corresponding local weights (e.g., regarding the service quality Q, the weight of criteria C_1 is W_1, the local weight of criterion C_{11} regarding C_1 is w_1, then the global weight of C_{11} regarding the service quality Q is / $w_{11} = W_1 \times w_1$ /).

$$W_i = \begin{bmatrix} \frac{w_{i1}}{\sum_{j=1}^{i} w_{ij}} \\ \frac{w_{i2}}{\sum_{j=1}^{i} w_{ij}} \\ \vdots \\ \frac{w_{ij}}{\sum_{j=1}^{i} w_{ij}} \end{bmatrix}$$

3.3. Establishing the Calculation Method for Aggregated Quality Value

The service quality assessment method is completed with the corresponding global weights of the first level criteria group and the second level criteria. In the further application step, the criteria group C_i and criteria C_{ij} act as evaluation index to be scored (graded) in order to obtain the aggregated service quality value Q. The aggregated single value is easier to be compared when supporting for decision making. The aggregated quality value Q calculated by the weights W_i and scores S_i of criteria group C_i is presented with equation (4). The aggregated quality value Q calculated by the weights w_{ij} and scores s_{ij} of criteria C_{ij} is presented with equation (5).

$$Q = W_1 \cdot S_1 + W_2 \cdot S_2 + \cdots + W_7 \cdot S_7 \tag{4}$$

And

$$Q = w_{11} \cdot s_{11} + w_{12} \cdot s_{12} + \cdots + w_{73} \cdot s_{73} \tag{5}$$

The weights and scores of third level sub-criteria are not taken into calculation directly. Only C_7 is developed with sub-criteria, these relevant weights ($w_{7j.k}$) and scores ($s_{7j.k}$) are to be used for analysis purpose (e.g. the potential service improvement aspects) in service feedback phase (e.g. survey of service satisfaction).

4. Results and Discussion

The global weight table of first level criteria group C_i and second level criteria C_{ij} are as most relevant results presented in Table 5. The entire quality criteria with aggregated (global) weights are listed, C_1 Speciality (0.27), C_3 Accessibility (0.11), C_4 Information (0.20) and C_7 Comfort (0.24) criteria groups are considered with higher weights. The results adhere to the characteristics of this new service, which are highlighted with Speciality. The mobility system of future may be a combination of transportation and information system, the real-time information is the backbone of such mobility services. On the one hand, the interoperability among the service providers and traffic control is realized and enhanced by the real-time information. On the other hand, the acquisition of real-time information is essential for the users, especially the real-time traffic condition reminder. The criteria C_{11} integrated smart phone application (0.07), C_{17} individual mini pod transit (0.07), C_{41} real-time information (0.19), C_{52} punctuality (0.06), C_{71} supplementary service (0.07) and C_{72} vehicle condition (0.14) are assigned with relatively higher weights. The MaaS operator, the service providers and the users are connected by the smartphone application. PFT service is regarded as opportunity to attract more private car users to try this 'semi-public' mobility service (private service experience in public vehicle). Service loyalty towards users could be affected by the punctuality. Connected AVs are in a wireless network, such wifi and charging (phone) requirement of users may have opportunities to be managed.

Considering the decimal form of the calculated weights and the potential aggregated service quality value Q, the importance of each criterion (C_i, C_{ij}) is 10 points when scoring the service quality criteria towards the evaluation index (criteria) system. Following one evaluation example is presented. The used numerical values have been determined by assumptions and are applied only for demonstration purposes.

Scoring example of criteria groups (C_1 to C_7) and second level criteria (C_{11} to C_{73}) is presented in Table 6. Scoring/grading of criteria groups is a kind of fuzzy scoring, because detailed description or judging criteria do not support this process. As the scored numerical values are according to experience more, the result is as a fuzzy/estimated value. According to equation (4), the aggregated quality value /Q_1 = 8.03/. Different scoring values may occur (e.g. criterion with higher weight may be scored with lower value) scoring for second level criteria. With detailed judging criteria description support (Table 1), not only according to subjective experience, but more objective score value is to be offered. For example, criteria group C_1 Speciality is scored according to general experience without knowing details of this new service. By supported by C_{11} to C_{18} scoring is clear about the quality criteria (evaluation index): the smartphone application with integrated functions, the selection of travel fellow and seat position, the PFT service, etc. The evaluation is unfolded by the hierarchical level of assessment criteria (index) step by step. The more detailed third level sub-criteria are also possible to be established, but considering the time limitation of questionnaire survey, two or three level criteria are sufficient for operation and analysis purpose. According to equation (5), the aggregated service quality value /Q_2 = 7.71/. 7 numerical values are in aggregation towards Q_1, 25 numerical values are in aggregation towards Q_2. From literature review, we also conclude that most quality assessment criteria (evaluation index system) applied three level evaluation method (e.g. Csonka and Csiszár, 2016; Jain *et al.*, 2014; Matijošius *et al.*, 2016; Barbosa *et al.*, 2017), such kind of three level assessment criteria is introduced as a comprehensive evaluation approach.

Table 5
Quality Criteria with Global Weights

	Q : **Service quality**		
	Sign	**Criteria**	**Weight**
C_1 Speciality (0.27)	C_{11}	integrated smart phone application	**0.07**
	C_{12}	travel fellow selection	0.01
	C_{13}	seat position selection	0.02
	C_{14}	application reminder	0.01
	C_{15}	personalization	0.04
	C_{16}	environment impact	0.04
	C_{17}	individual mini pod transit	**0.07**
	C_{18}	dynamic pricing	0.01
C_2 Availability (0.05)	C_{21}	operating hours	0.01
	C_{22}	frequency	0.01
	C_{23}	average distance to reach the service (GRT)	0.03
C_3 Accessibility (0.11)	C_{31}	ticketing and payment	0.04
	C_{32}	ticket validation	0.03
	C_{33}	booking	0.01
	C_{34}	tariff structure	0.03
C_4 Information (0.20)	C_{41}	real-time information	**0.19**
	C_{42}	feedback	0.01
C_5 Time (0.07)	C_{51}	estimated time	0.01
	C_{52}	punctuality	**0.06**
C_6 User care (0.06)	C_{61}	emergency device	0.03
	C_{62}	user support service by personnel	0.02
	C_{63}	special care (for mobility-impaired)	0.01
C_7 Comfort (0.24)	C_{71}	supplementary service	**0.07**
	C_{72}	vehicle condition	**0.14**
	C_{73}	waiting station (GRT)	0.03

The first research question, which quality assessment criteria are to be introduced, is answered by Table 1. The second research question, how are the weights of criteria to be determined, is answered by the sub-section 3.2 and the results presented in Table 5. However, the third research question, what are the application opportunities of this assessment method, is to be answered and discussed as following.

The aggregated Q values are to be regarded as the expectations/attitudes towards this new service (the MaaS based on AVs). The expected service quality evaluation survey among several groups (e.g. experts of transportation engineering, potential service providers, MaaS operator, users, it is assumed that they are all potential end-users of this service) are to be conducted as further application work to collect data. The expectation of service quality Q (mean value) is to be revealed by calculation result. These mean values are to be grouped (e.g. quality mean value of experts, quality mean value of service providers), an expected quality value interval is to be set in order to support decision making (e.g. a reference towards the targeted quality level) when planning such a new service. This assessment method is also applicable in the users' satisfaction survey (service implementation and perception phase). The design of user satisfaction questionnaire and analysis of survey results could be supported by established assessment method.

Establishing a quality evaluation index (criteria) system for this new service and present a method to calculate the aggregated, (expected) quality value is the aim of our work, but it is not the goal of service quality assessment. It is more valued to decrease the gap between the expected and perceived service quality in future application phases. Further applicable improvement solution is to be revealed via scoring/grades analysis (e.g. criterion with low scoring value is the improvement opportunity), in order to deliver a high level of user satisfied service.

Table 6

Quality Score Aggregated by C_i and C_{ij}

Criteria group and Weight (W_i)		**Q_1 = 8.03**	**Q : Service quality**			**Q_2 = 7.71**
	Scoring	**Score (S_i)**	**Sign**	**Scoring**	**Weight (w_{ij})**	**Score (s_{ij})**
C_1 Speciality (0.27)	9	**2.43**	C_{11}	9	**0.07**	**0.63**
			C_{12}	6	0.01	0.06
			C_{13}	5	0.02	0.10
			C_{14}	5	0.01	0.05
			C_{15}	6	0.04	0.24
			C_{16}	8	0.04	0.32
			C_{17}	7	**0.07**	**0.49**
			C_{18}	7	0.01	0.07
C_2 Availability (0.05)	7	0.35	C_{21}	6	0.01	0.06
			C_{22}	7	0.01	0.07
			C_{23}	5	0.03	0.15
C_3 Accessibility (0.11)	8	**0.88**	C_{31}	8	0.04	0.32
			C_{32}	8	0.03	0.24
			C_{33}	7	0.01	0.07
			C_{34}	8	0.03	0.24
C_4 Information (0.20)	8	**1.6**	C_{41}	9	**0.19**	**1.71**
			C_{42}	5	0.01	0.05
C_5 Time (0.07)	7	0.49	C_{51}	8	0.01	0.08
			C_{52}	9	**0.06**	**0.54**
C_6 User care (0.06)	6	0.36	C_{61}	8	0.03	0.24
			C_{62}	6	0.02	0.12
			C_{63}	8	0.01	0.08
C_7 Comfort (0.24)	8	**1.92**	C_{71}	4	**0.07**	**0.28**
			C_{72}	9	**0.14**	**1.26**
			C_{73}	8	0.03	0.24

5. Conclusion

The existing MaaS projects are under development or in implementation phase, the MaaS based on AVs is considered as the future solution. Integration of transportation modes has been emphasized for long time and driverless characteristic of vehicles is a new advantage regarding information management processes. The MaaS concept is incorporated with AVs to provide a high-quality mobility service, in order to attract more private car users to use the high-quality, personalized public transportation service.

The main contribution and novelty of our work was that we identified the quality criteria and introduced the calculated weights for this new service. AHP method was applied. The elaborated assessment method is applicable for decision making when planning and introducing such a new service.

We faced, as a lesson learnt, it was difficult to scale the subjective quality criteria, as well as assigned them with appropriate weights.

The further research directions are:

- assessment and comparison of existing MaaS models by applying multicriteria analysis methods,
- elaboration of information system model for autonomous mini pod service.

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ONE APPROACH FOR ADVERSE WEATHER IMPACT ANALYSIS ON URBAN TRANSPORT SYSTEM

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Abstract: Regardless of the resilience and level of cities development, it is generally known that adverse weather conditions impact on urban transport system functionality and performances. Nowadays, level of technology development and information systems enables the predictability of adverse weather conditions. Despite this, weather condition impact usually is not implemented in models and procedure which are used in transportation planning and traffic management. Changes in environment characteristics caused by different weather conditions affect the changes in behaviour of transportation system users. Weather conditions impact can be observed through two aspects, in user decisions that precede the movement and in user behaviour during the movement. First aspect is closely related to transport demand characteristics which are described by trip generation, modal split, time distribution, etc., while the second aspect is closer to transport supply characteristics which are described by street network capacity, travel time, level of service etc. Research of weather impact on transport system is a very complex task bearing in mind the interaction and interdependence between transport demand and transport supply. Also, transport system is dynamic, with many numbers of other influencing factors which makes it more difficult to evaluate and quantify only weather condition impact. In order to get comprehensive results about adverse weather impact on transportation system it is necessary to realize both, research of changes in transport demand as well as in transport supply characteristics. Quantification of weather impact on transportation system represents the first step in reduction and mitigation negative effects caused by weather conditions. In this paper one approach of adverse weather impact analysis on urban transport system will be presented.

Keywords: urban transport system, weather condition impact.

1. Introduction

For the last decades in transportation sector great efforts are being made to reducing the negative impact on environment through various transport policies and technologically solutions. Special attention is paid to reducing greenhouse gas emissions that transport directly contributes to climate change. In this paper, the emphasis will be on the feedback of the mentioned impact, i.e. it will be analyzed how climate change affects the transport system.
Definition of climate issued by the International Panel on Climate Change (IPCC), said " *Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period…*" (Intergovernmental Panel on Climate Change, 2007). It is evident that climate change results in changing the weather characteristics and it can be said that transportation system users through weather conditions are directly facing with the consequences of climate change.
Although it is known that adverse weather conditions affect the reduction of the functionality and efficiency of the transport system, consequences of climate change and weather conditions impact on the transportation system have not yet received the necessary attention in the literature (Böcker, Dijst, & Prillwitz, 2013; Clifton, Chen, & Cutter, 2011; Koetse & Rietveld, 2009). In order to estimate impact of climate change on transportation system it is necessary to understand and quantify the weather condition impact on transport system.
Previous research, have identified the weather condition impact on transport demand, traffic safety and through the impact on traffic infrastructure and transportation system user behavior impact on the transport suply (Maze, Agarwai, & Burchett, 2006) as the most significant.
Traffic safety is a very important criteria for transportation system quality, but in this paper the emphasis will be on analyzing the weather condition impact on transport demand and transport supply. Very often, imbalance between previously mentioned values can lead to traffic congestion which is most common consequence of adverse weather conditions impact, especially in urban areas.
The causes of this imbalance can be explained by the analysis of three possible scenarios:

- adverse weather conditions affect changes in transport demand,
- adverse weather conditions affect changes in transport supply,
- adverse weather conditions affect changes in both, transport demand and transport supply.

Within the first scenario, it is necessary to examine how adverse weather conditions influences changes in the basic travel demand characteristics, the total number of movements, mobility, spatial distribution, mode distribution, distribution by purpose and time distribution. Bearing in mind that, special attention should be paid to changes in the mobility, mode and time distribution as results of weather conditions impact on the individual transportation system user decision. On the other hand, it can also be assumed that there are no changes in the transport demand characteristics, but adverse weather conditions influences exclusively changes in the transport system supply. In that case, attention should be paid to the analysis of weather condition impact on changes in traffic flow characteristics.
For real estimation how weather condition impact transportation system it is not enough to make selective and separate survey on particulare segment or element of transport system, but it is neccesary to make comprenhensive analysis of

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weather condition impact on transport system in both, transport demand and supply. Based of that fact, during last years survays about weather condition impact on transport system were realised in Belgrade.

2. What is Adverse Weather Conditions From Urban Transportation Point of View

Research of weather impact on the urban transportation system was additionally intensified by actualization of climate changes problem as global phenomena for last decades. Through the literature, the most frequently weather conditions which impact were analyzed are precipitation and temperature, les often wind and ice.

One of the main conclusions of the Stern report (2007) is that benefit from intensive and preventive action on climate change outweighs the potential costs that climate change can cause. Also, in a situation of comprehensive action to mitigate the effects of climate change, the results would be visible after a long period of time. Since climate change is a global problem, it is very difficult to implement preventive measures on a global level (Stern, 2007). In such a scenario, the key to dealing with the effects of climate change is adaptation which implies an analysis of the possibilities and capabilities of urban transportation system adaptation to adverse weather conditions. Of course, after the adaptation as a transitional phase, all attention and energy should be focused on measures for climate change mitigation.

Adverse weather conditions from a geographic point of view are very relative terms, i.e. they are often described and defined according to different criteria. For example, In Glasgow (Scotland), as a European city with a significant number of rainy days during the year, and Seville (Spain) as a city with a significant number of sunny days and high temperatures, there are definitely differences in criteria for adverse weather conditions. The fact is that residents of a certain geographical area are adapting to the climate characteristics over time, and in that way they form the criteria. From transportation users point of view any change in weather conditions that results in a change of transportation user behavior should be taken into consideration.

There are different criteria for defining adverse weather conditions. Kyte (2001) presented the criteria which is describing the ideal weather conditions for transportation system functioning. Ideal conditions include (Kyte *et al*, 2001): dry surface, no precipitations, good visibility (more than 0.4km) and wind intensity lower than 16 km/h. As additional criteria for idea weather conditions it is also stated that the temperature should be above 10°C, which can fulfill the above mentioned criteria (Tsapakis et al., 2013).

In the initial analysis of weather conditions impact on the transportation system, it was usual research the difference between dry weather and some type weather conditions impact, such as rain or snow no taking into account the intensity of rain or snow. In more recent research, the impacts began to be analyzed and categorized in more detail. The categorization of impacts is mainly related to the intensity of the analyzed type of adverse weather conditions (Wang *et al.* 2006; Asamer & Van Zuylen 2011; Highway Capacity Manual 2010). In some research, as additional criterion to the intensity, the probability and frequency of adverse weather conditions occurrence in the research area were taken into account (Ivanovic & Jovic, 2017.).

Considering that the weather conditions are variable in both, spatial and temporal component, it is very important to obtain reliable data on their characteristics in the entire analyzed area. Also, for preventive action on negative consequences mitigation it is very important to have technology which can provide quality weather condition forecast.

3. How to Quantify the Weather Conditions Impact on Transport Demand?

Transport demand arises as a result of spatial separation of points where people meet their life needs such as habitation, business, school, shopping, entertainment, etc. In addition to the spatial separation of the origin and destination points every movement is characterized by the time, duration, purpose and mode of movement.

In analisis of the adverse weather conditions impact on the transport demand, it is important to examine and quantify the deviations caused by adverse weather conditions in aforementioned characteristics of transport demand. Even without previously carried out research, it can be assumed that weather conditions will not impact in the same way on each of the above characteristics, i.e. the consequences in the changes will not be the same.

For example, if it comes to commuters, it is very unlikely that weather conditions will affect the change in origin and destination points of movement, as well as of purpose, while in terms of the mode of movement, time and the duration of the movement, the likelihood for the changes increase. On the other hand, when it comes to movement for the purpose of shopping there is a greater likelihood of a change in the destination point in relation to initially planned, or even postponing or canceling movements under the influence of adverse weather conditions. Based on this it can be seen that determining the impact of adverse weather conditions on the transport demand characteristics is a complex task. Although it can be assumed that the consequences on the transport demand realization can be affected by weather condition, in order to mitigate negative consequence that impact must be quantified.

Impact of weather conditions on transport demand are most often analyzed in urban areas with an exceptionally high share of non-motorized movements in the total number of daily movements. This type of research is also important in areas that do not have a significant share of non-motorized movements in the mode distribution, because the weather conditions can influence both the redistribution between non-motorized and motorized modes, as well as between public transport and passenger cars. It would be implemented in traffic management strategies, considering great share of motorized movements (Petrović, 2017).

In the period from 2014 to 2016 in the city Belgrade were realized stated-preference and revealed-preference surveys about commuter behavior in different scenario of weather conditions. Most questions were related to changes in transport mode and mobility i.e. number of movements per day.
This type of research did not require a high level of detail in weather conditions categorization, i.e. intensity of weather condition is not quantify. The real transport demand characteristics of Belgrade commuters are recorded during days which belong to one of the following types of weather conditions:

- warm mostly dry days (Type 1);
- moderately warm days with high precipitation (Type 2);
- moderately cold, mostly dry days (Type 3); and
- cold days with heavy precipitation (Type 4).

The following Figure present some results related to the number of movements and mode distribution in different types of weather conditions (Figure 1).

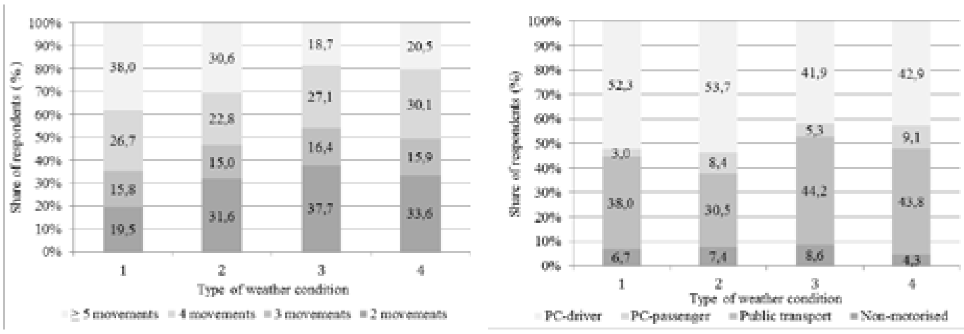

Fig. 1.
Number of movements and mode distribution in different types of weather conditions
Source: (Petrović, 2017)

The results obtained from the survey showed that the weather conditions affect the number of movements and choice of transport mode. Number of commuter movements does not vary, but the number of total movements during the day varies in different weather conditions due to changes in the optional movements that the employed residents do. A certain number of commuters change the transport mode for going to work and other purposes of movement in accordance to changes in weather conditions.
Weather conditions have a different impact on obligatory movements, in relation to non-obligatory purposes of movements. Based on the data collected by the research, a trip generation model in different types of weather conditions was developed, as well as model of transport mode distribution with a focus on the commuter trip. Based on the data collected by the research, trip generation model in different types of weather conditions has been developed, as well as a model of transport mode distribution with a focus on commuter trip. Developed models, which contain the impact of weather conditions and socio-economic characteristics of the individual on the trip generation and mode distribution, are in accordance with modern modeling procedures that take into account transportation user behavior. The developed models for trip generation and mode distribution for commuters in different weather conditions is proof that the weather conditions impact on transport demand can be quantified and have to be introduce in transport demand models.

4. How to Quantify the Weather Conditions Impact on Transport Supply?

When it comes to researching the impact of adverse weather conditions on the transport supply, the focus is mainly on changes in traffic flow parameters and street network capacity. These two characteristics are in a strong correlation, because street network capacity is changing through the influence on traffic flow parameters.
The first researches in this area were realized on non-urban motorway and highway section, i.e. on non-interrupted traffic flows. The assumption is that one of the reasons was a simpler procedure for determining the changes in correlation between the basic traffic flow parameters under the weather conditions impact. Also, with that road choice all other impacts such as intersections, public transport stops, parking places, etc., which could be affect in traffic flow parameters variation are eliminated. On the other hand, the first modern equipment for traffic flow characteristics recording is mainly installed on high-capacity roads characterized by high traffic flow.
Urban areas are characterized by interrupted traffic flows. The elements of traffic management and control at intersections are interrupting the traffic flows on the street network. Parameters, which are most frequently used in the analysis of urban traffic flows characteristics, are saturation flow and time delay. If it is assumed that the elements of traffic management are optimized for ideal weather conditions, the question is „Whether their effectiveness is the same under the influence of adverse weather conditions? “. This issue has led to numerous researches in this field. It is mainly about examining the possibilities of adjusting the traffic management to adverse weather conditions impact.

From the aspect of the transportation system supply, the street network capacity is one of the most important elements. High value of capacity utilization can lead congestion on the street network, which brings a number of negative effects, such as higher travel time, higher fuel consumption, increase in air pollution, noise, etc.
When it comes to urban areas, the research of the weather conditions impact was mainly analyzed at signalized intersections (Perrin et al., 2001; Asamer & Van Zuylen, 2012; Sun et al., 2013). The reason for that is the flexibility in capacity managing. Changes in the signaled intersections capacity under the adverse weather conditions impact were most often researched indirectly by monitoring the change in the saturation flow value, since most of the models for capacity calculating at signalized intersection are based on the saturation flow calculation. In addition to the capacity, there are paper which are based on the analysis of the adverse weather conditions impact on time delay at signaled intersections (Agbolosu-Amison, Sadek, & ElDessouki, 2004; Lieu & Ph, 2004).
According to different geographical areas of research, the characteristics of weather conditions and driver characteristics, capacity reduction under the adverse weather impact in previously mentioned research ranged from around 1% till around 30%. Based on that, it became clear that quality assessment of adverse weather condition impact implies researches at the local level, i.e. at analyzed urban area.
From 2014 to 2016, the research of adverse weather conditions impact on saturation flow and different speed categories (free-flow speed and average travel speed) was conducted in Belgrade. The research was carried out within the specific weather conditions which are characteristic for the analyzed area. It has been shown that the capacity under the influence of the analyzed categories of adverse weather conditions is decreasing from 2.2% to 11.9% for different rain intensity category (Ivanovic & Jovic, 2017), while during high snow and slushy surface reduction exceeded 30% (Ivanović, 2017). It has also been found that adverse weather conditions significantly influence the free-flow speed in regard to average travel speed, and that impact also was quantified (Ivanović, 2017).
Bearing in mind that the research was concentrate in street network capacity and speed changes, a step forward was preceded calibration of travel time functions under the weather condition impact. A travel time function presents one of the most important input parameters in traffic assignment modeling procedure. A special methodology of travel time function calibration under the weather condition impact was developed. Also, developed methodology was tested and validated on Transportation model of Belgrade (Ivanović, 2017). In the following graphs were presented few examples of calibrated travel time functions under the specific rain category impact (Figure 2).

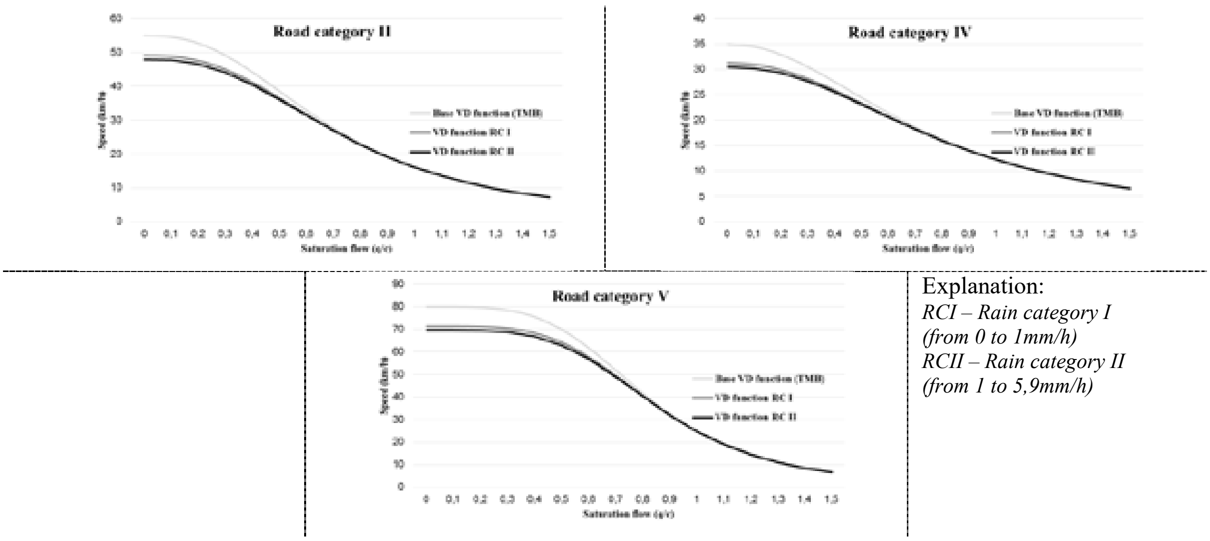

Fig. 2.
Calibrated VD functions under the rain impact
Source: (Ivanović, 2017)

Conclusion

For the last decades, the analysis of adverse weather conditions impact on transport system was further intensified by the climate change phenomenon. Having in mind urbanisation and traffic increase, it became very important to take into account all potential impacts that could have a negative impact on functionality and efficiency of transportation system. Analysis approach which is presented in this paper, recommends that in analyzing the adverse weather conditions impact on the transport system, it is necessary to include transport demand as well as transport supply. In order to determine prevent actions for reducing the negative consequences of weather condition impact on transport system, quantification of that impact represent the first and very important step.

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CAR-SHARING PROBLEMS – MULTI-CRITERIA OVERVIEW

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Abstract: Due to the growing popularity of issues related to sustainable urban mobility, more and more sharing economy solutions are emerging in urban transport systems. One of the popular options is to use short-period time vehicle rentals, known as car-sharing services. Although vehicle rental services should not cause any difficulties for users, author noticed various problems occurring at each stage of the vehicle rental process in global car-sharing systems. The aim of the work is to present problems appearing in car-sharing systems. The author has reviewed existing problems based on technical, economic, transport, social and other criteria. These problems have been referred to the whole process of using car-sharing services: from the moment of registration in the system, to the reservation of the vehicle, its use and return. The article presents the existing problems in car-sharing systems and proposals for their solutions. Classified problems occurring in car-sharing systems and the possibility of solving them, are a research niche in the field of car-sharing. The presented results have a chance to contribute to improving existing systems or creating new, more user-friendly services.

Keywords: car-sharing systems; car-sharing problems; car-sharing improvements; e-car-sharing; car-sharing for foreigners; car-sharing for seniors.

1. Introduction

In recent years, due to issues related to sustainable development, ecological restrictions and all attempts to change the attitudes of society towards the so-called "New mobility", sharing economy solutions in relation to transport began to be more and more popular (Okraszewska *et al*., 2014; Taniguchi *et al.*, 2014). Among the services offered on the basis of sharing economy, based on car vehicles, there were such forms of movement in urban transport systems as: car-sharing, ride-sharing, ride-sourcing, car-pooling. Depending on the type of service and system of operation, the services offer tend to move together with the use of a single vehicle, they are an alternative to taxis or give the possibility to rent the vehicle for a short period of time (Ferrero *et al.*, 2018; Hebel and Wołek, 2017; Shaheen *et al*, 2018). Among all the possibilities of sustainable transport, one of the most affordable and comfortable forms of travel for users who value the comfort of traveling by individual vehicles, due to the car ownership trend should be car-sharing (Giesel and Nobis, 2016). In addition, sharing economy services dedicated to the end user, based on the assumptions of corporate social responsibility (CSR) should have the system prepared for using by every stakeholders without additional support (Golba *et al.*, 2016; Turoń *et al.*, 2015). Despite this, users may encounter various types of problems while using the systems.
The author based on the analysis of the rules of functioning of individual car-sharing operators, her own experience related to the use of systems and based on a literature review identified problems that may occur while using car-sharing services.
The purpose of the work was to present a multicriteria overview related to problems that may occur in car-sharing systems, along with proposing their possible solution. The work will serve both present and future car-sharing operators in improving their services. In addition, it can help researchers who want to optimize car-sharing systems. And above all, it is supposed to be an assistance for current and future users of car-sharing allowing them to use the services in more convenient way.

2. Car-Sharing Systems

Car-sharing is a service, which is functioning in urban transport systems (COM 2016/0288, 2016), that allows one to rent a vehicle for a short period of time. The principle of system operation is very similar to the commonly developed short-term bike-sharing services (Czech *et al.*, 2018). The service consists in sharing car vehicles by a given car-sharing operator by means of dedicated mobile application system (COM 2016/0288, 2016).
The process of using the vehicle in car-sharing systems includes eight main steps, including: downloading the application for a smartphone, registering in the system, processing data and validating sent documents, making a vehicle reservation, getting to the vehicle, starting and ending the journey and making payments. The simplified to a maximum diagram, which illustrates the subsequent processes taking place in car-sharing systems are presented in Figure 1.

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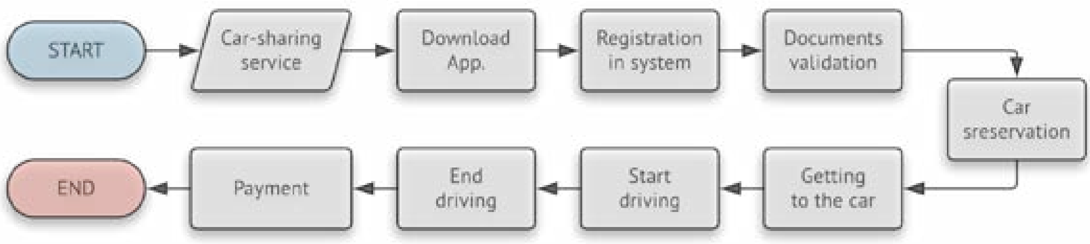

Fig. 1.
Basic car-sharing process
Source: author's own research

Depending on the method of returning the car-sharing vehicles, the above mentioned division of systems has been developed. There are three main types of car-sharing as (Ciari *et al.*, 2014; Ferrero *et al.*, 2017; Nourinejad and Roorda, 2015; Shaheen *et al.*, 2015):

- classic car-sharing = round-trip car-sharing,
- one-way car-sharing,
- free floating car-sharing.

In classic car-sharing, a vehicle rented from one location must be returned to the exact same place from where it was loaned (Shaheen *et al.*, 2015). In one-way car-sharing, a vehicle that was loaned from one point can be returned at another point designated by the operator (Ferrero *et al.*, 2017) (Shaheen *et al*., 2015). In turn, free-floating car-sharing is the most convenient and user-friendly form of car-sharing. In such systems, users have the option of renting the vehicle and leaving it anywhere in the city where the system operates (Ciari *et al*., 2014) (Nourinejad and Roorda, 2015) (Shaheen *et al*., 2015). It should be remembered, however, that this place can usually be car parks located in the public space. Currently, a fashionable solution is undertaking by companies that provide car-sharing services the cooperation with various other market entities from the service department. In this way, it is possible to leave vehicles at selected gas stations or parking lots in shopping centers.
Depending on the type of systems, various types of motor vehicles are used. Therefore, another car-sharing division is applied, that take into account the vehicle fleet. One can distinguish two main types of car-sharing fleets (Ferrero *et al*., 2018):

- fully thermic fleet,
- green fleet.

The fully termic fleet includes vehicles equipped with a classic drive (Ferrero et al., 2018). Usually, since they are vehicles, which operate in urban conditions, these are gasoline-powered vehicles. In turn, the green fleet is considered to include hybrid vehicles or electrically driven cars defined in car-sharing as e-car-sharing (Ferrero et al., 2018). Due to the current policy related to electromobility, the aim is to use electric fleet of cars in urban transport systems and in car-sharing (Sierpinski, 2014).

3. Car-Sharing Problems

Although the process of using car-sharing systems may seem simple and should be approachable for each user, there may be various types of difficulties at individual stages of using the systems. These difficulties often result from misunderstanding or inaccurate familiarization with the regulations and instructions for using particular systems.
In order to systematize individual obstacles related to the use of car-sharing, the following sub-chapters present potential problems of car-sharing that may occur immediately after downloading the application offered by a given operator.

3.1. Problems During Registration in the System

Depending on the type of system, there are various types of registration methods. After entering personal data, user must show a document confirming the possession of driving licenses and often also an identity card or other document confirming the identity of the system user like passport (Car2Go, 2018; DriveNow, 2018).
Depending on the system, the required document can be scanned or presented in the form of a photo to verify the data (Traficar, 2018). The next step is checking the data by the operator and issuing a decision on making the application available to the user or not. The problem arises when the user would like to use the system immediately after the registration and the operator reserves the time to process the provided documents in a specified time, e.g. 24 hours.
Another option during user registration is two-step verification. Then the operator, in addition to presenting the documents in the form of photograph, may require the appearance of the user via a video-interview to the operator's hotline with the help of communication applications (Panek, 2018). In this case, during the conversation, the user is

asked to present to the camera both a personal ID and driving license as well as presenting his face to compare the figure of a person with the person depicted in the photograph of the submitted documents (Panek, 2018).
Although such solutions provide greater security for users, the registration procedure may seem complicated and require too much involvement from the user, eg when traveling to the operator's office. Then the long-term rental services, where rentals with customer service are open 24 / h (Sixt, 2018) or ride-sourcing services such as Uber or classic taxis, having the advantage over the car-sharing services.
In addition, it should be mentioned that requiring the user to contact the customer service center in a personal manner contradicts car-sharing systems idea, according to which they were supposed to be based on automation in accordance with the services of Industry 4.0 - Transport 4.0 (Polish Portal of Innovation, 2018).

3.2. Problems with Access to a Given System Concerning Foreigners

An important issue from the point of view of accessibility of use of a given system is the issue of matching services to the needs of different types of users. Although car-sharing should support the city tourism and is supposed to be used as an alternative form of mobility for visitors and tourists from other countries (Singh, 2017), foreigners may encounter problems when trying to use the system. In some systems after attempting to register as a user of a country other than the country in which you are located currently, after submitting the address, he/she is required to verify the documents in the office of a customer service operator (car2go, 2018; DriveNow 2018).
In addition, the problem may also be the language of the application, which does not provide the possibility of choosing the English language as well as a non-intuitive interface that makes it impossible for the user e.g. to change the language - a frequent obstacle in systems available in Asian countries (Dowling *et al*., 2018).

3.3. Technical Problems during using Car-Sharing Vehicles

The first problem when using car-sharing vehicles may be a different way of opening the vehicle. Depending on the system, this process is done by scanning the QR code or automatically by confirming the opening of the vehicle in the application, after getting closer to the vehicle. However, in order to locate the vehicle in the place chosen by the user, it is necessary to move in accordance with the directions indicated on the map. In practice, users may encounter problems related to the fact that there will be a point marked on the map where the vehicle is located, for example, in a large public parking lot 100m away from the user, but it may be difficult to find the right vehicle among other cars. This problem practically does not exist when a vehicle with car-sharing is a car covered with emblems of a rental company or has a characteristic bright color. However, there are car rental companies which offer cars, which have only a small stamp referring to the vehicle operator. A comparison of car-sharing vehicles markings in the case of vehicle fleets in Germany and Poland is presented in Figure 2.

Fig. 2.
Marking of selected fleets in car-sharing
Source: author's own research

In the case of a problem with locating the vehicle the ideal solution would be to apply a system of light signalization of the vehicle when the user is close to the car. This solution is possible thanks to the "follow me home" function (Elo, 2018).
Next obstacles may appear during dealing with an electric car. Then it is important to check the procedures when: the booked vehicle is currently connected to the charging station; whether it should be disconnected and whether the equipment (cable) is the equipment of the vehicle or charging station. As well as it is important to know all procedure after the vehicle has been charged.
In addition, the problem with e-car-sharing vehicles refers also to the appropriate planning of users route in such a way that the level of energy available would allow for. In this case, the issues related to the responsibility of the user who uses the system deserve special attention.
The next obstacle concerned with car-sharing may be the procedure of returning the vehicle or leaving it in the so-called the "stop over" function. In such a case, to avoid the hassle of handing over the vehicle one should become familiar with the system in which the given operator operates. One should keep in mind issues related to area functioning. It is important to familiarize oneself with the rules of leaving a given zone or departure to a neighboring city. It may prevent the user to be subject to high fines, which one often can be unaware of.

Another issue concerns proper parking of the vehicle. First of all, the vehicle should be parked in places indicated by the system operator. Depending on the type of system, the operator may have purchased access to municipal parking lots. Then parking is included in the price of the service. However, it should be noted whether the car is rented, for example, within a free system, in which it is possible to park it in any parking lot in the city, or the user must return it to the indicated parking spaces or a specific base, which is attributed to this particular operator, in which the car can be left.

Another problem may be the inadequacy of systems regarding the age of the users. Due to the ageing of societies, it is important to customize services to the requirements of the elderly (Hensher, 2006) e.g. by providing vehicles, which enable those people make the getting in the car more comfortable as well as providing them with more intuitive applications interfaces.

Another trivial problem but important from the point of view of using car-sharing service should also charge level of smartphone on which the application is running. It should be remembered that during using the service, the phone constantly uses the Internet as well as the Bluetooth or Wi-Fi function, so the battery is quickly discharged. Then it turns out that cables for charging the phone are available in most vehicles with car-sharing. It should be remembered however, that if we are driving the electric car which has the very low battery charge, charging the phone in the vehicle will not be advisable.

3.4. Responsibility of users for Rented Vehicles

During using vehicles with car-sharing, special attention should be paid to the issues of user responsibility. The most important aspects include (Car2Go, 2018; DriveNow, 2018; Panek, 2018; Traficar, 2018): damage to the vehicle, improper parking of the vehicle, entering the vehicle to a prohibited place, eg leaving the vehicle in an underground car park which was not indicated by the operator. It should also be ensured that a vehicle borrowed by a given person is not made available to a third party even if the borrower is in the vehicle.

3.5. System Problems

In addition to typical technical problems that may appear during using the system, there are also typically research problems, which are attempted to be solved by the scientists around the world. One of these kind of system problems is the time in which after the vehicle has been booked the user has to reach the car. Scientific research shows that the vehicle should be located at a distance of 400 m from the user (Schmöller *et al*., 2015), however this problem is related to the next one, which require ensuring the right number of vehicles and their location in urban space (Boldrini *et al*., 2016 Jorge et al., 2015, Schmöller, S., & Bogenberger, 2014). All optimization and relocation solutions and appropriate organizational activities come with help. The cooperation with car dealers (Turoń *et al*., 2017) may be the right solution of the problem of equipping vehicles with an additional fleet.

The list of problems that may occur in car-sharing services along with potential possibilities of their solutions are presented in Table 1.

Table 1
Multi-criteria overview of car-sharing problems

Criteria	Car-sharing problem	Solutions
TECHNICAL	Problems with registering in the system	Unification of registration methods. Reduction of formalities to a minimum. Implementation of 24-hour helplines or customer service offices
	Registration by foreigners	Introducing the possibility of registration via video-chat. Introducing the possibility of registering at a car dealer that provides services to a car-sharing operator in the case of car-sharing offered by specific vehicle brands. Adaptation of mobile applications for use by people from abroad - English; intuitive interface facilitating the change of language. Development of consistent information systems, accessible to the end user.
TRANSPORT	Vehicle location	Introduction of vehicle response capabilities, e.g. by signaling with lights, that the user is approaching the reserved car ("follow me" function). Appropriate marking of the vehicle with car-sharing operator emblems.

Criteria	Car-sharing problem	Solutions
	Electric vehicle service	Appropriate education in the field of electromobility. Providing the user with additional training instructions for charging and use of the vehicle with an electric drive.
	The "stop over" procedure, the return of the vehicle and the place and method of parking the vehicle	Instructions informing about the rules and places where the return of the vehicle is possible and the instructions of the "stop over" function. Presentation of examples of base stations where you can leave the vehicle. Cooperation with urban road managers to create parking spaces intended for vehicles of car-sharing systems. Cooperation with vehicle dealers, petrol stations, shopping centers and other services, in order to improve the availability of parking spaces for car-sharing vehicles.
SOCI0-ECONOMIC	The user's responsibility for improper vehicle use	Instructions / brochures informing about the locations, which are non-permitted by the regulations in the form of picture instructions, provided to the user before driving a vehicle with car-sharing.
	Unacquaintance of the system	Educational and social campaigns promoting a new culture of mobility. Tailoring systems to the needs of people from abroad in order to improve the attractiveness of the region (the impact of car-sharing on tourism). Profits for those who enjoy car-sharing: the possibility of bus lanes, dared parking spaces, the possibility of entry into restricted traffic zones..
	No adaptation of services to the needs of older people	Introducing vehicles that are friendly to older people, for example, cross-over cars or SUVs. Introducing vehicles with automatic transmission and parking assistants. Adjusting the application interface to the needs of older people.
SYSTEM	Insufficient number of vehicles	Relocation of vehicles to reduce the time of reaching the vehicle. Optimization of the vehicle fleet. Improving fleet management.

Source: author's own collaboration

4. Conclusion

In summary, the paper presents problems that may occur during using car-sharing systems. The author attempted to analyze the individual obstacles depending on a particular aspect and present potential solutions to minimize the obstacles that the users of the system face. The analysis shows that many nuances are directly related to the regulations and instructions concerning using car-sharing vehicles, provided by operators. Therefore, the author notices the need to increase education regarding the use of shared mobility services. That kind of education is a chance to eliminate many problems of users related, among others to additional fees, sanctions or liability issues and also will have a positive impact on creating a new approach to the culture of mobility in society. These issues play a particularly important role in the current world policy on electromobility.

In addition, from the point of view of operators of car-sharing systems, their attention should be focused on improving issues such as: the availability of systems for foreigners, refining the interface, improving vehicle technical control, refining vehicle location systems, reducing data verification time or adapting services to the requirements of older people.

It is worth remembering that any attempt to eliminate problems that may occur in car-sharing has a chance to bring positive effects for systems operators, cities and also for all society by shaping new attitudes in the field of sustainable urban mobility (Okraszewska *et al*., 2014; Turoń *et al*., 2018).

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CAR-SHARING SYSTEMS VEHICLES VERSUS TAXIS IN URBAN TRANSPORT SYSTEM – LEGAL REQUIREMENTS, TECHNICAL SERVICE, OPERATION

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Abstract: Due to the significant development of car-sharing systems in recent years, on the market have appeared many operators offering short-term vehicle rental opportunities. Beside to organized operators, there are many platforms associating people who want to rent their private car for a short period of time (p2p car-sharing). Regardless of the type of system, vehicles used in them are characterized by different degree of wear, type of power supply or equipment. The legal responsibilities for used vehicles by system's users are different as well. Due to the safety of car-sharing vehicle users, authors noticed inconsistencies between vehicles used in car-sharing and vehicles used as taxis. Based on this theory, the scientific work is dedicated to comparison of car-sharing cars and taxis in urban transport systems. The analysis took into account legislative requirements, issues related to technical maintenance and the functioning as transport means in European systems. The obtained results may provide support in creating new regulations for the use of car-sharing vehicles or changing current legislation.

Keywords: car-sharing systems; car-sharing legislative requirements; degree of wear vehicles; peer-to-peer car-sharing.

1. Introduction

The effectiveness of the national economy depends not only on the potential of the means of production, but also on the rational management of them. The fact is that the most perfect device, in the hands of a person unprepared to handle it, becomes a useless device. It is no different in the case of vehicles. Problems of this type can occur during the standard using of vehicles by owners and are becoming more and more complicated during sharing the vehicle with other people. It can be indicated two main ways of sharing, first when the owner rent the car for a short period of time, via the organized platform independently (peer-to-peer car-sharing) or when the companies rent vehicles "by the minute" in organized form (organized car-sharing) (Shaheen *et al*., 2018). These types of activities are alternative, sustainable urban mobility known as car-sharing (Shaheen *et al*., 2015; Shaheen *et al.*, 2017).
At that time, all kinds of issues related to the operation of motor vehicles play an important, though often underestimated role. They are responsible for the required level of safety, vehicle equipment issues or counteracting excessive car use by ensuring their proper servicing (Bouman and van der Wiele, 1992).
Due to the fact that many car sharing systems appeared on the current market of urban logistics, the authors noticed that common vehicles are used in a similar way to taxis operating in urban conditions.
Despite this type of similarity, such vehicles are considered in various ways in the context of legal or technical requirements. Based on this theory, the aim of this scientific work is to compare passenger cars operating as car-sharing fleet and taxis. The analysis includes legal requirements, issues related to technical maintenance and their functioning as a means of transport in selected European systems.

2. Theory of Operation of Motor Vehicles - Basic Information

The theory of operation of vehicles is an interdisciplinary science, based on knowledge from many research fields. This is due to the fact that the operation is considered to be a group of all actions taken intentionally in the human-vehicle system, which occur from the moment of purchasing the vehicle for use in accordance with its purpose, until the time of its utilization (PN-82/N -04001). All organizational and technical as well as economic issues are recognized for such activities (PN-82/N -04001). Due to the fact that the problem of the use of motor vehicles covers both: use, maintenance, diagnosis, repair, maintenance, storage and decommissioning (PN-82 / N -04001) - it is important to familiarize with the basic relations in the vehicle system user.
In the life cycle of a vehicle, the car is a tool that allows achieving people mobility. In the case of a taxi - the human being present in the model will be the customer using the service or the driver of the vehicle. In turn, in the case of a car-sharing service, it will be the user-driver and / or passenger of the vehicle. However, in the analyzed process, the vehicle may also become the target of the operation itself. This happens at the moment when it is necessary to perform the scope of activities necessary to maintain the vehicle in a proper technical condition (Hebda and Mazur, 1984; Hebda *et al*., 1978). Then, every action of human-device revision is presented by means of a chain of action consisting of three elements. It can be presented with the formula (Hebda and Mazur, 1984; Hebda *et al*., 1978):

$$£ =< x, y, z > \tag{1}$$

x – person (the initiator - the purpose of action),

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y – the tool to achieve the goal of action,
z – the subject of activity.

The vehicle can be located in the chain of action as an intermediary or as a tool to achieve the goal of action. It can be presented with the formula (Hebda and Mazur, 1984; Hebda *et al*., 1978):

$$\pounds_u = < x, p, z > \tag{2}$$

x – the taxi or car-sharing driver,
p – the taxi or vehicle from the car-sharing system,
z – the taxi passenger or driver from the car-sharing vehicle.

That kind of characteristic case occur when x = z (for the car sharing driver). There the subject of the action is also the object of the action. This means that the vehicle is used when there is a chain of action equal to Łu = <x, p, z>, in which the vehicle is a mediator of operation. In the process of use, consumables and components of the vehicle are consumed, which affects the deterioration of the usable properties of the car, or prevents its further use.
The vehicle is operated when the goal is to restore its usability. The vehicle service chain can be presented in the form (Hebda and Mazur, 1984; Hebda *et al*., 1978):

$$\pounds_o = < x, y, p > \tag{3}$$

x – the person operating the vehicle,
y – materials, tools or devices necessary to operate the vehicle,
p – operated vehicle.

Due to the fact that the vehicle service process usually consists of many different activities, an agent of operation in the service chain will be a set of service means - sets of devices or specialist tools. The subject of the action does not have to be one person. It is often a group of people. It can therefore be concluded that the vehicle is operated only when it is used or operated (Hebda and Mazur, 1984; Hebda *et al*., 1978):

$$\pounds_e = \pounds_o \cup \pounds_u \tag{4}$$

$\pounds_e$ – operation chain,

$\pounds_o$ – service chain,

$\pounds_u$ – usage chain.

Based on the basic relations taking place in the vehicle-person system, it is important to look for various types of solutions that give the possibility of increasing the reliability of vehicles. Reliability of vehicles allows determining the efficiency of work, but above all about the life and safety of people using the vehicle.
A major problem may be the fact that a vehicle breaks down on a roadway, for example, in a dangerous place that threatens the safety of both the driver and passengers. The vehicle's technical condition primarily determines the reliability of the vehicle. The correct assessment of the vehicle's technical condition is not straightforward.
The complexity and diversity of vehicle construction often does not allow easy, fast and full identification of the technical condition of the entire vehicle (Bąkowski *et al*., 2011; Hadryś *et al.,* 2016; Hebda *et al*., 1978).
One of the activities aimed at maintaining the safety of motor vehicles at the required level is their approval (literature). The purpose of vehicle approval is to check whether the requirements for prototypes and vehicle assemblies are met in the relevant regulations in the relevant country (Laczyński, 2013). This happens in the results of tests of entire vehicles, as well as the most important assemblies, parts and elements of equipment. Vehicle manufacturers are required to obtain an approval certificate for a given type of vehicle. The approval certificate is issued after the completion and receipt of positive test results. Since 1998, European Union member states have agreed that the approval issued in one country should be valid and accepted in all member countries of the European Union (Wicher, 2004).

3. Car-Sharing Systems - Vehicle Fleet

Car-sharing systems - automated vehicle rental "by the minute" are services provided by operators organized in the form of enterprises, the platforms for renting vehicles or associations (Münzel *et al*., 2017; Shaheen, 2015). Regardless of the system, due to the issues of sustainable development and ecology requirements, vehicles used in the context of car-sharing as a part of shared economy conception should be environmentally friendly (Chen *et al.,* 2018; Golba *et al.*, 2015; Turoń *et al*, 2017). According to this principle, two basic types of vehicles appearing in the context of car-sharing services are distinguished. This division is created due to the type of vehicle drive. It can be distinguish: the fully

thermic fleet as well as the green fleet (Ferrero *et al.,* 2018). The fully thermic fleet includes all vehicles with classic drive (in car-sharing it means mostly gasoline engines). However, the green fleet includes all vehicles with electric or hybrid drive.
Research carried out by the authors of this work, made on forty car-sharing systems in Europe, indicates that in classic car-sharing the leading role is played by cars with classic drive. That cars belong to the "C" and "B" segment. Figure 1 presents an example of vehicles with classic drive used in European car-sharing.

Fig. 1.
Examples of vehicles with classic drive of European car-sharing systems
Source: author's own collaboration

A much smaller group of systems are those in which the fleet consists of electric vehicles. The growing interest in this type of systems indicates the implementation of a worldwide policy related to electro-mobility. Fleets used in these types of systems are called as e-car sharing. Despite the fact that e-car-sharing systems represent a small percentage in relation to global systems, a lot of research works are being conducted to promote the electro-mobility of vehicles (Berkelmans *et al.*, 2018; Schröder *et al.*, 2014; Wappelhorst *et al.,* 2014). In connection with this type of policy, typically electric car-sharing or pilot projects are implemented.

4. Taxis - Basic Information

The taxi acts as a means of transport used in municipal transport systems. It is a licensed vehicle that can be rented together with the driver who manages it (European Commission Report, 2016). A characteristic feature of the taxi as a means of transport is that it does not have predetermined travel routes (European Commission Report, 2016). Obtaining a taxi license is determined by separate regulations for individual countries, which in detail postulate the rules of access to the profession, technical requirements for the vehicle, places of movement, used tariffs for journeys and others.
Mostly vehicles used as taxis are mainly classic cars (Taxi report, 2016) (Taxi report, 2016)
Ecological restrictions, however, force taxi drivers to exchange fleets for more ecological vehicles or vehicles equipped only with electric or hybrid drives.
Also in Poland, according to the electro-mobility policy, there are more and more taxis with electric drive. The example of this type of fleet used in the Warsaw system has been presented in Figure 2.

Fig. 2.
Examples of taxi car with electric drive typical for a system implemented in Warsaw in Poland

Source: author's own collaboration

5. Vehicles of Car-Sharing System and Taxis - Legal and Technical Requirements for Vehicles in selected European Countries

Analyzing the legal requirements for the admission of motor vehicles for use in public traffic, there is a visible difference in the perception of a vehicle registered as a vehicle - a taxi, and a vehicle - used in a car-sharing system.
The problem is lack of specific regulations defining the technical requirements for vehicles with car-sharing. In turn, technical requirements related to taxis depend on the country. In selected European countries, in addition to the driver's license, a license for a vehicle used as a taxi is also required. These kinds of countries include Bulgaria, Latvia, Malta, Poland, Spain, Romania, United Kingdom (European Commission Report, 2016).
Each Member State at national level regulates the technical specifications of the vehicle, periodic vehicle control and safety equipment. All Member States provide data on the minimum length of the vehicle, the number of doors, the number of seats and the luggage space.
Technical specifications for taximeters are regulated at the national level in accordance with European Union Directive 2004/22 / EC (European Commission Report, 2016).Forty three local regulations specify other aspects, such as taxi color, medallion and advertising. In England and Wales, all standard settings for taxis and private car hire services are delegated to local licensing authorities. This led to the creation of over 300 different standards.
A list of different types of technical requirements for taxis in selected European countries is presented in Table 1.

Table 1
List of technical requirements for taxis in selected European countries

Country	Vehicle technical requirements
Ireland	- the same requirements regarding the roadworthiness test as for private motor vehicles (National Car Test), - taxis must be tested and must pass a roadworthiness test prior to granting the first license and each time an extension of the license validity - every year for most taxis and every six months for taxis that are more than ten years old.
UK – England (London)	-all new vehicles to be licensed must meet at least Euro 6 emissions standards when granting a license, - by 2018 they must be zero-emission vehicles. -vehicles already licensed by Transport for London may not be older than 15 years at the time of licensing; - in addition, the vehicle must meet the design standards set out in the special national conditions as well as national and European type approval requirements.
Germany	- the roadworthiness tests for taxi cars are compulsory every year, and if the taxi driver loses his driving license because of sanctions under the penalty point system, the passenger transport license is also withdrawn.

Source: (European Commission Report, 2016; Taxi Report; 2016)

6. Car-sharing Vehicles vs. Taxis - a Case Study on the Example of Poland

In accordance with the current legal regulations, operating in Poland, a vehicle registered as a taxi can only be provided if it is equipped in accordance with the Minister of Infrastructure Regulation on technical conditions of December 31, 2002, where the guidelines for the vehicle - taxis are specified. A vehicle registered as a taxi must meet the requirements of a "typical" car and additionally must be equipped with: an electronic taximeter with valid proof of legalization, at least two spaces for passengers, at least two doors on each side of the body or two doors on the right side, one on the left and one on the back of the body, a room for a handy passenger baggage, first aid kit, spare tire, additional light with the word "TAXI" (Minister of Infrastructure Regulation on technical conditions of December 31, 2002, Dz. U. z 2003 r. Nr 32, poz. 262). The vehicle used in the car-sharing system is subject only to the requirements as in the case of a "normal" motor vehicle. One of the basic problems that arise from the differences is the time to occur between the review periods. Periodic technical inspections of taxi vehicles and the car-sharing system vehicles are presented in the Table 2.

Table 2
Periodic technical inspections of taxi vehicles and the car-sharing system vehicles - legal requirements

The vehicle used as a taxi	The vehicle used in the car sharing system
Obligatory every 12 months	For a factory-new vehicle,

	the first review after 36 months, then the next service after 24 months, then every 12 months

Source: The Act - Road Traffic Law of 8 June 2017 Dz.U. 1997 nr 98 poz. 602

In summary, the vehicle used as a taxi must have an annual inspection at a vehicle inspection station to check its technical condition. In the case of vehicles used in the car-sharing system (assuming it is a new vehicle), such a review will take place only after 36 months. The difference from the vehicle driver's point of view is significant. Assuming that a taxi vehicle has one or several drivers, it can be stated that it is used in comparable conditions. However, the vehicle used in the car-sharing system is operated by an unlimited number of drivers. Due to the nature of the rental, due to the fact that it is a short-term rental ("by the minute"), there are infinitely many drivers of a given vehicle. Each driver, however, has his own style of vehicle use and adequate knowledge about the operation of motor vehicles; hence the technical condition in the case of a taxi and one or several drivers will significantly differ from the technical condition of the vehicle driven by an infinite number of drivers. Therefore, it is worth paying attention to the content of the Regulations for the use of car-sharing services. For example, one of the regulations of a randomly selected company providing such services is that "The user is obliged to use the Vehicle in a manner that takes into account its technical parameters, including payload. The Car-sharing company is not responsible for the User's use of the Vehicle in a way that does not take into account its technical parameters (indicated in the Vehicle's instruction manual, in the Vehicle registration document or in the Regulations). The User is liable to the Car-sharing company for using the Car in a way that does not take into account its technical parameters". Interpreting this type of entry in the regulations, the user should be prepared in the field of handling this vehicle, know its technical parameters and know how to use it in the selected vehicle model before proceeding to rent this type of vehicle. All these requirements are used to ensure the safety of the driver and passengers traveling with the selected vehicle.
In order to determine the average mileage traveled by car-sharing vehicles, data from one of the operators of the operating system in Poland were used.

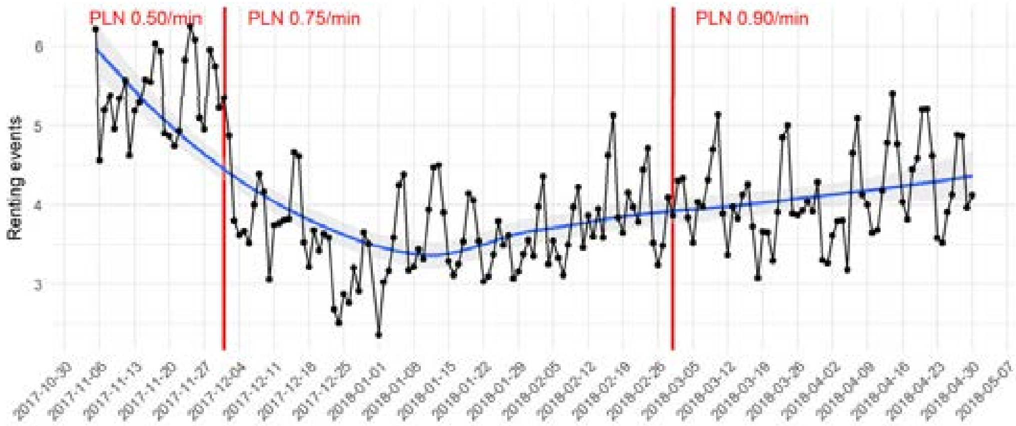

Fig. 3.
Renting events per the number of fleet cars in car-sharing system
Source: (Zielinski, 2018)

Based on the data presented in the graph above, it can be assumed that on average one vehicle is rented 4 times a day. The average mileage performed during one rental is estimated by the operator at the level of 7km. In the table 3 were presented average number of kilometers travelled by car-sharing systems.

Table 3
The number of kilometers travelled by one vehicle on a time scale in car-sharing systems

The number of kilometres travelled by one vehicle	Daily	Weekly	Monthly	Annually
	7 km	49 km	213 km	2 555 km

Source: author's own collaboration

The above Table allows specifying that one vehicle per year reaches a mileage of approximately 2,555 kilometers. On a scale of two years, it exceeds the level of 5,000 kilometers. At the same time, assuming that with the commencement of using it in the car-sharing system, the vehicle was brand new, it is also subject to warranty inspections by virtue of law. The following Table shows the intervals between the vehicle manufacturer's inspections, for selected two types of vehicles used in the car-sharing system.

Table 4
Warranty inspections of selected two vehicles

Vehicle	The period between the inspections
Renault CLIO IV 0,9l	30,000 km or after 12 months (first inspection), subsequent inspections every 30,000 km or every 24 months
VW Passat 1.6 TDI	15,000km or every 12 months - oil change in the engine, first inspection every 30,000km or after 24 months, another every 30,000km or 12 every months

Source: author's own collaboration

Analyzing review periods, based on legal titles and warranty titles, it can be concluded that service and maintenance inspections of vehicles used in car-sharing systems will be performed with an indication of the time period, not the number of kilometers driven. This creates the possibility that in the case of selected vehicle types, inspections will only be carried out after several years of use. It is associated with the danger that after such a period, the vehicles will be heavily used and their control at that time will be inadequate. Therefore, due to the overall car operation process, four types of specific operation processes can be distinguished:

- homogeneous operation,
- one-degree inhomogeneous operation,
- non-homogeneous 2nd-degree operation,
- non-homogeneous 3rd-degree operation.

Homogeneous operation includes the operation of vehicles for which the operating repertoire, the exploitation base and the operational schedule are unalterable in time. This means that the vehicle is in a cyclic - repetitive manner. We can include taxis in this group.
However, we can include vehicles used in car-sharing systems for the non-uniform level 2 operations. These vehicles, as well as vehicles from the homogeneous operation group, have constant operational repertoire, operational base and operational distribution, while the process of use and parking place is variable (Hebda and Janicki, 1977).

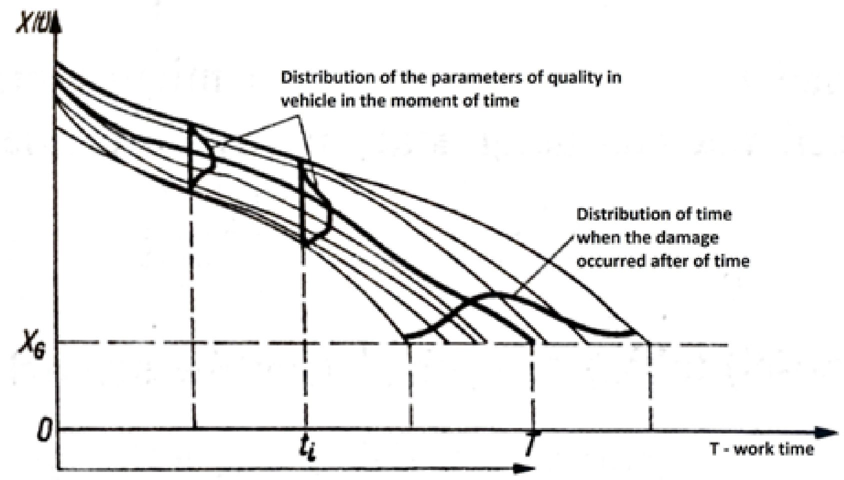

Fig. 4.
Comparison of the quality of vehicles on a time scale
Source: (Hebda et al., 1978)

The above graph presents the distribution of parameters characterizing the quality of the vehicle on the time function. It perfectly represents the course of the change of technical condition of the vehicle. Depending on the operation, the moment of damage may occur sooner or later. Assuming that at Point 0 on the X axis, we have the same vehicle used as a taxi, and in the car-sharing system, then in t_i point the technical condition of the vehicles will significantly differ from each other.

7. Summary

In conclusion, the analysis showed that vehicles used in car-sharing systems do not have additional requirements related to safety and technical issues as in the case of taxis. The examples of legal and technical requirements for taxis presented in the text indicate that depending on the country, there are many different approaches to aspects of ensuring the safety of both - the vehicle and its passenger during use. Different regulations affect the scope of control of these vehicles during operation. It can therefore be concluded that based on current legislative requirements, a taxi, driven by one or more recurring drivers, will be a safer vehicle for the passenger. While vehicles with car-sharing will be subject to technical control for the first time only after three years - for a new vehicle, or for a warranty title, depending on the vehicle and brand, this time may vary. Here it is also worth noting that vehicles used in car-sharing systems are usually new cars, coming from direct cooperation with a given vehicle brand (Turoń *et al*., 2017).

In addition, it is also worth paying attention to the liability of vehicle users (both taxi driver and rented car). The taxi and their driver / drivers seem to be more responsible for their vehicle. A car-sharing system user will pay less attention to the technical condition of the vehicle or will completely fail to check the technical condition before renting the vehicle. This is due to the specificity of the car-sharing systems referred to as "for minutes".

Therefore, basing on the presented conclusions and the continuous development of car-sharing systems, the authors propose to the management and legal authorities at the level of the countries concerned the development of legal regulations aimed at improving the safety of used vehicles by increasing the frequency of technical inspections of vehicles. In addition, educational activities for current and future users of all types of vehicle rental companies with appropriate vehicle behavior are also important. Such activities can be successfully supplemented by education curricula, driving license courses or any information content presented directly by the operators of the given systems. It is worth remembering that undertaking any actions in the field of increasing operational awareness will affect the improvement of safety but also reduce the economic losses of operators incurred due to the erroneous use of vehicles by system customers.

The presented analysis is the beginning of the research that the authors intend to conduct. The next step will be to undertake a comparative analysis of the use of vehicles from car-sharing and taxi services in all European countries - including the European Union and non-member states.

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SIMULATION AS A TOOL TO ANALYZE CHANGES IN TRANSITION TO SMART MOBILITY

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Abstract: Sustainable transport is one of the basic systems of Smart City. Smart mobility implies three ways: efficient urban and transport infrastructure planning, transition to sustainable modes of transport (public, non-motorized modes of transport, electric transport) and minimizing the number of residents' trips. These ways were considered in the case study of Naberezhnye Chelny. To increase the attractiveness and efficiency of public transport, macromodel based simulation of city transport system was conducted. Our developed transport macromodel also allows predicting the influence of Internet of Everything integration into usual life. Simulation shows how public transport routes' optimization together with application of E-learning methods into educational system of Smart City can help to reduce traffic loads. To improve bottlenecks of the city transport system we have built the set of transport micromodels of problematic areas and suggested some managerial decisions. To solve the Last Mile Problem, the intelligent system to evaluate the bicycle routes is suggested. The idea is to integrate bicycle lane with public transport routes to inspire residents to use sustainable multimodal schemes of transportation despite private cars.

Keywords: smart city, smart mobility, transport system, simulation, bike lanes integration into the public transport.

1. Introduction

The world is undergoing the largest wave of urban growth in history. More than half of the world's population now lives in towns and cities, and by 2030 this number will swell to about 5 billion. Much of this urbanization will unfold in Africa and Asia, bringing huge social, economic and environmental transformations. UN projections show the world's rural population has already stopped growing, but the world can expect to add close to 1.5 billion urbanites in the next 15 years, and 3 billion by 2050. The way, how the world meets the challenge of sustainable development, depends on this process. In 1950 about 2/3 of the population worldwide lived in rural settlements and 1/3 in urban settlements. By 2050, we will observe roughly the reverse distribution, with more than 6 billion people living in the messy, burgeoning athmosphere of urbanized areas. According to the Sustainable Urbanization Policy Brief, urban centres currently occupy less than 5% of the world's landmass. Nevertheless, they account for around 70% of both global energy consumption and greenhouse gas emission. Innovation in urban infrastrucure and technology is essential when addressing this issue. For instance, greenhouse gas emissions could be reduced by up to 1.5 billion CO_2 annually by 2030, primarily through transformative change in transport systems in the world's 724 largest cities (The Global Comission on the Economy and Climate, 2016).

Urban planning decisions and strategic design thinking in the context of rapid urbanization account for social equity, mobility patterns, global competitiveness and energy-efficiency. Strain on traditional service delivery from increasing populations poses a significant challenge to the sustainable growth of cities. Managing physical resources, such as energy or water as well as managing healthcare, traffic and city logistics, among others, is a major challenge that cities need to address to ensure sustainable growth in the future. As more and more cities are moving towards becoming Smart Cities, researchers and designers continue to find ways to improve our quality of life, including the use of Intelligent Transport Systems (ITS). With the prediction that, by 2050, 70% of the world's population will be living in cities, an incorporation of ITS with Smart Cities and Internet of Things (IoT) is one of the main ways to be put into the future plans.

One of the most perspective method is intellectualization of transportation process. Mobility is a key dynamic of urbanization. By 2005, approximately 7.5 billion trips were made in cities worldwide each day. In 2050, there may be 3-4 times as many passenger- and freight-kilometers travelled as in the year 2000. Transition to inclusive green and smart economy should be based on viable ecosystems, cleaner production, healthy consumer preferences. That is why in recent years in the field of architectural and urban science more and more attention has been paid to the concepts of "Smart Cities" and "Future Cities". At the same time, information technology is replaced by smart technology. Smart City is an urban environment, which combines a variety of technologies to reduce the negative impact on the environment in general and, thereby, to provide a more comfortable living conditions. The main goal of the Smart City idea is to create a sustainable model of urban development and to preserve the quality of life for urban citizens. One of the main challenges to be solved for the successful operation of the urban ecosystem is the problem of citizens' mobility. At the same time, the transport system should cause minimal negative impact on the environment.

2. Smart City and Smart Mobility

The active implementation of the concept of "smart cities" began in 2008 because of the financial crisis, which the IT sector correctly used. In November 2008, IBM's Chairman, CEO and President Sam Palmisano, during a speech at the Council on Foreign Relations, outlined a new agenda for building a "Smarter Planet" (IBM100, 2008). The speech

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emphasized how the world's systems and industries are becoming more instrumented, interconnected and intelligent, and that leaders and citizens can take advantage of this state of affairs to improve these systems and industries. In January 2010 Sam Palmisano gave a follow-up speech (Lindsay, 2010) to the Chatham House called the "Decade of Smart". He highlighted dozens of initiatives in which leaders created smarter systems to solve the planet's most pressing problems. The speech aimed to inspire others to follow the leads of these innovators by helping to create a smarter planet.

International consulting company McKinsey predicts the emergence of 600 "smart" cities by 2020. According to the forecast, they will generate at least two-thirds of the world's GDP. Although skeptics, referring to the popular site for startups Angel.co, note that of the few hundred projects that implement the concept of "smart cities", only a few are undertaking the implementation of the whole Smart City. Most of them are some individual elements: WI-FI benches, a smartphone instead home keys, services for waste disposal, tracking stolen bicycles using WI-FI. But even despite such negative assessments, today there are entire cities working in the Smart system. The first question is what is meant by a "smart city". The answer is, there is no universally accepted definition of a smart city. It means different things to different people. The conceptualisation of Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents. To provide for the aspirations and needs of the citizens, urban planners ideally aim at developing the entire urban eco-system, which is represented by the four pillars of comprehensive development-institutional, physical, social and economic infrastructure. This can be a long term goal and cities can work towards developing such comprehensive infrastructure incrementally, adding on layers of "smartness".

Some typical features of comprehensive development in Smart Cities are:

- Promoting mixed land use in area based developments in order to make land use more efficient;
- Expanding housing opportunities for everyone;
- Creating walkable localities – the road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance;
- Preserving and developing open spaces – parks, playgrounds, and recreational spaces in order to enhance the quality of citizens' life, reduce the urban heat effects and generally promote eco-balance;
- Promoting a variety of transport options: Transit Oriented Development (TOD), public transport and last mile para-transport connectivity;
- Applying smart solutions to infrastructure and services – developing e-governance to reduce cost of services and providing services without attending municipal offices.

In Russia, the priority project "Smart City" is included in the state program "Digital Economy". The planned technological solutions in the pilot cities will relate to six key areas:

- introduction of "smart" housing and communal services;
- formation of environment accessible, comfortable and safe for citizens' health;
- creating an innovative urban infrastructure;
- digitalization of building;
- digitalization of spatial planning;
- development of city transport systems.

Since the mobility is a key dynamic of urbanization, development of city transport system is one of the major area of the Smart City concept. Smart Cities strive to improve the overall quality of life by using interconnected smart devices and the IoT to understand residents' needs, and this must incorporate ITS. ITS is not only about running efficient transport networks, but also about predicting possible situations based on data analisys to make managerial decisions faster and more acurate. A future of connectivity and communication between vehicles, law enforcement to traffic control systems, emergency services to road incident data, public transport to events, etc.

One of the best tools to analyze the city transport system's operation is simulation (Tahon *et al.,* 2013). Macromodels are usually used to analyze the entire transport system and to identify the problematic areas. And micromodels help to analyse these problematic areas more detailed and to find solution. Simulation models usually become an intelligent heart of ITS.

At the same time, implementation of ITS is not the only necessary thing in transition to Smart Mobility. The change of mobility patterns have also to be ensured by:

- the paradigm shift in urban planning, encouraging compact cities as a way to increase accessibility;
- city dwellers should be able to get to their destination points using as little travel as possible;
- transition to more sustainable modes of transport, such as public, cycling and walking, as well as modal integration of these modes.

Transition to sustainable transport can be limited by some problems: imbalance between transportation supply and transportation demand, the so called "last mile problem" (LMP), discrepancy of transport and bicycle infrastructure to current traffic, etc. Multi-modal passenger transport systems can help to solve some of these problems. High-capacity public transport systems have to be integrated with other modes, including bicycle transport. This requires some infrastructural changes: creation of transfer nodes; streets have to be adapted with walkways, crossings, and bicycle lanes; bicycle infrastructure should include bike parkings, sheds and bikeways; minimization of conflict points where the motorized and non-motorized flows meet. Today, creation bicycle lanes usually causes narrowing the road, which can aggravate congestion. Therefore, all over the world, there some projects to separate cyclists and vehicles. SkyCycle is one of the most extreme such projects. By building a new network of cycle paths high above existing roads and railways, the scheme would create a series of cycle superhighways across London, with specific entry and exit points throughout the city (Daily Mail Reporter, 2012). Dominican architect Richard Morita Castillo offers to build bicycle lanes over city highway. Such overpasses for cyclists Castillo calls ecobahns (like autobahn) or Cycling underground. A similar solutions are proposed for Moscow and Kazan (Russia) (Macioszek and Sierpiński, 2018). And for Russia it is not only about the division of space and reduction the number of conflict points, but it is also necessary protection for cyclists in difficult weather conditions. Despite the fast growing researches on the bicycle lanes design (Aziz *et al.,* 2018; Bao *et al.,* 2017; Chen J. *et al.,* 2018; Chen X. and Yue, 2017; Kondo *et al.,* 2018; Larsen *et al.,* 2013; Sanders and Judelman, 2018), this problem is still actual.

3. Realization of Some Directions of Smart Mobility: Case Study of Naberezhnye Chelny

3.1. Short Characteristic of Naberezhnye Chelny Transport System

Naberezhnye Chelny city has a rectangular layout plan, due to its location along the Kama river, with a parallel location of industrial and rural areas. One of the peculiarities of the cities of such a layout is the uniform distribution of the population throughout the residential area, and in each residential microdistrict (complex) there are kindergartens, schools and shops. This was done with the aim of minimizing educational and everyday transport correspondences. Despite this, the problem of overloaded roads is actual for Naberezhnye Chelny. Since the significant part of trips during peak hours are labor trips, the separation of industrial and residential areas in the city creates problems at the intersections of longitudinal and transverse highways. 10-15 years ago, there was a network of factory routes to deliver workers to industrial zones. Currently, there are no such routes, but the route network of city public transport has not changed significantly. Therefore, employees are forced to travel to work on individual transport.

Public transport in Naberezhnye Chelny consists of 14 tram routes and more than 25 bus routes, where more than 400 vehicles operates every day. The predominance of a large number of low-capacity buses in the city passenger transport system leads to unhealthy competition between carriers, environmental problems, passenger transportation safety decrease and a heavy load on the street-road network.

The Strategy of social and economic development of Naberezhnye Chelny city till 2030 (City council of Naberezhnye Chelny city, Tatarstan Republic, 2016) is directed to increasing of the city transportation system's sustainability. However, from our point of view, the existing Strategy pays insufficient attention to non-motorised modes of transport as well as to multimodal transportation development.

3.2. The use of Macromodels to Optimize City Transport Routes

Analysis of the possibilities and designation of existing software developments for modeling traffic movement showed that the best option for solving the problem of forecasting traffic loads in urban areas is a specialized modeling package at macro level – PTV VISUM. One of the main factors affecting on the characteristics of transport systems is the transport demand of the population, which is the basis of origin-desination matrices. The study consisted of several stages. In the first phase, a survey was organized involving 953 respondents. The results of the survey made it possible to create an origin-desination matrix. After that, the macroscopic transport model of the city was created. Validation and verification of the model was carried out based on the results of field observations of traffic flows. The process of building a transport model of Naberezhnye Chelny is described in our previous papers (Makarova *et al.,* 2016; Makarova *et al.,* 2017a).

Simulation results helped to identify the bottlenecks of the city transport system. One of them is the central avenue connecting the old and new parts of the city. It is the road section, where practically all public transport routes overlap each other. Although the existing configuration of road network does not allow avoiding the overlapping of public transport routes, it is possible to reduce significantly an amount of routes, which pass through the same road section. Figure 1a presents a part of existing route network, numbers mean routes, which pass through problematic road section. The upgraded bus route network is shown on the Figure 1b. Simulations of the initial and proposed variant have showed a decrease in the transport load on the most problematic areas of the road network.

Fig. 1.
Scheme of the existing (a) and of the proposed (b) route network
Source: our macromodel built with the use of PTV VISUM

There was one more hypothesis how to reduce the transport load. Figure 2 shows a map of the city with the locations of educational institutions of higher and secondary special education put on it. Simulation results have showed that in the case of transition from the traditional form of education to the Blended Learning (that would decrease the number of educational trips), the transport load during peak hours could be reduced for 5-6%.

Fig. 2.
Location of educational institutions of Naberezhnye Chelny city
Source: own figure

3.3. The use of Micromodels when Changing Road Infrastructure

The situation in another bottleneck of Naberezhnye Chelny city's transport system could not be improved by public transport's route network optimization. At peak hours, this road section does not cope with the traffic flow: there are the overload, serious traffic jams and high statistics of road accidents. Drivers spend a lot of time maneuvering around corners because of the huge flow of vehicles.

The optimal method to analyze the situation on local areas of the city are micromodels (Makarova *et al.,* 2017b). We have created a simulation model on the basis of a discrete-event approach using the traffic library of AnyLogic 7. The simulation has showed that the geometry of the studied road segment adversely affects the characteristics of the traffic, since it does not correspond to the parameters of the traffic flow. To improve the situation, we proposed to organize a circular movement, which reduces the number of conflict points on this stretch of the road. The experiment was carried out by comparing two variants of the model with the similar input parameters of the transport flows (Figure 3). The research results demonstrate that parameters of traffic of studied stretch of road could be greatly improved (traffic density will decrease by 34%).

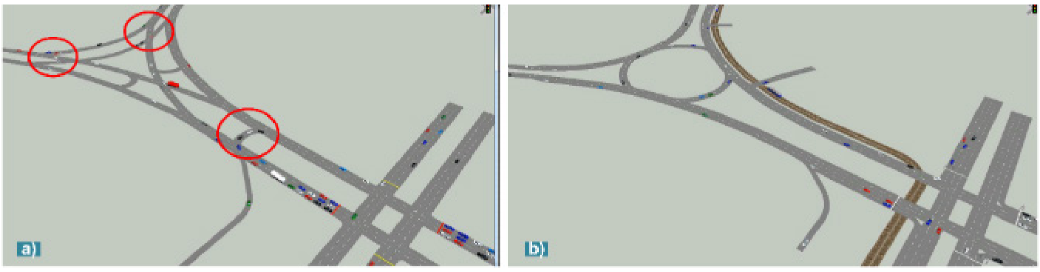

Fig. 3.
Simulation model a) before optimization; b) after optimization
Source: our micromodel built with the use of AnyLogic 7

3.4. Bicycle Lanes Development to Solve the Last Mile Problem

Increasing the popularity of bicycle transport is facilitated by infrastructure solutions:

- designing of bicycle paths taking weather conditions and relief of the terrain;
- integration of bicycles into public transport infrastructure;
- the creation of bike parking spaces in all points of attraction of passenger traffic and near the places of residence;
- creation of a public bicycle system, etc.

The Last Mile Problem (LMP) refers to the provision of transportation's service from the nearest public transportation node to home or office. From our point of view, in big cities, it is hard to persuade population to shift from driving individual cars to riding bicycles, but the use of transport as the addition to the public transport in the destinations, where the busstops are too far from the point of passengers' attraction, can increase the percentage of people using public transport. However, this requires solving the problem of bicycle infrastructure planning. The set of both technical, and scientific decisions is devoted to the solution of this problem (Liu *et al.,* 2012; Saplıoğlu and Aydın, 2018). The Russian document "Album of constructive elements of cycling transport infrastructure" (Department of transport and road and transport infrastructure development of Moscow, 2014) regulates the design of a bicycle infrastructure in Russian cities and gives examples of cycling schemes that take into account the needs of other road users and allow their integration into the traffic system.
In substantiating the change in transport infrastructure, the use of simulation models is an effective method (Ghanayim and Bekhor, 2018). Since the development of the bicycle infrastructure is a promising area that will require periodic analysis of the situation on the roads, an intelligent system for evaluating the effectiveness of the bicycle routes was developed (Figure 4). It consists of several modules: 1) data collection module (including the information on potential bicycle traffic), 2) data analysis module, 3) intelligent heart that is based on simulation models, and 4) the module of recommendations making. AnyLogic 7.3.3 was used to develop the simulation models. Modules for analyzing data and justifying recommendations are implemented in Delphi 7.

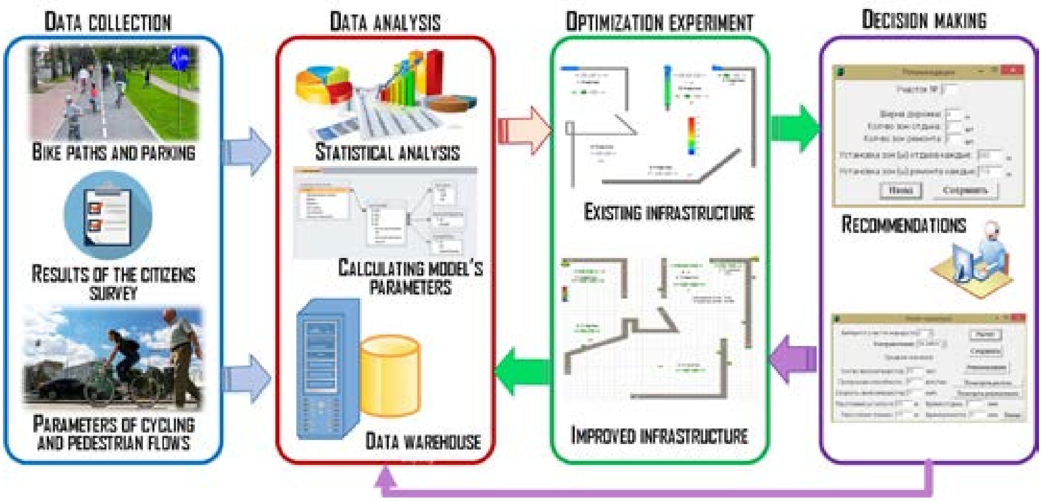

Fig. 4.
Conceptual sheme of intelligent system to evaluate the bicycle routes
Source: own figure

4. Conclusion

Today it is being discussed much about the meaning of the term “Smart Mobility”. Intelligent Transport Systems and infrastructure are the key points in ensuring sustainable mobility in Smart Cities, but they can not be really effective without coordinated planning, vision and managerial decisions. The possibility to implement the Smart Mobility concept into the transport system was considered in the case study of Naberezhnye Chelny. It is presented in the paper that the use of simulation in such directions, as the bus route network optimization, the road infrastructure improvement, as well as development of bicycle infrastructure in order to make it possible to create the multi-modal passenger transportation system consisting of public and bicycle transport. It was shown that decrease of route overlapping, the use of Blended Learning and road infrastructure changes in accordance with simulation results can decrease the transport load on the urban road network. At the same time, development of cycling both as a separate mode of transport and as an addition to public transport will help to solve the Last Mile Problem and, motivate people to use these sustainable modes of transport more than motorized transport. Implementation of solutions listed in the article can be realized independently of each other and give certain results. However, their integrated implementation will provide the maximum effect and will significantly improve the city transport system.

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SUSTAINABLE MOBILITY SCENARIO EVALUATION USING THE ANALYTICAL NETWORK PROCESS

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Abstract: Decision makers and stakeholders in the field of transport and mobility are facing challenges due to changing framework conditions. A demographic change is taking place in Europe and the demand for mobility is increasing. At the same time the energy consumption, emissions and costs should be reduced and access to mobility should be provided for all. Transport users already pay a significant amount, but the price they pay often bears little connection to o the real costs on society of their travel choices (Ricci *et al.,* 2006). A goal of the EU, over the last years, is to establish a transport system that meets society's economic, social and environmental needs and it is conducive to an inclusive society and a fully integrated and competitive Europe (Hoppe *et al.,* 2013). The ongoing trends and future challenges point to the need for satisfying rising demand for travel or accessibility in the context of growing sustainability concerns and in the context of socioeconomic changes. The aim of this paper is to evaluate the influence of certain megatrends on achieving sustainable mobility and at the same time to measure and test different trends scenarios that could lead to a more sustainable mobility.

Keywords: analytical network process, sustainable mobility, transport policy.

1. Introduction

Political and technological changes open access to the global knowledge economy—producing both new markets and increased competition. Based on scientific breakthroughs in recent years, the explosion in the knowledge on transport systems is set to deliver a continuous stream of new applications (Sindakis et al., 2015).
In the last ten years, there were huge advances in future studies and in detecting trends methodology, in particular in Europe. A trend in general is a direction, derived from past data. It is usually based on linear pattern, which only work in a specific context. Trends are usually described by time horizon, impact and geographical coverage.
Trend management, as a research discipline, arose from the concept of weak signals, introduced by Ansoff (1975) and Ansoff (1982). According to Ansoff (1982), weak signals are *"warnings (external or internal), events and developments that are still too incomplete to permit an accurate estimation of their impact and/or to determine their full-fledged responses.*'
According to (Anoyrkati *et al.,* 2016) factors like development of large metropolitan areas, ageing society, charges (e.g. for congestion) seem to be the most challenging for the further development of the passenger transport system in Europe. The same study identified the development of large metropolitan areas as the main key challenge – and at the same driver- for the improvement of transportation.
In this paper, the already defined trends by (Anoyrkati *et al.,* 2016) will be analyzed further in order to measure their impact in achieving sustainable mobility. The current understanding of sustainable development mainly relies on the definition from the United Nations' Brundtland Commission (1987) "*development which meets the needs of current generations without compromising the ability of future generations to meet their own needs*" – also it is subject to differing interpretation and has been developed further to many different definitions.

2. Methodology
2.1. Scenario Design

The method that was used for the development of the three scenarios was systematic formalised narrative technique. The objective of the scenario building process was to define midterm future scenarios (with the Horizon 2035) that would relate to the implementation of sustainable mobility.
The "exploratory" approach used, was based on a number of assumptions (Mietzner and Reger, 2005):
- The future is not only a continuation of past relationships and dynamics, because it can also be shaped by human action (policy);
- Exploration of the future can inform the decisions of the present (policy advice);
- Uncertainty implies a variety of "possible" futures mapping a "possibility space";
- Scenario building involves both rational analysis and subjective judgments and, consequently, requires participative and interactive methods, and is based on evidence (knowledge from literature/models), expertise (knowledge from experts) and creativity (for example: identification of wild cards, i.e. low likelihood high-impact events).

The three chosen scenarios based on exploratory methodology were:

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(1) S1 - Harmony - a well planned, harmonized scenario where sustainable mobility is achieved. The driving forces/external factors affect the policy formulation, which in turn employs directives that lead to sustainable development. The supply responds positively to the demand;
(2) S2 - Inexhaustible - everything is possible, so that there is uncertainty in achieving sustainable mobility due to the unpredictable ‘sensitivities’ of the trends. Harmonization of trends exists but distortion of harmonization is also possible and may impact the achievement of sustainable mobility;
(3) S3 - Entropy - disorder, leads to "destruction", the collapse of the system. The trends behave independently of each other, so that sustainable mobility cannot be attained. The policies do not impact on sustainable mobility and the driving forces do not impact on one another. Sustainable mobility cannot be achieve.

2.2. Determination of Relationship between the Megatrends and Scenario Testing

According to the founder of the ANP (Saaty, 2009), the model is based on ‘*the thinking man’s rational way to combine logic to identify connection among attributes and judgments to derive priorities from causal explanation. Its questions revolve around what dominates what on the average or on the whole and how strongly it is expressed verbally and translated numerically with the use of the absolute fundamental scale’*.
The ANP network represents a combination of graphic outline of the problem by elements and relationships between them. Relationships between the elements are the result of combination of mathematical relations and mimic of human reasoning in the decision process. A basic, Saaty’s fundamental priority scale is used to determine relative weights of each element in network by using pairwise comparison. In Saaty’s 1–9 scale, 1 indicates ‘‘equal importance”, 3 indicates ‘‘moderate importance”, 5 indicates ‘‘strong importance”, 7 indicates ‘very strong importance”, and 9 indicates ‘‘extreme importance”. Even numbered values fall in between importance levels.
The ANP was used for determining the relationship and impact between megatrends which were grouped into three categories (policy-economy—environment) based on the results of the Delphi study on the most predominant trends as described in Anoyrkati E et al 2016. At second stage, using the ANP the trends were tested in relation with the scenarios while a ‘what if analysis’ was performed to examine the direction that is imposed by a change on a particular megatrend on sustainable mobility
To enable participation of a wide range of stakeholders, two online questionnaires were utilized while 56 responses were received from nineteen different European countries covering all the transport modes and sectors (planning, modelling, engineering, travel behaviors, etc). The background of the participants was academics, policy makers or industry.

3. Analytical Network Process Application

According to Margenau and LeShan (1982) scientific theories must be verified: ‘*...scientific truth, that is to say the validity of an accepted theory, depends on two important kinds of factors: the guiding principles...and what we have called the process of empirical verification...these two factors are crucial in the establishment of any theory relating to any kind of knowledge’*. Whitaker (2007) conducted a study on validation examples of the ANP method, which revealed that this method is a useful tool for analyzing several levels of networks to enable informed strategic decisions.
The reasons, however, for using the ANP analysis approach in the present paper are as follows:

- the assessment of scenarios is a multi-criteria decision problem;
- there are dependencies among the groups/clusters of factors/trends and between these and the alternative groups/clusters under evaluation;
- the detailed description of the inter-relationships between clusters encourages the experts to carefully reflect on their selected priorities;
- the method allows the consideration of qualitative criteria;
- a huge pull of experienced participants has been possible to achieve, therefore the prerequisite on the knowledge of the experts has been fulfilled.

The application of ANP methodology in this research has been based on the following principles:
The trends landscape: definition of the main trends
As indicated by Whitaker (2007), a prerequisite of the successful application of ANP is the thorough understanding of the issue. Therefore, a systematic approach was used to gather and analyze the trends and megatrends affecting mobility. Literature review combined with expert knowledge, pertaining the Delphi method for the selection of the most important/prioritization, was applied.
Learning framework: adaptation of the model
Selecting strategies for acquiring sustainable mobility is a multi-criteria decision problem. The learning framework refers to the development of input elements (criteria) for the elaboration of the scenarios. The ANP model receives as input the values of critical factors (trends) associated with sustainable mobility and is be able to predict the impact generated with the use of a scale of estimations that are derived by the experts input.
Value capture mechanism: achieving optimization

Achieving the relative importance of some criteria and measures by simple weighting method is difficult. Capturing the value out of the responders' answers is a critical step in the process. This has been achieved by: 1. Using the experience of (the right) experts (rather than statistical data which often are not available) 2. Providing a framework for evaluation that measures relationships between interconnected factors to perform pairwise comparisons. Transport is a complex system that depends on multiple factors, due to the complexity of the system any intervention must be based on thorough consideration and analysis of the interactions of the factors (EC, 2009). The structure of the ANP model has not come from the numbers that are generated, but rather from the roadmap that has been designed.

3.1. How the ANP Works

As indicated above, the ANP allows the involvement and quantification of all relevant factors in the decision-making process, as well as all the identification of the existing influences between decision criteria and alternatives. (Jharkharia *et al.,* 2007) The procedure of the ANP application consists of two main phases (Mimovic, 2012):
Phase 1: It consists of setting the hierarchy of the criteria, which control the interactions in the network. During that phase the results on the most predominant trends identified in the literature review were further prioritized using the Delphi method. In the two round surveys the experts ranked the most important trends that affect sustainable mobility (Anoyrkati *et al.,* 2016). This was first in the ANP model, which enabled the elaboration of the factors included in the three networks (environment – economy- society). In this first phase, the influences of the trends were not yet identified.
Phase 2: In this phase, a map of the influences amongst the elements and clusters is constructed. The first step in this phase was to determine the influences between the elements within the clusters and the clusters themselves. This was achieved by launching a survey amongst experts. The results revealed the weights of the trends.
The intermediary stages in these two phases, have followed the approach suggested by Saaty (2001):
1. Decomposition of the problem: The decision problem is analyzed in its main components.
The main research question that drove the first stage was: what are the main trends affecting sustainable mobility?
Sustainable mobility depends upon a number of factors / trends that influence its successful implementation. Based on the existing knowledge and understanding, it is obvious that megatrends lead to serious challenges for the transportation system and the achievement of sustainable mobility. Therefore, there is a need for the transportation policy to adjust its developing routine to the current and future megatrends. However, different economic, social and environmental characteristics of various regions all over Europe cause different impacts of these megatrends on corresponding transportation systems. A literature review-based methodology and search on the term "megatrends" in passenger transportation reports was applied. Particular emphasis was given to the EC, ETPs and worldwide projects, which have studied the megatrends shaping the world we live, with emphasis on transportation studies. After thorough review of relevant and available literature, a consensus on the selection of the key global megatrends that impact on future of sustainable mobility was achieved through the application of the Delphi method, which allowed the ranking of, the trends based on experts' judgments (Anoyrkati *et al.,* 2016).
A compound ANP model was then developed in order to take into account the complexity of the decision problem and the elements involved.
2. Cluster formation– After identifying the main trends affecting sustainable mobility, the objective.
of the second stage was to generate clusters and identify the relationships between the elements within and between the clusters. This was again performed by a survey questionnaire where the experts were asked to indicate the influence paths of each of the clusters and trends. A map of influences/impacts was finally developed (See below figure 1).
3. Structuring of the ANP model –In this step, a series of pairwise comparisons are applied in respect to a certain component of the network. The ration scale used is 1 to 9 where 1 means that the elements are equally important and 9 means that the different of influence of the two elements is significantly important.
4. The sensitivity analysis: As a last step of the ANP analysis, a 'what if analysis is' was carried out to observe the change in the attitude of the system in case that some variables alternate. This is important in order to determine the impact of the changes and identify the elements (policies in this research) that would be affecting the application of sustainable mobility the most.

4. Results
4.1. Impact Analysis

In order to reach a geographical spread sample of participants, w an online questionnaire was used for the determination of relationships between the megatrends. The answers included three types of relationship (one way, feedback and does not have relationship) as per the ANP definition. The final outcome was to apply logic interactive matrix. The map of trends and cluster interaction that was obtained by the first questionnaire is illustrated below. One-way (→ or ←) arrows determine the impact of a trend over another. Two-way arrows define the mutual impact of the trends on each other (←→).

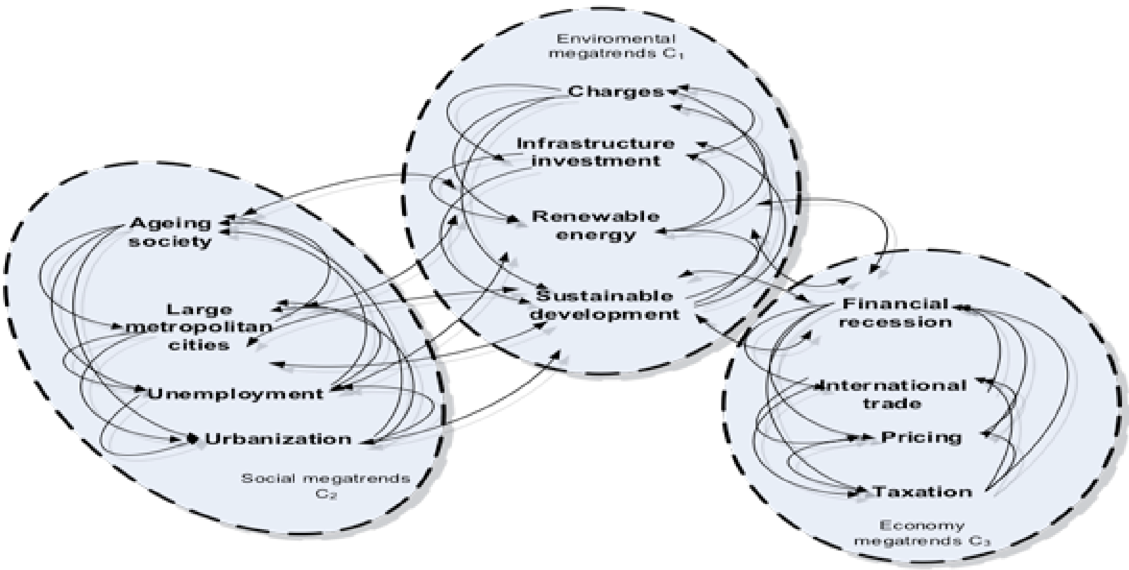

Fig. 1.
The trend relationship map

The calculation of priorities of the megatrends and scenarios were implemented through the software Super decisions @ Upon completion of all pairwise comparison matrices, 57 pairwise comparison matrices obtained for the whole model, the unweighted supermatrix is built. The corresponding priorities of the clusters have been obtained and used to weight this matrix. Raising the weighted supermatrix to limiting powers until the weights converge and remain stable the limit supermatrix will be achieved. Since all the columns of this last matrix are the same, only the resulting values of one column are shown due to space constraints.

Table 1
ANP resulting values

Elements	Normalized By Cluster	Limiting
Scenario 1	0.49855	0.041716
Scenario 2	0.27074	0.022654
Scenario 3	0.23071	0.019305
Financial recession	0.34902	0.103615
International trade	0.17523	0.052023
Pricing	0.21164	0.06283
Taxation	0.26412	0.07841
Charges	0.21584	0.076252
Infrastructure investments	0.28314	0.10003
Renewable energy	0.24749	0.087436
Sustainable development	0.25352	0.089566
Ageing society	0.20423	0.054359
Large metropolitan cities	0.3623	0.096431
Unemployment	0.23254	0.061892
Urbanization	0.20093	0.05348

All respondents considered that sustainable development is very "controlled" (Scenario 1 is the first choice for all groups of participants), and that indicates that economic, environmental and social factors are highly interconnected.
Looking into detail the effects of elements within the cluster, it can be noticed that in the environmental cluster the impacts of megatrends differ by groups, while for the other two clusters there is no deviation (table 2). According to all representatives and by group, the megatrend financial recession, from the economic cluster, has the greatest influence on the priority of the strategies. As far as the social cluster is concerned, it is megatrend large metropolitan cities.

Table 2
ANP network factor priorities consolidated

Clusters	Elements	All respondents		Groups of respondents					
				Policy makers		Industry		Academy	
		rang/ ideal	normal	rang/ ideal	normal	rang/ ideal	normal	rang/ ideal	normal
alternative	s1	1.000	0.5000	1.000	0.4927	1.000	0.5156	1.000	0.4785
	s2	0.540	0.2700	0.556	0.2739	0.501	0.2583	0.628	0.3009
	s3	0.458	0.2290	0.473	0.2333	0.438	0.2261	0.461	0.2205
C1	financial recession		0.3500		0.3562		0.3630		0.3285
	international trade		0.1751		0.1692		0.1616		0.1989
	pricing		0.2136		0.2058		0.2138		0.2183
	taxation		0.2614		0.2687		0.2616		0.2541
C2	Charges		0.2188		0.2151		0.2835		0.2187
	infrastructure investment		0.2817		0.2956		0.2506		0.2689
	renewable energy		0.2464		0.2466		0.2506		0.2416
	sustainable development		0.2530		0.2426		0.2446		0.2708
C3	ageing society		0.2038		0.1912		0.1916		0.2253
	large metropolitan cities		0.3619		0.3677		0.3735		0.3495
	Unemployment		0.2333		0.2354		0.2463		0.2135
	urbanization		0.2010		0.2056		0.1884		0.2117

4.2. Analysis of Sensitivity (What if Analysis)

The ‘what if analysis’ has revealed that the four megatrends that have the highest impact are: Taxation, Unemployment, Pricing and Charges. If taxation and unemployment are not treated as top priorities then sustainable passenger mobility will strive towards Entropy. The impacts effects on megatrends are more indeterminate when it comes to the pricing and charges. With the changes in the policy priorities of these two megatrends, harmonization of all trends will be in a state of dismay and passenger mobility will be inexhaustible.

According to the sensitivity analysis conducted per participant group, it can be observed that only industry representatives consider that the scenario 2 is possible to be dominant. This practically means, that they consider that sustainable mobility achievement will depend on the influence of ‘charges’ and ‘taxation’ trends. If a change occurs on the impact of the trend ‘unemployment’ that would possibly lead Scenario 3 to become the most likely.

Additionally, the analysis reveals that a change in the importance of the trend ‘pricing’, scenario S3 might become possible, but still Scenario 1 is most possible to occur.

Table 3
Priorities of scenarios

	Representative Groups			
Scenarios	**Policy Maker**	**Industry**	**Academia**	**Overall**
S1	1	1	1	1
S2	0.556087	0.500991	0.615797	0.53991
S3	0.473532	0.438385	0.445685	0.458151
Priorities:	S1> S2 >S3			

Table 4
Influence of key Megatrends on scenarios

	Representative Groups			
Megatrends	**Policy Maker**	**Industry**	**Academia**	**Overall**
Pricing	S1> S3 >S2	S1> S3 >S2	---	S1> S3 >S2
Taxation	S3> S2 >S1	S1> S2 >S3	S2> S1 >S3	S3> S1 >S2
Charges	S3> S2 >S1	S3> S2 >S1	S2> S1 >S3	S1> S3 >S2

Unemployment	S3> S1 >S2	S3> S1 >S2	S3> S2 >S1	S3> S1 >S2

5. Conclusions

A goal of the EU is to establish a transport system that meets society's economic, social and environmental needs and it is conducive to an inclusive society and a fully integrated and competitive Europe (EC, 2009). The ongoing trends and future challenges point to the need for satisfying rising demand for travel or accessibility in the context of growing sustainability concerns. Our research aimed to contribute to a more sustainable transport system in Europe, by focusing on Megatrends. Sustainable mobility is understood as a long term vision that needs to be achieved in the context of achieving a more inclusive and competitive society and economy in a continuous changing context.

A prerequisite of influencing the transport system is to understand the dynamics involved. The system of transport and mobility works as a market. To estimate the future development of demand and supply directions it is necessary to identify the main influencing trends. Our research was designed to integrate those megatrends with regards to their impact on achieving sustainable mobility using the ANP approach. Metanalysis on megatrends provided a deep understanding on this issue, assessing their impact but also based on scenario analysis, the elasticities were estimated too.

As further research, a state of the art on policies should be conducted. This can be compared with the findings of this paper so as to determine the policy gaps that need to be addressed in order to enhance the policies that relate to the main Megatrends identified. However, success of the measures for sustainability depend on their feasibility. Policy and planning are usually confronted with unforeseen development. Concrete measures won´t provide solutions by all means, however, we have aimed to make the elaborated knowledge valuable, therefore, general guidelines for policymaking and transport planning are developed.

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EQUITY NEEDS IN TRANSPORTATION EDUCATION AND ENGINEERING

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Abstract: The significance of the gender dimension in research and innovation increases. Initiatives to promote gender equality in the STEM field have been developed in Europe for nearly two decades but were insufficient to increase the number of women in engineering, particularly in positions of responsibility. The Impact of the European Parliament Resolution of 9.9.2015 on Women's Careers in Science and University had been discussed in Brussels two years later during EP debate From Resolution to Realisation and it was concluded that there is still an imbalance and need for integration gender equity issues in education and engineering. Gender equality in the context of engineering and the academia means: 1. Reduction of vertical and horizontal segregation (underrepresentation of women in male-dominated sectors). 2. Balancing the asymmetric gender culture in organizations (removing structural barriers for women). 3. Integration of a gender dimension in teaching and research (gender awareness-raising among the academic engineering staff). Transportation is one of the branches of engineering which is highly sensitive to social aspects. International groups of interdisciplinary researchers are trying to investigate the problem of social exclusion and to cooperate on knowledge-based inclusion mobility, accessibility and transportation plans. The European strategy toward improvements in mobility conditions of transport users covered not only general equality in transportation issues, but also gender aspects in the area of transport research. A short review of selected European actions and initiatives related to equity need in transportation was made, covering COST actions and EC programs to which authors contributed, starting from FW5 project in 2003. The strategy for EU Horizon 2020 resulted in increasing the number of research projects dedicated, directly or not, to equality in transportation engineering. However, despite enlarged knowledge on the social needs and European transport policies of inclusion, there are still many obstacles and barriers to implementing this knowledge in transportation education and practice. This paper presents selected results of current equity status in transport engineering education and equal career development for women in Poland, with a special focus on the Cracow University of Technology (PK) data. The main goal is to identify problems and barriers to constructing the tailor-made Gender Equity Plan (GEP) for PK.

Keywords: transportation, education, engineering practice, gender equality, European policy.

1. Introduction – Equity Needs in Engineering

In 2018 Poland is celebrating not only 100 years of independence, but also 100 years of women's rights. Woman received the right to vote, to study and to work, also in different engineering areas fully dominated by men. In Polish history, women have played different roles in society, both working and being responsible for the household. Parallely they have given voice to politicians that their "100 YEARS OF WOMAN VOICE" contributed to national development in all areas. It is valid in the transportation field, where they show that the place in which the Polish women stand today is not accidental, but it is made up of a million of initiatives and events that have taken place in the past. During the last 100 years transport has changed dramatically, mobility has increased and caused new problems, connected to road traffic density, high risk of fatal accidents and environmental pollution. Engineering methods and solutions seem to be a challenge for changing this situation toward sustainable transportation in sustainable development of sustainable societies. This requires engagement of all human resources and engineering talents which are able to develop new solutions. The lack of human resources among women engineers, without whom the male dominated engineering community will not alone be able to contribute to the social development challenges in a modern sustainable society today or tomorrow.

2. Transportation Equity as a Precondition of Sustainable Development

2.1. EU Strategy for Equality Between Women and Men

Equality between women and men is one of the European Union's founding principles. Already in 1957 the Treaty of Rome introduced the rule of equal pay for equal work. Much progress has been made since that time to get more women into the workforce. Today nearly 60 percent of women work in the EU, rising from 52 percent in 1998. The European Commission (EC) strategy is to get 75 percent equally for men and women by 2020. It is important that more women need to be involved to the European workforce to reach that goal and to get Europe's economic engine moving again. According to the EC strategy, Europe should make better use of women's talents, especially that they are recognized as problem solvers and excellent at multi-tasking. The European Commission adopted a new strategy called Women's Charter in 2010 with a commitment to include gender equality in all its policies. In order to fulfill the equity objectives, an action plan for promoting equality between men and women – the Gender Equality Strategy was adopted. The actions in the Strategy should help to address some of the remaining gender gaps. The gender gap in the employment rate was 12 percentage points in 2009. It is necessary to improve women's participation not only in the engineering field, organising better work-life balance, promoting female entrepreneurship and working with all Member States on the availability of affordable high-quality child care. The gender pay gap (the average difference between

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men’s and women’s hourly gross earnings across the economy as a whole) in the EU remains at 18%. With the European Social partners, EC is committed to work on improving the transparency of pay schemes. Raising awareness is also pointed out as being crucial. The European Commission will (cit.:Viviane Reding, EC Vice-President) *“introduce a European Equal Pay Day as from 2011 so that every year it can visualise how much longer women need to work than men to earn the same amount”*. It is also needed to make sure that women’s careers are not blocked by a glass ceiling effect. Today, only ten percent of the members of the management boards of large publicly listed EU companies are women. The European Commission plans to work together with the private sector to raise the number of women in economic decision-making positions – either through self-regulation or an EU initiative. Gender equality has become our European social and economic responsibility.
In *“Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions”* horizontal actions are listed too, regarding gender roles and several frameworks and tools aiming at promotion of equality.

2.2. European Transport Policy Toward Equality

According to the EESC Report (Transport 2016), European transport policy is dynamic and ambitious.
Transport is a sector of great importance to Europe. It is one of the EU’s most significant fields of action, because it has a huge impact on social and environmental well-being, both in cities and rural areas. A large number of the Transport, Energy, Infrastructure and the Information Society (TEN) Section's opinions each year relate to transport, which confirms its crucial role in EU.
Progress in the transport sector involves building better and greener infrastructure, which will boost economic growth and enhance trade. But it also means cutting CO_2 emissions and energy consumption, and tackling congestion and the lack of access which can isolate individuals – especially elderly or disabled people – in their homes. The transport sector should also stay smart and competitive as part of a socially fair transition towards clean energy and digitalisation. The EESC examines and assesses EU transport policies from the point of view of the needs and interests of all segments and concerns of European civil society.
It is stated that making the EU's strategic plans in the field of transport needs involvement of civil society actors in building stronger and more inclusive involvement of civil society, both in policy making and in policy implementation. The equal representation of social groups, *especially men and women* will be able to better promote a high level of civil society participation and involvement on transport related decision-making processes.

3. Women in Transportation - Studies and Research Results

One may indicate the two main gender based gaps related to women situation in transportation:
1. The difference in travel behaviour between man and woman;
2. The employment gap - most of people working in transport sector are men.

3.1. Studies on Transport and Travel Behaviour

European researchers, including Polish experts from transport research and education institutions, cooperated in several actions and programs related to women issues in transportation.
Women and their specific travel behaviour has been, since decades, the topic of only few research projects. The present studies show that there have always been important differences between men and women with regard to travel behaviour (Hansen & Polewoy 2011), sense of security and safety in driving (Suchorzewski & Kleszczewska 1994, She Moves 2014). As mentioned in the previous section, the gender equality is part of the political discourse in the European Union, however the transportation planning still tends to neglect the differences between men and women in transport behaviour. Moreover, only a few notable studies and initiatives have dealt with data on the extent of the difference as well the specific issues related to women and their travel patterns and obstacles.
One of the most interesting conferences, among different initiatives concerning equity related issues in Engineering, particularly in Transportation, is the international conference ‘Women’s Issues in Transportation’(WiiT), that is being organized in order to identify and discuss the different issues and solutions for women’s usage of transportation and their involvement in different transport related sectors. The major outcome of the fifth WiiT Conference, held in Paris in 2014, was the publication produced on behalf of the European Commission Directorate - General for Mobility and Transport (DG MOVE) (She Moves 2014). Some specific data on the women’s situation in transport sectors has been presented in this document. While over 50% of the population are women, the percentage of women in the driver population was in 2010 on average 45%, but the percentage varied between EU Member States. The highest share of female drivers in 2010 has been observed in Estonia (equal to 64%) and, what is highly interesting, this proportion has totally changed since 2001, when in Estonia the share in female drivers was 37%. In Poland, on the other hand, female drivers constituted 34% of total number of drivers in 2010, which means an 11 percent increase over almost 10 years. The equal representation of women and men among drivers in 2010 one may notice in Finland and Ireland.
In terms of travel patterns, European and US studies confirmed that women take more trips during the day, however those trips are shorter (Sarmiento 1998, Scottish Executive Central Research Uni 2000; McGuckin and Nakamoto 2004; Olde-Kalter et al. 2009, McGuckin 2009, Duchene 2011). Also trip purposes and the trip chaining are not similar for

men and woman: both Polish and other European studies (Nosal 2018) confirm that women are more likely to travel for shopping and escorting friends and family. Women are also not commuting that often in comparison to men, which may be a result of the trend of being part-time employed, working at home, taking care of others or just work closer to their home. Additionally, taking into account the caregiver tasks, women often realise different activities one after another during one trip: reaching schools as an escort, shopping and health-care facilities. The studies conducted in Poland (Zakowska & Pulawska 2014), based on several urban case studies confirmed the difference between men and woman travel behaviors. For Krakow, general comparison between men and women considering the usage of different transport modes shows that women seldom choose a car while travelling to the city center. A car is the favorite mode to travel for about 23% of men and 14% of women. Women also more often choose public transport – taking into account trips to city center slightly more than 75% of women use public transport, while tram and bus are chosen by around 60% of men. It is important to notice, that in this study only trips to the city center of Krakow, where good accessible public transport service exist, were taken into account (Zakowska & Pulawska 2014).

Some other data on travel behaviour in Polish cities has been examined in regard to the gender factor (Nosal 2018). These elaboration confirmed the existence of differences in the travel behaviour of women and men and this differentiation concerns mainly the trip purpose, the number of trips and the choice of the transport mode. This is a result of social roles assigned to women, especially in traditional society. In general, women in Polish cities show more sustainable travel behaviors than men, more often using public transport and traveling by foot.

With regard to the differentiation in travel behavior of men and woman, one may indicate also technical, physical and economical dimensions of public transport accessibility. Physical barriers are mostly related woman using public transport. Several barriers limit easy and convenient mobility while carrying small children or children's strollers and this influences the accessibility. These barriers are connected to the lack of enough space for carriers, crowded and high-floor vehicles or mismatched platforms, which makes it very difficult to get in and out (Women and Transport: Moving Forward 2000; SIZE Project; Puławska & Zakowska 2016).

The European EC projects in the area of mobility in the ageing population as SIZE and AENEAS (Zakowska 2012) aimed to explain and describe the mobility of senior citizens conditions, especially to evaluate the transport needs in relation to senior's gender, age and safety and to identify relevant solutions for existing problems and for "keeping the elderly mobile". Gender aspects of senior citizens mobility were researched extensively in SIZE EU project. As shown in summary report (Zakowska, 2014), the majority of the older population is female and older women are the fastest growing segment among car drivers. Since a first review on "Older female road users" (Ewans, 1998), where it was concluded that elderly women in traffic had been "an invisible group", research on this topic has risen (see for example (Siren, A., & Hakamies-Blomqvist, L. 2004, 2006)).

Since the 1960s, great societal changes have taken place, which have had a big influence on gender roles and spheres traditionally defined as "male" or "female". Higher education level and income among women have led to increased mobility demands by women, reflected in a higher number of daily trips, distance travelled, and time travelled. Socio-economic changes have also contributed to women's higher car ownership and car use (D'Ambrosio, L.A. 2008). Also car ownership among older women has significantly increased during the past decades, associated with greater car use and in maintaining a current license in old age. However, older women are still less likely to hold a driving license compared to men. When it comes to gender differences in modal choices, women walk more often and travel more by public transport. Women make, on average, fewer daily trips, especially by car. Women's travel has also been found to be limited to smaller geographical areas and to depend more on social factors. These differences to some extent decrease with age, which can be explained with social structures related to working life (Zakowska & Kubiak, 2004). It is important to base studies on differences in men's and women's travel behavior on knowledge about activities on various social arenas which generate trips. Gender differences pertain especially to the involvement in the labor market, household work and responsibility for children and elderly relatives, and these differences have an impact on men and women's everyday travel activities and use of transport modes. Examining older people's trip chaining in CONSOLE project, older women compared to men are more likely to make more complex tours, particularly shopping tours (Bell et al., 2013). Also, becoming dependent on public transport was more common in European countries among women than men.

In general, women report more unmet travel needs than men, which means that especially parts of their leisure activities remain unrealized (Siren, 2005). Women also report more difficulties with all transport modes than men, which could be due to both greater difficulties and a greater openness about difficulties. While women's problems seem to be more related to the dependence on others and on public transportation, older men's problems result from their car dependent lifestyle, which leads them to be less prepared for life without a car compared to women. An important barrier to mobility is perceived safety and security. This is especially true for older women, but very young as well.

3.2. Employment Gap in Transportation

Transportation is a male-dominated sector. The data about employment in transport sector indicates that only 20% of workers are women (Report on Equality of Women and Men, 2017). Furthermore, the payment gap in the transportation sector is around 20% (Women and Transport: Moving Forward 2000). However, the lack of the proper, gender-oriented data on the labour market in transportation limits the accurate identification of existing gaps (She Moves 2014). Some information one may find is on the woman presence in decision making bodies of significant transportation companies or committees. Political committees in EU in the transportation sector, transport research and advisory boards are

dominated by men - most boards have less than 15% female representation and none have achieved equality in this field (She Moves 2014). Only a few countries have developed a gender equity related politics for national transport committees or companies. In France, thanks to the women's movement, that pressed transportation operators to hire more women in order to better address women needs, today about 25% of highest positions are held by women. Only in Sweden is the equal 50-50 representation of women observed in the National Transport Committee.
In Poland some interesting examples of lack of equity in transport professional group is presented in current membership figures of engineers and technicians associated in the Polish State Association of Engineers and Technicians of Transportation SIRK RP. Less than 30 percent of SITK RP members are women only.

3.3. Recommendations

To tackle the issue of transportation inequity, the OECD (Duchène 2011) elaborated four main recommendations:

1. Integration of women into the policy making, decision-making, and planning of public transportation;
2. Incorporation of the gender-based solutions into policy making and transport planning;
3. Take actions for increasing the share of female employees in the transportation sector;
4. Consideration of gender dimension in statistical research and data collection.

Summing up the above consideration, authors state that ensuring equal opportunities for men and women in transport, issues related to mobility, security, employment and sustainable development should be taken into account. Despite the existence of data confirming the differences in transport behavior, they are rarely taken into account in the planning processes and strategies for the development of cities and regions. Therefore, first of all, emphasis should be put on increasing awareness of the benefits that planning will bring, taking into account the needs of all users, with particular emphasis on women and the inclusion of the gender dimension in emerging policies.

4. Cracow University of Technology (PK) Equality Facts in Career Development

4.1. Short Description of the University

Politechnika Krakowska, PK (Cracow University of Technology) is one of the biggest state technical universities in Poland, founded in 1945. PK is engaged in: educating highly qualified engineers who can cope with national and global industry challenges; educating academic staff by supporting the development of their scientific passion and their participation in national and international scientific exchange; serving the economy and the society as a whole by solving technical and technological problems and by implementing scientific studies into economic practice.
Cracow University of Technology consists of 7 Faculties: of Architecture, of Chemical Engineering and Technology, of Civil Engineering, Electrical and Computer Engineering, of Environmental Engineering, of Mechanical Engineering, of Physics, Mathematics and Computer Science. There are twenty seven scientific areas/ fields of study at PK, within them Transport Engineering is conducted at two Faculties: Mechanical Engineering (WM) and Civil Engineering (WIL).
Currently, the university has 13517 registered students (10878 full-time students and 2639 extramural students) as well as 235/262 doctoral candidates and 985 postgraduate students. University staff consists of 2110 employees, including 1188 academic teachers. The total budget of the University is around PLN 150 million. One of the largest departments is the Faculty of Civil Engineering, both in terms of quality and quantity of academic staff and the number of students educated (more than 2100 students registered). The University cooperates with many scientific centers around the world and is involved in many Educational Union programs which have given fruit in the form of joint scientific studies, exchanges of students and academic teachers, as well as the possibility of obtaining additional certificates and diplomas.

4.2. Equality Issues in Education Process

Considering the proportion of women and men along career tracing path from first year of bachelor courses (BA), through master degree courses (MSc) to doctoral courses (PhD) the share of women at PK, as a whole university, was about 36-42 % in 2011. But recently, their share at the stage of graduated students of BA and MSc courses increases on about 9 and 14 percentage points, respectively to about 50% or even more at the stage of MSc and PhD level of studying (Fig. 1).

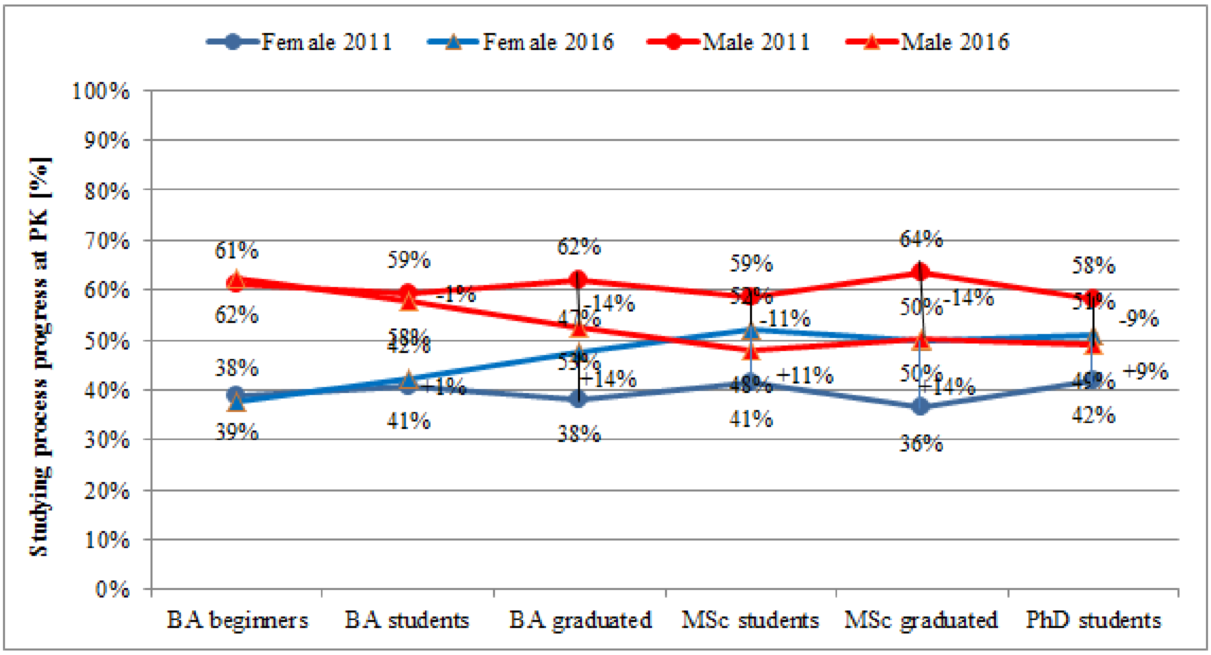

Fig. 1.
Studying progress process from BA to PhD level at Politechnika Krakowska from 2011 to 2016, by sex
Source: authors' work

The proportion of women among students of Transportation specialization at the Faculty of Civil Engineering and the Faculty of Mechanical Engineering is illustrated at Fig. 2 and Fig. 3 respectively.
The share of female students at Civil Engineering is not as large as at PK as a whole, but during last 6 years the number of female students significantly rises. Proportion of women studying at MSc and PhD courses changed from 41% to 52% at the MSc degree and from 42% to 51% at the PhD degree.

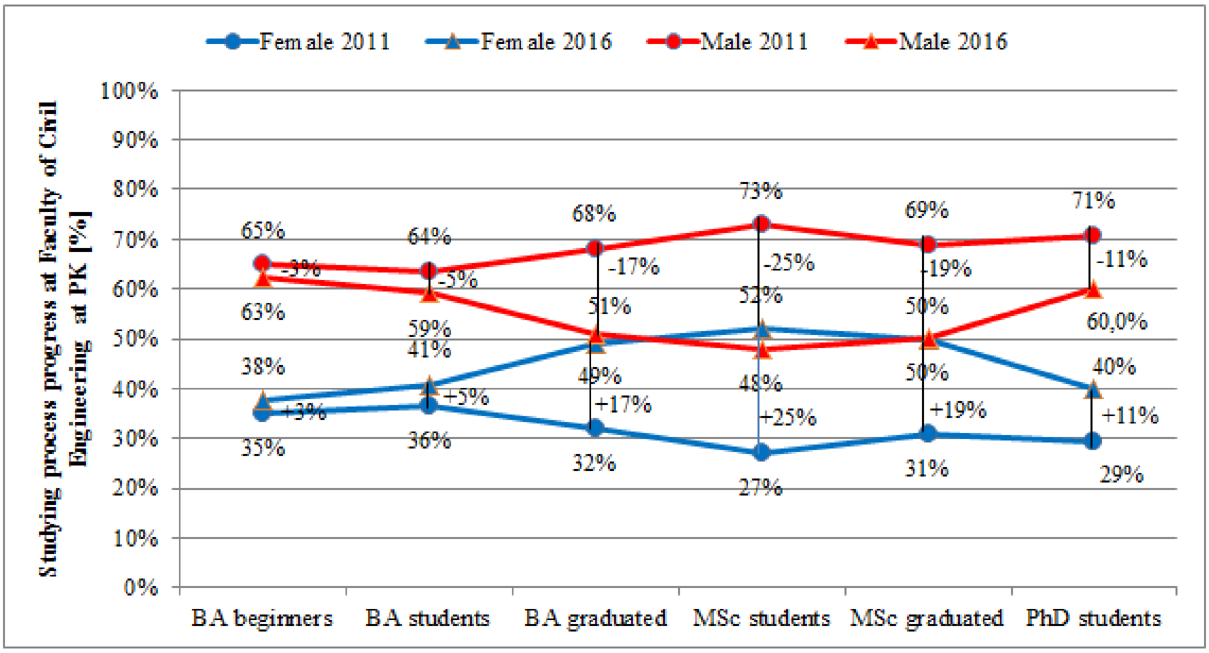

Fig. 2.
Studying progress process from BA to PhD level at Faculty of Civil Engineering of Politechnika Krakowska in 2011 and 2016, by sex
Source: authors' work

The same type of progress can be observed at the Faculty of Mechanical Engineering (Fig. 3), although the starting point is much lower. The share of women increased from 2011 to 2016 by about 16-20 percentage points especially at MSC and PhD courses. However, it is no more women studying there than 34% at MSc and 43% at PhD courses.

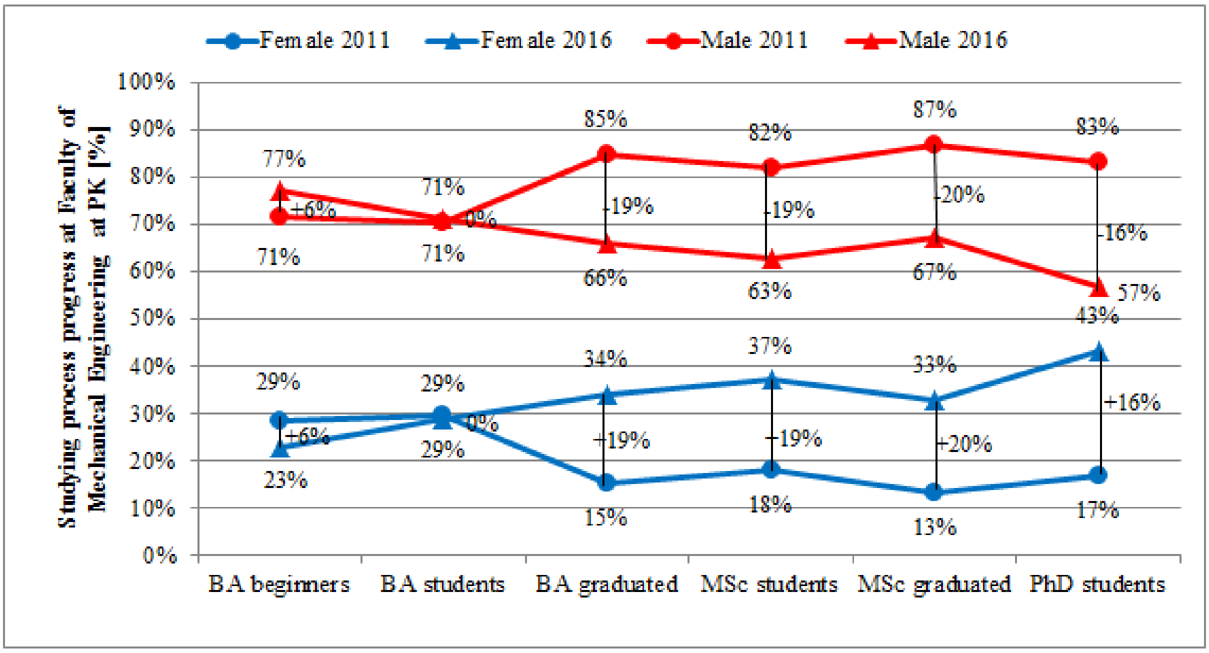

Fig. 3.
Changes of share in male and female students groups during studying process from BA to PhD level at Faculty of Mechanical Engineering of Politechnika Krakowska (2011 and 2016), by sex
Source: authors' work

The figures above support the evidence that there is a good tendency of increasing proportion of female transport students at PK. During the last five years the number of young women increased by 20 percent, while in comparison to men, whose number increased by 16 percent. The total number of students who decide to study engineering and among them such fields of study as transport is growing, but faster for female students. This documents the fact that more girls are brave enough and determined to become engineers.

4.3. Equality Issues in Career Development and Retention

The data collected by She Figures 2015 confirm the similar tendency of increasing number of young female engineers in other European countries. More and more young women are studying engineering and then they move forward and gain sequent degrees of academic education. Interestingly, their share in EU-28 is lower, than in Poland at PK. The same tendencies of changes are observed among researchers from initial stages of a research career to all senior academic positions. According to the structure of staff positions among academic staff described in She Figures 2015, the subsequent career levels has been accounted for the analysis in this article, as presented in the Table 1.

Table 1
Description of staff position

Grade	Position name	National classification	Description
A	professor	Full Prof.	Should include all researchers working in positions which are not as senior as the top position (A) but definitely more senior than the newly qualified PhD holders (C); i.e.: below A and above C
B	associate professor	Prof.PK, University professor, Habilitated PhD,	Should include all researchers working in positions which are not as senior as the top position (A) but definitely more senior than the newly qualified PhD holders (C); i.e.: below A and above C
C	assistant professor	PhD, Adjunct	The first grade/post into which a newly qualified PhD graduate would normally be recruited within the institutional or corporate system
D	other teaching staff	MSc	Either postgraduate students not yet holding a PhD degree who are engaged as researchers, (on the payroll) or researchers working in posts that do not normally require a PhD

Source: authors' work based on (She Figures 2015)

The proportion of women applying for the lowest academic position (Grade D) is similar to the share of women who are graduated at MSc courses. At PK, there is about 50% of young female researchers (Fig. 4).
However, at the next steps of academic career of women in engineering, the effect of "leaky pipe" is clearly observed. The gap between share of women and share of men widens. At PK, women represents only 34% of grade C staff, 26% of grade B staff and 12% of grade A staff. At the level of grade C the situation at PK is identical like in EU+28, at level of grade B it is on 2 percentage points better than in EU+28, but the proportion of women awarded with professor title is on 1 percentage point lower than average in other European countries.
The representation of women as students and then researchers at two PK faculties, that carry on education in the Transportation field of study is differ from one another (Fig. 5). The Faculty of Mechanical Engineering is much more men dominated than the Faculty of Civil Engineering. The proportion of women as students do not exceed 37% at any stage of studying excluding PhD courses where it is equal to 43%. The share of women researchers is rapidly dropping down from 38% for grade D staff to 19%, 7% and 5% for grades C, B and A, respectively.

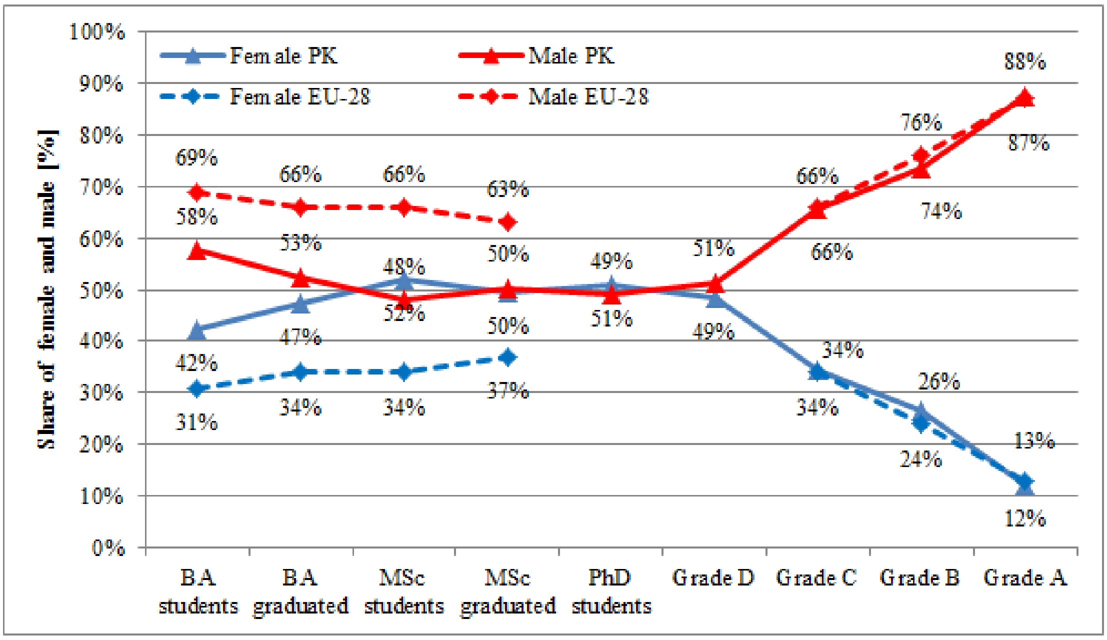

Fig. 4.
Participation of women and men at subsequent career levels at Politechnika Krakowska in 2016 and EU-28 in 2013, by sex
Source: authors' work

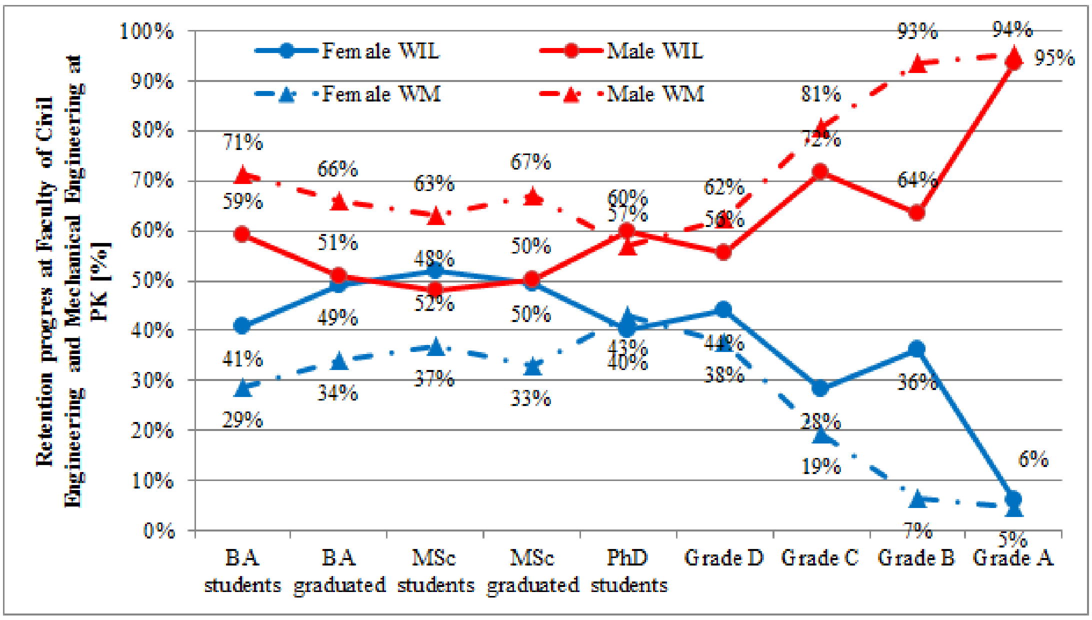

Fig. 5.
Participation of women and men at subsequent career levels at transport related two faculties: Faculty of Mechanical Engineering (WM) and Faculty of Civil Engineering (WIL) of Politechnika Krakowska in 2016, by sex
Source: authors' work

The evidence of facts, that are the typical picture of "scissors' diagram" presented above (fig.4,5), proves the difficulties faced by women employed at technical universities that are resulted from, on the one hand, the expectancy of fulfilling different social roles (in family and workplace) and, on the other hand, need to supply the sufficient financial resources. The negotiation of participation in different housekeeping and caring responsibilities is for women-scientist with partner is even more difficult, taking into account quite low earnings in the academy, compared to other sectors.

4.4. Remuneration of Academic Staff

Consideration of gender remuneration in research and innovation is paramount in creating equal working conditions for women and men. It is usually observed among academic employment and in the whole economy that women earn less than men. Absolute gender pay gap (GPG) is counted as a difference between female and male salary. GPG is often expressed in percentage as a rate of absolute gender pay gap to male salary.
The indicator elaborated to measure that issue and presented in She Figures 2015 as the unadjusted GPG represents the difference between the average gross hourly earnings of paid men employees and of paid women employees, expressed as a percentage of the average gross hourly earnings of paid men employees. It could be also adjusted according to differences in individual characteristics or other observable characteristics that may explain part of the earnings difference (She Figures 2015). The gender pay gap widens with age (She Figures 2015). It is extremely unusual for women to earn more on average than men (i.e. a negative gender pay gap), although, there are a few exceptions in particular age groups. In scientific R&D, these exceptions exist only in the younger two age categories (<35 and 35–44).
In this article the remuneration is considered as an annual salary for full-time contract. Two indexes has been chosen to compare female and male salaries. The first one is counted as a rate of female annual salary to average annual salary in group of academic staff position (Fig. 6), the second one refers women/male salary to average salary (Fig. 7).

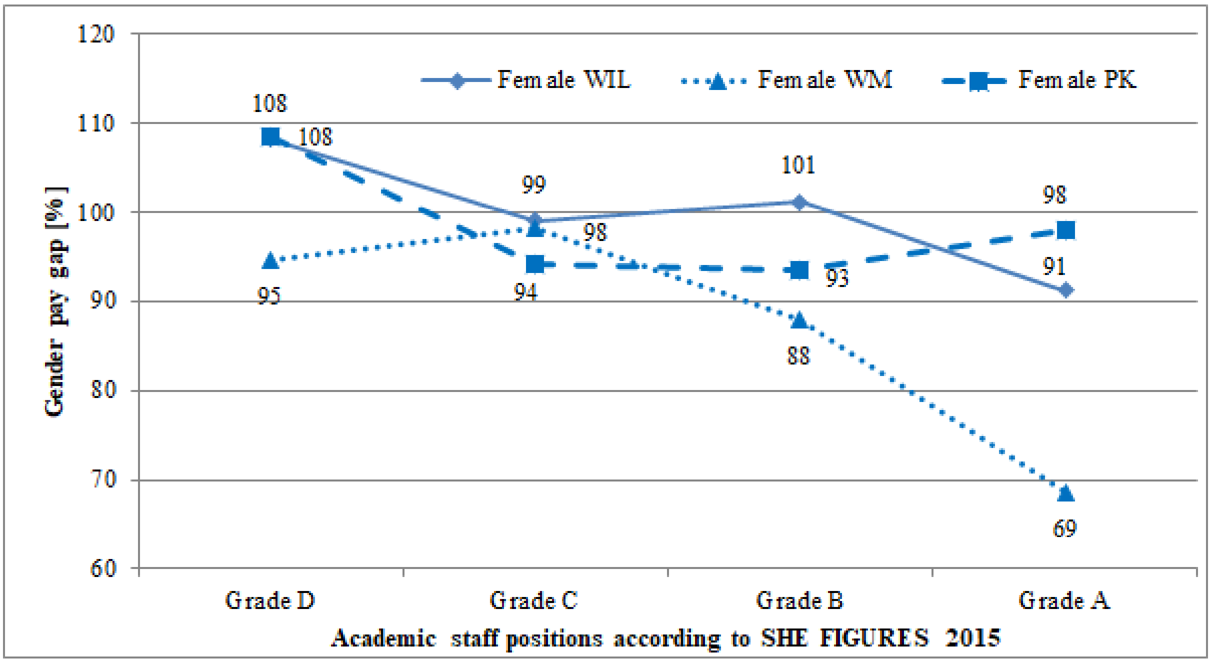

Fig. 6.
Comparison of average salary at Politechnika Krakowska, Faculty of Civil Engineering and Faculty of Mechanical Engineering in 2016, by sex and staff position
Source: authors' work

It is worth noticing that only young women researchers (grade D) employed at the Faculty of Civil Engineering and at PK (average of all staff working at grade D position) earn more than men at the same position. The difference is on about 8 percentage points. The remunerations of women researchers at the Faculty of Mechanical Engineering show that they earn less than men and their salaries state from about 95-98% (grade D and C) to 88% and 69% for employed at grade B and A, respectively.
Considering absolute pay gap in relation to average salary in age group it could be easily seen that the more discrepancy is the older the female researcher is (Fig. 7). The women over 54 year old earn 10 to 25 percentage points less than their male colleges at the same age at PK as the whole, Faculty of Civil Engineering, Faculty of Mechanical Engineering, respectively.

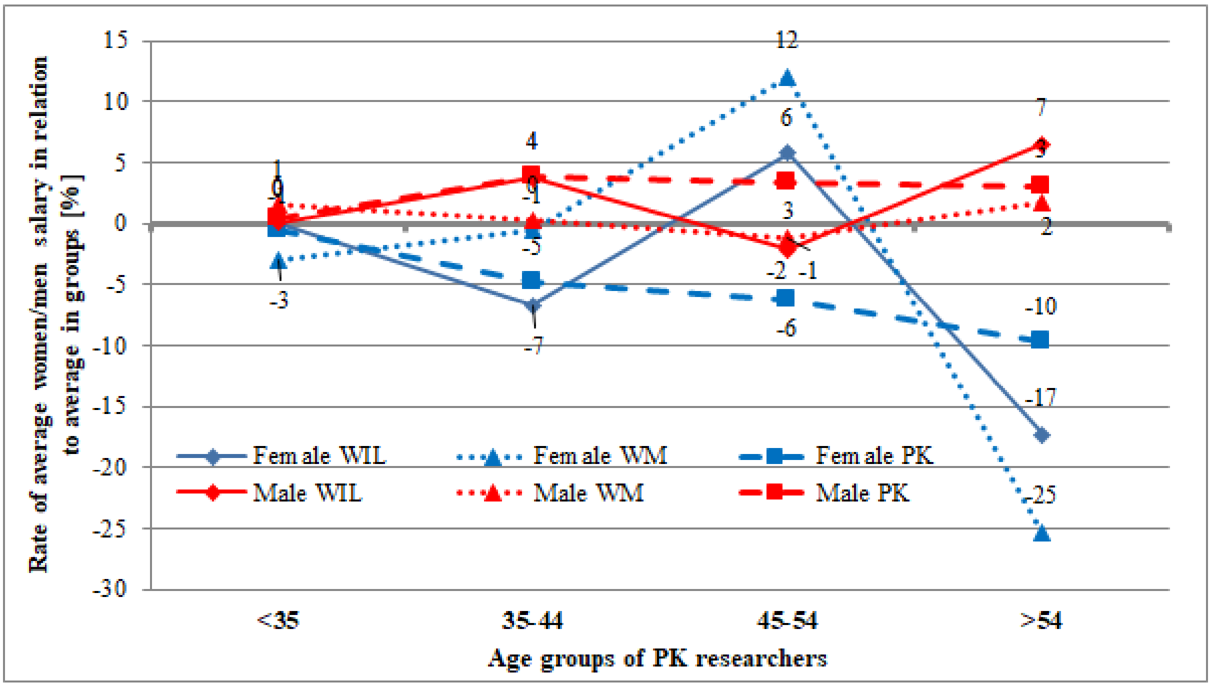

Fig. 7.
Comparison of average salary at Politechnika Krakowska and two transport-related Faculties, Civil Engineering and Mechanical Engineering in 2016, by age and sex
Source: authors' work

4.4. Decision Making Bodies and Decision-Making Processes

It is clear (Fig. 8) that the bodies and groups responsible for decisions at PK, are men-dominated. The top management consists of men only – Rector and Vice-Rectors are all men. Also the Senate (the most important decision-making body) is highly men-dominated (around 80% of the Senate members are men). On the other hand, one may notice that more and more women hold lower management positions – at Faculty level women constitute 29,6% among Vice-Deans and 16,3% among lower level heads (Institutes or Sections). A slight increase has also been observed in the share of women in the structure of the Senate – in a former term, the share of women was 20%, currently (2016-2020) we can observe an increase of 3%. There is a rising awareness of women under-representation in higher positions at PK, and in decision-making bodies. The big advantage in the current awareness rising is also the existence of a role models – a very few examples of women who have been successful in power positions in the former decades (eg. the Past-Dean of the Faculty of Environmental Engineering). On the other hand, however, one may observe no awareness of gender issues among decision-makers and researchers, among women researchers as well.

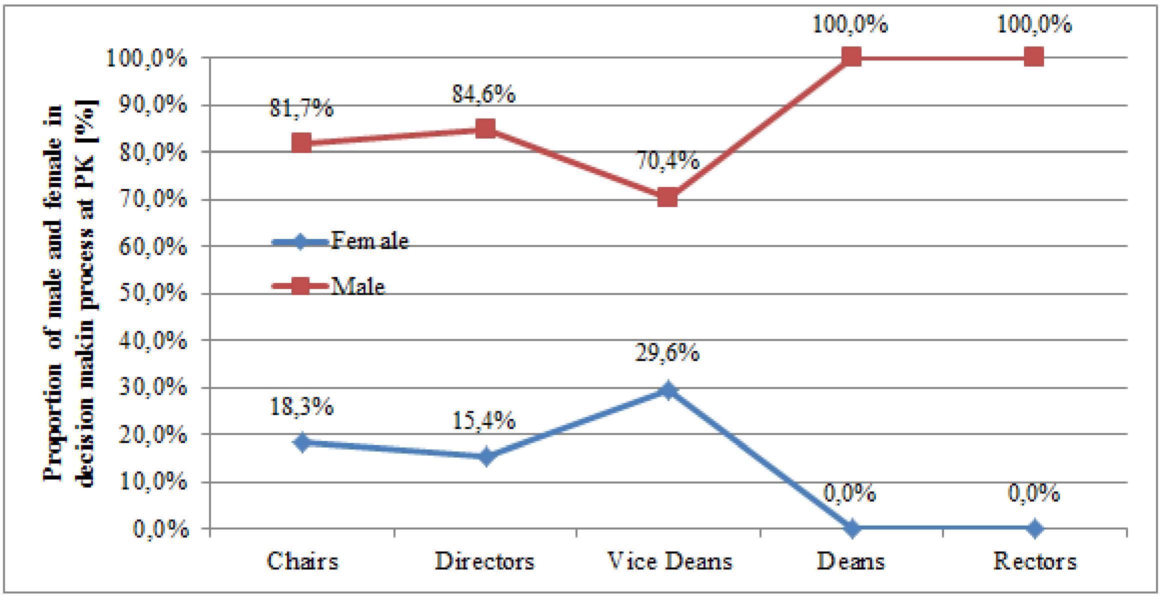

Fig. 8.
Participation of women and men at decision making process at Politechnika Krakowska in 2016, by sex
Source: authors' work

5. Conclusions

Despite the clear priority in EU policy to integrate the gender dimension into research area, transportation education system and transport sector in general, there are still many barriers that may limit the advancement of gender equality, including a lack of transparency in decision-making, institutional practices that indirectly discriminate against women, gender biases in the assessment of excellence, gender bias in the organisation of the workplace and other cultural stereotypes. On the other hand, an increasing number of female researchers influence the change in male vision of their role in the world, in science and society.

The Horizon 2020 for the period 2014 to 2020 is structured to respond to societal challenges that need innovative solutions. Innovation is needed in transport to meet worldwide challenges such as reducing greenhouse emissions and fossil fuels dependency without curbing mobility. Consideration of gender issues in research and innovation is crucial in building the knowledge base to support the development of a sustainable transport system responsive to the needs and constraints of all components of the society, equally men and women.

The ongoing elaboration of Gender Equality Plan (GEP) at PK, that is being realized as a part of Coordination & Support Horizon 2020 Action project GEECCO (Gender Equality in Engineering through Communication and Commitment), aims to develop some specific, knowledge-based solutions which could increase awareness of gender related issues. Some of the actions are directed to the whole academic PK community, some other to students or decision makers and researchers, namely:

- actions for all academic community: increasing visibility of women as engineers and scientists (reporting periodically in internal magazines well balanced information on women/men achievements, VMS screens, presenting notes on glass-cases and organising occasional exhibitions during university events);
- actions for specific staff groups: increasing awareness among different members of university society (distribution of leaflets, brochures and notes to enhance the awareness among researchers and other staff on the actual share of women and man in the current structure of PK, decision makers, administration staff and student advisory boards, etc.);
- actions for decision makers: organising trainings on gender bias and gender equality plan (GEP) at PK;
- actions for young researchers: meetings with role-models, open events to raise the awareness of the presence/share of women and man in the real structure of PK, empowering women;
- actions for students: including gender issues into curricula and recruitment process.

To reach the goal of equality, we have to design and develop actions for improving work-life balance so more women are willing to get involved in high positions of decision-making. This includes arrangement of mentoring and/or coaching plans to empower women and men toward their rights and unique skills and competences.

At the level of academic society (staff and students) specific actions are needed, to break the stereotypes of men engineering profession, in order to encourage men to take responsibility for family care through trainings and workshops that raise awareness. We all need to accept and promote situation that both women and men represent different abilities, social competences, point of view that give special synergy aspects and added value in solving any scientific or organizational problem so any structural bodies and scientific teams gain in balance representation of both gender representatives.

Finally, we need to develop actions (presenting role-models from the other universities and international bodies) for improving work-life balance so more women are willing to get involved in high positions of decision-making.

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POSSIBILITIES TO QUANTIFY FIXED COSTS FOR LONG-DISTANCE AND REGIONAL RAILWAY PASSENGER TRANSPORT

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Abstract: Enhancing the competitiveness of passenger railway transport can be achieved by providing quality services at a reasonable price. This can be achieved by increasing competition in the rail passenger service industry, i.e. by the opening of the market for domestic passenger transport services by rail. The Fourth railway package says that "competition on domestic markets should therefore be addressed at two levels with competition 'in the market' for those services that can be provided through open access and competition 'for the market' to allow the transparent and cost-efficient award of public service contracts." Railway undertaking can provide open access rail passenger services and simultaneously rail passenger services under the public service contract. Therefore, it is very important to know how to calculate costs for individual services. It requires knowledge of variable and fixed costs. Fixed costs are the overhead expenses but also part of the immediate cost (e.g. locomotive costs). Presently, it is a number of methods which are concerned with cost quantification into the product unit from simpler (such as absorbing costing) to difficult (such as Activity Based Cost method). The using of more difficult methods give more accurate results but at the same time, requires higher finance to implement them. Therefore, a method should be used which will be financial acceptable and provide a reliable allocation of fixed costs to individual services. This paper deals with the possibilities of utilization of selected calculation methods in railway passenger transport. It is the result of theoretical and methodological research of costs calculation with respect to railway passenger transport specifics. Based on this, we designed methods suitable to calculate fixed costs upon individual services. These methods were validated and compared using model situations.

Keywords: cost calculation methods, railway passenger transport services, variable and fixed costs.

1. Introduction

Currently, the optimization of costs is the one of main factors in achieving the economic efficiency of a company, transport companies not excluding. One of many factors for optimizing the choice of the transport mode is the overall transportation costs of a supply chain (Mueller *et al.,* 2014). Transport time and cost are decisive factors for shippers when they choose a mode for their transport (Hekkenberg *et al.,* 2017).

The costs at transport companies are specifically compared with other companies. The problem of cost reporting at the condition of the transport company and their classification to variable and fixed is very important in decision making tasks (Potkany, Krajcirova, 2017). Quantification of variable costs to a unit of product is relatively simple at companies providing railway passenger transport, but it is possible to classify them as variable costs for only a very small part of the total costs in the short-run. It is mainly the cost of employees which realize transport performances directly (such as drives of locomotives, train crew etc.), the part of costs which are maintenance costs, fees for the use of railway infrastructure and so on. Rail infrastructure fees are an important part of variable costs (Abramovic *et al.,* 2016) but these cost are different in each European country. Economic theory advocates marginal cost pricing for the efficient utilization of transport infrastructure (Andersson *et al.,* 2012). Currently, no universal model of access charges has been defined (Bugarinovic *et al.,* 2015).

The problem of the assignment of fixed cost to a unit of product is difficult and multidimensional in railway passenger transport (Černá *et al.,* 2017). Companies should be able to assign costs for different groups of passengers (pupils, students, pensioners, etc.) and different operative points of view, e.g. from the type of train (passenger trains, expresses, IC trains, etc.) and from railway passenger market segments (e. g. long distance and regional railway passenger transport). Presently, it is more important to know assigned fixed costs to long distance and regional railway passenger transport because some part of passenger services can be realized within open access and incumbents often have to prove that their unit costs for these services are lower than ticket prices (Tomes *et al.,* 2016). On the other hand, the unit costs for the services of regional railway passenger transport are required for example when undertaking to provide services in regional railway passenger transport under a public service contract in the case of a call for tender (Peceny *et al.,* 2016).

The costs of regional railway passenger transport are different before and after competition (Masek, Kendra, 2013). Guihery (2014) showed that the introduction of competition in the Leipzig region has reduced the level of subsidy by 20% and improved the productivity of the incumbent operator.

2. Material and Methods

Railway undertaking can provide services in the open access market and simultaneously services under the public service contract. Therefore, it is a very important that the undertakings which provide railway passenger transport services to know allocate costs into individual services as accurately as possible. This requirement is the more important the more services are differentiated (e.g. in the long distance railway passenger transport can be provided some part of services within open access and some part under the public service contract).

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A railway service involves using a large number of factor services, many of these being highly specific and each with its own physical lifespan. When it comes to considering line closures, the essential questions revolve around deciding exactly which costs are fixed (Button, 2010, p. 118). Apportionment of costs is not easy and it is influenced by a lot of factors in railway passenger transport. The same costs can be assigned once to the fixed and twice to the variable costs (e.g. from the long-run and short-run point of view). In economics, the short run is formally defined as that period of time during which at least one of the factors of production is fixed (Cowie *et al.,* 2010, p. 101). In the long run, variation in the level of output can be achieved, thus the firm is not restricted to using only one of them (Cowie *et al.,* 2010, p. 102). Therefore, it is important to firstly determine the time we want to find the costs structure.
Different methods can be used for allocating fixed costs to a particular product, activity or process. These methods are different not only in the way of allocating fixed costs to a product, but also by the results of unit costs of the same services. A controller can use any methods but he has to keep the fundamental principle of allocation of fixed costs – the principle of causality.

2.1. Simple Methods of Fixed Costs Calculation

It is possible to use the following simple methods of fixed costs calculation:

- absorbing costing,
- cost calculation by dividing.

Absorbing costing is the most widespread method in costs calculation. Their fundamental principle is to assign fixed costs to units of performances by an extra charge on the basis of determined parameters (direct costs, transport performances, hours, etc.) The problem is to find such a scheduling base that the proportion of fixed costs was associated, with a given performance that corresponds to the consumption of costs by such performance.
The same problems arise when the undertaking uses cost calculation by dividing. Simple cost calculation by dividing (in the easiest form) determines the fixed costs to a unit of performances such as the ratio of the total fixed costs and performances of the undertaking (amount of products, transport performances, etc.). This calculation can be used only in undertakings which provide homogeneous products or only one and the same services all the time. It can also be different conditions in these undertakings for the distribution of products to individual customers in regard of different additional services which are unavoidable for ensuring customer satisfaction (Kupkovič, 2002).
Foltínova presents these forms of cost calculation by dividing:

- simple cost calculation by dividing,
- cost calculation by dividing with a ratio number (cost calculation by dividing with equivalent numbers) (Foltínová *et al.,* 2007).

The main problem is to objectively find a measurable quantity. These quantities have to reflect the difference of the product and simultaneously have to be in a causal relationship with the change of costs.

2.2. ABC Methods

The decision-making procedures applicable to solve such problems can be made more reliable if the relevant information on basic components of business or technology processes are available. This information base can be produced by using cost and performance management methods combining financial and technology system parameters (Bokor, 2009).
Designing an Activity-Based Cost system was suggested by Cooper and Kaplan in two steps:

- to collect accurate data on direct labour and materials costs,
- to examine the demands made by particular products on indirect resources (Cooper, Kaplan, 1988).

ABC has emerged as a tremendously useful guide to management action that can translate directly into higher profits. Moreover, the ABC approach is broadly applicable across the spectrum of company functions and not just in the factory (Cooper, Kaplan, 1991)
The ABC method can be very helpful for transportation companies to determine the cost of their operations with increased accuracy (Baykasoglu, Kaplanoglu, 2008). The main idea of the ABC method is: the cause of costs is particular operations not transport performances. Operations are grouped with activities and consequently cost centres are created for each activity. The application of ABC methods is different in every undertaking and it must especially take into account the process management of the undertaking. The application of ABC methods in undertakings providing railway passenger services is even more exacting with regard to a lot of activities and processes which have to realize to provide safe and quality services. Nevertheless, it is possible to allocate some part of the fixed cost on the individual services with the use of the ABC method.

3. Results and Discussions

The costs structure has changed in undertakings providing railway passenger transport services since the last time. The reason for this change is especially:

- increasing of automation with the aim of reducing personal costs,
- adaptation of the portfolio of services to the market situation, this increases the requirements to project processing, processing of technological procedures and so on,
- increasing of overhead activities related to the increase and monitoring of the quality of the provided services,
- extension of the offer of additional services and so on.

With respect to these changes, a more effective calculation system is required which more precisely divides fixed costs to the particular services. I modelled dividing the selected fixed costs to long-distance and regional railway passenger transport by using different simple cost calculation methods and ABC methods. I took into account these fixed (common) costs:

- repair and maintenance costs,
- the cost for the sale of tickets,
- the cost of the reservation system,
- other direct costs,
- operating overheads.

I did not take into account real costs and performances. My intention was to show them how to change cost for a unit of performance by the use different cost calculation methods. The input data are shown in table 1.

Table 1
Input Data

Indicator	**Long-distance transport**		**Regional transport**	**Total**
	commercial trains	**other trains**		
Transport performances [mil. passenger km]	150	1 500	800	2 450
Transport performances [thousand train km]	900	15 500	6 000	22 400
Transport performances v [mil. seat km]	210	2 600	1 700	4 510
The number of sold out tickets [thousand]	400	23 000	65 000	88 400
Fixed/common costs [thousand €]				
Repair and maintenance costs	450			
The cost for the sale of tickets	55			
The cost of the reservation system	12			
Other direct costs	90			
Operating overheads	220			

Source: Author

To begin with I took into account a simple cost calculation method - absorbing costing. Transport performance was used as the base for the dividing of costs. The results are showed in table 2.

Table 2
Dividing Fixed/Common Costs by Using Absorbing Costing

Item of cost	**Costs calculation for**			**Total costs**	**Cost on the unit of performance**		
	Long-distance transport		**Regional transport**		**Long-distance transport**		**Regional transport**
	commercial trains	**other trains**			**commercial trains**	**other trains**	
Repair and maintenance costs	27.55	275.51	146.94	450.00	0.184	0.184	0.184
The cost for the sale of tickets	3.37	33.67	17.96	55.00	0.022	0.022	0.022
The cost of the reservation system	0.73	7.35	3.92	12.00	0.005	0.005	0.005
Other direct costs	5.51	55.10	29.39	90.00	0.037	0.037	0.037
Operating overheads	13.47	134.69	71.84	220.00	0.090	0.090	0.090

Source: Author

In the second instance I used a cost calculation by dividing the calculation of fixed/common costs (table 3). Transport performance was used such as the base for the dividing of costs but I took into account the different demands of particular types of services:

- long-distance transport – commercial trains – 115
- long-distance transport – other trains – 100 %
- regional transport – 95%.

Table 3
Dividing Fixed/Common Costs by the use of Absorbing Costing with the Different Demands of the Particular Types of Services

Item of cost	Costs calculation for			Total costs	Cost on the unit of performance		
	Long-distance transport		Regional transport				Long-distance transport
	commercial trains	other trains			commercial trains	other trains	
Repair and maintenance costs	31.91	277.49	140.60	450.00	0.213	0.185	0.176
The cost for the sale of tickets	3.90	33.92	17,18	55.00	0.026	0.023	0.021
The cost of the reservation system	0.85	7.40	3.75	12.00	0.006	0.005	0.005
Other direct costs	6.38	55.50	28.12	90.00	0.043	0.037	0.035
Operating overheads	15.60	135.66	68.74	220.00	0.104	0.090	0.086

Source: Author

In the third example I divided the fixed/common costs to the particular railway transport services on the basis of the cause of costs (application of ABC method). The results are showed in table 4. I took into account with the following cause of costs in the particular types of fixed costs:

- repair and maintenance costs – transport performances in seat kilometres,
- the cost for the sale of tickets – the number of sold out tickets,
- reservation system – the number of sold out tickets,
- other direct costs – transport performances in train kilometres,
- operating costs – transport performances in passenger transport.

Table 4
Dividing Fixed/Common Costs by the Application of the ABC Method

Item of cost	Costs calculation for			Total costs	Cost on the unit of performance		
	Long-distance transport		Regional transport				Long-distance transport
	commercial trains	other trains			commercial trains	other trains	
Repair and maintenance costs	20.95	259.42	169.62	450.00	0.140	0.173	0.212
The cost for the sale of tickets	0.25	14.31	40.44	55.00	0.002	0.010	0.051
The cost of the reservation system	0.05	3.12	8.82	12.00	0.000	0.002	0.011
Other direct costs	3.62	62.28	24.11	90.00	0.024	0.042	0.030
Operating overheads	13.47	134.69	71.84	220.00	0.090	0.090	0.090

Source: Author

Table 5 shows the comparison of dividing of fixed/common costs to transport performances unit by the use of different cost calculation methods

Table 5
Comparison of Dividing of Fixed/Common Costs by the use of Different Costs Calculation Methods

Method	Costs for transport performances unit		
	Long-distance transport		**Regional transport**
	commercial trains	**commercial trains**	
Absorbing cost	0.338	0.338	0.338

Cost calculation by dividing with ratio number	0.391	0.340	0.323
Application of ABC method	0.256	0.316	0.394

Source: Author

As you can see in table 5, the use of a different calculation of fixed costs gives the different results of dividing these costs to particular products and therefore also to the unit of transport performances. The differences between the use of simple cost calculation methods is lower than when we compare simple methods with the application of the ABC method. It is mainly caused as the ABC method allocates fixed costs more precisely in such a simplified form by the use of a causal relationship between cost items and the cause of these costs.
The use of the ABC method requires the more precise monitoring of costs and other needed parameters at the undertakings. In my research I showed that the ABC method can be applied simplistically at least for a part of the common costs and thus can achieve a more precise allocation of them for individual products.

4. Conclusion

The costs structure has changed in undertakings providing railway passenger transport services since the last time, with the share of overheads costs increasing on the one hand while on the other hand the share of variable costs decreases. The problems of variable and fixed costs is complex. It is often the same costs assigned to variable costs from the one point of view and to fixed costs from the other point of view. This disparity can happen in the case of different time or different monitoring costs to individual processes compared with total costs. Therefore, the undertaking needs to use a cost calculation system which allows them to allocate fixed costs to individual products as accurately as possible and simultaneously will be financial sustainable for the undertaking.
Currently, cost calculation methods exist which can divide a substantial part of the cost by real expended costs (for example the Activity Based Cost method), but their implementation is time and financially difficult and more often it is not possible in a business start-up. It is difficult to estimate the cost items and how they will be related with individual products in the future. In these cases, simpler methods can be used which can give relatively good results if they are implemented correctly.

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SROI: A COST-INCLUSIVE EVALUATION METHOD

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Abstract: This paper focuses on the Social Return On Investment (SROI), an investment project evaluation method which overcomes some issues of the well-stablished Costs-Benefits Analysis. It contributes to a wider investment analysis by using alternative tools, such as Pay for Success (PFS) and Social Impact Bonds (SIBs). The papar presents measures of economic and extra-economic values of transport infrastrucutral interventions based on the principles of "social accounting" and on the cost-benefit analysis. SROI offers an overview of how societal changes have been generated and experienced by beneficiaries and stakeholders. The method uses monetary values to represent the social and economic results of investments infrastructure investments, calculates the impact created by the project and conveys this impact in the form of a ratio. The emphasis is more on the creation of economic and environmental sustainable values than on financial variables. Using tools such as PFS and SIBs, SROI promises a new and more consistent form of investment projects evaluation which can guide funders and stimulate private investors, as well as public bodies.

Keywords: investment evaluation, transport infrastructures, social returns, pay for success, social impact bonds.

1. Introduction

Social Return on Investment (SROI) is a powerful method for measuring possible non-financial values of investment projects. It offers detailed insights of the social and economic impact of projects, it contributes to a wider analysis of investments and it offers an overview of how the effects generated by such investments have been appreciated and experienced by beneficiaries and stakeholders (Wright, Nelson, Cooper, Murphy, 2009). SROI has been defined in different ways but the common idea is that it is an analysis that captures social values generated by the public sector as well as by the private sector (Nicholls, 2017). Pay for Success (PFS) is a promising approach to public-private contracting that ties payment for service to the achievement of measurable outcomes. It tries to ensure that high-quality, effective social services are delivered to individuals and communities. Social impact bonds (SIBs) are a way of financing PFS agreements. Their reimbursement is contingent upon the social outcomes being achieved. We discuss on the SROI analysis of infrastructural interventions in the context of PFS and SIBs agreements. We argue that SROI is a cutting edge model for non-financial evaluation of investment project that can guide funders in their investment choices and can contribute to a more effective evaluation of PFS and SIBs outcomes. Although it makes use of monetary values to represent the social and economic results of infrastructure investments, the model is designed to measure the effective sustainable social and environmental value that is expected to be created by the project. It also aims at stimulating funding by private, public entities and national and supranational large infrastructural investment programmes, thus remediating or preventing the absence of effective sustainable social and environmental methodologies of evaluations. The rest of the paper is organised as follows: in the following paragraph the feasibility analysis of a project related to the transport sector is presented. Subsequently, the two instruments PFS and SIBs are presented. Concluding remarks close the paper.

2. Evaluation Process Applied to the Transport Sector and the use of SROI

To obtain desirable effects from infrastructural investments, central and local governments as well as private firms, need to develop careful economic and financial analyses which lead to the project investments appraisal. These, in turn, provide indications of the project's final impact on the economic system and of the utility through a comparison of the evaluated effects and the predetermined criteria of acceptability (Pearce, 1998).
Project appraisal can be defined as process by which the feasibility of a project is assessed. In addition, the procedure allows comparison between project objectives and the socio-economic objectives of a country (or of a different geographical area). As a consequence, the appraisal checks whether country's objectives may be met by the project under evaluation. An ex post analysis checks out whether the project has been carried out efficiently and accordingly to the plan.
It is also important to distinguish between the private and the public sector. Indeed, two crucial elements lead to the need of different project evaluation analyses for the two sectors. Firstly, differences in the objectives. The final aim of any private company is the maximization of the risk adjusted return expected from the investment. Therefore, investment evaluation is aimed at ensuring that the selected project has the highest expected risk adjusted return. On the other hand, in the public sector the objective is to ensure the maximization of the benefit to the community. Secondly, the private sector uses market prices for the evaluation of inflows and outflows, while in the public sector there are two circumstances for which market prices cannot be used for project evaluations: a) in some cases market prices do not exist because inputs and outputs are not traded on the market and, b) market prices are not the real expression of marginal social costs and of marginal social benefits. In these cases the values used are called "social prices" or "Shadow prices". Literature in this field, due to the importance of the area covered, is very plentiful and is rich of

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applications of evaluation models. Often in the practice, it seems that there is not an exact connection between an economic theory and the actual evaluation procedure because of the abstractness of the theoretical literature.
In principle, each project of the public sector has to prove its validity independently from the expenditure program it is part of. Actually, many expenditure centers and particular parts of budget refer to “sectors” to which investments are linked. This, in a managerial view, simplifies the procedures. It follows that in the short and medium term programming, what is important is the relative superiority of a project in comparison with others, rather than its absolute validity in the light of general criteria. In addition, in developed countries, the number of projects which have to be evaluated may be thousands per year. Thus, the decision-making process becomes extremely difficult without separating the projects on the basis of their sector belonging. In fact, a situation may be characterized by the existence of projects which involve hospitals, other may concern railways and others, schools. It is evident that it is enormously preferable to group projects in accordance with the sector to which they refer, in order to take advantage of the economies of specialization which come from an adequate division of labor within the administration.
In the following, characteristics of projects in the transport sector and problems related to their financial, social and economic evaluation will be examined. There exists several motivations which justify public intervention in the transport sector. In short they can be listed as follows:

1- The construction of infrastructures in the transport sector requires an enormous financial outflow. This makes investments unattractive and uninteresting to the private sector, unless a long monopolistic profit is ensured;
2- The possibility of using efficient and relatively low-cost transport services is a pre-requisite for economic and social development; in turn, the private sector, before a certain degree of economic development is achieved, is unwilling to supply adequate transport services;
3- Public intervention is also necessary to guarantee transport safety and to limit the negative impact on the environment;
4- The transport network must be planned taking particular account of the demand in the sense of considering the requests of mobility which come from different social groups. It must also be considered the localization of productive activities and it has to be coordinated in accordance with transport networks of border countries.

Therefore, Government objective in the transport sector is to ensure an efficient communication network in terms of distribution, quality and costs, either for goods or for passengers, substituting or coordinating private supply which, sometimes, appears to be inadequate.
When investment projects regarding the transport sector are analyzed, very different expenditure programs are considered, and they are necessarily interrelated. For example, interventions may regard the sub-sector of roads, of railways, of ports or airports. As a consequence, a great variety of projects is possible. Projects which refer to the road system may have the aim of building rural roads, motorways, roads intended at stimulating the development of some particular areas or they may aim at improving existing roads. Projects in the railway system may refer to the opening or to the closing of a railway line, to the improvement of existing lines through the implementation of high-speed or underground lines or they may involve the efficiency and the modernization of clearing points of goods. As for ports, many projects are concerned with the widening of mooring possibilities, construction of silos, implementation of an effective range of services for the clearing of goods or with the improvement of ferry-boats services for goods as well as for passengers. As for projects which are linked to air transport they ultimately involve the construction of new airports and the organization of services in the airports.
Notwithstanding the existence of heterogeneous types of investments, the financial and the economic analysis of these projects are very similar in most of the cases. Suppose, for example, that a committee, responsible for the transport sector, wishes to evaluate the project of a new motorway which links city A and city B. Suppose, also, that this project has the aim of decongesting the existing road (this may be due to narrowness of the road or to its poor condition). Let’s assume that the linkage between the two cities is also ensured by a railway. In order to individuate cash-flows, first of all, costs must be considered. These costs relate to investments necessary for the construction of the road and to running costs which refer, in particular, to maintenance costs. As for proceeds, they consists in inflows which come from the payment of tolls and from contributions. A crucial aspect of this analysis is that, besides, the estimated costs (for which, generally, standard costs per kilometer are used), tariff cash flows must be calculated with great care. These depend on the function of the future demand of users which depends, in turn, on the opportunity cost of choosing the new road instead of the railway. If it is assumed that the railway tariff is under the control of the same public committee, it is evident that the project cannot be analyzed, not even in financial terms, without considering the interrelations among the different transport possibilities. These interrelations are typical in this area of public sector interventions.
As for economic analysis, the characteristic of SROI is highly attractive because it overcomes some of the limitations of the cost-benefit analysis. In particular this involves:

1- Difficulties in foreseeing demand; that is, as in the aforementioned example, it is difficult to evaluate traffic when the life-time of the project is considered;
2- Considerable presence of “intangible effects”, as for example pollution and the visual quality of the countryside;
3- The problem of economic evaluation of social costs connected to road accidents;
4- The problem of economic evaluation of travelling time-saving (Wright, Nelson, Cooper, Murphy, 2009).

With regard to the first aspect, it must be born in mind that transport demand is a derived demand. Therefore, it depends, among others, on production volume, on the localization of industrial, agricultural and tourist activities, on the geographic distribution of population and its income characteristics, and so on. On the other hand if we consider the demand for a particular mode of transport, for example a motorway, this is strictly linked to its price and to the speed and the safety of an eventual alternative mode of transport. In fact, in the aforementioned example, traffic volume on the motorway depends on the efficiency of the railway because it covers the same route. In addition, the considerable presence of intangible effects bring about some problems of quantification, solved by SROI through the use of monetary units. Furthermore, if benefits are considered, it is quite evident that the share of benefits which do not have a clear market reference, in some projects, is of great importance. Thus, in these cases, project validity vitally depends on the evaluation of the effects of noise, pollution and saving of time, and on the quality of SROI evaluation.

To determine the validity of projects, a correct evaluation of traffic flow during the project's lifetime is of great importance. First of all, the forecast of traffic flow, which include passengers and goods, either by road or by railway, must be made in a scenario without the project. Then, the demand strictly in relation to the object of the project has to be estimated. The subsequent step is the analysis of economic costs of construction of the new road.

One key point in the evaluation process is the environmental impact of transport activity which will be linked to the value of the land and the social implication of the willingness-to-pay principle through the use of empirical methods.

As for benefits, we should consider inflows stemming from tolls and a decrease in transport costs for vehicles. Among other benefits, there is the reduction of negative effects which are not easy to quantify through reference to the market. The main ones are the following:

1- Time saving;
2- Reduction in accidents;
3- The saving of human lives;
4- Reduction in pollution and noise.

For these evaluations, social implications of new investments must be considered as for example social costs reduction in terms of value of the decrease in accidents and in human lives saved, thus considering, for example, reduction in costs related to hospital treatment. In the case of the transport sector these benefits have a particular importance. In addition, they are extremely complex due to the large amounts of intangible goods, externalities, and so on.

Finally, the economic validity of the project will be determined by analyzing the net present value of benefits deriving from the comparison between the situation with and without the project. The result, of course, can be expressed also in a form of ratio, as in the case of benefits/costs.

The use of SROI have positive and negative outcomes. One of the positive things is related to the fact that SROI includes information on the outcomes value assigned to specific programs or investments by the society (Yates, Marra, 2017a,b). Another advantage of SROI is the increasing dissemination of analytical skills and practice spilling from the public over the private sector in a continuous iterative interaction, where information is generated at the local level. In addition, SROI framework, used as a tool for assessing the performance of nonprofit organizations and social entities through projects implementation, is absolutely useful for obtaining quantitative measure of nonprofit performance (Cordes, 2017). By adding information on financial accounting and sustainability reports, SROI can be appreciated as an advanced method for valuating social impacts and values (Nicholls 2017). Finally, one of the major advantages over other forms of evaluation is that SROI allows programs to be ranked on the basis of their net contributions to the society (Yates, Marra, 2017a,b). Nonetheless, SROI can present some problems related to imprecise measurement of benefits and costs, and it can use crude methods to estimate impacts. Additionally, SROI can overlap cost and benefit analysis under different aspects.

3. Innovative Tools: Pay for Success (PFS) and Social Impact Bonds (SIBs)

Pay for Success (PFS) is an innovative framework to support discretionary social programming. Basically, it is a contract or a grant by which one of the parties – generally, but not necessary, a public agency or a not for profit entity – is committed to pay the other if, and only if, pre-agreed social outcomes are achieved. An independent evaluator, contractually appointed, validates the outcome(s), certifying whether the payments are due (an independent external validator may also be appointed in order to validate the methodology that the evaluator follows in order to certify the social outcomes). Tying payments to the achievement of measurable social outcomes, PFS aims at ensuring that high-quality, effective social services are delivered. The idea behind these contracts is that all or part of the payout will be funded from savings in the contracting agency's budgets directly or indirectly generated by the improved outcomes themselves. PSF can thus be an attractive solution for public entities aiming at allocating more effectively their resources, at achieving higher social deliverables, at scaling up social welfare and at testing new or innovative social services or ways to deliver them. PFSs have a high degree of flexibility. Among others, compensations can be graduated according to the actual social outcomes and can consider a floor reimbursement in any case. Hardly employed in continental Europe, PFS is gaining increasing attention in UK and US in the very last few years (It is reported that the very first PSF contract was signed in 2010 in UK. The aim of the project was to improve anti-recidivism programs outcomes for short term sentenced at Her Majesty's Prison Peterborough. For a review of the very first experiences in the US see (Lane, 2015)). Homelessness, prison recidivism, early childhood education, workforce development, substance abuse, chronic health conditions, and mental illness the main areas supported by social PFS programs

implemented to date. Recently, the PFS approach has been successfully employed to address environmental and infrastructure issues, too ((Appel, Bezak and Isle, 2017), reported and commented on the District of Columbia Water and Sewer Authority PFS experience). Anyway, regulation is needed to support its diffusion especially into civil law countries.
Social impact bonds (SIBs) are financial agreements used to finance social service providers entered into PFS contracts. These companies will receive the compensation agreed upon the PFS once the social outcome has been achieved and validated. Hence, they need up-front capital to finance their investments and their ongoing activities until the contracting public agency eventually pays. By means of a so-called social impact bond, private investors (financial intermediaries, philanthropists, companies, public agencies, etc.) funds (totally or in part) the service provider entered into the PFS contract and are repaid by the possible compensation that will derive from the PFS agreement. As a result, the financial risk associated with funding potential ineffective social services is shifted from the public sector to lenders. It is noteworthy, that outside investors whose payout relies upon the actual social output have a great interest in forcing service provider's management in achieving the social goals, thus aligning public and private interest in reaching effective social results. To avoid the investors bear the risk PFS compensations being misappropriated, an independent transaction coordinator manages the flow of money in the SIB and the contracting public agency is committed to make payment directly to the coordinator. Generally, other external consultants intervene providing legal, tax and financial advisory in structuring the SIB and oversights the ongoing activities.
The following diagram sketches the basics of a PFS-SIB agreement.

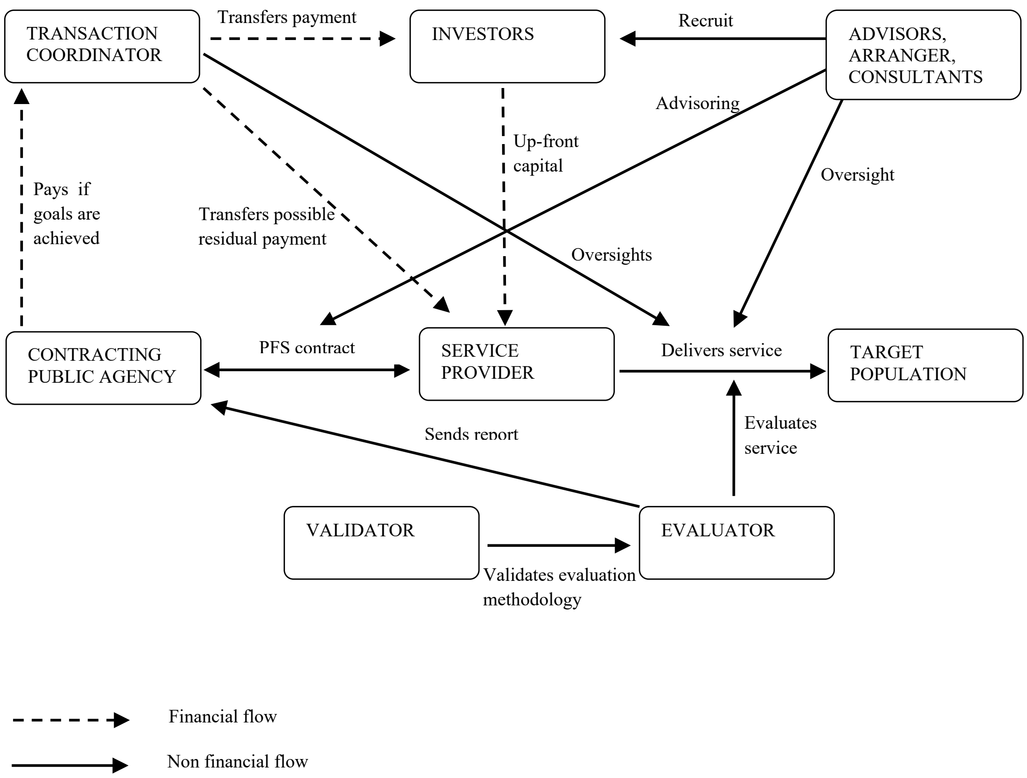

Fig. 1.
Social Impact Bonds flowchart

The term Social Impact "Bond" is somehow misleading. Actually, SIBs are mezzanine and structured form of financing that have the potential of not being represented by a series of tradable securities. Opinion is divided around the actual potential of SIBs in financing complex social interventions and shifting performance and financial risk from the public towards the private sector (for a comprehensive review on SIB scientific literature see Fraser et al. 2018; an interesting discussion on arguments for and against SIBs is provided by Child et al. 2016). To date SIBs hadn't succeed in attracting enough non-public resources unless granting substantial additional guarantees to investors. Moreover, SIBs raise questions about government's ability to ensure broader public values (Werner, 2013).

4. Conclusion

This paper supplies a re-reading of the existing literature of the methodologies utilized for developing feasibility studies of investment projects with an application to the transport sector. The innovative contribution is the possibility of using SROI, PFS and SIBs in the evaluation process to improve estimations and *ex ante* analyses.

PFS and SIBs are partnerships that involve the public, the private and the nonprofit sector. They are innovative and integrated contractual frameworks able to enhance public-private partnerships (PPPs). Anyway their employment is limited with respect to their potential especially in civil law countries. Moreover, difficulties in actually measuring the comprehensive social outcomes reduce their implementation in areas where a social program can achieve several and different social outcomes or where interactions with other social programs and other social goals have to be considered and adequately measured (think of, transportation or healthcare). The synthesis provided by SROI can be an useful tool to address these issues giving impetus to PFS and SIBs in modern social and environmental programming.

Although characterized by simplicity, SROI has some limitations to be aware of. First of all, the criteria is not the results of a specific approach suggested by the traditional theory, but a compromise between several approaches. As for financial analysis, it is not applied in a strict sense because it does not consider the expected cash flows which is referred to the precise decision-centre to which the expenditure is linked. In addition, it is not a pure financial analysis because: a) constant prices are used, even though they are modified by taking into account the relative price trend, and, b) costs and benefits are external and often do not involve monetary transactions, as for example the travel time for motorway users. On the other hand, it cannot be stated that the economic analysis is carried out strictly in accordance with the most accepted economic theory. Among others, evaluators do not use a homogeneous “numèraire” for the evaluation of costs and benefits and specific assumptions have to be formulated for benefits being expressed in monetary terms, implying a potential high degree of subjective discretion.

To conclude we can say that SROI’s most favorable result could be that even in private funding of social programs, it may help to better explain program logic and theory of change by making use of more analytical and cognitive understanding in funding decisions, which are not subject to any government regulation (Yates, Marra, 2017a,b).

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RAILWAY INFRASTRUCTURE DEMAND ELASTICITY AND TRACK ACCESS CHARGES MARK-UPS CORELLATION ASSESSMENT

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Abstract: The expected trend of the necessary unconditionally liberalization and full opening of the railway market in the countries of the Western Balkans is certain, and in such conditions, the issue of railway undertakings' access to the railway infrastructure and respectively the assessment of the track access charges (TAC), is particularly actualized. Pursuant to the European regulatory framework and the practice of infrastructure managers, different tariff models of railway infrastructure track access charges have been developed based on principles coverage of: (1) total direct costs, (2) average costs, (3) marginal costs and, (4) marginal costs added to a certain amount of mark-ups. The philosophy on track access charges model based on marginal costs increased by mark-up, basically rely on the Ramsey principle, where amount of mark-ups is determined by the demand elasticity. Researching area of this paper endeavours to perform a deeper analysis of the correlation between the track access charges mark-ups and demand elasticity of the railway infrastructure, as well as, its economic efficiency, especially in the conditions of supply determined by the poor condition and the limited capacities of the Western Balkans railway infrastructure network.

Keywords: Railway infrastructure, track access charges (TAC), Ramsey principle, demand elasticity, mark-up.

1. Introduction

Total length of railway infrastructure in EU 28 recorded 218.181km in 2015, of which 8.250km is for high speed lines (EC, 2017). Sustainable infrastructure financing is important not only for railway infrastructure managers but for the national governments, as well. For nearly two decades, the issue of an adequate charging system for using the infrastructure in EU legislative and regulatory framework is not lost on the actuality.

The specificities and complexity of the railway infrastructure charging system arise from its nature as a natural monopoly, where government has an important role in regulation to ensure keeping of low prices and higher quantity production. The monopolistic market structure is unfavourable from the point of view of service users, as well as from the aspect of social welfare (Petrović-Vujačić, 2010) due to loss in welfare, and from the point of view of efficiency, monopolies impose a deadweight loss or allocative inefficiency (Miller, 2006). Railway infrastructure remains a regulated monopoly that produces multiple outputs with specified rates and terms for allowing access to the network.

The main objective of this paper is to emphasize to what extent the demand for railway infrastructure products, train paths is dependent on the level of the track access charges, and in particular on the amount of mark-ups. In order achieve defined objective, the paper presents the track access charges legislative framework and dynamics of its implementation in European countries. There has been presented Ramsey pricing principle, as well as mark-ups dependence on the elasticity of demand. Furthermore, it is presented Case Study analysis of DB Netz methodology of mark-ups calculating and some theoretical assessments on mark-ups based on previous practical experiences.

2. Track Access Charges Legislative Background

European legislation has defined the framework for the use of railway infrastructure by Directive 2001/14/EC and Directive 2012/34/EU (Recast). In order to get clear picture of the dynamics in evolution of requirements for infrastructure management in the area of infrastructure charging, the relevant Directives' Articles will be presented on the whole.

Directive 2001/14/EC, Article 8(1): In order to obtain full recovery of the costs incurred by the infrastructure manager a Member State may, if the market can bear this, levy mark-ups on the basis of efficient, transparent and non-discriminatory principles, while guaranteeing optimum competitiveness in *particular of international rail freight*. The charging system shall respect the productivity increases achieved by railway undertakings. The level of charges *must not*, however, exclude the use of infrastructure by market segments which can pay at least the cost that is directly incurred as a result of operating the railway service, plus a rate of return which the market can bear.

Directive 2001/14/EC, Article 8(3): To prevent discrimination, it shall be ensured that any given infrastructure manager's average and marginal charges for equivalent uses of his infrastructure are comparable and that comparable services in the same market segment are subject to the same charges. The infrastructure manager shall show in the network statement that the charging system meets these requirements in so far as this can be done without disclosing confidential business information.

Directive 2012/34/EU, Article 32(1): In order to obtain full recovery of the costs incurred by the infrastructure manager a Member State may, if the market can bear this, levy mark-ups on the basis of efficient, transparent and non-discriminatory principles, while guaranteeing optimal competitiveness *of rail market segments*. The charging system shall respect the productivity increases achieved by railway undertakings. The level of charges *shall not*, however, exclude the use of infrastructure by market segments which can pay at least the cost that is directly incurred as a result of operating the railway service, plus a rate of return which the market can bear.

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Before approving the levy of such mark-ups, Member States shall ensure that the infrastructure managers evaluate their relevance for specific market segments, considering at least the pairs listed in point 1 of Annex VI and retaining the relevant ones. The list of market segments defined by infrastructure managers shall contain at least the three following segments: freight services, passenger services within the framework of a public service contract and other passenger services. Infrastructure managers may further distinguish market segments according to commodity or passengers transported.
Annex VI of the Directive 2012/34/EU is relating on the requirements for costs and charges related to railway infrastructure (referred to in Article 32(1). The pairs to be considered by infrastructure managers when they define a list of market segments with a view to mark-ups in the charging system according to Article 32(1) include at least the following: (a) passenger versus freight services; (b) trains carrying dangerous goods versus other freight trains; (c) domestic versus international services; (d) combined transport versus direct trains; (e) urban or regional versus interurban passenger services; (f) block trains versus single wagon load trains; (g) regular versus occasional train services.
It is evident that the Directive 2012/34/EU in comparison with the previous Directive 2001/14/EC has emphasized the market segmentation as obligatory. Furthermore, levying the mark-ups is now obligation for all market segments, not only for freight, as it was determined by Directive 2001/14/EC.

Table 1
Overview of rail infrastructure charges differentiation in IRG-Rail members

Country	Different charges according to the service type	In relation to Article 32(1) of the Recast		Charges (EUR/train km)	
		Market segment	Mark-ups	Freight	Passenger
Austria	YES	YES	YES	2,56	2,36
Belgium	YES	YES	NO	2,55	8,05
Bulgaria	NO	NO	NO	1,66	0,68
Croatia	YES	NO	NO	0,99	0,68
Denmark	NO	NO	NO	4,24	1,00
Finland	YES	NO	NO	2,14	0,51
France	YES	YES	YES	2,14	8,96
Germany	YES	YES	YES	2,92	5,06
Greece	NO	NO	NO	1,21	1,62
Hungary	YES	YES	YES	1,88	1,30
Italy	YES	YES	YES	2,33	3,09
Luxemburg	YES	YES	YES	1,80	1,97
Netherlands	YES	YES	YES	2,34	1,85
Norway	YES	NO	NO	0,81	0,4
Poland	YES	YES	NO	3,14	1,55
Romania	YES	NO	NO	3,03	2,39
Slovakia	YES	NO	NO	1,88	1,52
Slovenia	YES	NO	NO	0,99	0,01
Spain	YES	YES	YES	0,22	2,89
Sweden	YES	NO	NO	n.a	n.a
Switzerland	YES	YES	YES	5,75	4,87
UK	YES	YES	YES	2,07	4,16

Source: (Elaborated by Authors based on IRG-Rail, 2016 and IRG-Rail, 2017)

Table 1 presents differences in railway infrastructure charging system regarding the valid EU legislative. It is evident that there are a lot of discrepancies among the infrastructure managers regarding the different charges according to the service type and implementation of the Article 32(1) of the Recast. Namely, even majority of the infrastructure managers have set the charging policy based on differenced service type, a lot of them are still have not implemented mark-ups for different market segment.
It is noticeable, also, that the actual level of track access charges differs widely among countries and among passenger and freight services, as well. Analysing the track access charges distribution per European countries for passenger and freight services in 2017, it is evident that these amounts of charges are not harmonised. The average amount of track access charges (EUR/train-km) in passenger services segment is 4,13 and 2,78 for freight services (IRG-Rail, 2018). Revenue from track access charges increased by 1.5% and account for 34.5% of total infrastructure operating revenue (incl. state contributions) (CER, 2016). According to the *IRG-Rail, 2018* research, track access charges in Europe expressed in EUR/train-km, are in very wide range from 11, 36 in Lithuania and 0, 46 in Norway. The average track access charges amount is 3, 92 EUR/train-km. Track access charges average share between passenger and freight railway undertakings in Europe is 87% and 13%., respectively (IRG-Rail, 2018). The highest share of passenger track access charge of 99% is recorded in Spain, and lowest in Slovenia with just 1%. One of the key challenges for establishing a harmonized railway system is the development of a coherent access charging system (Ludvigsen, Milenković, 2016).

Even the different national track-access charges seem to be increasingly converging towards the European average, which is helpful in the context of the development of a Single European Railway Area for freight, with not only lower but standardized charges (EC, 2014), EU infrastructure charging policy is still differ a lot in pricing principles adopted by EU railway infrastructure managers. Full-cost pricing (FC) involves charging the user full costs (fixed and variable costs) incurred in provision of services and construction of infrastructure. This approach includes large sunk capital costs that are characteristic of railway operations, which prevents maximizing social costs, but provides a high recovery rate to the infrastructure managers and, thus, a low impact of the rail operations on the state's budget. If not properly implemented, full cost pricing may exclude services with lower willingness to pay (Prodan and Teixeira, 2015). A variation of full cost pricing (FC-) involves a contribution from the state budget, meaning that the full railway infrastructure costs are reduced for amount of state contribution. EU Directive 2001/14 recommended marginal costs pricing, meaning that the railway infrastructure charging should be set at the cost that is directly incurred as a result of operating the train service (EC, 2001) or directly-related costs what represents short-run marginal costs (SRMCs). Costs that take into account infrastructure capacity improvements in order to solve over burdened network or luck of infrastructure capacity are known as long run marginal costs (LMCs). If within the abovementioned costs are internalised external costs that an additional train produces during its movement, and then it is the so called marginal social costs (MSC). This pricing principle implies contribution from the state budget.
In present condition of charging system the share of marks-up on track access charges varies, as a result of the percentage of total infrastructure costs coverage from charges. The differences shown may partly reflect the overall cost levels in the different countries, and the different levels of efficiency with which rail infrastructure is constructed and maintained. It also reflects differences in local circumstances and different objectives concerning the government contribution to infrastructure costs. Differences in the level of charges can also reflect excess costs for some railways when the network is over-dimensioned for current demand ECMT/OECD (2005).

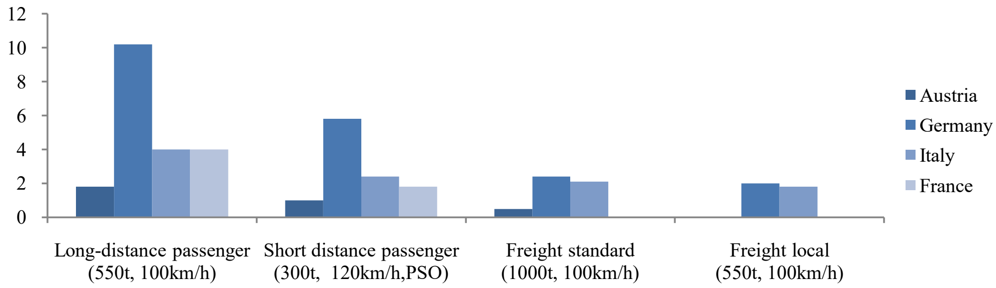

Fig. 1.
Distribution of mark-ups by infrastructure managers in Austria, Germany, Italy and France (EUR/train km)
Source: (Kruidhof, 2018)

The levels of mark-ups in some EU countries differenced in accordance with the services market segment is presented in Figure 1. Mark-ups for the long distance and short distance passenger services are significantly higher than for freight services. The highest mark-ups are charged in case of German infrastructure manager. Regarding the freight mark-ups there is higher level of harmonisation among examined countries.

3. Ramsey Pricing Principle in Railway Infrastructure Charging System

Railway infrastructure charging system set on marginal costs plus mark up is based on Ramsey pricing principle. (Ramsey pricing principle is the sophisticated model of a society's optimal saving was published in 1928 by the British mathematician and economist) that considers responsiveness of railway undertakings to the costs and the amount charged to railway undertakings' willingness to pay. Even this pricing principle could implies deficit for infrastructure manager it is considered as a better than charging on MC principle, in terms of cost recovery, and better than charging on FC principle, in terms of efficiency (Ferizović et al., 2017).
From an economic point of view the aim of Ramsey pricing principle is to maximize social welfare under the conditions of cost coverage constraint. It considers the fact that the infrastructure manager supplies different products. They can be defined from the demand side and the supply side. Rail infrastructure slots can be differentiated according to different regions, different times and different customers. Ramsey pricing tries to find mark-ups for these products to cover the deficit that results from short run marginal costs pricing (Benedikt, 2008).
Ramsey pricing allows for a detailed price differentiation by the infrastructure manager. If the demand for different market segment are known and the differentiation is well done, price differences are to be expected between different regions, times and trains (Benedikt, 2008) and when the services provided are significantly different according to the elasticity of demand.
It is important to underline although it is designed to cover all infrastructure costs, the differentiated system of prices doesn't automatically provide (dis-) investment incentives for infrastructure. Ramsey prices build upon marginal costs and therefore face the same information restraints as short run marginal cost pricing and it doesn't exhibit enough elements to sufficiently incentivize the infrastructure manager to invest in the right quality and quantity of the

infrastructure. Thus, dynamic allocative efficiency is not automatically achieved by this pricing principle (Benedikt, 2008).
Ramsey pricing principle presents inverse elasticity rule, meaning that individual price of service rises above marginal cost in according to the price elasticity demand of service, as it is stated in formula bellow:

$$(p_{i-} - MC_i) / pi = - \lambda / \varepsilon_i \qquad i = 1, 2 \ldots n \text{ and } 0 < \lambda < 1 \qquad (1)$$

Where are:
Pi - charge for service *i*
MCi - direct (marginal) costs of railway service *i*
ε_i - price elasticity of demand of railway service *i*
λ - parameter (Ramsey number)

Ramsey number λ tends to be represented as being bounded between 0 and 1 in equation (1) is as follows (AAPT, 2005):
1. If λ were equal to 0, then the price in each market would just be equal to the long-run marginal cost of production $pi = MCi$. However, this outcome cannot arise because it requires that no common costs of production are being recovered in the first place; and
2. If λ were equal to 1, then the utility would be charging the unregulated monopoly price for each service *i* $(p_{i-} - MC_i) / pi = 1/ \varepsilon_i$.

Price elasticity of demand εi , is always negative. So if services are independent, the Ramsey prices are above marginal cost prices. This means that the demand is reduced below the value at which social welfare is maximized. Recall that an inelastic good is one for which the demand is relatively insensitive to price changes, i.e. $|\varepsilon i|$ is small (Courcoubetis and Weber, 2003).

3. 1. Mark-ups and Infrastructure Demand Elasticity Correlation

A weakness of marginal cost pricing is that it may not allow the supplier to recover its costs, but the monopoly power set the price higher than marginal costs, determined by the elasticity of the market demand, because it is the only bidder in the market (Pindyck, Rubinfeld, 2005). Referring to the previous, infrastructure manager as a natural monopol can set the price higher then marginal costs.

From the Ramsey pricing model (1), for $\lambda=1$

$$(p_{i-} - MC_i) / pi = -1/ \varepsilon_i \qquad (2)$$

this ratio gives a rough rule for determining the price of the left side of the equation:

$$(p_{i-} - MC_i) / pi \qquad (3)$$

is the mark-up added to the marginal cost as a percentage of the price. Equation denotes that the margin should be equal to the negative inverse elasticity of demand (the amount obtained will be positive because the elasticity of demand is negative) in accordance with the above, this equation can processed in order to express the price directly as a mark-up above the marginal cost (Ĉiĉin-Šain, 2007):

$$p_i = MC_i /(1 + (1/ \varepsilon_i)) \qquad (4)$$

The Ramsey infrastructure pricing model taking into account the different elasticity of demand for different types of railway services (freight, passenger, high speed, intercity, suburban, parts of the network, etc.) mark-up is accounted for each type of service, as a percent of marginal costs, but inversely proportional to the elasticity of the transport demand (demand of the railway undertaking). This principle does not apply when all transport services are the homogenous and there is no services differentiation (Bugarinović, Bošković, 2008).
Ramsey pricing railway infrastructure principle requires a need for knowledge on demand elasticity for different types of railway services, based on which the effective charge could be defined, inversely proportional to the elasticity of demand. It could be considered two approaches in calculation in order to determine costs mark-ups:

- top to bottom approach which is based on the use of accounting reports; and
- bottom-up approach which is based on engineering models, and used when it is difficult to accurately calculate demand (routes demand, utilization of the infrastructure capacity traffic volumes, etc.).

Social welfare maximizing price is achieved when the marginal costs are equal with the demand, MC=D in $Q1^c$ and $Q2^c$ for market segments MS1 and MS2, respectively. The quantities which maximizing the monopolist's profit ($Q1^a$, $O2^a$) are where marginal revenue is equal with the marginal costs, or MR=MC. Obtained prices $P1^a$ and $P2^a$ for the MS1 and MS2, respectively at which a monopolist maximizes its profit.

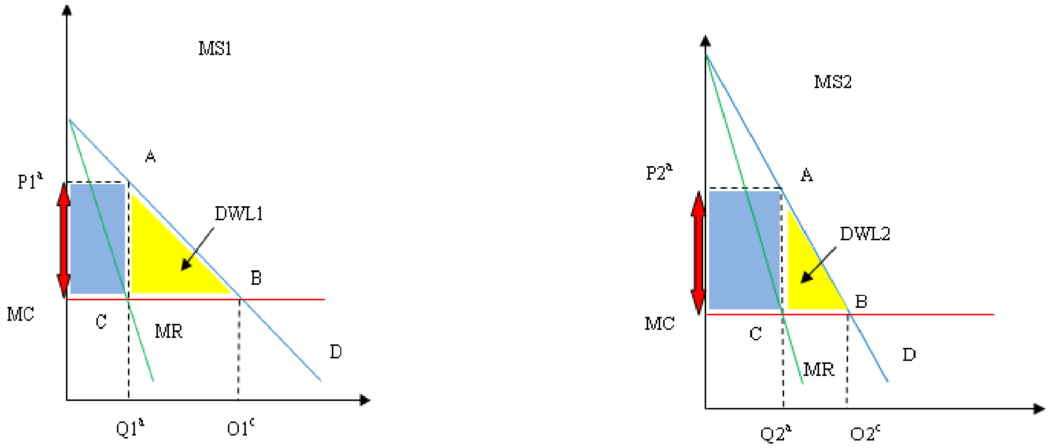

Fig. 2.
Relationship between demand elasticity and mark-up amount
Source: (Elaborated by Authors based on Cowen, Tabarrok, 2018 and Niemeier, Müller, & Ehmer, 2008)

The prices $P1^a$ and $P2^a$ are reducing customer surplus, declining the social welfare imposing deadweight losses DWL1 and DWL2 (yellow triangles ABC) but rising the monopoly surplus (blue rectangles), presented in Figure 2. The level of declining the social welfare is determined by demand elasticity. More price elastic demand imposes a greater deadweight loss than the demand with the lower degree of price elasticity.

As the railway infrastructure is a natural monopoly, considering the previous stated economics principle, differences in track access charges between the routs and railway market segments could cause discrepancies in service users' willingness to pay. All potential users who value service more than the marginal cost, but less than the monopoly price, decide to give up of purchases that cause the inefficiency of the monopoly.

If demand for a particular type of service in one market segment is sensitive to a change in the price, the application of the track access charge above marginal costs will lead to a significant decline in demand. Conversely, if the demand for a service in another market segment is not sensitive to the change in price, the application of the track access charge defined above marginal costs will not lead to a significant reduction in demand. It means that the relatively elastic demand of railway service will decrease murk-up value, while relatively inelastic demand of railway service will increase the value of mark up (Figure 2). In accordance with the aforementioned economics theoretical principle, the railway market segments with the relatively inelastic demands pay the highest charges, based on higher mark-ups. Ramsey pricing has the effect of pricing inelastic services significantly above their marginal costs and these services or market segments whose demand is more price sensitive tend to be subsidized or cross-subsidized.

3.2. Case Study Analysis of mark-ups and Market Segment Demand

For the purpose of this paper it will be elaborated the case of German infrastructure manager DB Netz (based on DB Netz Network Statement 2019. The charges system of DB Netz is a in accordance with the EU Directive 2012/34 with the basic objectives: (1) Necessity to secure sufficient funds to finance the infrastructure; (2) Each customer has to bear the costs directly incurred (marginal costs) as a result of operating the train service and (3) Remaining costs should be allocated on all users in order to maximize market demand.

The baseline in the creation of the charging system of DB Netz is based on the assumption that changes in the cost of the train track in a market segment will imply a change in the demand of end users. Namely, an adjustment in train path charge in one market segment will affect railway undertaking regarding the train path cost share in revenue. Railway undertaking will response in order to correct retail price of the service what will have an influence on the demand of final service costumer and market share of railway, as well. Finally, the impact on train-path demand results in the changes in demand for train paths in response to the changes in final customer demand.

The train path charge per market segment is composed of the three components: direct costs of train operations (marginal costs), the mark-up on full costs, and other elements. In order to calculate the train path price per market segment, the direct costs of train operations and the price elasticity of train path demand must be determined for each market segment. It could be noted that the price depends only on the input parameters: marginal costs, turnover per train path km, and end customer elasticity. The determination of λ results from the ancillary condition that the sum of the price per market segment, multiplied with the quantity per market segment, must be equivalent to the overall cost. By means of λ, the price for all segments of the transport services can be finally calculated, with λ being identical for all segments in order to comply with the condition of the Ramsey rule (DB Netz, 2018).

Starting from the Ramsey pricing principle formula:

$$(p_i - DC_i) / pi = - \lambda / \varepsilon_i \tag{5}$$

in which i indicates the respective segment, the reaction of final customers to train path price changes determines segment price elasticity, therefore elasticity formula could be written as:

$$\varepsilon_i = \varepsilon_{FCi} * pi / Ri \tag{6}$$

By substituting formula of elasticity (3) in original Ramsey formula (2), after arranging a mathematical expression, it is obtained:

$$pi = DC_i + \lambda\, Ri / \varepsilon_{FCi} \tag{7}$$

where are:

DCi - direct costs (per train path kilometer)
pi - track access charge (per train path kilometer)
εi - price elasticity of demand for tracks
ε_{FCi} - price elasticity of final customer demand
Ri - revenue of railway undertaking (per train path kilometer)
λ – parameter values can be between 0 and 1 (It determines the level of charges: the higher λ, the higher the charges level. The calculation of the 2019 train path charges of DB Netz AG is based on a value of λ = -0.0991).

For the purposes of this paper, DB Netz freight traffic charges were analyzed. Results of the analysis are presented in Table 2. The main segments of freight transport are: dangerous goods block train, local freight train for dangerous goods, local freight, load run, empty run and locomotive run, standard, fast, express, point to point, spatially flexible train run, very heavy temporally flexible train run. In total, according to the freight service type there are defined 41 market segment.

Table 2
Summary statistics on TAC for freight regarding the demand elasticises of market segments in DB Netz

Variable	Valid MS number	Min	Max	Mean	Standard deviation
DTOC (*EUR/train-km*)	41	0,668	2,414	1,195	0,4333
Mark-ups (*EUR/train-km*)	41	0,731	4,102	2,094	0,9175
TAC (*EUR/train-km*)	41	1,590	5,480	3,289	1,1386
Mark-ups share in TAC (%)	-	45,9	74,8	63,7	-

Source: (Elaborated by authors based on DB Netz, 2018)

It's noticeable that mark-ups values vary in the range from 0,731 EUR/train-km, what is minimum value up to 4,102 EUR/train-km, as a maximum and the average value of 2,094 EUR/train-km. Standard deviation as measure of variation of mark-ups from the average in absolute terms is 0,9175. The recorded differences in mark-ups values for different segments reflect the variability in the price of infrastructure charges where the minimum price is 1,590 EUR/train-km and maximum price is 5,480 EUR/train-km.

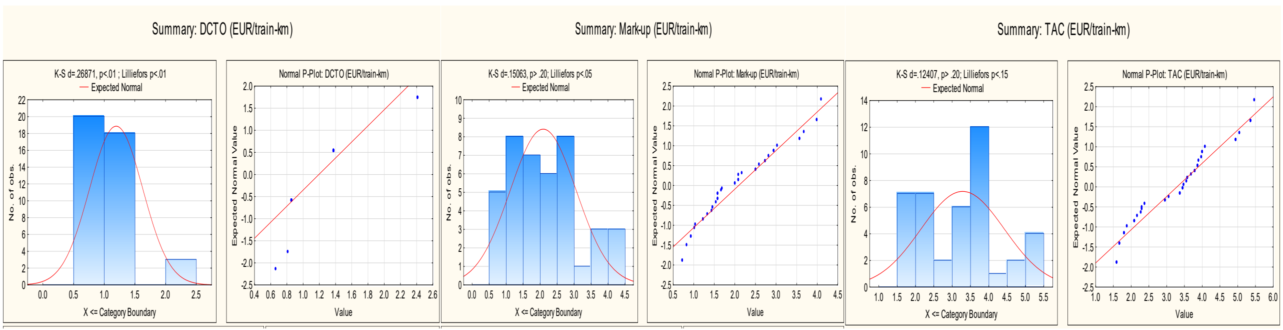

Fig. 3.
Summary statistics on DTOC, mark-ups and TAC
Source: (Authors)

Results on summary statistic for the variable: direct train operating costs, mark-ups and track access charges are presented in Figure 3. The statistical analysis has shown that the share of the mark-ups in the track access charges is relatively high in average amount of 63,7%. The minimum value is almost of the a half of the price in amount of 45,9% and maximum value of 74,8%.
In the Figure 4 is given 3D presentation of mutual relationship of direct train operating costs, mark-ups and track access charges for the freight traffic. The surface area presents variability in direct train operating costs and mark-ups amounts implying the changes in the amount of the track access charges for all 41valid market segments.

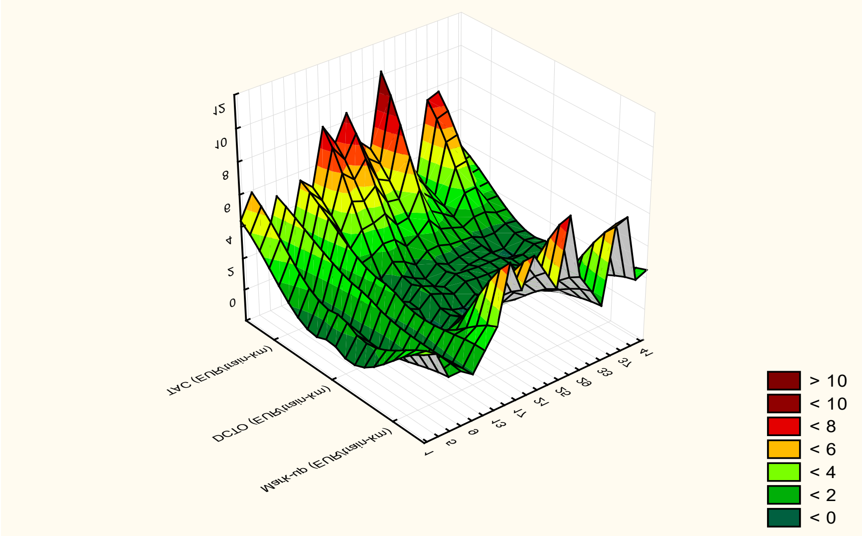

Fig. 4.
3D sequential graph on relationship between DTOC, mark-ups and TAC of DB Netz freight charges
Source: (Authors)

Furthermore, the analysis of the methodology of DB Netz charge system confirms that its principles are in line with the EU Directive 2012/34 and can be summarized as follow:

1. The level of infrastructure charges do not exclude the use of infrastructure by market segments which can pay at least the cost that is directly incurred as a result of operating the railway service, plus a rate of return that the market can bear;
2. The mark-ups are determined in such a way that railway services cover the total cost incurred by the operator of the railway tracks;
3. Distribution of the costs relay on the relative viability of the relevant transport services and their market segments;
4. The level of the mark-up is based on the ability to pay of the market segment and do not exclude the use of infrastructure by market segments, and
5. The mark-ups are determined in order to ensure the competitiveness of the related market segments.

4. Assessment of Mark-ups of Track Access Charges in Terms of Economic Efficiency

General goals of levying mark ups (IRG-Rail, 2016) could be summarised in recovering of fixed costs, net of public subsidies, allocating the costs incurred by the infrastructure manager to different market segments according to their elasticises, and achieving the optimum effective level of use of the of the available infrastructure capacity. The main issue in determining the mark ups is to gain the correct level: is the one that deteriorates the competitiveness of railway undertakings less. Each price rise does deteriorate the competitiveness, but the loss can be minimized, if considering the price elasticity of the downstream market (IRG-Rail, 2016).
Considering practical experience of EU railway infrastructure managers, general and specific problems which may prevent from achieving an optimal assessment of mark-ups are:

- Different approaches and methodologies of the EU infrastructure managers to evaluate the price elasticity of railway market segments and to calculate mark ups.
- Existing national legal framework, high public and political interests and the fact that not all member states cover the fixed costs of their infrastructure managers completely.
- The competitiveness of the rail undertakings is always deteriorated when setting prices above direct costs in comparison to a situation without mark-ups and the position of railways in comparison to other modes is worse off.
- Services within the framework of public services contracting are further subsidized and therefore the determination of price elasticity for these market segments is more complicated, and infrastructure managers have to resort to a different mechanism to define the level of mark ups. Under a franchising or competitive tendering system publicly supported services, if the operator includes expected demand levels, and if the government support does not change with actual demand, then the operator will be sensitive to the variable part of the access charges (ECMT/OECD 2005).
- Price differentiation can be justifiable as the differences in prices allow users to purchase more of the services. Regulators usually consider price differentiation as a price discrimination, as an unfair to cause one service user to a higher mark-up above the marginal cost than another type of service user (http://regulationbodyofknowledge.org).
- There is always a fear that dominant operators will use their market power to secure favourable treatment, and this fear is particularly strong where the dominant operator is part of the same organization as the infrastructure manager and it is possible to design mark-ups that favour the dominant operator (ECMT/OECD 2005).

- Market-driven train operators, such as the various freight operators, can reasonably be said to have a price elasticity of demand with respect to the level and structure of access charges. They will respond to the cost signals that the access charges send (ECMT/OECD 2005).
- Lack of information as a limit to the definition of market segments and insufficient data quality on the characteristics of demand elasticity to assess the level of mark ups. In theory, the economic benefits of Ramsey pricing apply to a separated rail infrastructure company as much as to a vertically integrated railway, the practicality of Ramsey pricing is greatly reduced with a separate infrastructure company dealing with train operating companies not freight customers, and are remote from the detailed market information that would allow managers to price to market. Using Ramsey pricing, the price-to-cost ratio in less elastic markets would be much greater for infrastructure than in an integrated company because track access charges are a fraction of total freight charges (World Bank, 2011).

5. Conclusion

European legislation is explicit in the request to the European infrastructure managers when it comes to the system of charging fees for the use of infrastructure which will maximize its economic efficiency. Basically, the system is based on the Ramsey principle and requires the infrastructure managers that their fee systems implement the segmentation of the railway services market and mark-ups determined by demand in a particular market segment. As a result, railway infrastructure manager can obtain the higher profit from the services with lower demand elasticity, as the increase in price implies a slight decrease in demand for this service. Services with the inelastic demand can partly cover costs of the services with elastic demand, enabling to equalize the price of the service with elastic demand at the marginal cost, and in some cases can even go below the marginal cost.

The presented Case Study has emphasized an example of a mark-ups calculation in real conditions and showed the complexity of the applied methodology. The need to know demand trends for each defined segment, as a key input for the calculation of mark-ups is the most sensitive part, because insufficient and inadequate data can indicate the wrong conclusions and calculations of mark-ups.

Bearing in mind that the countries of the Western Balkans are in the process of restructuring and market liberalization, it is essential that railway infrastructure managers prepare in due time for the application of an adequate collection system based on EU legislation in force and positive European practices. Thus, a greater degree of uniformity would be beneficial (Nash, 2005). It is therefore necessary to provide infrastructure managers with incentives to reduce costs and manage their infrastructure efficiently (EC, 2001).

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INSURANCE AS AN INSTRUMENT OF RISK MANAGEMENT IN LOGISTICS SYSTEMS

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Abstract: Logistics systems, like other business systems, are characterised by a large number of risks changing often in place and time. Risk management in supply chain and logistics involves identification of possible threats to the system or process, undertaking measures with the aim to reduce the possibility of their realisation and minimize any loss events in case those threats are nevertheless realised. The aim of risk management is to set up optimal control over the identified risks, which results in more stable systems, reduction in cancelled operations or failures in operations and maximising system reliability, effectiveness and profitability. One of the instruments of risk management in logistics systems is insurance. The most frequent line of insurance used for coverage of risks in logistics systems or processes is transportation insurance, including wide range of different types and subtypes within this insurance line. Insurance can cover the risks that business and logistics systems are always exposed to in those situations when their in-house management is not cost-effective. In insurance practise, it is often difficult to assess the amount of risk related to logistics systems and processes and to determine premium rate of insurance. A number of statistical methods, as well as mathematical and actuarial models, are used in the process of assessing risk of any particular insurance coverage.

Keywords: Logistic, transport, risk, insurance, utility.

1. Introduction

Risk management is a process of making decisions on acceptance of known or assessed risks and/or implementation of actions in order to reduce consequences or probability of their occurrence. The objective of response to an identified risk in the logistic system is to find and apply adequate risk control method. The most common problems in practice are inefficient, poorly established or a non-systematic risk control process. That often leads to increased probability of realisation of unwanted effects, i.e. increase of total risk of the system's business operations. There are various risk management methods, whose complexity can be in interval of very simple to extremely complex ones, and their implementation depends on the size of the observed logistic system, available information, available time for analysis, implementation costs, human resources, numerous limitations, etc. Transportation insurance is a very efficient instrument for risk management of logistics systems. In the world practice, various terminology related to transport insurance, logistics and supply chains is used as the widest term (Seltmann, 2004). In certain cases, the insurance can only partially cover the damage that complex supply chains and logistics systems may suffer, because the damage and costs incurred by the interruption of the continuity of the logistics processes can be significantly higher than individual or aggregate claims that may be covered by insurance.

According to Mau and Mau (2009), there is a positive correlation between the reliability of supply chains or logistics systems and risk management, in case of usual, standard risk management activities. However, when the applied level of management significantly increased, the level of reliability is generally not increased in proportion to the costs, which most often grow rapidly. In addition, in the majority of cases in the logistics systems practice it is impossible to achieve absolute reliability, that is, there is always an area of unreliability. For this reason, as part of possible activities of logistics systems towards minimization of risk, the role of the insurance institution appears. The risk assessment includes the assessment of individual impacts of all known risk elements (including major risk events, indirect events, causes of events, different constraints, etc.), as well as the overall risk assessment, i.e. the reliability of the entire system (including the duration of the risk, the direct and indirect consequences, spatial scope, etc.).

Implementation of actuarial principles in transportation insurance is often limited by the fact that this insurance covers an almost unlimited set of different insurance items, a large number of different circumstances characterized by specific logistic processes, with the fact that there is permanent market variability, seasonal effects on risk and many other factors. In transportation insurance, risk quantification is often done without the use of exact mathematics, statistics and different models, but based on intuition, experience and knowledge of risks.

2. Credibility, Vagueness and a Lack of Data Necessary for Risk Assessment

Actuarial scope in insurance implies the application of actuarial and mathematical methods, models and techniques in order to examine the phenomena, facts and unforeseen circumstances faced by the insurer, as well as to neutralize the financial effects of those circumstances on the insurer. One of the most important activities of insurers in the function of providing adequate insurance coverage is the segment of underwriting in insurance. Underwriting involves the process of analyzing, selecting and classifying the insurance claims, assessing the exposure of potential clients to certain risks, and determining the terms and prices of the insurance cover (Macedo, 2009; Klen, 2004.). The main role of an

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underwriter is to ensure profitable insurance portfolio, i.e. that ratio between earned insurance premium and paid claims is on the level of projected objective.
There are six prerequisites for accepting insurance risks, which are considered ideal for an insurer (addapted, Rejda, 2008):

- Extensive number of risk exposures in the past;
- Claims must be accidental and unintentional;
- Claims must be determined and measurable;
- Claims should not be catastrophic;
- Claims probability and the consequences of damages should be calculated;
- The insurance premium must be economically acceptable.

In practice, insurers are exposed to a large number of risks that do not meet criteria of an ideal risk. For this reason, insurance business is followed by uncertainty, ambiguity, vagueness and errors in the process of acceptance of risk. Having in mind that any natural person or a legal entity has an objective to maximise the expected utility of its assets, whose value is assumed to be subject to changes under influence of various deterministic and accidental factors, a criterion is defined for maximisation of expected utility (EUM - Expected utility maximization). In this paper, we illustrated EUM application to insurance from the aspect of the insured and the insurer. As common attribute of all insurers is risk aversion, functions are defined as a risk aversion measure from the aspect of persons whose goal is maximizing the expected utility of capital. Considering the main property of the EUM criteria – linearity, it is shown that this property is not always adequate to describe the preference of individuals. Allais's paradox was presented, as a motivation for the introduction of different approaches to describe the preferences of individuals. They represent the generalization based on EUM criteria.
Many insurance contracts are contingent on rare events such as different rare events, unknown risks, disasters, terrorist activities, political risks etc. whose probabilities are not known with precision. Such insurances are said to be subject to term ambiguity (Kunreuther et al., 1995; Viscusi, 1993). This term also applies to some lines of transportation insurance. There is by now a body of evidence to show that, faced with offering an insurance contract under ambiguity, insurers increase their premiums, reduce limit coverage, or are unwilling to provide insurance at all. In the practice of insurance, actuaries and underwriters from insurance and reinsurance companies are asked to quote prices for hypothetical contracts in which the probabilities and consequences of loss are relative known or unknown.
There is plenty of evidence based on experiments indicating that individuals treat unknown probabilities differently from the probabilities that are well predicted. Ellsberg's classic work (1961) found that, for events involving profit, individuals prefer a lottery with well-predicted probabilities compared to those with unknown probabilities, unless the chances of winning are small. A number of experiments confirmed the Ellsberg hypothesis.
The insurer can influence a certain number of risks, implementing the principles and tenets of modern business. However, there are numerous risks beyond the influence of insurers as well as the risks with the limited impact. For this reason, the insurance company must implement a systematic approach to managing risks, using modern actuarial, financial, legal, technical and other mechanisms, in order to protect itself as well as to protect its clients. Characteristics of the risks inherent in the logistics systems and processes predetermine the nature and modalities of insurance. Considering the number of entities and the complexity of supply chains and logistics systems, the existence of a multitude subsystems and relationships between entities, in practice, a large number of different nonlife insurance is applied as a risk management instrument.
Table 1 shows the most important types of insurance exist in supply chains and logistics and entities that need insurance:

Table 1
Nonlife insurance in supply chains and logistics

Importer/carrier - Goods in transit insurance (Marine cargo insurance) - Liability insurance - Insurance of customs debt	**Enterprise** - Property insurance - Employees’ insurance - Liability insurance for loss/keeping of goods	**Forwarding agent** - Professional liability insurance - Goods liability insurance - Warehouse operator’s liability - Insurance of forwarding agent’s interest - Goods in transit insurance (transferrable)
Consolidator of goods - Liability insurance for accuracy of transportation and storage documents regarding goods in transit	**Liability of employees in ports and terminals** - Accident insurance for employees - Liability insurance for employees in ports and terminals	**Maritime or river carrier** - Insurance of vessels and liability - Third-party liability insurance - Liability insurance according to rules of P&I Clubs - Goods in transit insurance

	- Property insurance and general liability	(transferrable)
Customs authorities - Receivables insurance - Credit insurance - Guarantee insurance	**Liability of ports and terminals** - Liability insurance of ports and terminals - Warehouse operator's liability - Property insurance and general liability	**Road or rail carriers** - Road and rail carriers' liability for goods - Insurance of carrier's interest - Goods in transit insurance (transferrable) - Third-party liability insurance

Source: adapted, Brown et al.*, 2012*

In practice, underwriters' decisions are usualy made based on individual risk perception, especially in transportation insurance. For the insurer it is very important to obtain complete and accurate information for assessing the level of risk of insurance coverages. However, there is a situation in practice where insureds deliberately select information or provide false information on the level of internal or external risks that is in insurance called anti-selection (adverse selection) (Werner and Modlin, 2010; Rejda, 2008), which is present in transportation insurance lines. Anti-selection is very unfavorable for insurance companies and is seen as one segment of operational risk in insurance. In transportation insurance, expert assessment of riskiness of certain risk elements of the observed logistic process is often performed in order to review the total risk, based on which the premium rate or insurance premium is determined. Definition of insurance contract elements and evaluation of the premium rate include expert consideration of influence of numerous factors, including potential initial risky events, indirect events, causes of events, modalities of various influences, and the like. If underwritters and actuaries regularly determine higher premium rates than real ones due to inadequate expert judgment of risk parameters, this can contribute to a reduction in the demand for insurance and lead to market failure of the insurer and miscarriage to perform the expected profit from the activity. On the contrary, contracting of premium rates lower than the actual ones generates risks of inability to fulfil obligations from an insurance contract, insured's interests are impaired, insurer's business reputation is lost, etc., and in certain cases there are risks of impairment of insurer's liquidity and solvency. Numerous problems related to decision-making are characterized in insurance, especially transportation insurance. In practice, it is often that different underwriters have different perceptions about the risk of the same or similar insurance coverage, also, inconsistancy in underwriters' information in process of risk assessment modeling.

3. Expected Utility Theory

The Utility theory is widely used in the field of risk management and insurance because the behaviour of the decision maker regarding risk level and its acceptability is described in accordance with the individual significance of money. From the aspect of the insurer, the policyholder often decides to pay a premium that is higher than the expected amount of loss based on the Utility theory (Trownbridge, 1989; McClenahan, 2001, 2004; Brown and Gottilieb, 2001; Kaas et al., 2009; Daykin et al., 1995). The above problem is mathematically formalized using the appropriate utility function and utility curve for the purpose of a more realistic and accurate presentation of the value of money. The individual's risk attitude, within the expected utility theory, is determined by the shape of the utility function that is presumed to be his choice. The utility function is concave for an individual who is risk-averse, convex for the risk-seeking individual, while for the risk-neutral person utility function is linear. However, while economic theory and practice suggest that individuals under conditions of uncertainty do not behave in accordance with the basic principles of conventional theory, there is no new unified and universally accepted theory that would be compatible with all the previous knowledge about the choice of an individual under uncertan conditions. Violation of the axiom of uncertainty led to development of Machina's generalized expected utility analysis and Chew-MacCrimmon theory. The most common alternative to the expected utility theory is the prospect theory. According to this theory, a loss has a greater value in the absolute value than the profit of the same value, so in case of losses a decision-maker strives to take risks, while in case of profit strives to avoid risks.

Bernoulli assumed that the utility of capital x, can be measured by a function $u(x)$ which, in general, is not linear, and proposed a utility function $u(x)=\ln x.$ He introduced the assumption that the increase in utility is proportional to the relative change in capital, or if the capital x increases by dx, then the increase in utility $du(x)$ is proportional to $\frac{dx}{x}$, for $du = k\frac{dx}{x}, k = \text{constant}.$ By solving the differential equation we obtain $u(x)=k\ln x + C, C = \text{constant}.$

In the modern form, Expected Utility Theory was developed by Neumann and Morgenstern (1947). They have shown that an individual whose preferences satisfy certain axioms (ordering, continuity, and invariance), under uncertain conditions, will choose between alternatives in order to maximize the expected utility associated with the possible results of his choice. Individual preferences are defined through a set of all possible alternatives. Let Q and R be any two possible alternatives that belong to a set of possible alternatives and probabilities $p \in [0,1]$. The third alternative from a set of possible alternatives is a combination of the previous two, Q has probability p, and probability of R is $(1-p)$.

Axiom 1. (Ordering). The axiom involves completeness and transitivity.

Completeness means that when choosing between the alternatives q and r it must know exactly which alternative is preferred or that both alternatives are equally attractive.

Transitivity means that if Q is preferable to R and R is preferable to S, then Q is preferable in relation to S.

Axiom 2. (Continuity). Let Q, R, and S be any three alternatives, Q> R> S. Then, there must be a complex alternative composed of Q and S with the probability p and $(1-p)$, that will be indifferent with respect to R. Axiom explains existence of the alternative that is unlimitedly better or worse than other alternatives.

Axiom 3. (Independence or linear probability). Let Q, R, and S be any three alternatives such that Q ≥ R. Then p: (1 - *p*), the compound probability of the alternatives Q and S must be slightly preferable with respect to $p:(1-p)$, compound probability alternative R and S.

If u is a utility function, defined on a real interval, and X and Y random variables, then

$X \succcurlyeq Y \Leftrightarrow E\{u(X)\} \geq E\{u(Y)\}$.

The relation $\succcurlyeq$ is called preference relation. Specially, it is $X \sim Y$, when random variables have the same expected utility. The function u can be defined to linear transformation, which enables scale adjustment that measures the utility. In this way, it is also permissible that the function u takes negative values.

Let random variables be defined on the probability space (Ω, $\mathscr{F}$, P). Preference relation on set $\mathscr{F}$ is defined as $FX \succcurlyeq FY \Leftrightarrow X \succcurlyeq Y$. In this way, preference relation is defined over the class $\mathcal{X}$ of random variables, and distribution functions from set $\mathscr{F}$.

For a fixed utility function, let

$$U(F) = \int_{-\infty}^{\infty} u(x)\,dF(x)$$

ultimate for each $F \in \mathscr{F}$. Then $U(F)$ is called utility functional.

Let F_1 and F_2 are distribution function and $p \in [0,1]$. Function $F^{(p)}$ is called the mixed distribution F_1 and F_2, if

$F^p(x) = pF_1(x) + (1-p)F_2(x), \quad x \in R.$

The main characteristic of expected utility maximization criterion is

$U\left(pF_1(x) + (1-p)F_2(x)\right) = pU\left(F_1(x)\right) + (1-p)U\left(F_2(x)\right),$

which means U is linear functional.

Let X be a random variable that presents the capital of the insurer. In this case, the utility of capital $u(X)$ is also a random variable, so the expected utility of capital is further considered as $E\{u(X)\}$. The expected utility of capital is completely determined by the distribution function of the random variable X. In that sense, it is sufficient to consider the relation of preference $\succcurlyeq$ to the set of distribution F. There is a great number of evidence that point to the fact that individuals' behaviour under uncertainty conditions is not in accordance with the independence axiom. Allais paradox was of great importance for development of more general criteria. Accidental profits are observed $X_1, X_2, X_3\ i\ X_4$ with values $x \in \{0, 10\text{M}, 30\text{M}\}$ and corresponding probabilities:

Table 2

Example of the Allais paradox

	0$	10M$	30M$
F_1	0	1	0
F_2	0.01	0.89	0.1
F_3	0.9	0	0.1
F_4	0.89	0.11	0

Most people will prefer to earn X_1 in relation to X_2 because of belief that it's better to get 10M $ guaranteed rather than the posibility to gain $ 30M with the risk of not getting anything, so $F_1 \succ F_2$.

If we observe the income X_3 and X_4, the probability of not getting anything is high and approximate. A person who chooses between such income is ready to lose, so he chooses an option that allows a higher potential gain, so $F_3 \succ F_4$.

Mixed distributions are observed $\frac{1}{2}F_1+\frac{1}{2}F_3$ and $\frac{1}{2}F_2+\frac{1}{2}F_4$. If preference relation $\succ$ is defined according to utility functional, then, based on linearity is $\frac{1}{2}F_1+\frac{1}{2}F_3 \succ 1$.

On the other hand, a direct calculation presents $\frac{1}{2}F_1+\frac{1}{2}F_3 = \frac{1}{2}F_2+\frac{1}{2}F_4$.

Therefore, linearity of the utility functional that is characteristic for EUM approach led to a conclusion that is contradictory to results obtained by a direct calculation.

EUM criteria can be used to determine the insurance premium acceptable for insurer. Let's mark with ξ the insured's loss, which the insurer takes as a substitute for the premium H. The insurer with the utility function $u_1(x)$ and insurance reserve w_1 wishes to maximise utility of its capital. Pursuant to the principle of expected utility maximisation, the acceptable premium for the insurer H, must satisfy inequality $u_1(w_1) \le E\{u_1(w_1+H-\xi)\}$, so for the minimum acceptable premium *Hmin* is valid $u_1(w_1) = E\{u_1(w_1+H_{\min}-\xi)\}$

The insurer finds acceptable the insurance premium that guarantees that the expected utility of its capital, in case of writing of and insurance contract, would be at least on the level of utility of its initial capital.

The experimental literature has proved the robustness of ambiguity reaction under different experimental conditions but while the issue of comparing individual valuations under known probabilities (risk) versus unknown probabilities (ambiguity) has been dealt with in several papers, little attention has been devoted to the analysis of the effect that alternative representations of ambiguity may have on individuals' reaction to uncertainty. We will consider this from the insurance underwriters' point of view.

According to the expected utility theory, an underwriter that prefers a certain outcome will charge higher premium, while loss variance around given medium value is increased (Goovaerts and Taylor, 1987). In the context of this study, we can analyse two risks. For risk no. 1 experts estimate a probability p of the known loss L. Let r_1 be premium collected for full insurance of this risk. For risk no. 2 probability of occurrence of this event is still p, but potential loss is uncertain, although experts estimated that it is limited L_{min} and L_{max} (usual limit of loss per written insurance policy). The resulting insurance premium (i.e. premium is such that the underwriter does not care whether to insure this risk or not), r_2, is defined by (Kunreuther et al., 1995).

$$U(A) = p\sum_{i=L_{\min}}^{L_{\max}} q_i U(A-L_i+r_2)+(1-p)U(A+r_2)$$

where q_i is probability that the insured loss would be L_i, A is insurer's assets, and U is the utility function of the underwriter. Let's assume that the expected value of loss in this distribution would be the same as the known loss L. In this case, premium r_2 will be higher than r_1 for underwriters who prefer a certain outcome.

If we consider a situation with ambiguity or uncertainty about probability of occurrence of the said event, we can assume that that the underwriter has k various experts' opinions about probability of the stated loss in the stated time. Let experts' evaluations on probability be marked as p_i, i = 1...k. Underwriter's best forecast on probability of loss occurrence is an estimate by one number, p = f (p_1...p_k).

Expected utility theory means that when insuring a single risk, ambiguity should not affect the premium charged by the underwriter if the underwriter believes the experts' estimates (Hogarth and Kunreuther, 1989). In order to show this, we will define that r_3 is premium when the probability is ambiguous with the best approximation, $p^* = f(p_1...p_k)$, and the loss varies between L_{min} and L_{max}. In order to operationalize p*, let's assume that n experts disagree and that linear weigh rule is used for combining their various estimates of probability. All other procedures for the same estimate p*, for an uncertain probability, will lead to the same qualitative forecast (Hogarth and Kunreuther, 1992).

4. Conclusion

In transportation insurance, many risk elements influence the overall risk level, independently or in interaction with each other. Considering the number of risks in transport, it is very difficult to simultaneously analyze and evaluate all risk elements, especially with a high degree of reliability. It is often impossible or very difficult to make clear delineations between identified risk elements, which can be classified according to various criteria. In addition, certain elements and sub-elements of risk lead to the total or partial exclusion of others, while certain elements and sub-elements are not even included, due to their number and assumption of their minor importance. Insurance premiums are generally determined by actuaries and underwriters, based on experience and available statistical data on earned premium, claims, costs, etc. Provision of required numbers of statistical data on homogenous groups of subject matters of insurance can be a big problem. Utility theory solves numerous issues in the area of risk acceptance in insurance, uncertainty, imprecise decision-making and the like, due to many influences and limits on one side, and lack of representative data on the other side. Expected value of a certain loss observed as a stochastic category can be used as a measure for risk level or an instrument for comparison of various alternatives regarding risks; however, this value does not always present a real criterion. Potential clients in insurance often do not accept the expected values principle, but base their decisions on financial standings and readiness to independently accept and carry the risk. Utility theory is to a great extent applied in risk management and in transportation insurance because the decision-maker's behaviour on the risk level and its acceptability is described realistically, taking into account certain subjective factors regarding individual meaning of money.

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USAGE OF MARGINAL ABATEMENT COST CURVES IN PRIORITIZATION OF R & D ACTIVITIES IN VEHICLE ENGINEERING

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Abstract: In this article the author shows the importance of abatement cost curves especially in R & D activities in vehicle engineering. The second chapter shows the abatement cost curves and their specialties. The third chapter shows the results of environmental abatement cost curves in Hungary and its changing over time. Fourth chapter introduces the further sectors and analysis. Finally, a conclusion is drawn based on the environmental experiences.

Keywords: road transport, abatement cost curve, environmental pollution, safety.

1. Introduction

In the last few thousand years, our natural environment has provided a stable base of living. In the early ages humanity made insignificant changes to the environment, global changes were not detected. In the last two or three hundred years, there has been an explosion in the development of industrial and technical sector that supplied people with a multiplied set of tools to encroach nature (*Zoldy, 2011*), (*Szwaja, 2018*). Motorization has been developed so dynamically that air, soil, and water pollution is now a direct threat to natural ecosystems and biodiversity (*Kivevele et al., 2011*). Sustainable development means "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." (*Stern, 2006*) Transportation cannot be replaced entirely because it is a part of the production chain (*Bóna et al., 2018*). Societies are horizontally and vertically differential (*Szabó et al., 2018*). The manpower, raw material and semi-finished and finished products must be transported. It has also become clear that since technological solutions have proven insufficient to handle the negative impacts of transportation (this includes external effects, such as pollution or congestion), demand management is also one of the cornerstones of reviewing transport policy measures in Hungary and the EU (*Uhlik et al., 2012*). These measures also include the development of public transport that is affordable, sustainable and meets the needs of the local population in order to be competitive with individual (passenger car) transport.

2. Methodology – Abatement Cost Curves

A Marginal Abatement Cost Curve (further on MACC) is a set of options available to an economy to reduce pollution. It can be derived from the cost curves. It is an economic tool to highlight priorities for politician s and decision makers. With the help of the curve emissions trading, eco-driving, carbon taxation, electric mobility, alternative fuels or road safety investments and technological solutions can be prioritized in order to shape policy discussions.
Economists have used MAC Curves to explain the long-term effect of measurements and their assessment. Various economists, research organizations, and consultancies have produced MAC curves (*Vogt-Schilb, Hallegatte, 2014*), (*Loughlin et al., 2017*). Bloomberg New Energy Finance and McKinsey & Company have produced economy wide analyses on greenhouse gas emissions reductions for the United States. ICF International produced a California specific curve following AB-32 legislation as have Sweeney and Weyant. The Wuppertal Institute for Climate, Environment and Energy produced several Marginal Abatement Cost curves for Germany (also called Cost Potential Curves), depending on the perspective (end-user, utilities, society). The US Environmental Protection Agency has done work on a MAC curve for non carbon dioxide emissions such as methane, N_2O, and HFCs. Enerdata and LEPII-CNRS (France) produce MAC curves with the POLES model for the 6 Kyoto Protocol gases, these curves have been used for various public and private actors either to assess carbon policies or through the use of a carbon market analysis tool. Typically, MAC curves cover emissions reduction opportunities across a number of sectors in an economy including power, industry, waste, buildings, transport, agriculture, and forestry.
Marginal abatement cost curves are beginning to gain traction as an assessment tool to compare the merits of competing carbon reduction projects and technologies.

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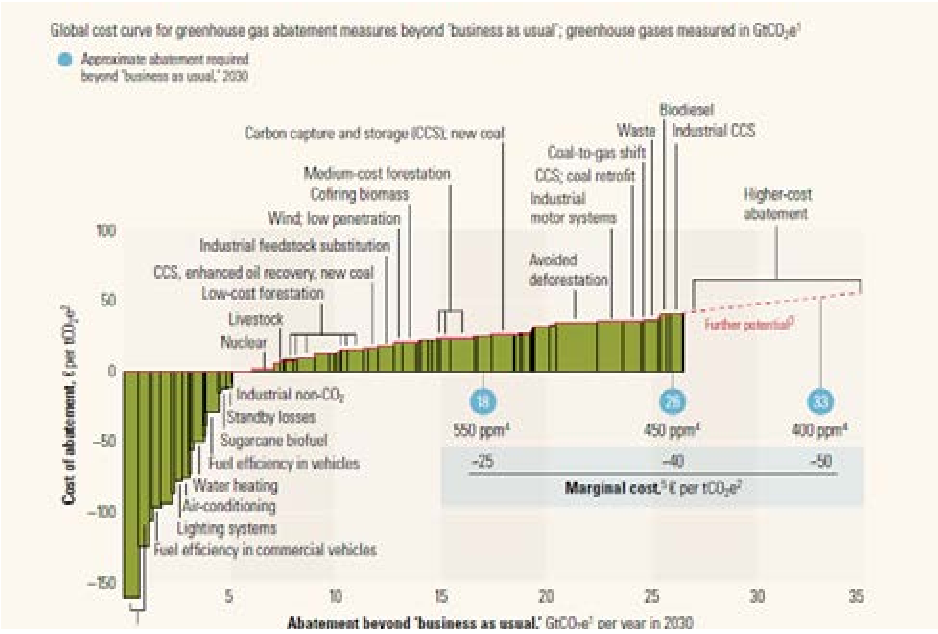

Fig. 1.
Marginal Abatement Cost Curve
Source: (Kesicki, Ekins, 2012)

Fig. 2. presents a simplified overview of five indicative vehicle drive train technology. In all of the bundles, the volume of abatement increases over time, as the uptake of the abating technology increases over time. Moving between bundles shows the difference in abatement achieved by different technologies, e.g. although 'Stop-start petrol' has lower emissions than 'Conventional petrol', it has higher emissions that an 'Electric & plug-in hybrid' vehicle (of the same size), so the difference in abatement in 2020 between using the 'Stop-start' rather than the 'Electric & plug-in hybrid' bundles is shown by the distance a to b (note that uptake of electric is not exactly the same in each year as uptake of stop-start, so it is a difference between the bundles, not the technologies). As it is a forecast the discount ratio plays an important role – see later.

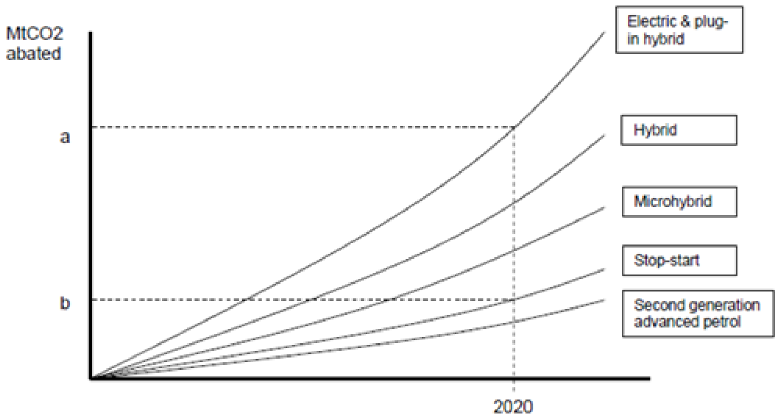

Fig. 2.
Stylised representation of technology bundle uptake and abatement
Source: (Shukla, 1995)

Fig. 2 is also useful in understanding how to interpret technology bundles in a MACC. A MACC which showed all technology bundles could be used as a ranking tool, as a method for selecting a technology bundle consistent with policy ambition, acceptable costs and emissions reductions targets.

3. Results –Sectoral Compare, Long Term Discount Rate

There are technological approaches that are decreasing the fuel consumption and/or environmental emission. These technological approaches have costs on individuals and on the society as well. As it was clearly described above author has investigated the marginal abatement cost curve of transport sector. There is a rational contradiction between transport and environmental protection. There are more affordable sectors where societies can gain cheaper results on environmental protection. Transportation cannot be replaced because it is a part of the production chain. There is well-known connection between economical development and transport performance, which need to be decoupled. Societies are horizontally and vertically differential. Manpower, stock and semi finished and finished products must be transported. Author has investigated the possible cost of greenhouse gas reduction in other sectors compared to transport.

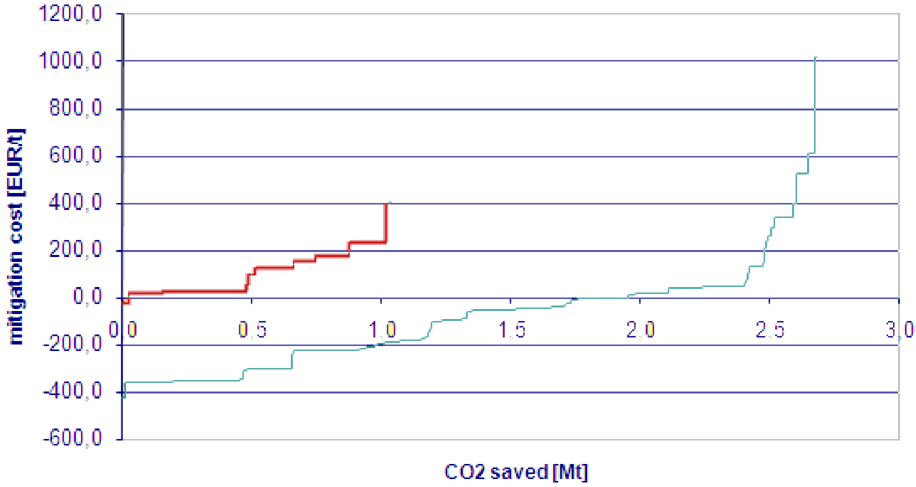

Fig. 3.
Difference in abatement cost curves in Transport sector (red) and Residual sector (blue)
Source: own calculation based on MAC curves for Hungary by Ecofys Netherlands BV, ERTI, Golder Associates, MAKK, SIU

Author has found the same economic results for industrial sector as well. As it was previously described not only sectoral cross-comparison is possible, but dynamic evolution of MAC curves (Fig. 4.):

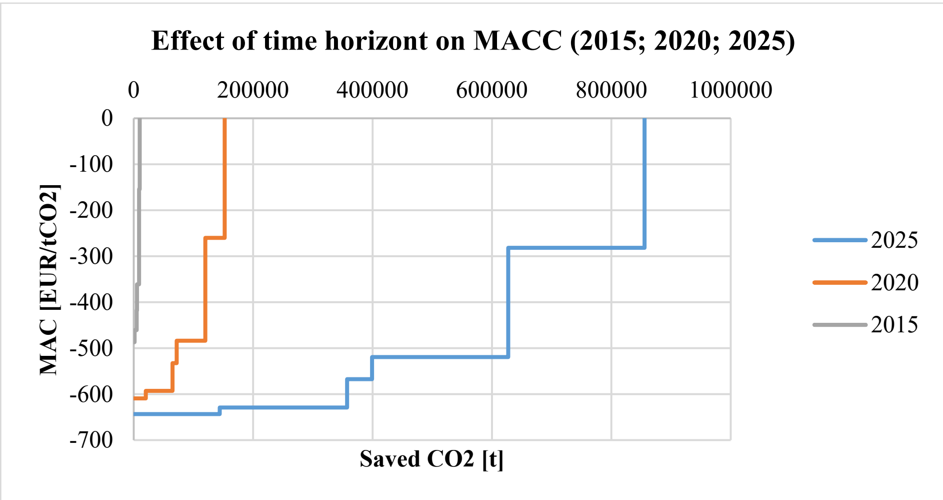

Fig. 4.
Difference in abatement cost curves in Transport sector (red) and Residual sector (blue)
Source: own calculation based on MAC curves for Hungary by Ecofys Netherlands BV, ERTI, Golder Associates, MAKK, SIU

As MACCs are basically based on forecast of abatement cost of technologies, the discount ratio of forecast plays a very important role. Author shows the effect of changes in discount rate (Fig. 5.):

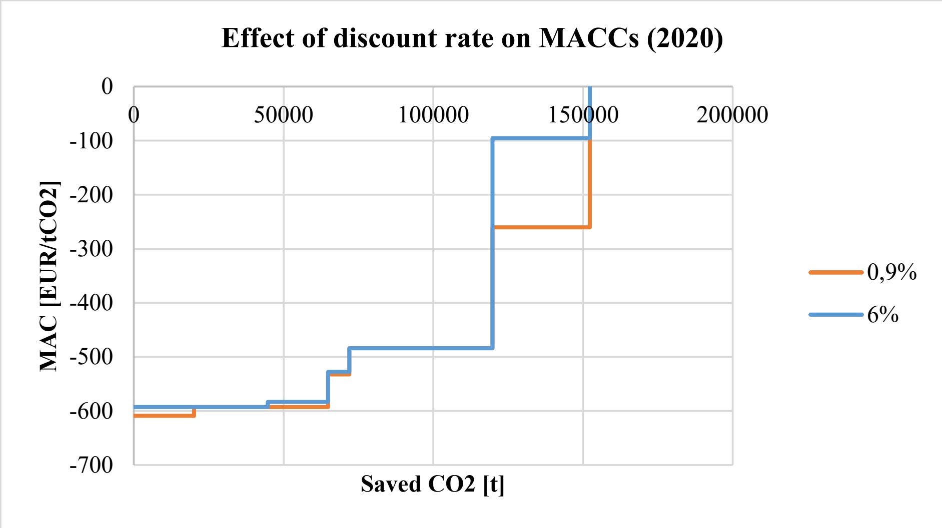

Fig. 5.
Difference in abatement cost curves in Transport sector (red) and Residual sector (blue)
Source: own calculation based on MAC curves for Hungary by Ecofys Netherlands BV, ERTI, Golder Associates, MAKK, SIU

5. Conclusion

There is a conventional notion that elasticities of substitution are always estimated on the basis of historical data. It is a critical parameter in top-down modelling and it provides a good approximation of prospective technology options. When elasticities are estimated from historical data, there is no guarantee that the parameter values will remain valid into the future under different abatement policies. Author showed the disadvantages of usage of MACC. With critical view the MACC is beneficial tool for decision makers. This tool is not only capable of following the market tendencies, but also capable for supporting the cross-sectoral analysis.

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ROAD INFRASTRUCTURE AND ITS IMPLICATIONS FOR REGIONAL ECONOMIC ACTIVITY AND PRODUCTIVITY IN THE CSEE COUNTRIES

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Abstract: Transport infrastructure investment affects various economic variables, including economic growth, economic development, productivity of production factors, employment, trade and many others. The focus of this research is on the implications of road infrastructure development for regional economic activity and productivity in the countries of Central and Southeastern Europe. The analysis is carried out at the level of NUTS-3 statistical regions of the following countries: Poland, Slovakia, Romania, Bulgaria, Croatia, Slovenia, Serbia, Macedonia and Albania. The regions are divided into two groups depending on the level of road infrastructure development. All regions with completed core road network along for the CSEE countries relevant TEN-T corridors, including the Baltic-Adriatic, the Orient-East Med, the North Sea-Baltic, the Mediterranean and the Rhine-Danube corridor, are considered to have developed road infrastructure. Total GVA, GVA per capita, employment rate and labor productivity of these regions are compared with appropriate values of other regions. Due to deviations from normal distribution of data, the non-parametric Mann-Whitney test is applied. Economic activity, measured by GVA, both total and per capita, as well as labor productivity are higher in the regions with developed road infrastructure. On the other hand, the same conclusion cannot be made in terms of employment. It means that road infrastructure development creates more significant impact on the productivity of labor than on the level of employment.

Keywords: Road infrastructure, investment, CSEE, NUTS-3, TEN-T corridors, GVA, productivity, employment.

1. Introduction

Transport infrastructure investment creates positive effects for various economic variables, including economic growth in real terms, economic development, regional development, productivity of labor and capital, level of employment, volume of foreign trade, value of assets, location of direct investments etc. The main focus of this research is on the implications of road infrastructure development for regional economic activity and productivity in the countries of Central and Southeastern Europe (CSEE).
The results of previous empirical researches, as well as some theoretical considerations on economic impact of transport infrastructure investment are analyzed in the next chapter. Special attention is paid to direct, indirect and second round impacts of transport investment, as well as to impact on level of employment.
Also, a brief review on EU TEN-T policy is made in the third chapter. Investment in the Baltic-Adriatic, the Orient-East Med, the North Sea-Baltic, the Mediterranean and the Rhine-Danube corridor and their estimated impact on GDP and employment, as well as road infrastructure investment in the countries from our CSEE sample are presented.
The applied methodology and the used data are explained and presented in the fourth chapter. Finally, research results and concluding remarks are made in the fifth chapter of the paper.

2. Economic Impact of Transport Infrastructure Investment

Miljković & Petrović Vujačić (2016) identified three channels of infrastructure investment impact on economic growth:
- operating costs channel,
- construction industry channel, and
- positive signals channel.

Transport infrastructure investment affects economic growth through the operating costs channel by lowering costs of individual firms, and thereby raising their competitiveness, which stimulates the production and contributes to economic growth, but also opens the door to greater savings and investments. Investment in transport infrastructure, also affects aggregate demand level by stimulating the construction and related industries. Moreover, investment in transport infrastructure provides positive signals to key sectors of the economy and create positive expectations which encourages private investors to invest more (Miljković & Petrović Vujačić, 2016).
Schade et al. (2015) defined two direct impacts of transport investment:
- transport effects, i.e. changes in travel time, modal split and transport costs, and
- economic effects, i.e. impacts on aggregate demand through investment.

All indirect impacts identified by Schade et al. (2015), including higher revenues, GVA and employment in transport and other sectors of the economy, end up increasing total factor productivity (Fig. 1.). Increased total factor productivity, and as a final result increased gross domestic product, further create second round impacts by new investments.

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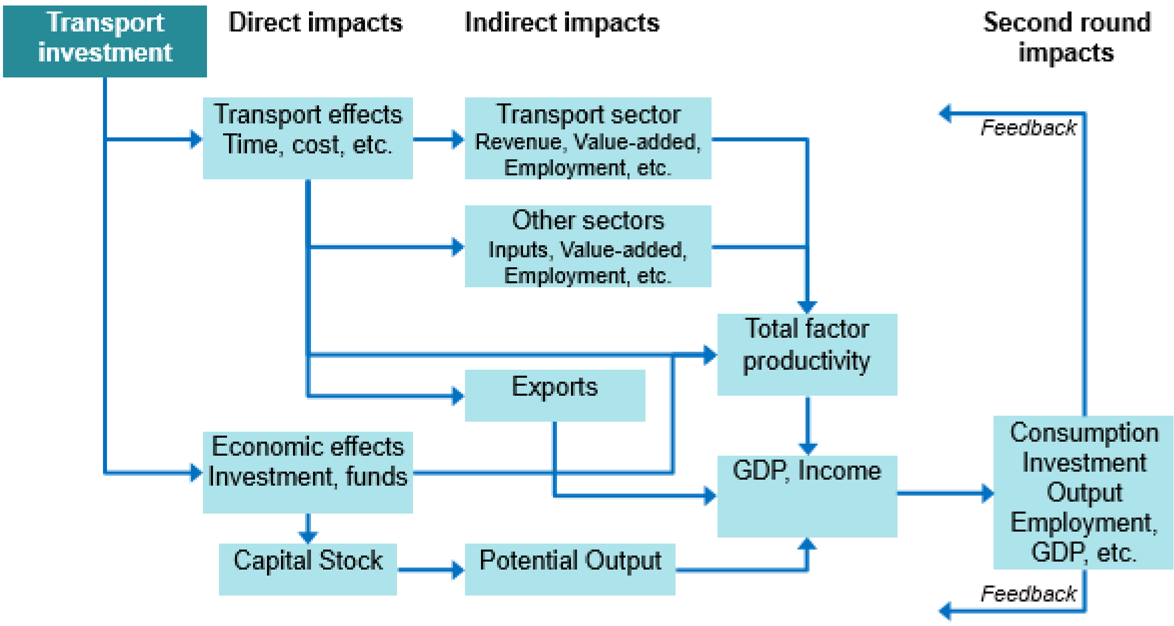


Fig. 1.
Direct, indirect and second round effects of transport investment
Source: Schade et al. (2015)

Schade et al. (2015) paid special attention to economic impact of TEN-T investment and they identified two impact chains generating the economic impact together leading to the economic multiplier that is then composed out of the following:

- impact of the investment, i.e. the money spent, and
- impact of the productivity changes within the transport system and in other transport using sectors (Fig. 2.).

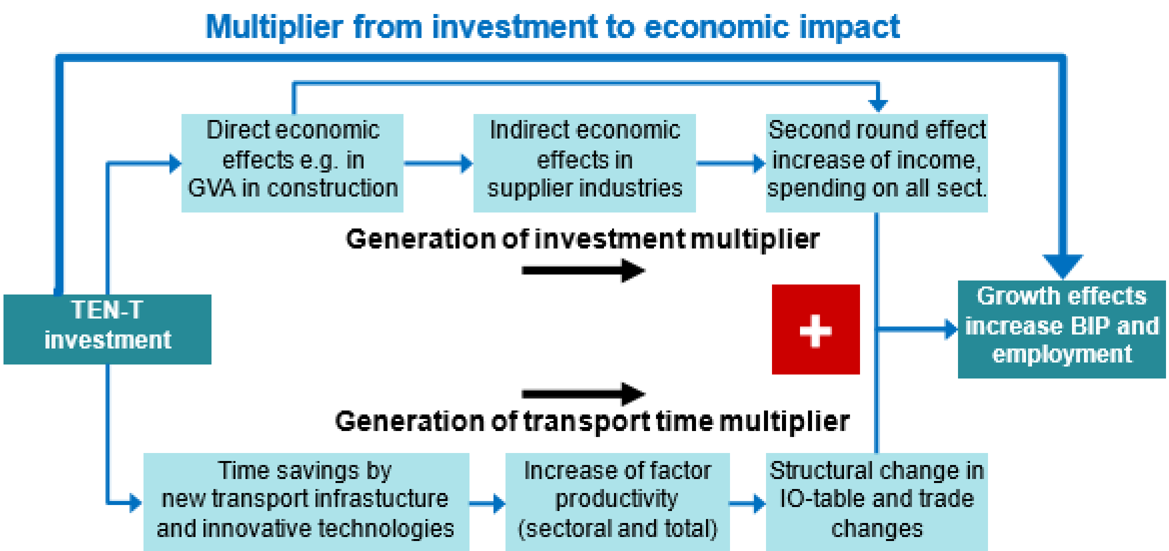


Fig. 2.
Multiplier from TEN-T investment to economic impact
Source: Schade et al. (2015)

The study of NRA (2013) was focused on researching impact of transport infrastructure projects on employment. There are three distinct employment effects that are identified:

- direct effect, i.e. the employment generated specifically as part of the project,
- indirect effect, i.e. the employment generated by the intermediate products and services used in the construction of the project, and
- induced effect, i.e. the employment generated in the economy as a whole as a result of the increases in employment (from the direct and indirect effects).

Transport infrastructure projects create on average 24,223 job-years for one billion euro invested, which is higher than energy and health infrastructure projects, and almost equally as energy infrastructure projects. Only telecommunication projects create considerably higher number of job-years for one billion euro invested (NRA, 2013). In the next figure, employment effects of transport infrastructure projects by transport mode are presented.

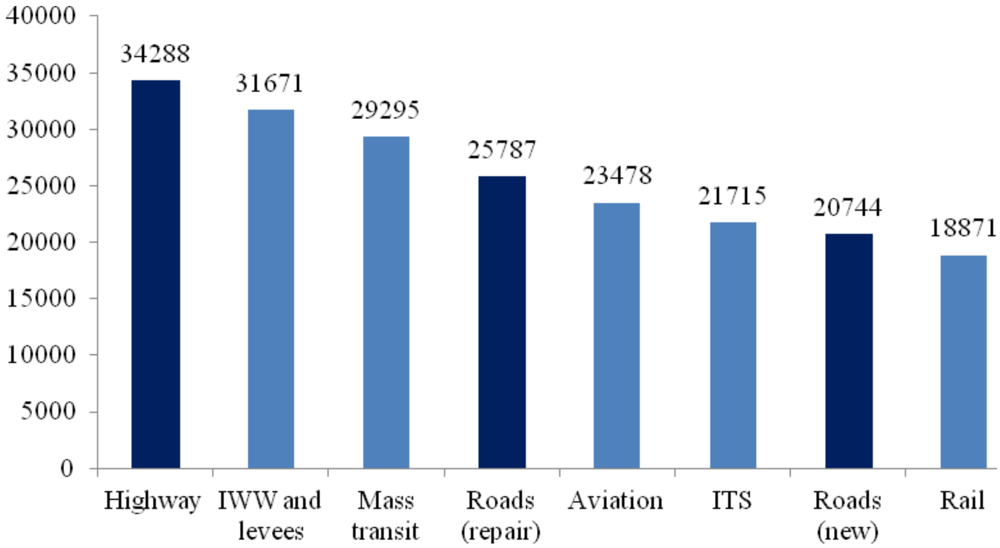


Fig. 3.
Employment effects of transport infrastructure projects, in number of job-years for one billion euro invested
Source: NRA (2013)

3. Road Infrastructure Investment in the CSEE Countries

During the period 2010-2016, the average yearly investment in road infrastructure projects amounted to from 124 million euro in Slovenia till 4093 million euro in Poland. Share of total transport infrastructure investment in GDP was at the level of around one to two percent (Fig. 4.).

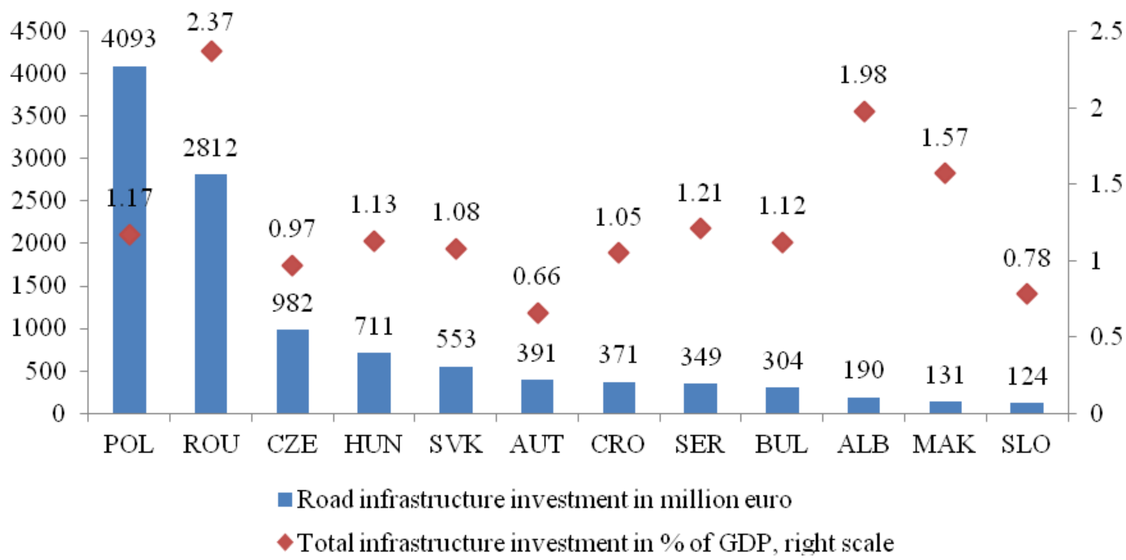
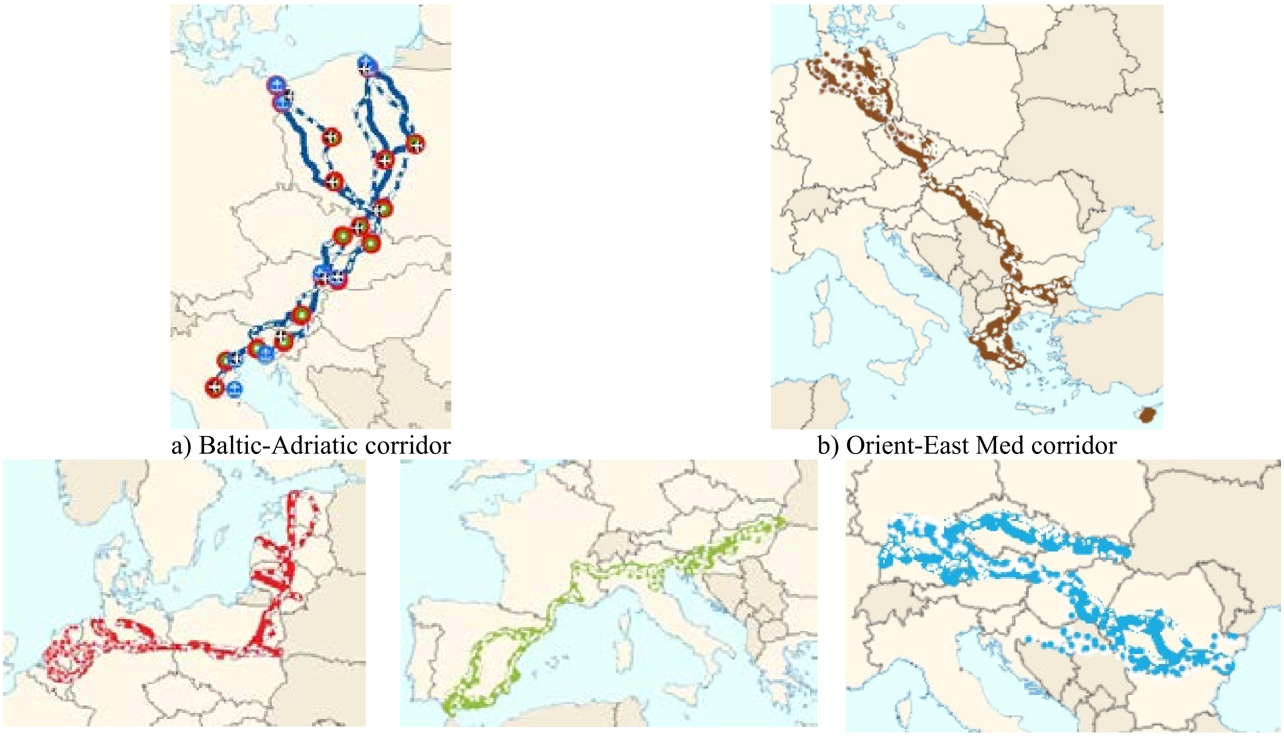


Fig. 4.
Transport infrastructure investment in the CSEE countries, yearly average for the period 2010-2016
Source: OECD (2018)

One of the focuses of the EU transport policy is related to development of the Trans-European Transport Networks (TEN-T). The relevant TEN-T road corridors for the CSEE countries include the Baltic-Adriatic, the Orient-East Med, the North Sea-Baltic, the Mediterranean and the Rhine-Danube corridor (Fig. 5). The Baltic-Adriatic, the Orient-East Med and the Rhine-Danube corridors pass through three countries from the sample of this research, while the Mediterranean corridor crosses the territories of two countries from the sample and the North Sea-Baltic corridor passes through only one country of the sample (see more information about the sample in chapter 4).



a) Baltic-Adriatic corridor b) Orient-East Med corridor

c) North Sea-Baltic corridor d) Mediterranean corridor e) Rhine-Danube corridor

Fig. 5.
Maps of the TEN-T corridors relevant for the CSEE countries
Source: DG Mobility and Transport (2018)

Bodewig (2018), Brinkhorst (2018), Trautmann (2018) and Grosch (2018) estimated in their work plans for the above mentioned TEN-T corridors the effects on GDP and employment for the period 2015-2030 (Fig. 6). Their estimations are based on the calculation of Shade et al. (2015) who determined that one billion TEN-T investment could produce 4.35 billion GDP and 16,300 job-years.

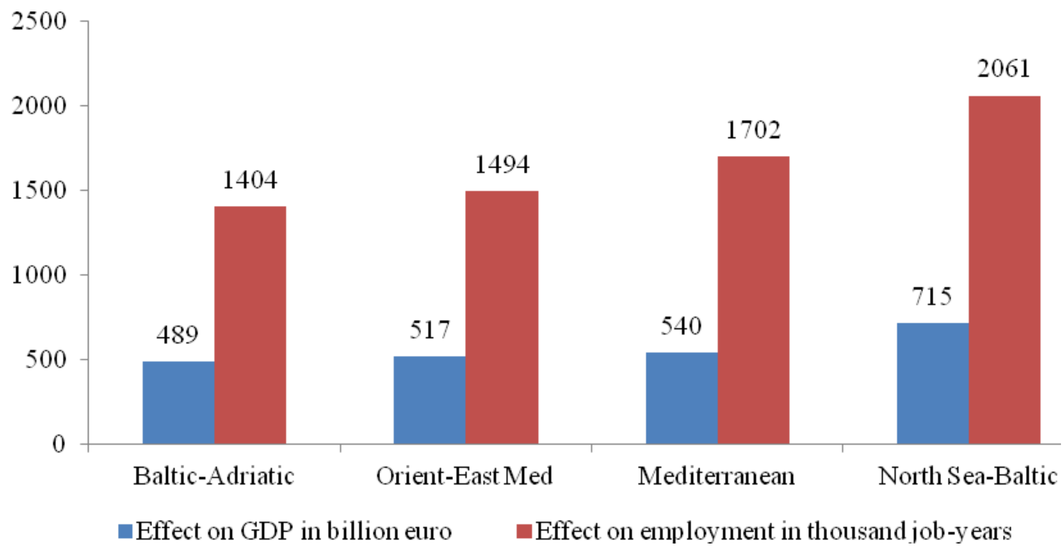


Fig. 6.
Estimated effects of TEN-T investment on GDP and employment for the period 2015-2030 by corridors relevant for the CSEE countries
Source: Bodewig (2018), Brinkhorst (2018), Trautmann (2018), Grosch (2018)

Beside impact on GDP and employment, Shade et al. (2015) also concluded that TEN-T investment could positively affect innovation deployment, by enabling multimodality and efficient freight logistics, boosting intelligent transport systems, as well as new technologies and innovation. There is also significant environmental impact in terms of impact on decarbonization and resilience to climate changes, as well as impact on safety improvements and application of innovative financial instruments.

4. Research Methodology and Data

In accordance with previous empirical researches, as well as theoretical considerations, the following hypotheses are made:

1) Regions with completed core road TEN-T corridors achieve higher total GVA as compared with regions without core road network.
2) Regions with completed core road TEN-T corridors achieve higher GVA per capita as compared with regions without core road network.
3) Regions with completed core road TEN-T corridors achieve higher employment rate as compared with regions without core road network.
4) Regions with completed core road TEN-T corridors achieve higher labor productivity as compared with regions without core road network.

The sample is consisted of the NUTS-3 statistical regions of the following CSEE countries: Poland, Slovakia, Romania, Bulgaria, Croatia, Slovenia, Serbia, Macedonia and Albania. The regions of these countries are divided into two groups:

- the regions with completed core road TEN-T corridors, and
- the regions without completed core road TEN-T corridors.

For EU member countries, the relevant TEN-T corridors include the Baltic-Adriatic, the Orient-East Med, the North Sea-Baltic, the Mediterranean and the Rhine-Danube corridor, while for the non-EU countries the relevant routes include those which are planned to be connected with the above mentioned corridors in the future. The classification of regions is done by using TEN-T interactive map viewer. Distribution of regions by countries and groups is presented in Table 1.

Table 1
Number of regions in the sample by countries

Country	Regions with completed core road network	Regions without core road network
Bulgaria	18	10
Croatia	12	9
Poland	48	24
Romania	26	16
Slovenia	8	4
Slovakia	4	4
Serbia	11	14
Macedonia	4	4
Albania	7	5
TOTAL	138	90

Source: Authors ' calculations

Data on total GVA, population and number of employees are collected from the relevant databases of Eurostat and Statistical office of the republic of Serbia. Total GVA is expressed in current euro million. GVA per capita is expressed in euro thousand. Employment rate is estimated as ratio of employees to total population. Productivity of labor is calculated as GVA per employee and expressed in euro thousand. All data are collected for the year 2014. Descriptive statistics is presented in the Table 2.

Table 2
Descriptive statistics of the variables

<table>
<tr><th>Variable</th><th>Region</th><th>Observations</th><th>Mean</th><th>Standard deviation</th><th>Minimum</th><th>Maximum</th></tr>
<tr><td rowspan="3">Total GVA</td><td>With completed core road network</td><td>138</td><td>3874.54</td><td>5518.54</td><td>169.46</td><td>47983.89</td></tr>
<tr><td>Without core road network</td><td>90</td><td>2011.54</td><td>2070.17</td><td>196.76</td><td>12074.02</td></tr>
<tr><td>All regions</td><td>228</td><td>3139.14</td><td>4570.89</td><td>169.46</td><td>47983.89</td></tr>
<tr><td rowspan="2">GVA per capita</td><td>With completed core road network</td><td>138</td><td>7.34</td><td>4.71</td><td>1.66</td><td>30.75</td></tr>
<tr><td>Without core road</td><td>79</td><td>5.62</td><td>2.95</td><td>2.04</td><td>15.13</td></tr>
</table>

Variable	Region	Observations	Mean	Standard deviation	Minimum	Maximum
	network					
	All regions	217	6.71	4.23	1.66	30.75
Employment rate	With completed core road network	131	0.3824	0.1052	0.1695	0.7268
	Without core road network	74	0.3630	0.0995	0.1696	0.5978
	All regions	205	0.3754	0.1033	0.1695	0.7268
Labor productivity	With completed core road network	131	19.46	8.51	6.65	44.81
	Without core road network	74	16.69	7.38	5.57	35.69
	All regions	205	18.46	8.21	5.57	44.81

Source: Authors' calculations based on Eurostat (2018) and Statistical Office of the Republic of Serbia (2018)

If we compare the means, we can see that all variables (total GVA, GVA per capita, employment rate, labor productivity) have higher values in regions with completed core road network. The next step is to test these differences and to research if we can conclude the same for the whole population.
Therefore, we carried out the following normality tests: skewness/kurtosis normality test, Shapiro-Wilk normality test and Shapiro-Francia normality test. P-values of these tests are presented in the Table 3.

Table 3
Results of normality tests

Variable	Region	Skewness/kurtosis test p-value	Shapiro-Wilk test p-value	Shapiro-Francia test p-value
Total GVA	With completed core road network	0.0000	0.0000	0.0000
	Without core road network	0.0000	0.0000	0.0000
	All regions	0.0000	0.0000	0.0000
GVA per capita	With completed core road network	0.0000	0.0000	0.0000
	Without core road network	0.0002	0.0000	0.0000
	All regions	0.0000	0.0000	0.0000
Employment rate	With completed core road network	0.0362	0.0200	0.0216
	Without core road network	0.3353	0.1214	0.1898
	All regions	0.1448	0.0096	0.0131
Labor productivity	With completed core road network	0.0760	0.0014	0.0039
	Without core road network	0.1223	0.0133	0.0283
	All regions	0.0143	0.0000	0.0001

Source: Authors' calculations

Considering the results of the normality tests, which mostly reject null hypotheses on normal distribution of data, the non-parametric Mann-Whitney test is applied for testing all hypotheses, rather than t-test on mean differences.

5. Research Results and Concluding Remarks

The results of the Mann-Whitney test are presented in the Table 4. We can conclude at the significance level of 1% that regions with developed core road infrastructure achieve higher total GVA and GVA per capita than regions without the core road infrastructure. The same can be concluded for labor productivity, but at the significance level of 3%. These conclusions are in line with results of previous empirical researches, as well as with theoretical considerations presented in the chapter 2 of this paper.

Table 4
Results of the Mann-Whitney test

Hypotheses	Mann-Whitney test statistics	P-value	Conclusion
H_0: $GVA_{road} = GVA_{non\text{-}road}$ against H_1: $GVA_{road} \neq GVA_{non\text{-}road}$	-3.666	0.0002	Null hypothesis can be rejected at the significance level of 1%.
H_0: $GVApc_{road} = GVApc_{non\text{-}road}$ against H_1: $GVApc_{road} \neq GVApc_{non\text{-}road}$	-2.789	0.0053	Null hypothesis can be rejected at the significance level of 1%.
H_0: $EMPL_{road} = EMPL_{non\text{-}road}$ against H_1: $EMPL_{road} \neq EMPL_{non\text{-}road}$	-0.892	0.3722	Null hypothesis cannot be rejected.
H_0: $PROD_{road} = PROD_{non\text{-}road}$ against H_1: $PROD_{road} \neq PROD_{non\text{-}road}$	-2.172	0.0299	Null hypothesis can be rejected at the significance level of 3%.

Source: Authors' calculations

On the other hand, it was not confirmed that regions with completed core road network achieve higher employment rates, what was one of the most important benefits of infrastructure development estimated by Schade et al. (2015). Moreover, we can conclude that investment in core TEN-T corridors rather stimulate productivity than only employment level.

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SMART TRAVEL APP ENABLED TAXIS: IS IT A BOON OR BANE FOR SUSTAINABLE ROAD TRANSPORTATION IN INDIAN CITIES?

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Abstract: Innovation and emerging technology are influencing the road transportation system in urban areas across the world. 'Smart Mobile Travel Apps' enabled taxis are observed to significantly influence the accessibility and mobility, particularly in cities. For example, while they are offering new opportunities in the urban local accessibility system, they are also bringing in certain mobility and functional challenges. Therefore, using the case studies of two Indian cities such as Delhi and Kolkata, this study examined how these taxis (1) influence the accessibility in terms local travel behaviour and impacts on other modes of transportation, and (2) impact traffic movement on the roads in terms of congestion, queue length and delay. For this purpose, an explorative survey research method was used. Findings suggest that 'Smart Mobile Travel Apps' enabled taxis have provided opportunities for higher local accessibility for travelling short distances in the cities. However, it has also created challenges for public transportation systems such as bus transportation system as a significant segment of people prefer these taxis to other modes of transportation. Also, in the absence of proper traffic regulations, control measures and road infrastructure such as pick up and drop off points, road side parking spaces and sleep ways, they become obstacles for effective mobility and cause significant queue lengths, congestions and travel delay.

Keywords: cities, mobility, road infrastructure, smart mobile travel apps, traffic.

1. Introduction

The emergence of smart mobile App enabled vehicles on the roads and the business operation of vehicles provided both opportunities and challenges to the road transportation system in the cities. Incidentally, 'Smart Mobile Travel Apps' enabled taxis are observed to significantly influence the accessibility and mobility, particularly in cities. For example, while they are offering new opportunities in the urban local accessibility system, they are also bringing in certain mobility and functional challenges. These vehicles work on the principles of picking up and dropping off the riders on demand basis or allowing ride sharing following similar business operations (McKinsey & Co., 2015). Technologies such as GPS navigational device, smartphones and social networks, enable this process, in which an optimization algorithm takes the ride request from a smartphone call, uses GPS device to determine the location of the request and instantly provides route to the nearest available driver or vehicle pick up station for the real-time matching of drivers and riders (Bajpai, 2016; Das and Ngobeni, 2017; Rayle, Shaheen, Chan, Dai, & Cervero, 2014).Consequently, the riders get on demand access to hire or share cars, scooters, bikes and even auto-rickshaws in some countries. In this system, the social network software complements this coordination and develops trust and accountability between drivers and riders (Al-Ayyash, Abou-Zeid, Isam, 2016; Bajpai, 2016). Furthermore, it is also observed that the smart app-based real time ride sharing and taxi services (provided by service providers such as UBER, OLA, Meru and many others), have experienced unprecedented expansion to provide a variety of mobility need (Al-Ayyash, Abou-Zeid, Isam, 2016; Bajpai, 2016, Das and Ngobeni, 2017).

It is evidenced that these mobile apps enabled vehicles have brought in a number of benefits. Evidences from Canada and USA on demand car sharing programme suggest that each car sharing vehicle had replaced 9 to 13 vehicles among their members (Martin, Shaheen, & Lidicker, 2010; Shaheen & Chan, 2015). This has brought an argument that service of these car sharing will enable reduction in number of personal vehicles and help in reducing GHG emissions (Bajpai, 2016; Zhan, Qian, Ukkusuri, 2015; Zhang, Ukkusuri, Lu, 2016.) because of lesser number of vehicles on the roads. Further, they offer advantages to the riders with short wait time, flexibility in using them at any time, location, lower cost and free from hassles of parking (Shoup, 2005). Further, these vehicles could able to reduce vehicle travel distance and gas miles that are often spent to search parking spaces in large metropolitan areas (Transportation Alternatives, 2008; Zhang, Ukkusuri, Lu, 2016).

However, despite the benefits documented and opportunities to reinforce sustainable road transportation, certain challenges are also experienced because of plying of these vehicles and the nature of their operations. The challenges of these smart app enabled vehicle services and their operation include but not limited to the impact on the road infrastructure such as demand for separate lanes, specific parking facilities, pick and drop off operations in busy streets. Further, these taxis have impacted the business of the traditional taxi services and behaviour of urban travellers, which consequently have influence the overall sustainability of road transportation system in cities. Literature suggests that these aspects have not been explicitly explored particularly in the cities of a developing country such as India. Therefore, using the case studies of two Indian cities such as Delhi and Kolkata, this study examined how these 'Smart Mobile Travel Apps' enabled taxis (1) influence the accessibility in terms local travel behaviour and impacts on other modes of transportation, and (2) impact traffic scenario on the roads in terms of congestion, queue length and delay. An explorative survey research method was for the purpose conducting the study. Findings suggests that although, the Smart Mobile App enabled taxis have offered certain benefits such as their availability on demand on any location at any time, ride sharing and less expensive than the normal taxis at certain point of the day such as during off peak hours

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and availability of type and number of such taxis, they have brought in certain challenges in terms of reduction of peoples' preference to use of public transportation system in terms buses, and adding to the congestion and delay when they stop on the roads and unauthorised areas on road sides to pick up and drop off riders leading to holding up vehicles behind them.

2. Case Study Area

Two mega cities of India such as Delhi and Kolkata were used as case study cities for this study. Data were collected from the busy roads of the important areas of these cities. Delhi metropolitan area is located in the Northern part of the country. It includes the national capital New Delhi as well as encompasses the Provincial capital of the Delhi State. It has a population of about 26 million and area of 1484 square kilometres (Sq. Km.) having a population density of more than 17000 persons /Sq. Km. The city also encompasses large scale commercial and industrial activities in addition to the governance and administrative functions. Besides, it is at the centre of an urban agglomeration of 4 or more large industrial cities around it. A floating population of 1.0 million travel to the city every day. As a result, there is a large demand for both intercity and intra-city local transportation facilities. The city offers a variety of public transportation services that include metro rail, public bus system, taxis, Auto rickshaws, etc. Additionally, in the recent years, Smart Mobile Travel App enabled taxis operated by companies such as UBER and OLA are also available to the people.
Kolkata is a metropolitan city located in the Eastern part of India. It is the Provincial capital of West Bengal State of India and has a population of about 15 million. Besides, about a million people transit to the city every day for various purposes. The area of the city is about 1886.7 sq. km and has a population density of 7483 persons/sq. km. It acts as the major commercial hub for the Eastern region of the country. The city has a demand for a large scale intra-city movement for the millions of people for different purposes. A local transportation system in the form of Metro rail, local rail system connecting regional cities, public transportation system using buses and local taxis, three wheeler auto-rickshaws and human driven tricycles is operational in the city. Furthermore, e- auto rickshaws (battery driven tricycles) by individual service providers and Smart Mobile Travel App enabled local taxis operated by UBER and OLA have become integral parts of the local transportation system.
Both the cities have largescale intra-city movements for different activities of the local population as well as for the floating population. It is also seen that operation of Smart Mobile Travel App enabled taxi services have also been significantly established. However, the operation of these taxis while offering certain travel services, their operational behaviour on the roads are creating certain road transportation related challenges in both the cities. So, the study was conducted by considering these two cities.

3. Methods

An exploratory research method constituting both quantitative and qualitative methods was used. Data were collected through road traffic survey and stakeholders survey. Also, expert discussion was conducted by following non-structured interview process. A survey was conducted among various stakeholders in important areas of the two cities. Table 1 presents the profile of respondents of the survey. A total of 127 people were surveyed which includes 60 from Delhi and 67 from Kolkata. The respondents constitute 17.3% Smart Mobile Travel App enabled taxi drivers, 12.6% normal taxi drivers and 70.1% taxi users (26% tourists and 44.1% local taxi users). The roads passing through four major urban activity areas in Kolkata where survey was conducted are International Airport, Esplanade (commercial centre), South city area and City Centre 1. Similarly, arterial roads in the Chandnichowk, Paharganj. Karol bag and Connaught place areas of Delhi were chosen for the survey purpose. These areas were chosen because Smart Mobile Travel App enabled taxis are observed to be predominantly operating in and around these areas. The survey was conducted by using a random sampling process and semi-structured interview mothed. The survey focused on the variables such as the challenges caused by these taxis, faced by travellers, and the impact of these taxis on the road infrastructure and traffic movement. A five point Likert scale ranging from 1 to 5 (with 1 indicating posing no challenge, 2- posing somewhat challenge, 3- posing fair amount of challenge, 4- indicating serious challenge and 5 -indicating severe challenge) was used to get the perceptions of the challenges created by the Smart Mobile Travel App enabled taxis on the road infrastructure and traffic movement (Carifio, and Perla, 2008; Gross, 2018; Li, 2013; Peeters, 2015). Since, this method is observed to be useful to obtain and evaluate the perceptions of people on various variables with regards to challenges related to different fields that includes but not limited to psychology, marketing and sales management, urban development, health services, etc., (Moshin, Beach, and Kwan, 2017; Pakzad, Osmond, and Corkery, 2017; Shan and Yu, 2014; Jamieson, 2004), it is found to be relevant to this study and therefore used. Also, open ended questions about the above variables were also asked to get in depth perception of the respondents. Further, road traffic survey on eight important roads in the selected areas was conducted both in the peak hours and relatively off peak hours of the day to take cognizance of the traffic scenario such as operational behaviour of the se taxis, queue length created because of the manoeuvrability and stoppage of these taxis on the roads, congestion and delay. The traffic survey includes volume, queue length survey and delay. Besides, discussions were also conducted with urban development experts, urban planners, transportation planners and engineers, and smart technology experts.
The data was analysed both by using quantitative statistical methods and qualitative narrative analysis. Appropriate statistical analysis such as tabulation, percentage analysis descriptive statistics and evaluation of mean score on the Likert scale were used to arrive at the results. Also, the responses from the interviews were analysed by using manual

qualitative method of analysis to draw inferences. Further, the congestion level was analysed by using Level of Service (LOS) method. The LOS is calculated by using the volume to capacity ratio. The average hourly volume of vehicles on the roads were calculated by converting all the vehicles to Passenger Car Units (PCU) and the capacity of the roads was estimated by using the saturated flow rate proposed by (TRB, 1994, Appendix B-Traffic Level of Service Calculation Methods, B 6-7; and on the assumption that major roads would receive 60% of the green time and roads perpendicular to the major roads would receive 40% of the green time. The queue length and travel holding time of vehicles or delay was computed directly from the field observations or measurements.

Table 1.
Respondents Profile

Types of Respondents	**Kolkata**		**Delhi**		**Total**	
	Number	**%**	**Number**	**%**	**Number**	**%**
App enabled Taxi drivers	12	17.9	10	16.7	22	17.3
Traditional taxi drivers	8	11.9	8	13.3	16	12.6
Tourists taxi users	14	(20.9)	19	(31.7)	33	(26.0)
Local people taxi users	33	(49.3)	23	(39.3)	56	(44.1)
Total Taxi users	47	70.2	42	70.0	89	70.1
Total	67	100.0	60	100.0	127	100.0

(Source: Field Survey, 2017)

4. Results and Discussions

4.1 Influence the Accessibility in Terms Local Travel Behaviour and Impacts on Other Modes of Transportation

Both the Cities- Delhi and Kolkata offer public transportation system in terms of Metro railway, and public bus transportation system services and have taxi and auto rickshaw services. Besides, a large segment of the population uses individually driven cars and motorbikes for their local movement needs. However, the availability of the Smart Mobile Travel App enabled taxis offer an additional dimension to the local accessibility services. Table 2 presents the change in the preferences of people with regards to their mode choices for local accessibility. It is found that preferences of people towards mode choices in the wake of the availability of the Smart Mobile Travel App taxis have been changed. The survey results suggest that more than 20% of the people surveyed prefer Smart Mobile Travel App taxis to other modes of travel. Although, the use of private vehicles and use of Metro rail have marginally impacted (showing a reduction by 1.7% and 3.2% respectively), the public buses and conventional taxis and auto rickshaws have been severely impacted. The choice of people to use the buses and private taxis and auto rickshaws show a reduction of 12.6% and 5.3% respectively. This indicates that there is a clear change in the choice of modes and preference towards the use of Smart Mobile Travel App taxis, particularly at the expense of public buses and conventional taxis and auto rickshaws. The discussion with the stakeholders indicates that this happens because of the availability of the such taxis on demand at any location at any time, and less expensive at certain point of time and for the hassle free services[2]. Further, experts and travellers opine that, during the peak hours' people prefer such taxis to travel short distances, as the buses travel at a very slow speed because of high congestion and absence of dedicated bus lanes[3]. Accordingly, it is found that the floating population to the cities, occasional travellers, those who travel short distances, people using smart phones and having internet connectivity, and those who travel to important nodal points such as airports, railway stations, government offices, shopping centres, etc., prefer such taxis[4]. However regular and long distance travellers still prefer Metro rail, buses and private cars[5].

Table 2
Mode choices before and after the availability of smart app enabled taxis

Mode	**Preference of people previously**		**Current preferences**	
	Number	**%**	**Number**	**%**
Bus	37	29.1	21	16.5
Metro Rail	43	33.9	39	30.1
Private vehicles	49	35.6	43	33.9
Conventional taxis and auto rickshaws	29	22.8	22	17.3

[2] Road users, tourists and transportation planning experts
[3] Urban development experts, Smart Travel Mobile App enabled taxi drivers and travellers
[4] Tourists, smart phone users, short distance travellers and urban planning and transportation planning experts
[5] Regular travellers

Smart travel app enabled taxis	-	-	26	20.4
N	127			

(Source: Field Survey, 2017)

4.2 Impact on the Traffic Scenario on the Roads in Terms of Congestion, Queue Length and Delay

4.2.1 Perception of the Stakeholders on the Challenges Caused by the Smart Mobile Travel App Enabled Taxis

Table 3 presents the perception of the respondents on the challenges that are caused by the Smart Mobile Travel App enabled taxis with regards to road infrastructure and traffic movement on the roads of Delhi and Kolkata. The analyses were carried out on aggregate basis as no stark difference between the two cities were observed. Further, the low Standard Deviation (SD) values on the responses on various indicators indicate consistency in the responses, so they are accepted for interpretation. According to the perception index based on the mean Likert scale score (LI), unauthorized parking on the road sides (LI=4.17), pick up and drop off of the customers (by encroaching the lanes and stopping on them) (LI=4.01) and causing congestion (LI=3.86) on the roads are the three serious challenges that are caused by the Smart Mobile Travel App enabled taxis. These findings were corroborated by the experts and other stakeholders- because of the nature of the operation of these taxis, they have to stop and park the vehicles on unauthorised areas on the roads and at times on the roads itself[6]. Since there are no regulations or control measures available as well as no such road infrastructure such as specific pick up and drop off areas, and both off road and on road parking areas while they are in the idle condition are available for these vehicles, these challenges of encroachment of the roads, holding up of vehicles and congestion occur. Further, these taxis pose fair challenges with regards to crossing of lanes (LI=3.44), and risk of the travellers to reach the taxis by crossing the road (LI=3.12). Abrupt crossing of lanes by these taxis often observed as the drivers look to pick up a rider from the road sides, which created risks to the other vehicles on the roads[7]. However, occurrence of traffic accidents (LI=2.95), and obstruction of pedestrian movement (LI=2.64) by these taxis also occur to certain extent. Therefore, it is found that operation of these taxis and their manoeuvrability on the roads cause fair to serious road and traffic related challenges.

On the other hand, operation of these taxis fairly cause several social and traveller related challenges such as they are not affordable during peak hours. Additionally, reliability and availability of internet to find locations, waiting time, and availability only in certain locations are concerns, which are corroborated by the experts[8]. Similarly, refusal and cancellation, and sharing the taxi with strangers also are other challenges to certain extent.

Table 3

Perception of the stakeholders on the challenges caused by the smart travel app enabled taxis

Challenges	Perception index (Mean Likert scale score)	Standard deviation	Rank
Unauthorized parking on the road sides	4.17	0.34	1
Cause congestion	3.86	0.26	3
Boarding and dropping off on the busy roads (encroachment of the lanes)	4.01	0.29	2
Crossing the lanes	3.44	0.23	5
Obstruct Pedestrian movement	2.64	0.27	13
Risk of the traveller to reach the taxi by crossing the road	3.12	0.31	8
Traffic accidents	2.95	0.27	10
Sharing the taxi with strangers	2.75	0.24	12
Availability in certain locations	3.05	0.22	9
Reliability of the internet and finding the location	3.23	0.27	6
Waiting time	3.14	0.34	7
Refusal and cancellations	2.88	0.32	11
Affordability in peak hours	3.76	0.22	4

(Source: Field Survey, 2017)

(Note: 1- posing no challenge, 2- posing somewhat challenge, 3- posing fair amount of challenge, 4- indicating serious challenge and 5 -indicating severe challenge)

[6] Urban planning and transportation planning experts and travellers

[7] Travellers

[8] Urban planning and Information Technology experts

4.2.2. Impact on Traffic Movement

The impact of the Smart Mobile Travel App enabled taxis on the traffic movement was analysed based on traffic congestion, queue length (number of vehicles on the roads stopped behind the Smart Mobile Travel App taxis if it stopped on the road) and delay (holding time of the vehicles behind these taxis when stopped on the roads). It is found that the selected major arterial roads on which survey was conducted both in Delhi and Kolkata during peak hours' experience LOS of "F". This indicates that all the major roads are severely congested with high delay. On the other hand, some of the roads during the off peak hours in Delhi and most of the roads in Kolkata have a lower LOS (ranging between B and E), indicating lesser congestion with certain amount of manoeuvrability of the vehicles (Table 4). However, it could not be ascertained that whether the operation of the Smart Mobile Travel App enabled taxis on the roads impact the LOS and congestion since the significance of these taxis on the total volume of vehicles on the roads could not be ascertained. Therefore, the role of these taxis on the level of direct congestion with regards to volume of vehicles is not conclusively established.

However, in the absence of specific lanes, pick up and drop off points, and parking areas on the road sides for these taxis, and owing to the lack of adequate control and regulatory measures apparently they stop on the busy roads or park on unauthorized areas on the road sides to pick up and drop off travellers. Consequently, it is found that the number of vehicles queue up behind the stopped taxi range of minimum of 3 to 6 vehicles and maximum of 6 to 23 vehicles on different roads in Delhi and minimum range of 2 to 3 vehicles and maximum range of 6 to 9 vehicles on different roads in Kolkata. Similarly, the holding time of these vehicles behind taxis is observed to range between minimum of 0.5 to 2 minutes and maximum of 2 to 7 minutes in Delhi and minimum range of 0.5 to 2 minutes and maximum range of 1 and 5 minutes in Kolkata. In other words, it is found that the stoppage of these taxis on the roads hold from a minimum of 3 vehicles to a maximum of 23 vehicles in Delhi and minimum of 2 vehicles to maximum of 9 vehicles in Kolkata. Similarly, the holding time ranges from 0.5 minutes to 7 minutes in Delhi and 0.5 minutes to 5 minutes in Kolkata (Table 4). These holding up the number of vehicles and time contribute to the congestion and delay on the roads of these cities.

Table 4
Impact of smart travel app enabled taxis on the traffic movement

Roads in the Area	Peak hour		Off peak hour		Queue length (Number of cars behind the taxi if stopped on the road)	Holding time of other vehicles stopping on the road
	Volume by capacity ratio	Level of service (LOS)	Volume by capacity ratio	Level of service (LOS)	Range in number of vehicles	Range in minutes
Delhi						
Chandnichowk	1.75	F	0.93	E	6-23	2-7
Paharganj	1.67	F	1.03	F	4-17	2-5
Karol bag	1.43	F	0.83	D	3-9	0.5-2
Connaught place	1.27	F	0.72	C	3-9	0.5-3
Kolkata						
International Airport	1.12	F	0.63	B	3-7	0.5-3
Esplanade (commercial center)	1.46	F	0.82	D	3-9	1-5
South city area	1.23	F	0.73	C	2-7	0.5-2
City Center 1 of Kolkata	1.14	F	0.76	C	2-6	0.5-3

(Source: Field Survey, 2017)
(Note V/C<0.60- LOS A; 0.61≤V/C≤0.70- LOS B, 0.71≤V/C≤0.80- LOS C, 0.81≤V/C≤0.90- LOS D, 0.91≤V/C≤01.0- LOS E, V/C≥01.0- LOS F)

5. Conclusion

Local transportation in the cities of India has been a serious challenge although several modes of public transportation are available. In recent years, the availability and operation of the Smart Mobile Travel App enabled taxis on demand added one more dimension to the existing local transportation challenges. The operation of the Smart Mobile Travel App enabled taxis brought certain advantages and benefits to the people that includes availability on demand at any location at any point of time if internet connectivity is available. They are also sometimes cost effective, particularly

during off peak hours, and assist in ride sharing as argued by several scholars (Al-Ayyash, Abou-Zeid, Isam, 2016; Bajpai, 2015; Das and Ngobeni, 2016). Consequently, this study shows that there is an apparent shift in the modal choice of the travelers towards these taxis. However, the operation of such Smart Mobile Travel App enabled taxis engendered certain road infrastructural, traffic movement and mode choices challenges in the cities. It is found that because of the operation of these taxis, although Metro rail and use of private vehicles have not been significantly influenced, reduction in the use of conventional taxis and auto rickshaws and more importantly the use of public buses has been observed. In other words, a shift in the mode choices is experienced, particularly it is negatively influencing the use of public buses in the cities. Further, according to the respondents, the operation of these taxis cause three serious challenges such as unauthorized parking on the road sides, pick up and drop off the customers by encroaching the lanes and stopping on them and congestion on the roads followed by crossing of lanes, and causing risk to the travelers to reach the taxi by crossing the road. The stoppage of these vehicles on the busy roads also cause significant queue length (holding of vehicles behind them) and delay, which contributes to the existing congestion level. Thus, the study revealed that although the operation of these taxis brought certain advantages to the travelers, it has engendered serious road infrastructural and traffic movement challenges on the roads of the cities of India. These challenges call for enacting of appropriate regulations and control measures for the operation of these taxis on the busy roads as well as creation of additional infrastructure such as specific parking areas, pick up and drop off points, and slipways for the smooth operation of these vehicles and movement of other vehicles on the roads without holding up and delay.
The study has certain limitations. In the absence of structural statistical data, the study is relied on limited survey data from a few roads in the important areas of two cities of India as well as qualitative perceptions of the respondents. However, despite the limitations, the study revealed that although the Smart Mobile Travel App enabled taxis have been advantageous to certain extent, it has brought serious challenges with regards to operation of public transportation system in terms buses, need for additional infrastructure such as road side parking areas, pick up and drop off points, and slipways for the smooth operation of these vehicles and for the general traffic movement in the cities of India.

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BALLAST FLYING INITIATED BY ICE DROPPINGS – PROBLEMS, MEASURES AND A NEW MONITORING APPROACH

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Abstract: Under certain conditions in winter, snow or ice can adhere on the surface of vehicles. If ice chunks fall from the bottom side of a vehicle while the train is moving fast and if there is a ballasted track, the impact can be high enough to strike single stones out of their cohesion structure and the so-called ballast flying might occur. When disengaged stones gain enough height, collisions with the underside of the vehicle are possible. Thus, such stones may be smashed into the ballast bed and pull out further stones or lead to further detachments. Due to these mechanisms an avalanche effect can appear. Such events are able to cause heavy damage on the vehicle surface and on the infrastructure. Furthermore, people near the track could also be endangered. The target of possible measures can be on the one hand to prevent the impact or reduce the impact force of the ice droppings and thus avoid the avalanche effect or on the other hand, to prevent ice or snow adherences on the bottom side of the vehicles in general. In this paper, the state-of-the-art measures for both purposes are described and divided into three categories: measures on the vehicle side, the infrastructure side and the operation side. In a funded research project, a new approach of a measure to prevent the occurrence of ballast flying was elaborated. The idea is to monitor the bottom side of the train with a wayside monitoring system and to identify critical ice or snow accumulations. One of the key findings is that in principle the detection of dangerous ice accumulations seems to be possible with existing technologies. A comparison between measurement methods and their applicability in a future measurement system shows that a light-section based detection approach seems to be most promising.

Keywords: ballast flying, track infrastructure, infrastructure application, monitoring system, operation safety.

1. Introduction

Ballast flying is a known problem in railway operation. In the 1980ies ballast flying was linked to snow and ice adhesions on the train surface. The problem was solved with the lowering of the height of the ballast bed between the sleepers. Although that is a common measure nowadays, higher operation speeds cause ballast flying even with that measure. With the implementation of high-speed trains, ballast flying was also observed without winter conditions because of the aerodynamic load (Jönsson et al., 2009). In the research project "DEUFRAKO-AOA-Aerodynamics in Open Air", it was found that the length of the train has a main influence on the appearance of ballast flying. Experiments in Korea 2001 showed that ballast tends to move at gust speeds above 20 m/s (Kwon and Park, 2006). Although many researches were carried out, the formation of ballast flying is not completely understood (Kaltenbach, 2008). However, in this paper the focus lies on ballast flying initiated by ice droppings. At high speeds, the impact of the ice chunks is high enough to strike single stones out of their cohesion structure. When these disengaged stones gain enough height, collisions with the underside of the vehicle are possible. On the one hand, such stones may be significantly accelerated and are able to pull out further stones from the ballasted bed. On the other hand, the impact on the vehicle can lead to further detachments of snow or ice accumulations as well as to high damage on the surface of the train. Due to these mechanisms an avalanche effect can appear, which intensifies damages of vehicles (under-floor-area, vehicle exteriors, etc.) and on the infrastructure (signal masts, noise barriers, etc.). Furthermore, workers near the track, people waiting at platforms or walking on roads beside the track could also be endangered. That phenomenon has occurred at train velocities above about 55 m/s (Investigation report, 2010 and 2013) yet.

2. Measures

Measures against ballast flying induced by ice droppings can be divided in three categories: measures on the infrastructure side, on the vehicle side and in the railway operation. Furthermore, it can be differed between measures to prevent ballast flying events in general or at least to reduce the probability of those and measures, which reduce the damage or endangerment of the events. Wayside damage reduction can be achieved with the building of rock guards at locations, where ballast flying is observed regularly or where the probability is high due to high train speeds or favorable climatic conditions. With that measure, an effective protection of roads beside the track or workers around the track can be accomplished. As mentioned in Chap. 1, the lowering of the height of the ballast bed between the sleepers by 4-5 cm is a common measure on the infrastructure side. As an additional reduction of the propagation of ballast flying, the cohesion of the ballast bed can be raised with certain substances. Common methods are for example gluing with resin or the fortification with polyurethane (Ballast stabilization and sleeper rehabilitation, 2017). The only wayside measure to prevent ballast flying reliably is to replace the ballast bed with a slab track. Especially for newly built tracks, this is an option to prevent ballast flying events. The application of track coverages of the ballast bed

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between the sleepers (like a slab track, but with ballast bed) was not considered as possible due to causing difficulties in the maintenance of the ballast bed (Knoll, 2017).
Damage reduction on the vehicle can be achieved with fortification measures on the surface. A common method is to protect pressure tanks, cables or other objects on the surface with steel plates from the impact of disengaged stones. A measure to reduce the probability of ballast flying is to improve the shape of the surface of the vehicle. A smooth, closed and plane surface shape prevents that a high amount of snow and ice can adhere on the surface and thus the probability of a critical ice dropping is reduced. That is also the reason why train categories have a different risk potential regarding the initiation of ballast flying. A way to prevent the occurrence of ballast flying is to remove the whole adhesions from the vehicle surface regularly with mechanical or chemical (special fluids) measures or simply park the vehicle in a heated environment. The removal would have to be planned in the operational circulation. If it is not possible to remove the adhesions, another approach is to prevent the accumulations by heating of special areas on the surface itself, where it was observed that snow and ice adhesions are likely. Furthermore, special fluids can be applied on the surface, which prevent or highly reduce the amount of snow or ice adherences (Knoll, 2017). The Deutsche Bahn uses a wayside de-icing system for their high-speed trains, where the train surface is covered by a layer of glycol. This measure reduces the ice attachment by up to 80%, but it has to be reapplied regularly (New glycol spray site for ICE-deicing, 2013).
The measure in the railway operation is to reduce the maximum speed of the train for a certain period. The Austrian Federal Railways (ÖBB) limit the track speed to 44.4 m/s, if there are snowy conditions and temperatures around freezing point and if there is no lowering of the ballast bed between the sleepers in that track section. Furthermore, if snow and ice adhesions are detected on the train during a visual inspection or if ballast flying was detected on the track section recently, the track speed is limited, too (Knoll, 2017). In Germany, the Deutsche Bahn AG reduced the track speed to 55.6 m/s temporarily to prevent ballast flying, which caused train delays of 10 to 20 minutes (ICE-trains operate slower this weekend, 2017). The speed reduction does not prevent the ice dropping itself, but it highly reduces the impact force in the ballast bed. Thus, the probability of the initiation of an avalanche effect decreases.

3. Approach of a Wayside Monitoring System

To avoid measures in the railway operation and the resulting impacts on the schedule, the University of Applied Sciences St. Poelten (Carl Ritter von Ghega Institute for integrated Mobility), the Vienna University of Technology (Institute of Transportation and the Institute of Building Construction and Technology), the Johannes Kepler University (Institute of Technical Mechanics) and the Rail Tec Arsenal sat up a study to examine the applicability and meaningfulness of a wayside monitoring system to observe the bottom side of vehicles during regular operation (Intelligent monitoring system to detect ice chunks to prevent ballast flying initiated by ice droppings, 2014). To develop such a monitoring system, it is crucial to investigate the characteristics of the ice and snow adherences. Thus, the undersides of vehicles of high speed passenger trains were examined during snowy periods in winter. This showed that a significant amount of snow and ice adhere on the surface, especially in cavities and behind edges in the bogie area. Between the bogies of a wagon, the surface is smooth and showed nearly no adherences.
To get a better understanding of ballast flying, a theoretical mechanical calculation was carried out. An interesting finding was that in case of mass equality between the ice dropping and the gravel, disengaged stones could possibly hit the vehicle surface. A detailed description of the environmental analysis and the monitoring approach in general can be found in (Michelberger et al., 2017). In the following, the boundary conditions of the measurement task, the considered measurement methods and the developed concepts of a measurement system are discussed in detail.

3.1. Boundary Conditions of the Measurement Task

In general, the target measurement system has to record 3D surface models of the bottom side of the vehicle and to compare those with reference models without any accumulations. By evaluating the differences, ice and snow adhesions might be detected.
Because ballast flying has only occurred at train speeds over 55 m/s yet, the focus of the monitoring system lays on high speed passenger trains. To monitor the bottom side of vehicles in operation, sensor components have to be located in the superstructure and have to base on contact-free measurement principles. To avoid operational disadvantages, the crossing speed must not be limited by the measurement system. The sensor components will be exposed to various weather conditions. Especially, fresh snow may be raised in the air by fast moving trains, which troubles the sight and may disturb the measurement process. To prevent this, measurements have to be done in sections with reduced operating speed, like railway stations or narrow curves (it is assumed, that a limitation of the maximum crossing speed to 22.2 m/s is sufficient). In addition, sensors have to be protected against dirt by suitable measures. In case of using laser based sensors or illumination for cameras, neither locomotive drivers or railway staff working near the track nor passengers in opposite trains or on platforms must not be endangered or irritated by the radiation.
The maximum measuring distance was estimated by the difference between rail level and floor level of the vehicles (about 1.25 m for passenger vehicles (railjet - technical description, 2008)). To prevent damage on the sensor components, the level of those was determined on the level of the ballast superstructure or slightly lower. Thus, a height difference of 0.25 m between sensor level and rail level was supposed. Due to the assumption that the snow and ice

accumulations do not reach the rail level, the measurement range was determined between 0.4 m and 1.5 m above the sensor components (see Fig. 1).
In consideration of a diminution of the width of the car body in the underside area and that the snow or ice accumulations are mostly located in the bogie areas, the width of the area to record was determined to 1.8 m. For those suppositions, a standard gauge track was assumed.

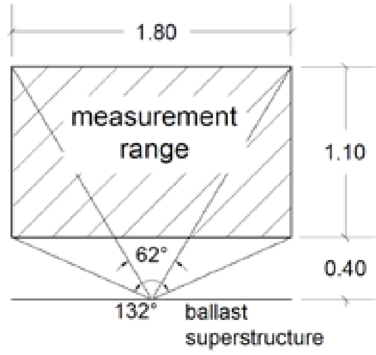

Fig. 1.
Cross section of the area to record and the required viewing angle

3.2. Measurement Methods

According to the danger of mass equality of ice adhesions and gravel, the monitoring system has to be able to detect dangerous ice accumulations with dimensions of at least several centimeters. Building on this demand, some requirements regarding accuracy of the distance measurement methods and spatial resolution were derived. The parallel and longitudinal spatial resolution was determined to the lower centimeter range. Under the assumption that uncertainties of the distance between sensor and vehicle surface due to horizontal motions of the railcar body, loading conditions and abrasion of wheel and rail, are identifiable with the monitoring system through reference points on the surface, which are not vulnerable to ice adherences, the required accuracy was determined to the lower millimeter range.
In a literature research, potentially applicable measuring methods were identified. Furthermore, the feasibility of the measuring process was discussed with lots of sensor manufacturers. Because of the ongoing invention of new methods, the list of the mentioned methods is not claimed to be exhaustive. As one-dimensional techniques distance measurement with ultrasound, laser and Frequency Modulated Continuous Wave Radar (FMCW) were considered. Furthermore, the two-dimensional distance measuring methods laser scanning, light-section, Time-of-Flight-camera (ToF) and light field camera were compared. The second respectively the third dimension is reached with the motion of the train. Ultrasound technique and ToF-cameras were sorted out previously, the former due to vulnerability to turbulent airstreams during the train pass-by and the latter because of a lack in the spatial resolution.
To figure out which method seems most applicable, the methods were compared with each other through a rating matrix (shown in Table 1). The rating scale ranges from “++” – the measurement method exceeds the requirements – to “--” – the measurement method is far away from satisfying the requirements.
The triangulation technique with one-dimensional laser distance sensors even exceeds the requirements. The FMCW-Radar shows a general lack of accuracy and spatial resolution. Two-dimensional methods indicate a worse accuracy, but their advantage is that only a few sensor components must be arranged parallel. This offers some further advantages, e.g. fewer sensor exits must be prevented from dirt. In order to that, the two most promising two-dimensional techniques – laser scanning using the phase difference technique and light-section – were also considered in the further development. In contrast, light field cameras have never been used to measure such distances and were rejected from further sensor evaluations. However, with further development, they could be applicable as well.

Table 1
Rating matrix of measurement methods

measuring method\criteria	accuracy	spatial resolution
1D		
Laser distance measurement - triangulation	++	++
Laser distance measurement - time of flight	+	+
Laser distance measurement - phase difference	++	+
FMCW-Radar	--	--
2D		
Laser scanning - time of flight	--	-
Laser scanning - phase difference	-	++
Light-section	-	++
Light field camera	*	++

* must be evaluated through test series

In addition to distance measurement methods, area and line scan cameras in context with automatic image evaluation software were investigated as a potential assistant component. They could help for example in a field test phase of the measurement system to control the results manually. Cameras applicability was evaluated separately because their measurement principle is not comparable with distance measurement methods. Due to the considerably simpler uniform illumination of the recording area, which is necessary for high shutter speeds and in further consequence for sharp images, line scan cameras are preferable.

3.3. Measurement System

Building on the selection of appropriate measurement methods, four rough concepts of possible monitoring systems were elaborated.
The first concept (A1, shown in Fig. 2) contains many one-dimensional triangular laser sensors combined in one or multiple rows. Every sensor delivers the height information of the surface along a longitudinal line over the whole train. For the evaluation, all lines are combined to create a three-dimensional surface model. If the surface of trains is monitored with cameras in an initial observation phase, representative lines, where e.g. the ice and snow accumulations appear first, might be found. In that case, the number of sensors can be reduced even if this concept (A2) violates the defined requirements of the parallel spatial resolution. Selected laser triangulation sensors in both concepts have very high sample rates. Thus, potential measurement sections can also be found in areas with high track speeds, if snow resuspensions are unlikely (e.g. tunnels).

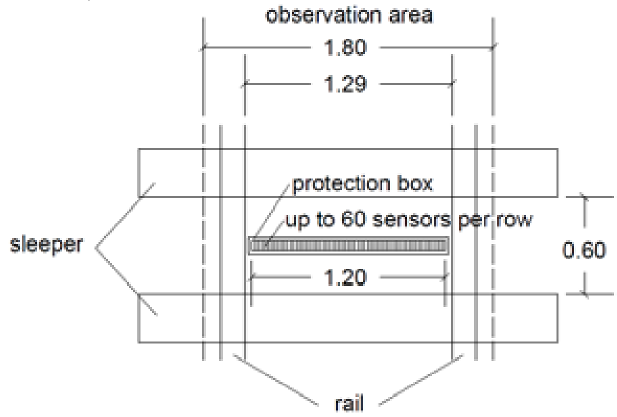

Fig. 2.
Ground plot of the sensor arrangement of concept A1

The next concept (B, depicted in Fig. 3) contains a light-section measurement system composed of camera-high power line laser-camera-units. The cameras record pictures of the projected laser line from the high power line laser. To avoid shadowing effects two cameras are arranged longitudinally in one unit. Due to the large viewing angle, up to three parallel units might be necessary.

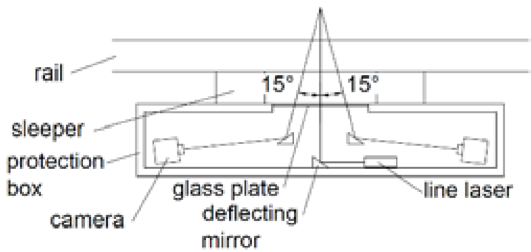

Fig. 3.
Longitudinal section of a camera-high power line laser-camera-unit

The last concept (C) uses a laser scanner, which measures distances with the phase difference technique. The laser scanner is located under the level of the superstructure to cap the required viewing angle with one sensor.
The different concepts were compared with each other through a rating matrix (shown in Table 2). Spatial resolution and accuracy were rated equally to the comparison of the measurement methods. In addition, the rating system comprises the following criteria:

- Cost: from “++” < 30000 € to “--” > 100000 €;
- Eye safety: “++” safe and “--” dangerous;
- Disturbance: “++” none and “--” possible;
- Measurement on clear ice: “++” possible and “--” uncertain;
- Evaluation time: from “++” low effort to “--” disproportional high effort;
- High speed: from “++” applicable for train speeds of 97 m/s an higher to “--” for train speeds up to 22.2 m/s.

Table 2
Rating matrix of the measurement system concepts

criteria\concepts	A1	A2	B	C
Cost	--	+	-	--
Spatial resolution	+	--	++	+
Accuracy	++	++	+	-
Eye safety	--	--	--	++
Disturbance	--	--	++	++
Measurement on clear ice	--	--	++	--
Bonus criteria:				
Evaluation time	++	++	-	-
High speed	++	++	--	-

The importance of the criteria can be chosen by an infrastructure stakeholder or a future developer of this monitoring system. Without any weighting of the criteria, concept B (light-section method) seems most applicable and is therefore recommended for further development.

4. Conclusion

Measures against the phenomenon of ballast flying initiated by ice droppings could be taken on the infrastructure side, on the vehicle side and in the railway operation itself. Furthermore, they can be divided in measures to prevent ballast flying or at least lower the probability and measures, which reduce the damage of ballast flying events. In general, measures on the infrastructure side, like rock guards or lowering the height of the ballast bed, are limited to one point on the track, thus it's a high effort to set measures on the whole railway network. Possibilities on the vehicle side range from smoothening the surface to planning the removal of snow and ice adherences regularly or even prevent the snow from adhering on the vehicle. The measure, which is used frequently nowadays, is to reduce the track speed at certain track sections to 55.6 m/s (Germany) or 44.4 m/s (Austria). Although it is an effective measure, it has a great impact on the schedule and may result in delays for the passengers.
A different approach examines the measurement of ice and snow accumulations on the surface of trains with sensor components, which are located in the ballast superstructure. A key finding of the carried out research project is that the measurement of ice and snow adherences on the vehicle underside while regular train operation seems to be possible. The most promising measurement methods are one-dimensional triangular laser distance measurement, light-section, and laser scanning using the phase difference technique. Relating to cost, achievable spatial resolution and accuracy, eye safety, possible disturbance and measurement on clear ice surfaces, a monitoring system using light-section distance measurement seems most applicable. Up to now, no measurements in the field were carried out, so the next development step would be a test phase with a prototype.

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MANAGING LIGHT RAIL INFRASTRUCTURE – TOWARDS PREDICTIVE MAINTENANCE

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Abstract: Usually designed as secluded networks in urban areas, light rail transit (LRT) infrastructures show specific properties regarding design, network-size, and operational factors. These constraints have led to the currently prevailing maintenance strategies amongst operators; while for heavy rail networks, various operators in Europe have already established condition based maintenance strategies, LRT-operators predominantly rely on qualitative observations and estimations when predicting future needs for maintenance. In a steadily growing market of LRT-systems, approaches for data-based and efficient maintenance strategies that meet the systems' specific constraints are required since (public) funds for maintenance works are usually scarce. The present paper first gives an overview over the recent development of LRT-systems and – based on a specifically generated database of LRT-systems and their properties around the world – aims to prove it is a rapidly growing market. Subsequently, operational as well as physical constraints of LRT-systems regarding condition-monitoring and maintenance works are assessed and compared according to the systems' different properties. Decisive factors that influence the condition of LRT-infrastructure are identified and expressed through representative and measurable parameters. Different methods to forecast the network's condition or the end of it lifespan and thereby set the basis for predictive maintenance are presented. Finally, recommendations for implementing condition-based maintenance for LRT-infrastructure on the long term are given.

Keywords: light rail transit, asset management, predictive maintenance.

1. Introduction – Light Rails on the Rise

At the end of the 19th century, the tram became the first mass transportation system suitable for densely populated, well-grown and historical city structures around the world. Using electric propulsion to transport large numbers of people gave cities the opportunity to spatially expand while maintaining high accessibility. But success was not lasting: soon the automobile pushed tram systems out of the cities. In the US, the automotive industry did not hesitate to buy up and systematically shut down various tram systems to increase demand and space for their own products.
However, the "car-friendly city", a doctrine for urban planning of the 1950s, soon led to deserted city centres. The paradigms of urban planning began to change, the quality of urban spaces, especially in city centres, returned into focus (Reinhart, 1987). This development coincided with a global oil crisis that lead to a further demand for energy-efficient public transportation systems.
Trams and light rail transit (LRT) systems (from now on "light rail systems") were soon regarded as a cost-efficient alternative to costly state-of-the-art subway systems. Originating in West Germany, so-called "*Stadtbahn*"-systems were soon implemented in various cities in Europe and the United States. In France, the launch of the Nantes light rail network in 1985 marked the start of a remarkable development. No less than 26 all-new tram systems have since been opened in France.
Following the rise of new light rail systems in France, West Germany and other European cities, light rail systems have established themselves as a popular way of providing high-level public transportation services in urban areas. Compared to subway systems, the investment costs are moderate; compared to cheaper bus systems, performance and – not to be neglected – public perception are better. In French cities, light rail systems are often well nestled into urban spaces through integrated architecture and striking, colorful vehicle design. Green track design and catenary-free routes are options that aid in further adapting light rail infrastructure to its surroundings.
After the millennium, the number of new light rail systems has rapidly increased, especially in growing economies outside Europe. In Turkey, for example, ten completely new systems have been put into service, with many more currently under construction. Turkey is just one example for a hotspot of light rail development with many other new systems in the United States and North Africa. Chinese cities that mainly used to implement subway systems in the past have just recently turned their attention towards tram systems after 2010 which led to a further boost.
Overall, the trend continues rapidly in an upward direction. After 2010, this can be primarily attributed to the market entry of Chinese Cities. There is also a trend in the type of systems - at the beginning of the upturn, "Stadtbahn" or "LRT"-systems that underpass city centres in tunnels while being operated on surface level on the outer branches were more favored. Recently, tram systems with level guidance through the city centres have become more popular. The implementation of modern tram systems along with a reduction of car traffic has become recognised practice for urban planning.

2. Track design in Strict Boundaries

Track design of light rail systems depends on numerous boundary conditions. Unlike mainline railway infrastructure, there are additional requirements to the tracks, for example sharing it with other transportation modes such as car

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traffic. Also, different light rail network operators have different design principles. This diversity is due to the secluded development of most light rail networks.
Basically, a distinction must be made between covered and open superstructure. While open superstructures usually use Vignol Rails with sleepers on a ballast bed, such as mainline railways, grooved rails on slab track are generally used for covered superstructures that are used by other modes of transport. Grooved rails allow establishing an even surface with the road covering while keeping the space for the wheels' flanges clear (VDV, 2007). On the one hand, track coverings can be made of concrete or asphalt to allow road vehicles to use the track space in either longitudinal and transversal direction. On the other hand, if the track does not have to be shared with other transport modes, coverings with vegetation ("green track") are used to well-integrate rail infrastructure into urban space by even promoting it (Kehrer, 2013).
Apart from the superstructure, the different systems also differ with regard to their alignment limits. In the case of horizontal alignment, the absolute minimum radius depends on the geometric boundary conditions of vehicles (narrowest possible radius of curvature) and on centrifugal forces acting on the passengers, which clearly depend on the operating speed. Regarding longitudinal alignment, sag and crest radii are also limited by geometric and dynamic boundary conditions by the vehicle. The maximum gradient is limited by the adhesion between steel wheel and steel rail but is usually higher than for mainline infrastructure.

Table 1
Comparison of applied rules for the routing of different light-rail traffic systems

City	Country	Gauge	max. lateral Force [m/s²]		Min. Curve Radius		Max. Gradient [‰]		
		[mm]	Mixed Traffic	Secluded Track	regular	exception	In Stations	regular	exception
Wien	Austria	1435	1	0,654	25	18	40	50	100
Basel	Switzerland	1000			20	15	40	40	70
Zürich	Switzerland	1000			80	18,5	70	70	80
Melbourne	Australia	1435			25		66,7		
Minneapolis	USA	1435			30,48	25	20	40	60
Athen	Greece	1435	0,98	0,65	35	25	40	40	90
Aarhus	Denmark	1435					30	50	90
Edmonton	Canada	1435	0,657		180	35	10	45	67
german Alignment directive	Germany	1435	0,98	0,65	25		40	40	-
		1100	0,98	0,65	25		40	40	-
		1000	0,98	0,65	25		40	40	-

Table 1 compares different guidelines with respect to their alignment limits While the centrifugal force is generally limited to around 0.65 m/s² in all networks, this limit is raised to up to 1 m / s² if the track is operated in mixed traffic. The differences of the individual traffic systems considering the minimum curve radii are noticeable. While well-grown traditional tram systems allow radii of down to 18 or 15 m, the minimum for the newly constructed tram systems such as Athens or Minneapolis are limited at 25 m, while for the light rail transit system in Edmonton, the minimum is at 35 m.
The analysis of the routing guidelines of different operators illustrates the strict boundaries for light rail infrastructure given by their surroundings such as limited street space and given gradients.

3. Big Challenges for Small Networks

Limited financial resources for maintenance and generally increasing loads (increased axle loads of new vehicles as well as extended operations) on their networks makes it necessary for urban rail network operators to minimize maintenance costs while maximizing availability (Fischmeister & Oberhauser, 2016).
Light rail networks set specific constraints for the maintenance of the infrastructure. Compared to the maintenance of mainline rail networks, apart from the infrastructure design, there are differences with regard to the following aspects:

- Operations and requirements regarding availability;
- common rail defects;
- maintenance measures.

Operations of light rail systems differ significantly from those of mainline railways. They usually serve as main axes for accessing densely populated urban areas which leads to dense operating intervals. Generally trams hardly ever operate on service intervals of more than 12 to 15 minutes, with often more than one line sharing a section of track. At peak times, intervals of 2 to 3 minutes per line are possible.
Due to frequent operations as well as the lack of two-way track operation, the time windows for maintenance measures are limited. In order to carry out maintenance during service hours, the measure either has to be carried out at a speed

similar to the average travel speed or it can be interrupted very frequently. Most maintenance activities are therefore carried out during the night, outside the operation hours. However, there are more and more networks, where operations are not interrupted during the nighttime, at least on weekends.
Occurring rail defects in the light rail sector differ with regard to their characteristics from those on mainline Vignol rails. Due to the comparatively large forces while accelerating and braking, wheel burn is a common damage. It is caused by the transition from adhesion to sliding friction through the spinning of traction wheels (see Figure 1, left). The heat causes a transformation in the material structure. The heterogeneity in the material structure can subsequently lead to the formation of cracks.
Another common damage in light rail networks is rail corrugation. The wavelengths vary from 3 to 30 cm, with corrugations of grooved rails in urban networks usually having a wavelength of about 5 cm. Driving over corrugations has a significant impact on both noise emissions and service life of the rails. Figure 1 (right) shows the corrugation on a grooved rail.

Fig. 1.
Common rail defects of grooved rails

Rail breakage also occur relatively frequently in urban networks. In addition to temperature and bearing conditions, naturally the load history as well as rail profile and rail condition have an influence. Inadequate welding of rail segments can also cause rail breakage.
Overrunning such rail defects - combined with increased rolling noise and increasing noise emissions - has a negative effect on the service life of the rails.

4. Decisive Parameters on Service Life

When taking a look at the different components of a basic light rail covered track superstructure (Fig. 2), service life is defined by the critical service life of four different types of components. While the covering can be accessed directly and usually without moving rail and track slab, both rails and track slabs are critical components for operation. Seams are usually accessed, when other components are removed, therefore it is important to guarantee at least the service life of their connected elements.
Usually designed as slab track, light rail superstructures Due to the narrow radii of curvature and the high load frequency, horizontal rail wear is regarded as the decisive parameter for the service life of grooved rail infrastructure. Experience also shows that track slabs might be superficially renewed while rails are changed but are no critical element themselves due to their long service life. Grooved rails have average lifetimes of 8 to 45 years, strongly depending on different factors (Wiener Linien, 2014).

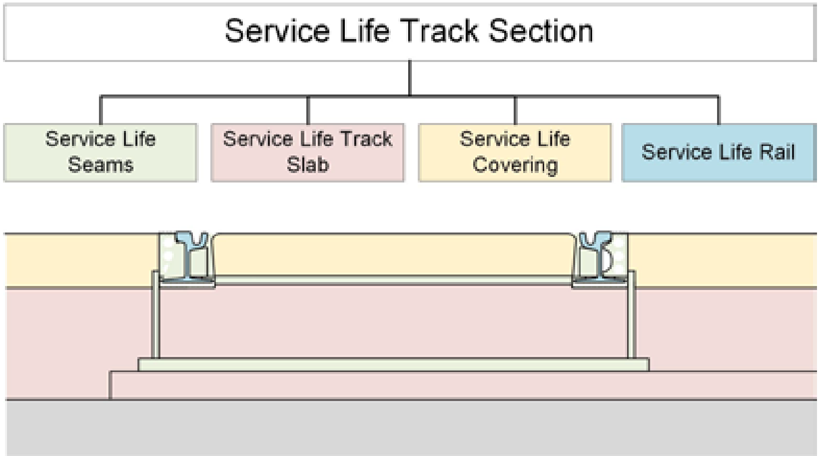

Fig. 2.
Elements of superstructure

Service life of grooved rails is believed to be mainly influenced by the following parameters (Kollenberg, 2017) & (Zaussinger, 2009):

- Horizontal alignment;
- Load frequency and gross tonnes;
- Load characteristics (vehicle configuration);
- Operational characteristics;
- Superstructure design and rail properties (wear resistance);
- Maintenance strategy and measures.

As experienced by network operators, both curve radius (horizontal alignment) and gross tonnes per year (load) are the most decisive factors for track service life. However, these observations are limited due to their lack of data analysis including the other factors. In order to take into account load characteristics like vehicle configuration, very detailed operational data and a determination of the effects of different vehicles on the infrastructure have to be known. Sections with regular acceleration and breaking manoeuvres often show different behaviour than ordinary track sections, especially regarding rail defects. However, these characteristics can be mitigated by regular maintenance measures. Naturally, rail characteristics such as hardness are decisive for the rail's service life. Different rails are also subject to different maintenance strategies. While regular rails usually are maintained by regular grinding and build up welding (to add material that has been lost due to wear), modern, head hardened rails can be used for a "build in and forget" strategy, where hardly any rail treatment has to be carried out during its service life – and still being a cost-efficient solution.
Maintenance strategies and measures have a big impact on light rail infrastructure's service life. As for any infrastructure, the lack of proper maintenance leads to a loss of service life and therefore cost efficiency. Generally a preventive approach is both good for service life and availability as compared to a reactive approach.
However, preventive maintenance has to rely on statistical data if the present and future states of specific track sections are unknown. Therefore mean time between failures have to be taken into account. Therefore, sections that actually behave better than the statistical average might be subject to unnecessary or premature maintenance and renewal. Therefore and in order to reach the highest possible cost efficiency while maintaining high availability and a high service level, the prognosis of specific sections' conditions should be taken into account. However, forecasting such conditions requires a lot of data.

5. Forecasting Future Conditions – Towards Predictive Maintenance

The prognosis is generally defined by Erdmann as *"judgment of probability on the occurrence of events or the achievement of a condition in the future [...]."*
Predictions are based on past observations on the one hand and to a theory for state development (degradation function) on the other hand. These two components are generally needed to make statements about future conditions. The accuracy of the formulated forecasts strongly depends on the input data (observations), the degradation function and the selected method.
In order to derive a degradation function, basically, a distinction can be made between:

- Empirical statistical models;
- Numerical simulation models.

While the statistical models usually determine deterministic formulas for the prognosis of future states on the basis of a statistical evaluation of real condition data and their development, for example by means of correlation or regression analysis of the examined parameters, for (numerical) simulation models all physical interactions and effects are mathematically defined a priori. The model is then adapted to the required boundary conditions to be applicable to the specific tasks. Passing through the simulation by means of numerical methods then maps the actual state development. Condition data offers the possibility to evaluate the model.

6. Conclusions

Light rail systems are conquering urban areas all over the world. Due to their isolated evolution and the limited network size, there are hardly any uniform standards and best practice approaches regarding maintenance and life cycle management of infrastructure. However, with the growing market and the ever-increasing need to efficiently use public funds, maintenance of light rail infrastructure has to be taken to a higher level.
Infrastructure design as well as operation characteristics differ from those of mainline railway infrastructures. Challenging alignment parameters as well as frequent operations and a high expectancy regarding the infrastructure's availability lead to specific requirements regarding maintenance works.
The rail was identified as the crucial element, defining the whole tracks service life. Parameters that influence horizontal wear as major degradation to rails were given and discussed regarding the availability of data. Finally, the advantages of predictive maintenance approaches were outlined and the basic approaches were shown.

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POSSIBILITY OF INTRODUCING INTELLIGENT TRANSPORT SYSTEMS IN COURIER SERVICE IN BOSNIA AND HERZEGOVINA

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Abstract: The environment in which to carry courier services covers a wide transport network. In order to cover the traffic network, it is necessary to combine multiple types of communication systems. Using several different systems enabled real-time communication to users and providers of courier services as well as mutual exchange of information in real time enables the significant flexibility of the courier service. The rapid development and use of intelligent transport systems and other modern technology tracks their wide application and in the field of courier services. Active use of these technologies increases service quality and at the same time improves the market position of courier providers. In order to achieve the expected efficiency, productivity, profitability and customer satisfaction, it is essential that the courier service is based on the highest standards of intelligent transport systems. The paper explores the possibilities of using intelligent transport systems in courier services in Bosnia and Herzegovina. Currently, in the territory of Bosnia and Herzegovina, 16 operators offers courier service.

Keywords: Intelligent transport systems, courier services, delivery, transportation.

1. Introduction

The activity of postal traffic deeply affects the everyday life of people and society as a whole, and is also maintained on economic, political, social and cultural activities in each state and environment. The postal service itself imposes continuous coordination in the international relations and organization of the UN (United Nations). So postal traffic becomes part of the international division of labor in its activities.
Technical and technological development, in particular in the field of transport technology, also focuses on the development of postal traffic. The concept of transfer in the field of postal traffic implies a continuous transfer of postal items in all phases of technological processes. The simplest of the technological processes of postal traffic can be displayed through 5 phases: reception, shipping, transport, arrival and delivery. By observing the individual phases of the technological process of postal traffic, current achievements in the field of intelligent transport systems can be applied to individual phases or a complete technological process depending on the system that wants to be implemented and the effects that they want to achieve.
Post traffic is the subsystem of the transport system, and in most countries it is an important part of social and economic life, but also business on the market. Each country makes strategic plans and decisions that will contribute to the development of postal traffic. Through the Strategic Plans are defined the services and technologies that need to be implemented in the postal system. Bosnia and Herzegovina currently does not have a postal strategy, but individual private and public postal operators led by the experience of international operators introduce intelligent transport systems into their business.
Users of courier services from the newly established market situation, ie the emergence of modern and intelligent transportation systems, expect the services provided by courier services to be as fast, quality and cheaper as possible.
Such and similar customer requirements represent the goals and tasks that a courier organization puts before itself with the aim of cost-effective and efficient business. In order to achieve the expected efficiency, productivity, profitability and customer satisfaction, it is imperative that the courier service is based on the highest standards of intelligent transport technology.
Experience has shown that the introduction and implementation of intelligent transport systems in courier companies have the following effects: raising the quality level, increasing the efficiency of the complete system, reducing delivery costs, bringing customers closer, compete on the market, meet customers' requirements, and simplify adaptation to other systems.

2. Intelligent Transport Systems

Intelligent transport systems include a wide range of tools and techniques for managing transport networks as good services for all process participants (cars, people, goods, passengers, etc.). ITS tools are based on three key concepts: information, communication and integration. Collecting, processing, analyzing, integrating data, and providing information is the core of ITS.
The ITS core has been applied to information and control technology on transport systems. The integration of these technologies for application in ITS functions is based on the principles of system engineering.
Many transport problems stem from lack of timely, accurate, and easy-to-use information, or simply lack the appropriate coordination between decision-making and system users.
Within ITS develop intelligent vehicles, intelligent road, wireless smart cards for toll dynamic navigation systems, adaptive systems of traffic light intersections, more efficient public transport, fast distribution of shipments supported

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by the Internet and wireless technologies, automatic reporting and positioning of vehicles in an accident, biometric protection systems for passengers and others, which can be applied or have an impact on courier services.
ITS functionality is upgraded to the classical functions of the transport and traffic system so that new areas and spaces are created in solving problems posed to the traffic company including postal traffic. Intelligent Transport Systems (ITS) is the management and information - communication upgrade of the classic traffic and transport - logistic system with essential improvements for network operators, service providers, users and the society as a whole. The introduction of a system approach in the implementation of intelligent transport systems ensures that it detects and classifies how system components affect each other and how they function as a whole, and coordinate functions within the system and all subsystems. Systematic architecture should not provide the specification of all technologies.
Consequently, the system is always developed and designed as an open system, because specific systematic links will bring benefits in the future, such as replaceable products, including competencies, risk reduction and lower costs through standardization. The main feature of system architecture is to provide a strategic framework through which the activities of different participants can be integrated into a complete and functional system.
Looking intelligent transport systems and the postal system is important to notice the following subsystems of ITS which can be involved in the formation of the postal system with the included ITS elements:

- control subsystem,
- information subsystem,
- a communication subsystem,
- sensor or indicator subsystem,
- technological processes as postal subsystems.

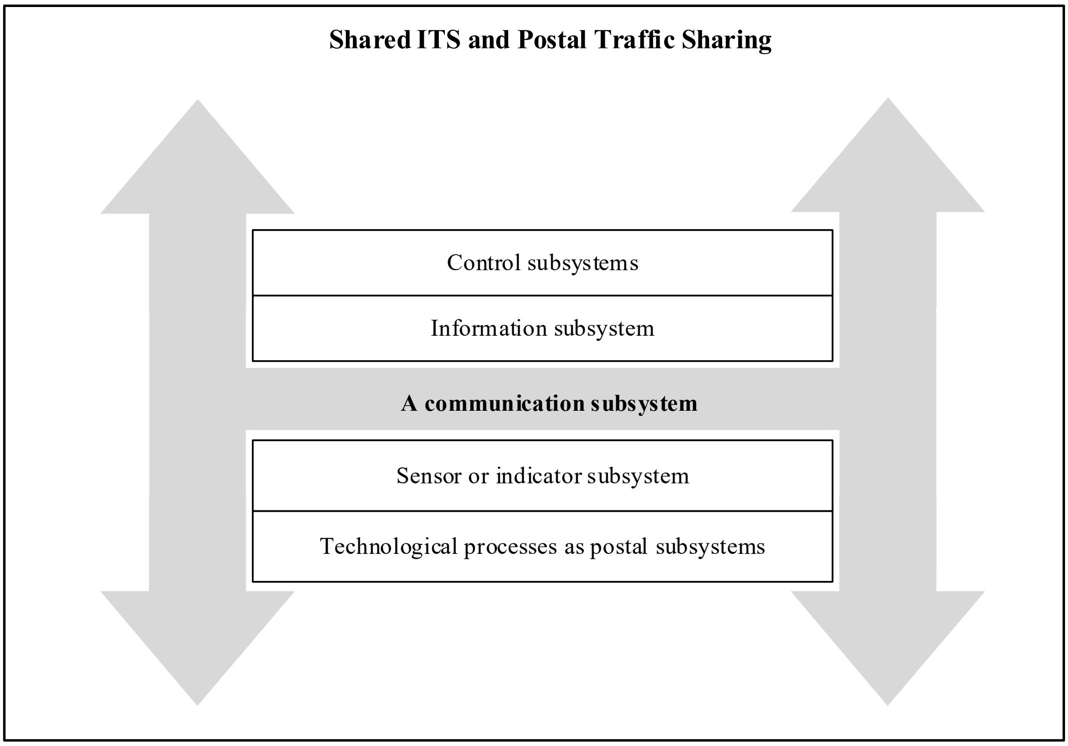

Fig. 1.
Postal items in the ITS system
Source: Authors

At today's level of technology and technology development, certain models of postal traffic have been set up under the subsystems of intelligent transport systems shown in the previous picture. These two traffic systems are actively integrated into one comprehensive system that benefits both the postal traffic system and its stakeholders.
Intelligent logistic systems use certain sensors and devices that collect data on various events, forward data, analyze data, and provide timely information to other systems to effectively manage processes or parts of the process.
In the implementation of intelligent transport systems, in order for the entire system to function and perform its task, it is necessary to use standardization of the process, standardized communication mode, standardized message formats and information among all stakeholder in the process of postal traffic.
Benefits from the introduction of intelligent transport systems are linked to the following indicators:

- Increasing the level of security,
- the efficiency of the flow of vehicles, goods and people,
- productivity and cost reduction,
- more efficient technological processes in traffic,
- better quality services for end users through providing timely information,

- benefits to the environment.

ITS implementation reduces operating costs and improves productivity. As reducing the cost of interest to all traffic stakeholders, they are mostly implemented in that context. The most important users of ITS or stakeholder groups can be:
- end users,
- network operators,
- system owners (shareholders);
- service providers (including courier services),
- tourist organizations,
- local community,
- city administration etc.

3. Courier Services in B&H

Courier is a person who personally delivers someone's messages or packets, most often faster than regular postal service or out of their system, and if it is more courier within an organization, it is a courier service.
Courier services relate to the correctly identified transfer of individually addressed items from senders to recipients in domestic and international traffic. The courier service represents the individual performance and tracking of the transport of the consignments, with delivery in as short a time as possible, and it is characterized by high reliability on the way from the sender to the recipient compared to regular cargo transport.
The mail is sent mainly from the business premises of the user or home of the sender, mainly by his own autonomous network (for the transfer uses his own means and the infrastructure is used by other modes of transport, most commonly the road, rail and air infrastructure) and hand over the addressee to the address of the business premises or home of the recipient.
Under the concept of transfer in the field of postal traffic and connections, we mean the continuous transfer of postal items in all phases of a single technological process, pickup shipment from consignor, then dispatch, transportation, arrival and final phase's delivery of the shipment to its consignee.

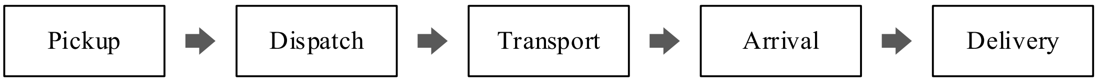

Fig. 2.
Technological processes of postal traffic
Source: Authors

Reception of postal items is the first technological phase in the process of transferring the consignment in which the consignor submits the consignment for delivery to the consignee and requires postal service execution. Delivery begins at the moment the shipment is received and runs until the exchange of processed goods with the means of transport. The goal of the technological phase dispatch of shipment is to process the shipment in detail for further transfer. The technological phase of transport begins with boarding and ends with the unloading of postal items from the means of transport. In this technological phase, unlike previous ones, we have a very small number of technological operations related to transport technology, loading and unloading of consignments. The goal of this technological phase is the spatial transfer of postal consignments. The fourth technological phase in the process of transferring consignments in which the consignments arrive at the postal center will be processed and transported to the postal offices for delivery to the recipient. The technological phase begins with an exchange of conclusions with the postal postal center, and ends with an exchange of conclusions with the postal office. The aim of the technological stages of receipt, conclusions open, postal items processed to delivery post offices or addresses.. Provision is the last technological phase in the process of transferring postal consignments in which consignments are prepared for delivery and delivery to the consignee.
From the aspect of coverage of the area, there are two types of courier services:
- global - who carry shipments of goods to a wider area of one state,
- local - who mainly carry shipments on a smaller area, within a country or city.

With this division of courier services, their processes differ, i.e. there are several sub-processes in order to ship the consignments or to carry them from the sender to the recipient.
Of course, the technological processes also depend on the way the organization of the logistics network of the courier service, and in such cases also define different types of processes and subprocesses.

The sudden development of technique and technology, and the more active use of the Internet, have produced new effects on courier services.
With the expansion of the market for the sale of goods not only in the classical way in the stores, but also in electronic stores or through electronic channels, the need for transport or delivery of items has increased. Electronic sales channels are placing ever greater demands on courier services in terms of services provided by courier services such as time-

based deliveries to certain terms, real-time mail tracking, integration of courier systems with electronic channel systems, timely information to senders about the status of consignments being shipped during the day and so on. These requirements are conditioned by courier to introduce modern technology and keep pace with other transport sectors in the field of engineering and technology.
Due to increased mobility, the need to reduce total operating costs and increase productivity and other factors of successful business, today, courier business occupies a very high position in the global and European economy, and the economic impact of the express courier service company in Europe is reflected in the following:

- Express courier services are one of the growing sectors in Europe,
- Express courier service providers provide guaranteed, fast, reliable, on-demand, integrated, global, door-to-door shipment transmission that is monitored and controlled throughout the entire transmission process,
- Express courier companies simplify and speed up the process of merchandise trade. They organize the takeover of consignments, usually at the end of the working day, allowing the sender to access the information on the progress of the shipment from takeover to delivery and issue proof of deliveries,
- Express courier services enable European companies to maximize the efficiency of their business - reducing interruptions in production and enabling the best international techniques such as custom-made,
- Express courier services enable small companies to use high-quality, fast delivery services that they themselves could not provide,
- Express courier services also contribute to regional development by linking geographic peripheral areas with large centers.

Looking at the total BiH postal sector, the number of employees is approximately 6.800, out of which 5.317 are waste to public postal operators, which is 78%. The total number of employees in B&H in 2014 is approximately 822.000, of which 0.82% is in the postal sector.
In Bosnia and Herzegovina has registered a total of 17 operators who have the right to carry out transport of shipments, of which 3 operators are public postal operators who have the statutory secured postal service, while the other 14 postal operators are entitled to universal postal services. Three public postal operators are state-owned while others are private owners.

Table 1
Three public postal operators owned by the state of Bosnia and Herzegovina

Operator	The area where it operates
JP BiH POŠTA d.o.o.	Federation of Bosnia and Herzegovina
HRVATSKA POŠTA D.O.O.	Federation of Bosnia and Herzegovina
PREDUZEĆE ZA POŠTANSKI SAOBRAĆAJ REPUBLIKE SRPSKE A.D.	Republic Srpska

Source: http://www.rap.ba/index.php/registar-ovlastenja-jpo.html

National postal operators are labor intensive companies with a large number of employees and have an important place in national economies.
In Bosnia and Herzegovina, the number of employees in national postal operators is about 78% compared to the entire postal sector.
In addition to three public postal operators, in Bosnia and Herzegovina, the following private operators have the following license for performing postal traffic:

Table 2
Private postal operators in Bosnia and Herzegovina

Operator	The area where it operates
Express one	Bosnia and Herzegovina
A2b express delivery	Bosnia and Herzegovina
City express	Bosnia and Herzegovina
Dhl international-Sarajevo	Bosnia and Herzegovina
Euro-express"	Bosnia and Herzegovina
Expo	Bosnia and Herzegovina
Express courier	Bosnia and Herzegovina
In time	Bosnia and Herzegovina
Intereuropa rtc	Bosnia and Herzegovina
Lagermax aed bih	Bosnia and Herzegovina
Mhs	Bosnia and Herzegovina
Astra - šped	Bosnia and Herzegovina
Rhea express	Bosnia and Herzegovina

Source: http://www.rap.ba/index.php/registar-licenci.html

4. The Application of Intelligent Transport Systems in the Courier Services

Intelligent transport systems have the ability to provide information transparency, easier management, and improved traffic system response to provide intelligent system attributes, characterized by the ability to adapt to changing conditions and situations where it is necessary to collect enough data and then process them in real time.
Intelligent transport systems in courier services have their place in all stages of service, but the most important role is at the transport stage, ie when transporting and sorting consignments and monitoring postal items to the final destination.
It is precisely the opportunities offered by the ITS system to real-time collect information on shipments and to ensure online access to this information by interested users has had an impact on the development of Intelligent Shipments in courier traffic. Postal and courier traffic in its business includes all forms of traffic (road, air, water and rail) in which ITS has its place, which then attracts the fact that ITS has taken its place in this field of man's activity. ITS in the postal and courier traffic places their place in all stages of service, but the most important role is at the transport stage, ie when transporting and sorting the consignments, monitoring them to the final destination, etc. Concrete benefits of ITS can be observed through different groups of indicators or categories of ITS effects.
Intelligent transport systems can include: automated vehicle location, automatic dispatch of goods, computer dispatching, driver monitoring, real-time shipment monitoring, temperature control in vehicles that carry sensitive shipments such as medical devices and aids.
The intelligent transport system in the postal sector has the most important role to provide the necessary information on the current state of the vehicle and consignment in the transport system, and then to be provided to service users so that they can: - make correct decision-making decisions, be informed of shipments and statuses (damages, disruption, delays in delivery, extraordinary situation etc.) all in order to improve the processes in the transport system and to better inform the users of the service. Intelligent transport systems, with the help of such information as are necessary to carry out technological processes in postal traffic, have the potential to influence the transformation of technological processes, to provide flow of information on shipments and to access this information by courier staff and courier service users, they can easily track their shipments through different communication channels (web pages, applications, etc.). The intelligent transport system is one of the best tools to address all the problems related to rationalization and optimization of transport, making its use indispensable in the modern organization of concentration and diffusion of express consignments.
Intelligent transport systems in courier services can be classified into several groups, namely:

- Intelligent transport systems for managing vehicles and drivers,
- Intelligent transport systems for shipments management,
- Intelligent transport systems for warehouses,
- Intelligent transport security management systems.

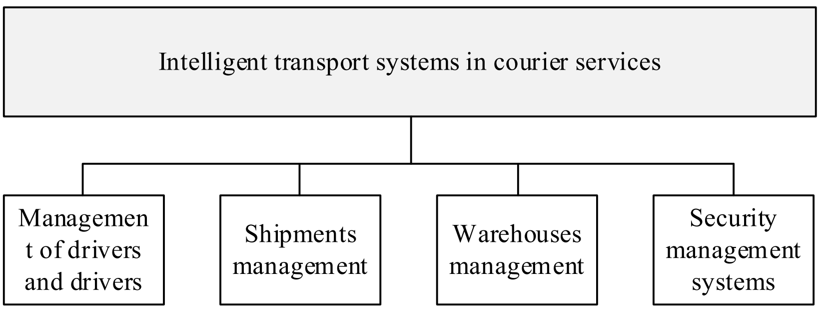

Fig. 3.
Classification of intelligent transport systems in courier services
Source: Authors

4.1. Intelligent Transport Systems for Managing Vehicles and Drivers

Determining driving rows - these plans are mostly executed manually according to available (limited) information, which is a significant loss of time and human resource engagement. Additionally, due to the complexity of these processes, planners are more inclined to existing solutions, even when changing conditions, rather than creating new lines of transport. With the introduction of ITS, it is possible to have a better collection of relevant data and a faster and simpler determination of optimal transport routines using IT support.
Vehicle fleet monitoring - means continuous monitoring of all vehicles, whether they are in operation, in garages or in service. In this way it is possible to react if the vehicle leaves the defined route of movement or does not move to defined times, by identifying each individual vehicle. At the same time, it is possible to have insight into the condition of the fleet and the utilization of individual vehicles in order to rationally plan existing and possibly necessary transport capacities.
Dynamic Routing - Depending on road conditions or in response to new requirements for postal services, it is possible to determine the current best route for each individual vehicle. Decisions are made based on the current location of the vehicle and in accordance with the given limitations (e.g. minimum time of travel, shortest route, type of service, etc.). This enables direct and real-time directing vehicles that are already moving on a route.

Remote Diagnostic of the Vehicle Status (Telemetry) - Vehicle-mounted devices it is possible to determine the telemetry of the vehicle's condition and during carriage. It is therefore possible to prevent (minimally alert the driver or service provider) in case of possible deviation from normal values, thus preventing more serious damage to vehicle elements or the occurrence of traffic accidents.
Remote tracking of vehicles - vehicles fitted with a vehicle can monitor real-time fuel consumption, engine load, driving mode, speed of movement on individual sections, etc.
Tracking Vehicle Driver Movements - The device installed in the vehicle and the mobile scanner can be tracked if the driver leaves the vehicle and the cargo and responds in time in unforeseen situations.
Drivers Information - Installed application on mobile scanners or vehicles enables drivers to be informed about different traffic and other circumstances (eg petrol stations, weather conditions, free parking spaces, etc.), enabling the driver to make high-quality decisions in specific situations.
Automatic toll collection and parking - Using RFID (Radio Frequency Identification) labels or "smart" cards, it is possible to automatically pay tolls and parking without the need to stop the vehicle.
Automatic passage - By identifying a postal vehicle as well as transported content, it is possible to automatically enter such vehicles without the need for retention on ramps, checking of documents and etc.
By using the devices and applications management system vehicles and drivers can significantly contribute to reducing the cost of consumption of vehicles, vehicle wear and tear as well as reducing the time to destination and increasing the productivity of drivers and vehicles.

4.2. Intelligent Transport Systems for Shipments Management

Information about shipments on the way from source to destination have value for users as well as the consignment.
Using information about shipments that are significant for users provide opportunities courier service to deliver new services to their customers, and thus improve the existing service.
In postal traffic, the following technologies are used to track and position postal items:

- aRFID - Active RFID technology,
- pRFID - Passive RFID technology,
- BC - Bar code (2D and QR code).

Each shipment must have a unique identification (barcode or RFID tag) and by scanning a mobile scanner or some other device in the individual stages of the process or passing the vehicle, it is possible to actively track and manage the shipment in the delivery process. The system monitors the position of the vehicle and the consignment and compares the geographic location of the planned address and informs the driver in the case of a scanning of delivery that the consignment is for that address or not. This control of delivery of dispatches makes it possible to reduce the possibility of delivery errors and active control over the shipment. By combining different technologies, it is possible to track the complete transport chain in real time from the takeover, transportation, manipulation to delivery to the recipient address. An example of combining different communication technologies in courier delivery.

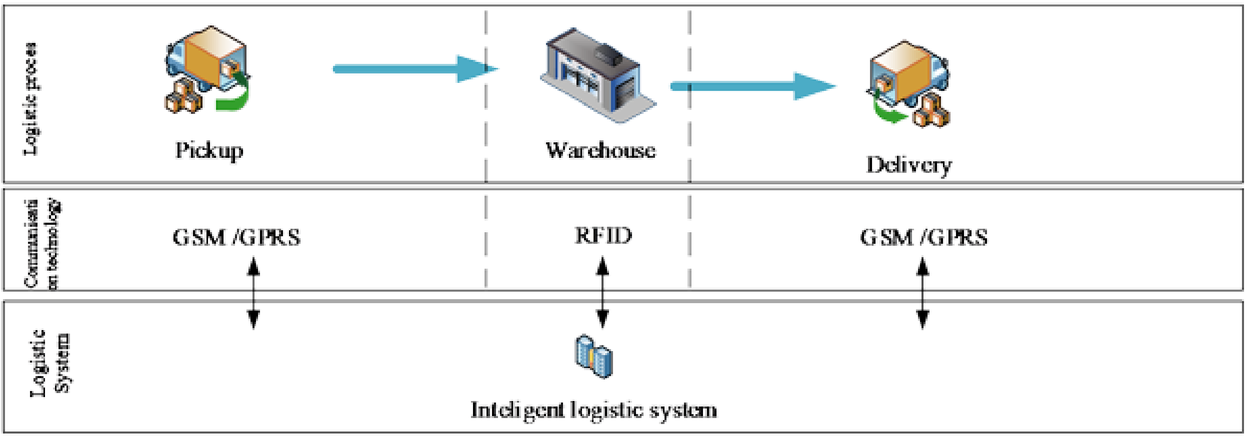

Fig. 3.
An example of combining communication technologies in express delivery
Source: (Deljanin et al., 2017)

During tracking, track & trace systems have the ability to generate reports such as:

- A report on consignments of unknown status, or for consignments not delivered within the envisaged deadline,
- A report on lost consignments that did not arrive at the destination due to possible wrong sorting,
- Report on the total scope of scanning,
- Report on damages during the delivery process.

These systems have a large number of options they provide:

- dynamic planning of resources (people, vehicles, processing capacity, delivery, takeovers),
- collecting data directly from the process in real time (statistics, analyzes, etc.),
- indirectly higher security and postal and postal workers (reaction in the case of intolerant deviations from expected routes or times),
- alternative routing depending on consignments (data on shipments involved in the transfer process are known from the moment of entry of consignments into the process),
- flow control through a complete network,
- control of partners working on the delivery of shipment to the operator.

From the aspect of service users, track & trace system provides:

- tracking the shipment from pickup to delivery time,
- greater security in the operator due to the transparency of the delivery process,
- a quick insight into the event with the shipment,
- special requirements regarding delivery (delivery place of shipment),
- immediate confirmation of delivery of the consignment or current report on the reasons for non-delivery,
- higher transmission speed,
- possibility of monitoring through the operator's website or mobile application.

Companies that introduced Intelligent Transport Tracking Systems have reduced seizures and stolen shipments by 75%.

4.3. Intelligent Transport Systems for Warehouses

Contemporary organization is almost unimaginable without automation of goods flow. This implies an IT solution - a software that manages storage processes and mobile computers for pedestrian storages and forklifts that communicate over a wireless network through private storage software.
Using advanced scanners, RFID technology and automated sorting of warehouse consignments are known to increase productivity and reduce post-processing time in post offices. These technologies make it possible to reduce errors when sorting items to a minimum.
The WMS is a key part of the supply chain, primarily intended for controlling the movement and storage of materials within the warehouse and recording the associated transactions, including delivery, receipt, disposal, and exclusion. This information system can be described as a combination of advanced technology and handling process in order to optimize all warehouse functions.

4.4. Intelligent Transport Security Management Systems

Remote control of vehicle functions - this application assumes the possibility of remote activation of certain functions in the vehicle, such as lights, alarms, locks, etc. An application can also be used to unlock the transport space only after confirmation that the vehicle is in the location foreseen in the order of delivery.
Alarms in case of incidents - Incorporating alarms that the driver can turn on (usually silent alarms) in the event of an attack or other incident, it is possible to receive information about such an event immediately and take appropriate action.
Vehicle tracking after alienation - In case of alienation, the car can still be tracked to facilitate its return.
Monitoring the security situation in facilities - special cameras and applications allow to respond in time to emergency situations such as robberies, fires, etc.
Private postal operators in Bosnia and Herzegovina are actively working on the implementation of such systems in their business as compared to public postal operators. Operators who have implemented intelligent systems are: Express One, DHL, EuroExpress, A2B Express Delivery. Analyzing the market in Bosnia and Herzegovina, it can be concluded that the company Express One is the leader in the implementation and use of intelligent transport technologies in the field of courier delivery, as only one of the 17 operators offers its customers real-time tracking of shipments. Without modern technologies and combining multiple communication technologies, it is not possible to create an intelligent transport system that enables real-time monitoring.

5. Conclusion

The environment characterized by continuous technological development provides space for new operators to gain market share as new or modified services, as well as in the area of traditional transfer services.
Personal mobility and easy internet access leads to increased demand for the use of courier services.
In Bosnia and Herzegovina, the growth of the number of packages per year is 21,4%, which is a strong message to world operators, that the market is still in the development phase and that it has potential for new revenues. Postal operators in BiH, both the private and the public must follow the trends of development of postal services in the European Union and the world, to introduce new services in its business and thus contribute to improving the quality and offer services of the postal market. With the approach of Bosnia and Herzegovina to the European Union, the postal

services market will be liberalized, after which it is possible to enter global courier delivery operators, which will offer customers more transparent service delivery services and new services that bring modern technology. New services also bring new revenue to postal operators as well as better positioning and attracting new customers.
The capability of high-tech solutions is constantly increasing, with a continuing reduction in their costs in the future so that the ITS function can be widely applied to the cost of deploying and utilizing it in all traffic areas including postal traffic.

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CONSIDERATIONS ON THE RAILWAY COMMUNICATIONS BASED ON LONG TERM EVOLUTION FOR RAILWAY (LTE-R)

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Abstract: Railway critical and non-critical communication systems must evolve into a new stage where the trains, vital infrastructures and passengers must be interconnected for a maximum level of safety, security and mobility. Achievement of this vision requires many changes on the train control systems, services and ground signaling applications. For a safer rail traffic system, a reliable bidirectional train to ground communication is imperative. This survey paper analyzes both challenges and opportunist of using the LTE-R (Long Term Evolution for Railway) as a replacement for GSM-R (Global System for Mobile Communications-Railway). The main objective of this paper is to analyze the opportunity of implementing different radio communication architectures for various railway operators. The proposed papers presents how the railway communications based on the LTE-R standard can increase operational efficiency of the railway transport system and enhance safety and the passenger services (mobile ticketing, video streaming). It can be deployed in many different frequency bands and offer multiple features, related to encryption and authentication for security purposes, based on advanced multiplexing (orthogonal frequency division multiplexing), advanced modulation (up to 64 quadrature amplitude modulation) and transceivers with MIMO (Multiple-Input and Multiple-Output) technology. Implementation of the all IP (Internet Protocol) LTE-R standard, based on MIMO principle, brings advantages such as: less power consumption, low latency, flexible architecture and strong end-to-end data protection. All the major opportunities and challenges related to present and future railway radio communications where analyzed. The most important requirements and related services (security, radio convergence and coverage) of both technologies where summarized to determine which is more suitable for the specific demands: increased traffic, safety and security, improved travel comfort and information services for passengers (real time information about the localization of the train and infotainment). Communication between train and ground systems where analyzed (TETRA, 3RP, Wi-Fi) to determine the requirements for a future railway radio communication operational standard.

Keywords: railway radio communication, GSM-R, LTE-R, MIMO.

1. Introduction

Mobile communications have experienced explosive growth in recent years, penetrating in a variety of areas and involving more and more technologies. Wireless networks complete, and even replace, wired networks in many homes and offices. In addition to wireless networks, mobile networks offer mobile transfer rates comparable to wireless networks, but with the advantage of higher coverage (Hyeon Yeong Choi, 2014).
The requirement for wireless (radio) multimedia applications has increased significantly in recent years and the need for of the user to communicate faster and more efficiently at a lower cost is not only a reality but also a permanent necessity. Finding innovative solutions is always a challenge for both manufacturers and network operators.
In this regard, LTE or Long Term Evolution is the last step towards the 4th generation of radio technologies and promises to increase the capacity and the speed of mobile networks. According to the idea of innovation, the LTE standard assumes the use of the OFDMA technique for the downlink transmission technique (Hyeon Yeong Choi, 2014), (Tingting and Bin, 2010).
LTE (Long Term Evolution) technology represents the next level of development of the 3rd Generation Partnership Project (3GPP). LTE technology continues the evolutionary path launched by 2G GSM / GPRS technology and continued with 3G UMTS / HSPA technology. LTE components are formally known as E-UTRA (Evolved UMTS terrestrial radio access) and E-UTRAN (Universal Terrestrial Radio Access Network), (Evolved UMTS (Universal Mobile Telecommunications System) terrestrial radio access network), but are often called LTE after the project name (www.3gpp.org, 2015).
Long Term Evolution succeeds in increasing the speed and capacity of mobile networks so downlink speed can reach up to 100 Mbps and uplink up to 50 Mbps for a 20 MHz band. LTE is a technology of 3.9G and is the step ahead of LTE Advanced, the fourth generation of radio technologies (4G). The LTE objectives considered were: transfer speed and much improved latency, emphasis on simplicity, radio frequency flexibility at which increased capacity was added and a lower cost per bit (Popa, 2012).
LTE-Railway (LTE-R) communications services on the rail will be used to operate trains and subways, replacing wireless analog technology. New communications technology has been tested since February in Korea, including tests related to interoperability of systems with equipment installed on trains and track. Compared to 2G GSM technologies, LTE-R uses 4G, providing a collective connectivity to person-to-person communication previously used. The technology operates in real-time, with critical accidents in the event of an accident.
LTE-R must be considered a Next Generation Network (NGN) due to the fact that in many terms, including speed and bandwidth, superseded GSM-R, allowing the support of time-sensitive applications and providing quality of service management.

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2. Theoretic Background

The GSM-R system, designed as an integrated ground train communication network, involves the existence of GSM terminals both on the train and on the trackside equipment (signals, track balises, track circuits, etc.). The equipment of the train locomotive is made with specific equipment so that the on board GSM-R terminal can transmit the GIS position of the train (determined by a GPS receiver on board), the known position in the track, the speed, the known route, the state train etc. The dispatching achieved by means of GSM-R is governed by a set of rules accepted in Europe, hereinafter the ETCS (European Train Control System - the European Train Control).

In recent years, to meet the increasing demands for new high-speed broadband mobile communications systems, work (LTE/SAE, 2009), (Tingting and Bin, 2010) outlined the long-term evolution of railways (LTE-R) on based on the Long Term Evolution (LTE) standard (Sharma, 2008).

In his work (Ke Guan, 2011), the authors are studying the new communication technologies related to LTE-R and MIMO.

The study focuses on the MIMO performance at a relatively short distance between transmitters or receivers and this is different from high speed. Thus, the MIMO performance study in LTE-R is required to re-evaluate real-time data transmitted at high train speeds (Ke Guan, 2011).

The MIMO principle can be analyzed from two separate scenarios. First scenario is bases on a single “actor” and the other on a multitude of actors involved. For the first scenario the main logical step is to increase the data rate of the radio link between the mobile “structure” and the base structure but this would involve more power for the transmission of the mobile device and short life span for the battery. Increasing the power of the mobile transmitter have some safety issues so another method could be used and consist in increasing the radio frequency bandwidth.

For the second perspective there are multiple users that are communicating wireless, using the same frequency of the system and the most important aspect is that the users are communicating at the same time (Bliss, 2005), (Brown, 2012).

In any railway system based on radio links there is going to be multiple users (trains, trains controllers and drivers, trackside maintenance personnel, operation and emergency safety personnel) that need to connect simultaneous without delays and constrains due to the mobile and fixed railways structures which will cause reflection, refraction and diffraction of the radio signal. As an example, an antenna array is used for receiving the signal, while there are two trains in moving, following different routes, each transmitting a signal to CTC (Centralized Control Traffic) at the same frequency. The trains, T1 and T2, are simultaneously transmitting the signals S1 and S2 as presented in Figure 1.

In this case, the superposition of the two signals from the trains, at each of the two antennas, A1 and A2, can be derived by two distinct equations (1), (Bliss, 2005), (Brown, 2012):

$$\begin{aligned} A_1 &= CC_{11} \times S_1 + CC_{21} \times S_2 \\ A_2 &= CC_{12} \times S_1 + CC_{22} \times S_2 \end{aligned} \tag{1}$$

Where:

CC_{11}= complex channel coefficient between train transmitter T1 and antenna A1;
CC_{21}= complex channel coefficient between train transmitter T2 and antenna A1;
CC_{12}= complex channel coefficient between train transmitter T1 and antenna A2;
CC_{22}= complex channel coefficient between train transmitter T2 and antenna A2;

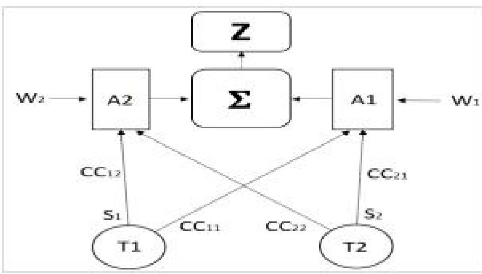

Fig. 1.
Double Array Configuration of Antennas Used to Mitigate Co-Channel Interference

At the receiving end the receiver can apply certain values for the weights W1 and W2 for the both received signals, S1 and S2 and the merge them before reaching the output .The resulting signal ***Z*** will be equation (2), (Brown, 2012):

$$Z = W_1 \times A_1 + W_2 \times A_2 = (W_1 \times CC_{11} + W_2 \times CC_{12}) \times S_1 + (W_1 \times CC_{21} + W_2 \times CC_{22}) \times S_2 \tag{2}$$

The weights applied can be calculated so that the signal contain only the terms with S1 which means only the signal from the transmitter of the train T1 is received, while the signal from T2 is blocked. Assuming the previous criteria and that the channel coefficients are normalized, then the following system of linear equations can be used to derive the weights W1 and W2 and block the signal from S1, in equations (3), (Brown, 2012):

$$W_1 \times CC_{11} + W_2 \times CC_{12} = 1$$
$$W_1 \times CC_{21} + W_2 \times CC_{22} = 0 \quad (3)$$

Using multiple antennas for broadcast and reception allows the creation of multiple independent channels and in addition to creating spatial diversity, arrays of antennas can be used to direct the energy and create multiple parallel communication channel (spatial multiplexing to broadcast) for vital railway services.
Using several antennas for broadcasting and receiving of the signal is called MIMO (Multiple Input Multiple Output) and is used to increase the:

- system performance (lowering bit packet error rate);
- channel transfer rate;
- system overall capacity;
- Coverage area while lowering the power used for transmission.

However, the four criteria mention above cannot be met simultaneously. For example, an increase of the transfer rate often leads to an increase in the error rate or to the increased of the power required for transmission. The way MIMO systems are built depends on the value assigned by the designer according to the cost and space attributes. Although each antenna placed on the railway infrastructure added more safety for the system also adds extra costs but overall could be a major update in vital wireless communications used in railway systems, figure 2.
Within a MIMO technology based system communications a high volume data stream is divided into *Nt* independent streams of data (Popa, 2012).

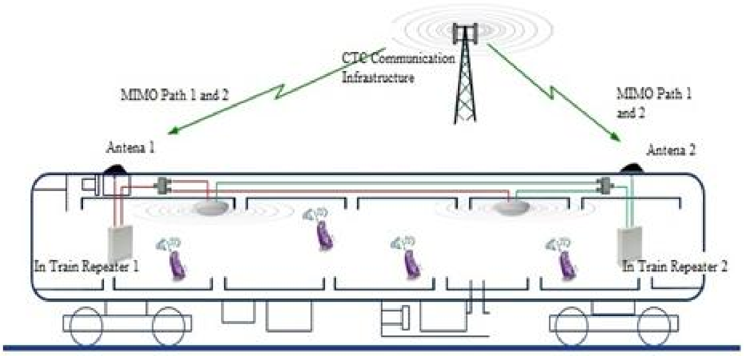

Fig. 1.
MIMO Architecture for Trains
Source (www.rosenbergerap.com/Solutions)

If the data streams can be decoded then the nominal spectral efficiency increases by *Nt* times. This increase means adding additional antennas could increase greatly the viability of very high volume data traffic, such as wireless broadband Internet access for the passengers of the trains and also, access to passenger information and infotainment. This passenger oriented services consist in multimedia content, and knowledge of the train location in real time, figure 3 (www.rosenbergerap.com/Solutions).

Fig. 2
Access to Internet for Passengers
Source: (www.rosenbergerap.com/Solutions)

The signal at the receiver end can be mathematically modeled as follows in equations (4), (Brown, 2012):

$$y = Hx + n \quad (4)$$

Where n is zero-mean complex Gaussian noise with independent real and imaginary part, the matrix H characterizes the channel transition property, in which each entry h_{ij} represents the path gain from j-th transmitter antenna to t-th receiver antenna. Typically, the vector from transmission is normalized by *Nt* so that each symbol of x has the average energy Ex/Nt.The resulting matrix for the H channel is formula (5), (Brown, 2012):

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1Nt} \\ h_{21} & h_{22} & \cdots & h_{2Nt} \\ \vdots & \vdots & \ddots & \vdots \\ h_{Nr1} & h_{Nr2} & \cdots & h_{NrNt} \end{bmatrix} \quad (5)$$

Assume that the channel and the vector matrix elements are complex Gaussian variable, independent and identically distributed, with zero mean covariance matrices that can be written as $\sigma_h^2 I$ and $\sigma_z^2 I$ (Brown, 2012). By using linear algebra elements it is demonstrated that *Nt* streams of data can be decoded if a value *Nt* exist and have a nonzero values in the channel matrix or a rank (H)≥*Nt*. In order to be able to properly assess the benefits of MIMO technology systems, we must emphasize that the most known results related to spatial multiplexing are based on equation (4) which does the following assumptions (Brown, 2012):

- because the elements of the matrix H are random scalars, it is assumed that there is no propagation and therefore fading is flat ,nonselective in frequency;
- because the signals used are considered identical probabilistic variables they appear as uncorrelated;
- Any kind of interference is usually ignored and the thermal noise is negligible.
- All of the above mentioned goals cannot be met in a real MIMO based system (www.rosenbergerap.com/Solutions), (Moreno, 2015).

The access to a broadband network would enable the onboard staff to improve the services by providing a central overview of the occupancy of the each car of the train. In terms of safety, the video monitoring and fast response emergency services could also greatly improve. Using a wireless network build with MIMO involve some technical issues due to the fact that the equipment (antennas) have to be integrated in the trains structure and fulfill all the railway regulations. Another issue is caused by the fact that a radio link has no external boundary and the electromagnetic waves do not stop when they "enter" the trains. Linking two or more train section requires a bridge for short distances and also to prevent two neighboring trains from an unwanted connection .Regarding security of the train, the wireless network must consist in dedicated solutions (firewalls, malware detecting applications, antiviruses) to prevent unauthorized persons to gain access to the trains internal network and compromise the safety and security of the passengers and trains (Alexandru, 2008), (Schilperoort, 2017).

3. Main Findings

Implementation of the all IP (Internet Protocol) LTE-R standard, based on MIMO principle, brings advantages such as: less power consumption, low latency, flexible architecture and strong end-to-end data protection. Nevertheless, the LTE-R, thanks to a better efficiency of the spectrum, increase the link capacity based on OFDMA and FDMA and can augment and allocate radio uplink/downlink >300Mbps with configuration of 4x4 MIMO antennas and 20MHz large channels (Schilperoort, 2017).

Orthogonal frequency division multiplexing (OFDM) represents a very "compelling" solution for meeting the requirements of next generation wireless communication systems for railways. The transmission bandwidth in OFDM is divided into many narrow sub channels, which are transmitted in parallel under fading channel, and inter symbol-interference (ISI) can be almost completely avoided by adding a guard interval to each block of the data. When using OFDM in a MIMO system we need to know the status information for the communication channel at the reception for a coherent detection of the received signals and for combining with diversity or suppression of spatial interference. Estimating the channel for transmission can be done in two distinct ways: by training and in "blind" (Schilperoort, 2017), (Tchao, 2013).

In case of training estimation, known symbols are transmitted to facilitate estimation of the channel parameters based on reception algorithms. For "blind" techniques, the receiver must determine the information without the help of known symbols. Robust and high-rate data in highly mobile environments faces critical challenges due to the time variant channel conditions where synchronization, estimation and data recovery are affected. This unwanted situation is created by the high Doppler shift and spread of signal between transmitter and a fast moving receiver.

In critical systems such as the railway system the communication are vital so a redundant array of multiple antennas in conjunction with distributed receiving end must be considered (Wagdi Mohamedsalih Satti, 2016).

GSM-R shares the same working frequency band with the public land mobile communication network, which will cause serious co channel interference. With the increase of various railway services, the frequency resources will be seriously limited, particularly in railway hub areas. LTE-R system can achieve high capacity, low latency, and high reliability. In order to make the train operation control system work better, maintaining a reliable communication link between the train and the ground, dedicated mobile communications play a key role. Such a communications system is called the global system for mobile communications for railway (GSM-R), a narrow-band communication system. With the rapid growth of railway services, broadband communication systems for railway called long-term evolution for railway (LTE-R) will be deployed (Ke Guan, 2011), (www.3gpp.org, 2015).

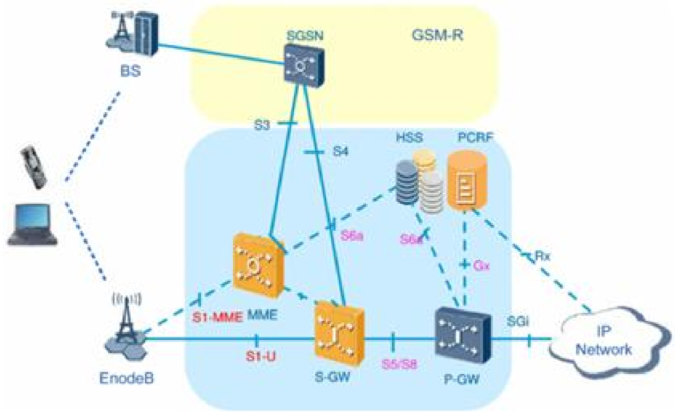

Fig. 4.
Communication Network Architecture of LTE-R
Source: (Bo Ai, 2014).

A moving train cannot be connected to ground based infrastructure by any other mean than radio systems. Various rail operators have property technology alongside their tracks and inside their trains, but without necessarily being interoperable, or with specific adaptation to match vital application requirements. It is common to see railway administrators deploying different radio systems with different purposes in the same network: TETRA/3RP, IEEE 802.11 a/n Wi-Fi, GSM-R (Ke Guan, 2011), (Bo Ai, 2014), (Bertout, 2012). The TETRA/3RP system is used for train to ground communications and use UHF (Ultra High Frequency) in the 420-470MHz band while PMR (Professional Mobile Radio/Private Mobile Radio) and TETRA standard use the 450MHz band. These communications standards are used for voice in shunting areas, remote controls of the maintenance vehicles and locomotives in depots. However this standard has serious limitations regarding railway safety: very limited bandwidth, UHF spectrum is overloaded.
The main advantages of using Wi-Fi and DCS technologies are: large bandwidth (10/20 Mbps uplink/downlink), low packet loss, fast roaming, and light core network infrastructure. The main drawback of Wi-Fi and DCS is represented by serious range limitations (radio coverage from 250m to 450m), unlicensed band (2.4GHz and 5GHz can be easily jammed and some interference are known), no standard roaming solutions. DCS radio systems are mainly used in metro signaling systems and represent various adaptations of the Wi-Fi operational standard but with increased radio link and interference risks. In article (Ke Guan, 2011), GSM-R is derived from GSM (2G+) technology and have a range of 7-15 km and offers low bandwidth, fast handover (up to 500km/h), imbedded voice rail features (group, broadcast, emergency calls) and use 800/900MHz band (Bertout, 2012), (Ke Guan, 2011).
The best selection for an wireless communication system for railways need to consider performance and service attributes such as voice support, availability, "maturity" of the standard and frequency band in Table1.

Table 1
Wireless Technology Comparison (Performance and Industrial Support)

	GSM -R	TETRA	P25	Wi-fI	LTE
Operational voice support	+	+	+	VoIP	VoIP
Broadband data support	<10kb/s	<10kb/s	<100kb/s	>10Mb/s	>10Mb/s
All IP (native)	-	-	-	+	+
Vital traffic support	+	+	+	-	+
P2T/call set up time	1 to 5 s	250ms	800ms	100ms	100ms
Handover mechanism	Standard	Standard	Standard	Proprietary	Standard
Priorities/ pre-emption	+	+	+	3 levels/no	9 levels/yes
Choice for operating frequency	900MHz UIC	400MHz PRM	700MHz +VHF	2.5 / 5 GHz	400MHz to 3.5 GHz
Market support (vendors)	3 vendors	+	Limited (US specific)	+	+
Maturity	End of Life 2025	Mature	Mature	Widely adopted	Emerging

Source: (Bertout, 2012), (Bo Ai, 2014)

OFDM has a great development, being used today in a large number of wireless and wireless transmission technologies, based on standards or proprietary solutions. Its undeniable advantages, of which we remind the high resistance to the inter-symbols interference phenomenon, reliable and costly implementation based on numerical signal processing,

flexibility of implementation across different frequency band makes the OFDM the perfect alternative for GSM-R based systems. Of course this technology also has disadvantages that cannot be ignored such as high sensitivity at phase frequency and noise offset, asynchronous data communications services such as web pages are characterized by short bursts of communications and high data rates, specific complex electronics, including the FEC (Forward Error Correction), are constantly active independently of the data rate. All of the disadvantages listed above remain open for improvement in the future.
LTE-R equipment and subsequent developments will benefit from extensive testing and can be taken over by LTE-R networks once they have reached full functionality. Last but not least, the important costs caused by rail staff communications through other mobile operators' networks will be reduced by using LTE-R networks and at least offset by revenue generated by multiple services provided to customers, rail and passenger operators. New technology that offers a number of major advantages for rail transport are expected to be replaced in the near future with the 5G standard.

5. Conclusion

Implementation of LTE-R in the rail sector can be achieved with investment and migration costs comparable to those required for the exploitation of an analogue network during the lifetime of the investment. At the same time, LTE-R benefits from all the benefits provided by one of the most dynamic markets of the current period, which has worldwide annual growth rates of more than 30%. The LTE-R system is almost completely standardized, which guarantees the sustainable development of its features and the reduction of acquisition and operating costs. This market has created and will further develop commercial and maintenance networks, a situation that will allow LTE-R networks to operate with relatively low maintenance costs.
All the major opportunities and challenges related to present and future railway radio communications where analyzed. The most important requirements and related services (security, radio convergence and coverage) of both technologies where summarized to determine which is more suitable for the specific demands: increased traffic, safety and security, improved travel comfort and information services for passengers (real time information about the localization of the train and infotainment). Communication between train and ground systems where analysed (TETRA, 3RP, Wi-Fi, DCS) to determine the requirements for a future railway radio communication operational standard. If the trains were equipped with broadband networking it would be possible to implement numerous other applications that airline passenger has learned to take for granted: onboard entertainment, access to internet from the train, up-to-date information about connections and/or delays.
LTE - R standard represents the next step in the evolution of mobile communications but its use as an operational standard that meets all the requirements of the rail systems is "threatened" by the development of integrated systems based on Sky Bender technology involving the provision of all-IP full service through the Centaur Project.
A moving train cannot be connected to ground based infrastructure by any other mean than radio systems. Various rail operators have properly technology alongside their tracks and inside their trains, but without necessarily being interoperable, or with specific adaptation to match vital application requirements.

Acknowledgment

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EFFECTIVE DATA TRANSMISSION THROUGH WIRELESS SENSOR NETWORKS IN ROAD TUNNELS FOR LARGE URBAN CLUSTERS

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Abstract: The traffic flow detection is an important field of Intelligent Transport Systems (ITS) and must be reliable and fault tolerant. Because the cities are growing, the number of roads are growing too, so more traffic sensors are needed. Most Intelligent Transport Systems (ITS) are using cables for transmitting traffic data from sensors. Vehicular communications represent the backbone of future transport, as the direction towards autonomous vehicles is obvious and the need for vehicles to be aware of their environment through data exchange with other traffic participants and/or infrastructure equipment is also clear. There are several signal propagation phenomena that makes the data transfer difficult, even in the absence of other communications on the same channel or frequency band. These occur in cities (due to building reflection, penetration etc.), but also outside of cities (in tunnels). In this paper we will overview the most important signal propagation issues and we'll concentrate on signal propagation in tunnels, considering that this is the main problem outside the cities and a method of controlling the data and radio transmission is presented, based on the Wireless Sensor Networks (WSN) principles that require a particular network configuration. Furthermore, signal dissemination in an open space is analyzed (in road intersections or on a road traffic segment in Bucharest), as well as inside an existing road tunnel. As a method of implementing and efficiently transferring information through network nodes, the paper proposes an algorithm for routing and formation of mobile network groups. The proposed algorithm has the following advantages: to increase traffic safety by preventing accidents and road events, through the efficient and intelligent use of communication channels (dynamically adjusting time intervals in service and control channels).

Keywords: WSN, routing algorithm, road tunnel, data transmission.

1. Introduction

Wireless sensor networks have seen a significant development in last years. New communication techniques and protocols, as well as physical implementations of network nodes based mainly on microcontrollers and Mixed Signal Processors (MSP) have emerged (Nedelcu *et al.,* 2010).
For these types of networks, the most important design objectives are:

- automatic network configuration - setting optimal routes from the network nodes to a data concentration point;
- ensuring connectivity between nodes when malfunctions occur - establishing new communication paths if certain nodes become inactive or defective;
- providing minimal energy consumption at network node level - to ensure the longest battery life for the nodes; an optimal search is made between the data transmission period (transmission being energy-consuming) and node consumption;
- compiling and fusing sensor data - building a coherent image of the state of the environment or process controlled by overlapping and aggregating the data transmitted by each node;
- establishing a balance between the transmission power of a node and the coverage distance - Adjusting the transmission power according to the distances between the nodes and taking energy consumption reduction into account.

A network node consists of an intelligent circuit (microcontroller, signal processor or mixed signal processor), one or more sensors, and a dedicated radio transmission and reception circuit (Palpanas, 2012).
At node level, sensors generate either digital signals or analog signals. These signals are considered by the parallel interface and the analog interface of the microcontroller. Adaptive circuits are sometimes required for amplifying, filtering, and sampling signal-generated signals (Cirstea et al., 2012).
Data transmission is obtained by using radio waves. Frequency bands for industrial, scientific and medical are being used (ISM bands - industrial, scientific and medical use) are usually used because a transmission license is not necessary. Transmission frequencies range from 6.78MHz to 254GHz.For network communication, these frequencies are mainly used: 2450MHz (Bluetooth), 5800MHz (HIPERLAN) 2450MHz and 5800MHz (IEEE 802.11 standard). Due to the lack of restrictions on the use of these frequencies, designers must consider the possibility of interference with other equipment that communicates and exchange data at the same frequency.
The main objectives of a wireless cognitive system are (Haykin, 2005).

- *Analyzing the use of electromagnetic spectrum.* Detection of unused portions of the spectrum and estimation of the average capacity of the spectrum.
- *Predictive modeling*. The prediction of a time interval in which the unused portion of the spectrum would remain available for use by the second user.
- *Power transmission control*. Maximize the data transmission speed for each user, while respecting power constraints.

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- *Dynamic spectrum management*. Sharing the unused portions of the spectrum between secondary users geared towards minimizing running costs.
- *Routing packages*. Designing a self-organizing scheme for routing packets over the radio network.

A problem in terms of intelligence is that the WSN, wireless sensor networks, which usually contain hundreds or even thousands of terminal nodes, and which must transmit the collected data or commands to a data repository and vice versa to the terminal nodes. Often such networks are deployed in large territories and require the use of defining features, depending on the size of the surveillance, such as:
- high density of terminal nodes;
- severe conditions for power supplies;
- in some situations, a low reliability of the nodes;
- Large storage and computing needs for large data processing;
- In some situations, a high-speed response to the information received from the terminal nodes.

WSN's are currently considered to be among the major technologies developed in the early 21st century and are based on a combination of wireless communication and mechanical-microelectronic systems, MEMS, as well as other sensor categories.
Constructing small, intelligent, low cost sensors that can be embedded as terminal nodes in wireless systems developed on physical surfaces, coupled with reliable power supplies, nodes that can connect to wired networks, such as the Internet, creates special opportunities for the development of civilian and military applications in different fields of activity.

2. Related Work

In the paper (Stangaciu, 2015), IEEE 802.15.4 standardized access protocol analyzes are performed and the main problems that arise when applying this protocol in real-time systems are shown.
A sensor network consists mainly of built-in (fixed) or mobile microsystems, usually poorly equipped in the hardware department, with a limited battery power, with superior sensing capabilities and also with wireless communication capability.
These hardware nodes are independent but their functionality is of importance only when they function as a whole with the purpose of fulfilling a function, a role (Baniata and Hong, 2017).
Thus, there is a need to establish a reliable communication between these nodes in order to create a network of sensors. Particular attention is paid to the real-time systems in the past, where not only the outcome of the operation is important, but also the time needed to obtain the result is equally important (Stangaciu, 2015).
In order to achieve real-time communication, whether if it's about real-time hardware communication or real-time software communication, the protocols presented above on each level must meet real time requirements.
This can be done when the protocols on each level work in real-time, but more easily if there is a fairly close connection between these levels.
An essential parameter in real-time systems is time. In the case of wireless communication between 2 nodes of a sensor network the time frame between the transmission of a data packet of one node and the reception of this packet by the receiving node can be approximated as follows (Ali *et al*., 2008):

$$T(S, N) = T_C + T_t + T_{pp} + T_p + T_q + T_S \qquad (1)$$

where:
$T(S, N)$ – The transmission time of a packet from node S to node N.
T_C– The time required for the S node to gain access to the communication environment.
T_t– The transmission time of the packet in the communication medium - depends on the size of the packet and the applied coding line (modulation type).
T_{pp}– The signal propagation time from S node to N node which depends on the physical factors of the environment and distortions.
T_p– Processing time depends on data processing algorithms implemented in the network.
T_q – How long a packet sits in a queue to be sent; This parameter is influenced by the degree of network load, network traffic.
T_S– The switching time of a node from the sleep state to the operating state and vice versa.

3. Study Area and Proposed Model

The propagation environment is one that presents certain difficulties, especially in transmitting data from the installed monitoring equipment. To increase efficiency in data transmission, additional sensors will be installed into the traffic tunnel management and monitoring system.
In order to emphasize the applicability of this system, a particular tunnel will be considered , which has a distinct feature compared to other urban road tunnels, namely the existence of a curve..

The proposed tunnel is the Free Press Square Passage in Bucharest, Romania.

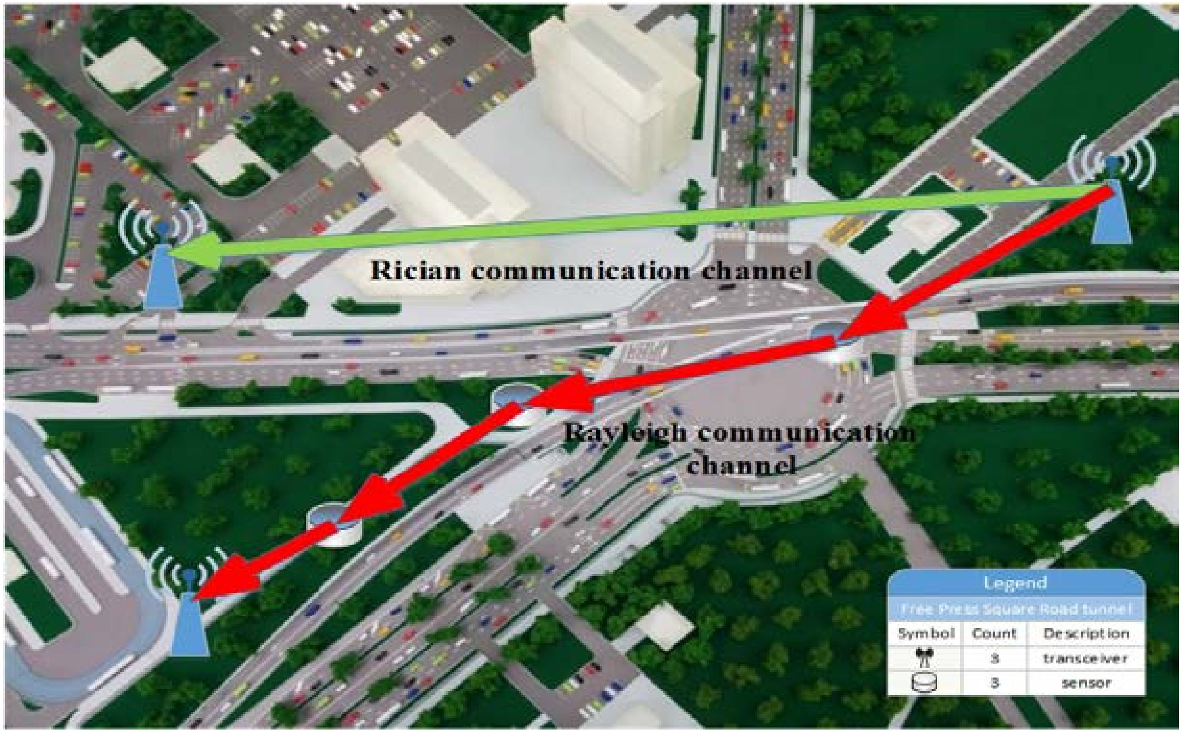

Fig. 1.
Free Press Square Channel Simulation

In Fig. 1, the road tunnel in the Press Square is presented. Two signal propagating methods were studied: the Rician channel is simulated in the linear road tunnel section, and the Raylegh channel is simulated in the curved road section.
The tunnel has the following features:
Longitudinal track: Passage access ramps have a gradient of 4% for design speed V = 60 km / h (in the direction of Ploiesti - Kiseleff) and 5% for design speed V = 50 km / h (in the direction of Marasti), the convex connection curves have R = 2,000 m, 2,800 m and 3,000 m radius and the concave connection (under the roundabout) of R = 3,350 m. The main access axis presents 12-13 degree left turn.
Retaining panels of reinforced concrete molded wall with the facing vertical wall with a height of between 3 m and 7 m; the ramp radius is made up of reinforced concrete with a minimum thickness of 0.60 m on the area of the classical support walls and a minimum thickness of 0.80 m on reinforced walls area.
Non-line of sight is the main reason for proposing this model. It is a way of propagating a radio frequency that is partially or completely covered by obstacles.In general, obstacles can be: high buildings, high power conductors, trees, and the surrounding landscape. Any of these obstacles absorb or reflect radio signal; all this limits the signal transmission capability. A line of sight is obtained through a Rayleigh channel shaped signal propagation.

3.1. Motivation for Using WSN Based Communication in Tunnels

Based on the parameter extraction from the measurement results, the large-scale fading characteristics of wave propagation in curved arched tunnels are quantitatively analyzed and discussed in this section.

In open space, the attenuation is 20 dB higher at 500 m compared to 50 m.

$$L = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) \quad (2)$$

Where: d – distance, λ – wave length

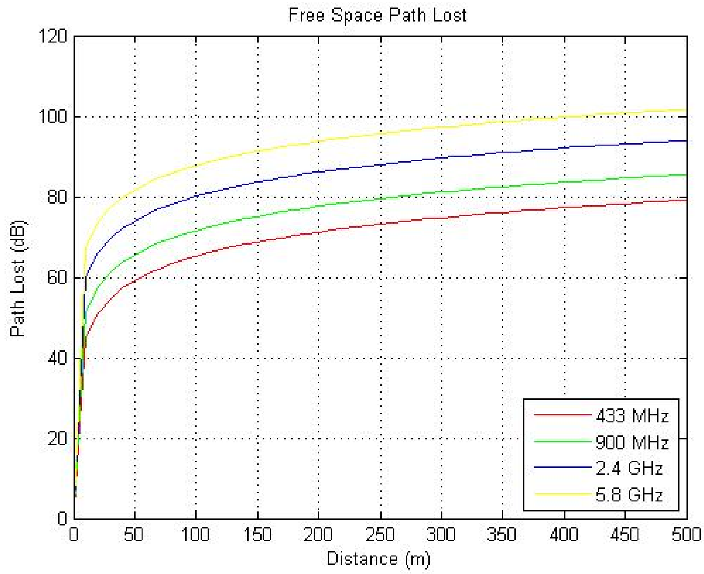

Fig. 2.
Signal attenuation variation depending on open space distance for different frequencies

Relations (3) and (4) were used in an Matlab environment for signal strength simulation (Jinyun and Rodney G. Vaughan, 2012), (Cyril-Daniel Iskander, 2007):

$$y_i = \sum_{n=N_1}^{N_2} s_{i-n} g_n \tag{3}$$

Where $\{g_n\}$ is the set of tap weights given by:

$$\{g_n\} = \sum_{k=1}^{M} a_k \, sinc[\frac{\tau_k}{T_s} - n], \ -N_1 \le n \le N_2 \tag{4}$$

Si – input samples, Yi – output samples
n the equations above:
Ts - is the input sample period to the channel.
τ_k , $1 \le k \le M$, is the set of path delays. M is the total number of paths in the multipath fading channel.
a_k , $1 \le k \le M$, is the set of complex path gains of the multipath fading channel. These path gains are uncorrelated with each other.
N_1 and N_2 are chosen so that is small when n is less than N_1 or greater than N_2 .
We model a narrowband propagation channel by considering a sinusoidal transmitted carrier in equations (5) and (6), (Jinyun and Rodney G. Vaughan, 2012), (Cyril-Daniel Iskander, 2007):

$$s(t) = \cos \omega_c \, t \tag{5}$$

This signal received over a Rician multipath channel can be expressed as in equation (6):

$$s(t) = A \cos \omega_c \, t + \sum_{n=1}^{N} r_n \, \cos(\omega_c \, t + \Phi_n) \tag{6}$$

Where: A is the amplitude of the line-of-sight component, ,r_n is the amplitude of the n-th reflected wave, Φ_n is the phase of the n-th reflected wave, $n = 1 .. N$ identifies the reflected, scattered waves.
Rayleigh fading is recovered for $A = 0$. In the expression for the received signal, the power in the line-of-sight equals $A^2/2$. In indoor channels with an unobstructed line-of-sight between transmit and receive antenna the K-factor is between, say, 4 and 12 dB. Rayleigh fading is recovered for $K = 0$.
The Rice factor K of the faded envelope is a measure of the power in the faded envelope that has been produced by the means of broadcast and reception Jinyun and Rodney G. Vaughan, 2012),
A 5-multipath signal is transmitted in the considered road tunnel. Doppler deviation is calculated for 80 km / h, k-factor for the Rician model is 10 (Gheorghiu, R.A., *et al.*, 2017), (Surugiu, M.C., *et al.,* 2015).

Table 1.
Parameters used for both channels

ChannelType: 'Rician'	**ChannelType: 'Rayleigh'**

InputSamplePeriod: 1.0000e-06	InputSamplePeriod: 1.0000e-06
DopplerSpectrum: [1x1 doppler.jakes]	DopplerSpectrum: [1x1 doppler.jakes]
MaxDopplerShift: 177.7600	MaxDopplerShift: 177.7600
PathDelays: [1.0000e-07 1.2000e-06 2.3000e-06 6.2000e-06 1.1300e-05]	PathDelays: [1.0000e-07 1.2000e-06 2.3000e-06 6.2000e-06 1.1300e-05]
AvgPathGaindB: [-0.2500 -5.2500 -10.2500 -15.2500 -20.2500]	AvgPathGaindB: [-0.2500 -5.2500 -10.2500 -15.2500 -20.2500]
K Factor: 10	NormalizePathGains: 1
DirectPathDopplerShift: 0	StoreHistory: 0
DirectPathInitPhase: 0	StorePathGains: 0
NormalizePathGains: 1	PathGains: [-0.2852 - 0.1549i 0.6660 + 1.0225i -0.1938 - 0.2118i 0.1193 + 0.1328i 0.0161 - 0.0482i]
StoreHistory: 0	ChannelFilterDelay: 4
StorePathGains: 0	ResetBeforeFiltering: 1
PathGains: [0.6662 + 0.0475i -0.3680 - 0.0874i 0.0682 - 0.1773i -0.0717 - 0.0409i -0.0297 - 0.0805i]	NumSamplesProcessed: 20000
ChannelFilterDelay: 4	
ResetBeforeFiltering: 1	
NumSamplesProcessed: 20000	

The result of the simulation is shown in Fig. 2. For the same input parameters, the signal transmitted on the Rayleigh channel without line-of sigth is more disturbed than the signal transmitted on the Rician channel, in which there is a direct line-of-sight component.

The authors believe transmission on the Rayleigh channel corresponds to a communication path between two transceivers at the tunnel ends.

The Rician channel corresponds to the transmission between 2 sensor nodes in line of sight. Several line-of-sight transceivers are located along the tunnel, but the required emission power is lower than with the use of 2 transceivers in the tunnel access ways.

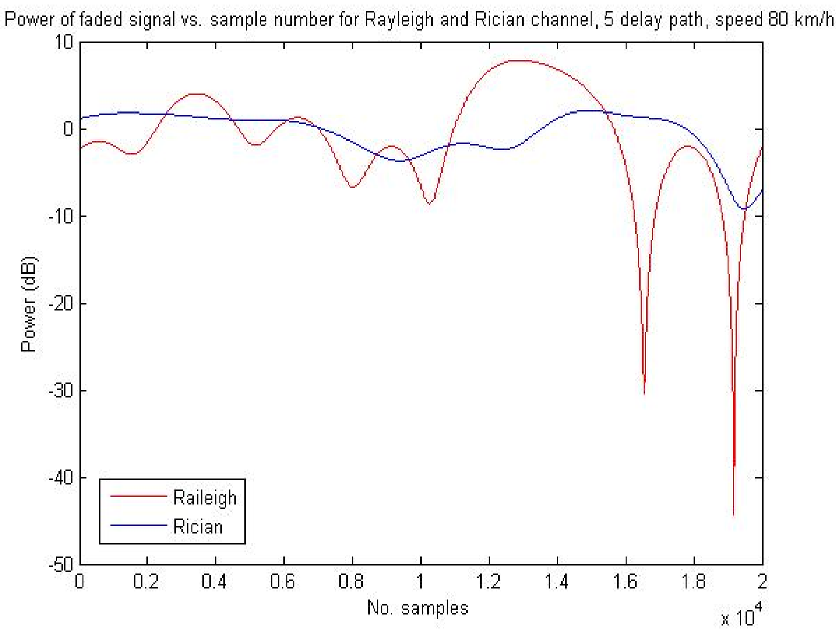

Fig. 3.
Signal attenuation variation in Rayleigh channel and Rician channel multipath communication

In Fig 4 a), a WSN to vehicle message flow is demonstrated. Each vehicle that passes by a transceiver can get a certain type of message as showned. Emergency messages have a high priority.

Meanwhile, depending on the chosen route, a tranceiver at one of the tunnel entrances will transmit a reconnaissance beacon to identify the neighboring network equipment. If a neighboring tranceiver is identified, the Rician transmission channel will be used. If the identified network equipment is one of the in the line-of-sight tunnel sensors , then, the Rayleigh transmission channel will be used (Fig. 3 b).

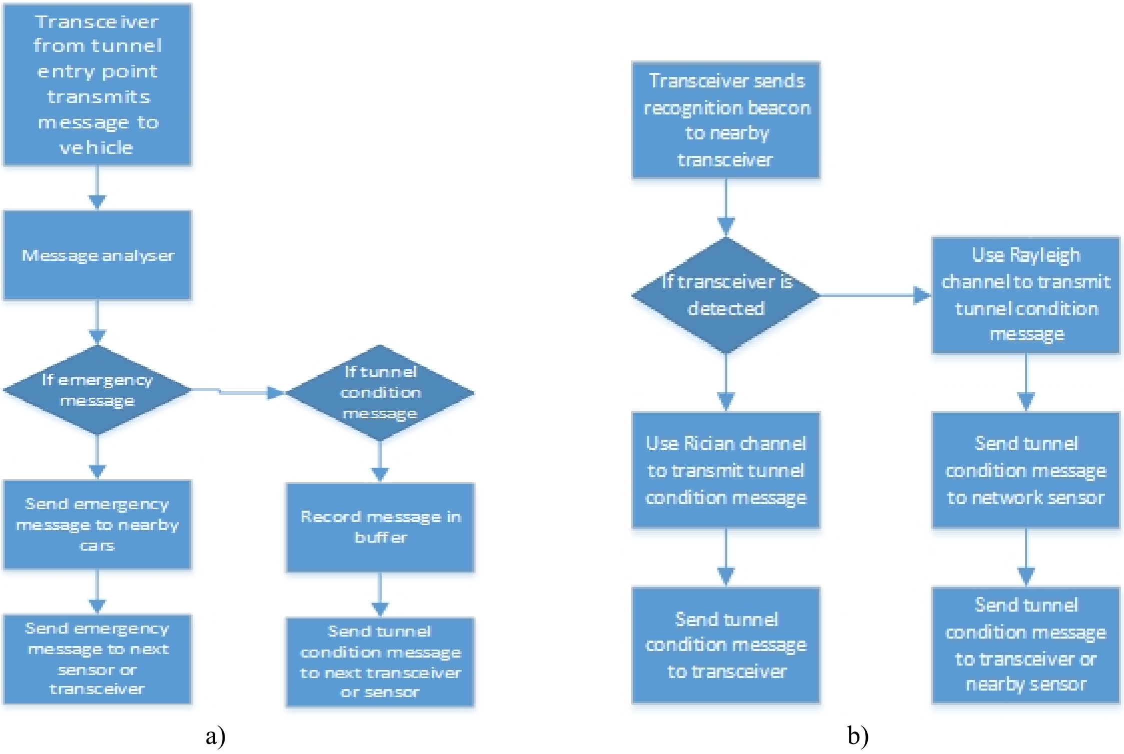

Fig. 4.
Proposed message flow algorithm

4. Conclusion

The traffic flow detection is an import field of Intelligent Transport System (ITS) and must be reliable and fault tolerance. Because the cities are growing, the number of roads are growing too, so that there are needed more traffic sensors. Most Intelligent Transport System (ITS) are uses cables for transmitting traffic data from sensors. This becomes expensive because of using increasingly cables. The relay network, known as smart grid system, is most suited wireless communication technique because it has a lot of advantages such as reliability against failures and offers redundancy, self-configuring and self-healing. For example if one node or path is not active, it can find a neighbor active node to transmit the data to the data collector, using different algorithms schemes. In this paper is presented a design method of data transmission and radio controls for traffic detectors, relay network.

In recent years, urban sensing systems that provide users with valuable information using data collected with a large number of sensors experienced a continuous development.

The adaptive location of mobile nodes in wireless acquisition networks takes into account both transmission conditions (for correlation with them) and the ability to reduce power consumption. Thus, the network lifetime is extended by reducing the transmitter power while must remain within acceptable accuracy (1-2 m).

Due to strict WSN network requirements, to implement new algorithms they must meet scalability, energy efficiency and precision.

Also, a network sensor performs additional functions such as tunnel noise monitoring, traffic monitoring and incident detection, fire detection, flood detection, etc.

Although the constructive parameters of the tunnel (section shape, material, etc.) influence to some extent, the signal propagation, they are not taken into account in the present simulation because it equally influences the reception of the transmitted signal, given that the simulation refers to the same tunnel type. Instead, the signal propagation is influenced by the tunnel curvature, which is reflected by the Rayleigh channel shaping.

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AN EXPERIMENTAL SURVEY ON WI-FI EFFICIENCY FOR SMART SUBWAY APPLICATIONS

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Abstract: The subway is an efficient urban, or peri-urban public transportation with the advantages of being non-pollutant, regulated and not subjected to traffic jams. When endowed with park and ride terminals, the subway network contributes significantly to reducing emissions in large cities. However, traveling in an extensive subway network may prove difficult to some passengers, commuters, persons with disabilities, taking into consideration the rapid access to information, guidance, e-ticketing and optimal route finding. Modern applications develop Internet of Things, Internet of Trains and indoor WiFi based localization techniques. Subway operators need to assess the transport demand, to detect and rapidly restore traffic disturbances and to inform the travelers. Smart subway is a concept that gathers together all that information flowing, based on wireless networks of sensors, information and communication technologies etc. In this paper a survey on the efficiency of WiFi for developing and supporting smart subway applications is carried on. A series of experiments in the underground environment and an evaluation of WiFi signals usability in different scenarios are performed, to evaluate some specific characteristics, such as: maximum coverage, propagation conditions, channel usability, channel throughput, density of access points etc. The tests are carried on in several specific scenarios, such as: evaluation of WiFi maximum range in tunnels - for train driver's early warning or train arrival applications; channel usability and throughput in railway stations (density of simultaneously used channels). The tests were performed in different conditions on the Bucharest subway network (M1 and M4) for single ovoidal railway tunnel profile and in some stations, on the platforms and in adjacent facilities. The possibility of employing WiFi localization and passenger counting for determining transport demand is also investigated and recommendations are provided.

Keywords: Smart subway, WiFi interferences, quality of service, received signal strength, WiFi localization and passenger counting.

1. Introduction

Smart subway (smart metro) is a relatively new concept, in the context of the implementation of Internet of Things, Internet of Trains, smart mobility / smart cities etc., to support fast movement and rapid self-guidance when traveling on metro lines. The concept relies intensively on mobile communications and information technology, with support for localization in underground environments, wireless access to Internet and metro schedules, and even augmented reality for a precise guidance to correct platforms, lines etc. according to trains schedule. Applications may include (but not limited to):

- Subway maps/routes, schedules information and optimal route dynamic guidance, according to running times, or fastest/shortest/minimum transfers criteria;
- Outside guidance running on GPS to find nearest subway station, or underground guidance based on WiFi localization or other technical solutions – with support for augmented reality;
- Real-time notifications regarding accidents, service disruptions, delays, train arrival at the platform etc.;
- Electronic ticketing, payment etc.

2. Literature Survey

Many authors focus in present on the information applications employed in urban mobility. Digital wireless communication technologies, with their rapid evolution, help providing useful information to travelers, supporting traffic and public transport management and information collection. However, the subway environment is very specific and sometimes radio signals propagation (physical layer) needs a more detailed assessment to provide propagation models, information regarding propagating conditions in real environment and post-experiment analysis to ensure the best communication solutions. The scientific literature is relatively rich in this aspect, with many studies and models regarding the conditions the radio signals propagate in the tunnels, considering the shape of the tunnel, walls' profiles, walls' materials and dimensions. In this study a subway-specific environment is considered for analyzing firstly the physical layer influences regarding the signal propagation, in a real subway environment consisting of stations, train tunnels and passenger tunnels. The scientific literature survey revealed that there were performed a series of studies regarding different types of tunnels, or similar environments: for industrial applications, for road transportation, railways etc. A complete study for the subway environment has not yet been performed. This environment is being composed of inner spaces such as large halls (subway stations) with pillars, tunnels with specific automation equipment and underground travelers' passages. In such a complex environment, a study regarding the conditions of radio-signals propagation is considered useful for the future development of modern information applications, such as passenger information and guidance systems, passenger counting and localization, emergency warning etc. Antenna design and positions, communication algorithms and other specific features may then be better developed, knowing the physical layer conditions that apply. No matter what application is designed for communications, preliminary knowledge of the propagation is required.

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2.1 Modelling the Signal Propagation in Tunnels

A series of studies regarding radio signals propagation in tunnels can be found in the scientific literature. According to A. Hrovat (Hrovat et al., 2014), modeling the radio signals propagation in tunnels plays an important role in designing the wireless communication systems and services. The main modeling approaches for tunnel propagation of radio signals can be classified in four directions, namely: employing numerical methods for solving Maxwell equations, modal (waveguide) approach, the method of tracing rays, and the two-slope path loss modeling. An important development in this area is that leaky feeders technology has been abandoned, giving place instead to usage of base stations for ensuring coverage of radio communications in tunnels, mainly because of higher risk of the first technology in case of fire, conducting to the failure of communication in the entire tunnel. There are some parameters of the radio communication in tunnels that are of a real importance in case that an analysis of the signal quality is needed: these might include: probability density function of the received signal strength, duration of fades, level-crossing rate etc.
There are also several propagation studies in the scientific literature, some of them being based on the ray theory, or the modal theory. Dudley et al. (Dudley et al., 2007) state that the propagation is not prohibitive in terms of signal attenuation in the tunnels, therefore the tunnel must behave as a waveguide. Moreover, its dimensions have to be superior to those of a normal waveguide, that the wavelength has to be much smaller than the cross-section of the tunnel. At 2.4 GHz, the wavelength of the WiFi signals are around 12.5 cm, so this condition is obtained in subway tunnels. Usually, the ray theory describes the propagation conditions in a tunnel considering the cross-section shape, the origin point (where the transmitter is placed) and geometrical specificities (dimensions: width and height of the tunnel). For obtaining the reception conditions, the contributions of all rays connecting transmitter with receiver are considered (reflections on the walls, absorption coefficients of the walls etc.).
Some authors (Lienard et al., 1997) showed that if the distance between the transmitter and the receiver of the radio signals becomes greater than the largest cross-section tunnel dimension, the waves remain almost linearly polarized. Then the electric field radiated by the antenna and its images becomes (source: Mahmoud & Wait, 1974):

$$E(x,y,z) = \sum_m \sum_n (R_{TM})^m (R_{TE})^n E_d(S_{mn}) \tag{1}$$

where $(R_{TM})^m$, $(R_{TE})^n$ are the received magnetic and electric fields strengths at the reception point, $E_d(S_{mn})$ is the electric field radiated in free space by the image source S_{mn} and corresponding to rays having *m* reflections on the walls perpendicular to the transmitter dipole axis and *n* reflections on the walls parallel to the dipole axis.
In the modal propagation theory, Mahmoud et al. (Mahmoud, 2010) show that any electric field component $E(x,y,z)$ can be expressed as the sum of the modal components:

$$E(x,y,z) = \sum_m \sum_n A_{mn}(0) e_{mn}(x,y) e^{-\gamma_{mn} z} \tag{2}$$

where $A_{mn}(0)$ stands for the complex amplitude of the mode in the excitation plane, $e_{mn}(x,y)$ the normalized value of the eigenfunction, γ_{mn} the complex propagation constant. The authors also show that in the case of lossy dielectric walls of tunnels, approximations are needed. In (Molina-Garcia Pardo et al., 2008) is given an example of calculation for a rectangular shaped tunnel, orthogonal model, with walls characterized by an equivalent conductivity of $\sigma = 10^{-2}\, {S}/{m}$, and relative real permittivity of $\varepsilon_r = 10$.

Table 1
Example of attenuation for a 1 km length tunnel for hybrid modes, 2.4 GHz

	n = 1	**n = 2**	**n = 3**
m = 1	4.6 dB	17 dB	38 dB
m = 2	6 dB	18 dB	40 dB
m = 3	8 dB	21 dB	42 dB

Source: (Molina-Garcia Pardo et al., 2008)

When considering a typical tunnel environment, where the propagation medium is the air and the reflection/penetration medium is the concrete wall, the reflection coefficient depends on the signal wavelength λ, angle of incidence θ_i, relative permittivity *r*, conductivity σ and relative permeability μ_r of the wall and polarization of the radio wave (Saunders, 1999). Similarities with the radio propagation of signals in waveguides appears in tunnels with transverse dimensions that are several times larger than the wavelength of the signal (Zhang, 2003). Due to this waveguide effect, as also demonstrated by effective field tests, the attenuation of radio signals in tunnels is significantly lower than in open space and decreases when frequency increases. Considering a hypothetic waveguide with pure metallic walls, the electromagnetic field propagation allow transverse electric (TE) and transverse magnetic (TM) modes to propagate through the waveguide. The indices *m* and *n* denote the electric and magnetic fields peaks in the transverse plane. The basic mode in a waveguide is TE_{10}, with no peaks of the magnetic field and a single peak of electric field in the transverse plane. The TE and TM waveguide modes propagate when the frequencies are higher than the cutoff frequency f_{mn}, where *m* and *n* denote the TE and TM waveguide modes. The waveguide effect is not present for frequencies situated lower than cutoff frequency, and the signal energy lowers exponentially with distance (Deryck, 1978). The two-slope path loss model is suitable for analyzing signal propagation in tunnels with line of sight, with transmitters and receivers positioned aside from tunnel's walls and floor. These models are applicable when measurements of received signal strength are available (Masson et al., 2009).

Static modelling of radio signals propagation in tunnels may be sometimes complicated or time consuming, but these difficulties become even harder when obstacles and moving objects need to be considered for obtaining more accurate results. Moving objects in road and railway tunnels induce rapid modifications in the propagation conditions, leading to the need for empirical path loss channel model employment, suitable for planning mobile communication system coverage in tunnels, which are mostly, due to difficult propagation conditions in road and railway tunnels, two-slope models (Hrovat et al., 2014).

2.2. Elements that Influence the Radio Signals Propagation in Tunnels

There are many elements that have to be considered when analyzing the influence on the radio signals propagation along the tunnels designed for roads and railways. Considering their variation in time and space, these can be further divided in static elements and dynamic elements. Static elements include: frequency and modulation of the employed radio signals, geometrical parameters of the tunnel, such as cross-sectional shape, cross-section dimensions, walls properties (surface roughness, absorption coefficient and other electromagnetic properties), fixed obstacles, materials and positions, antennas features etc. Dynamic elements include vehicles and traffic. Following is a brief description of static elements influences:

1. The tunnel geometry and especially the cross-section have an important influence on the attenuation rate. The most employed shapes of tunnels in different modeling approaches include rectangular and circular shapes. But most tunnels, for example, designed for railways, have an ovoidal shape. Therefore, Chang-sen (Chang-sen, Li-fang, 2010) propose the following equation for the radio signal attenuation:

$$\alpha = \xi\lambda^2 \left[\frac{\epsilon_r}{w^3\sqrt{\epsilon_r - 1}} + \frac{1}{h^3\sqrt{\epsilon_r - 1}}\right] \tag{3}$$

   where *w* is the maximum tunnel width, *h* the maximum height, and *r* is the relative permittivity of the tunnel walls and floors. The value of coefficient ξ varies with the shape of the tunnel: values ξ = 5.09, 4.343, 5.13 and 4.45 are used for a circular, rectangular, arched and oval tunnel, respectively.

   It has been demonstrated theoretically and experimentally that elements with important influence in signal attenuation are the cross-section shape and dimensions, and the curvature of the tunnel. Vertical and horizontal dimensions of the tunnel cross-section influence the correspondingly polarization modes. Tunnel curvatures allow only reflected waves to reach the receiver.
2. The tunnel walls composition is affecting less the signals propagation. The attenuation rate of the vertical polarized waves is higher than that of the horizontal polarized waves, if the tunnel width is larger than its height.
3. Antennas positions, radiation pattern and polarization. These elements influence non line of sight (NLOS) and line of sight (LOS) propagation conditions, and the usage of omnidirectional and directional antennas must be adapted to the local conditions. Measurements made by different researchers showed that the most suitable position of the antenna for reduced attenuation is in the middle of the cross-section, while placing the antenna near the tunnel's walls creates worst conditions for propagation.

The influence of trains over radio signals in tunnels is analyzed in (S. Wang, 2010).

Concluding, it must be said that modeling for radio signals propagation through tunnels is an important step in the design of smart applications using radio communications. Users of the transport system expect the provision of mobile wireless services in tunnels with the same efficiency as in open space. In addition, the provision of wireless services is critical for public protection and disaster relief forces in underground environments.

3. Development of Communications Towards Internet of Smart Trains (IoST)

The transport demand on railways is always seen as a convenient mode that is less pollutant, rapid and safe. However, in urban areas, the subway must be further extended as an alternative to the congested surface road traffic. This means extending the network, improving the comfort, introducing new information services, e-ticketing and last, but not least, improving the preventive maintenance, in order to keep trains to schedule and avoid interruptions. With the new development of communication technologies and big data concept, with the extension of wireless sensor networks, the future seems to be that of the smart trains, inter-connected via Internet. Figure 1 shows an overview of the possible features of IoST.

IoST features and provided services must be finely tuned according to railway type: urban (either surface – light metro, or subway, urban/intercity (peri-urban), intercity, or high-speed lines. However, even if tunnels may be present on all types of lines, the subway environment is 100% developed in inner spaces, with stations, platforms, pedestrian tunnels and trains tunnels. This is the most challenging environment for the implementation of such wireless technologies and experimental studies have to be carried on in order to determine which technologies are the most appropriate for ensuring enough bandwidth, coverage and quality of service for a such large palette of applications. While not specially developed for such applications, the IEEE 802.11 Wi-Fi continues to be very popular amongst travelers and it can be employed as a means for indoor localization, useful for determining the transport demand, passengers flowing, e-services and e-information for multimodal transport. Also, this communication technology may be employed as a secondary means for communicating emergency warnings, routing and other useful information to travelers.

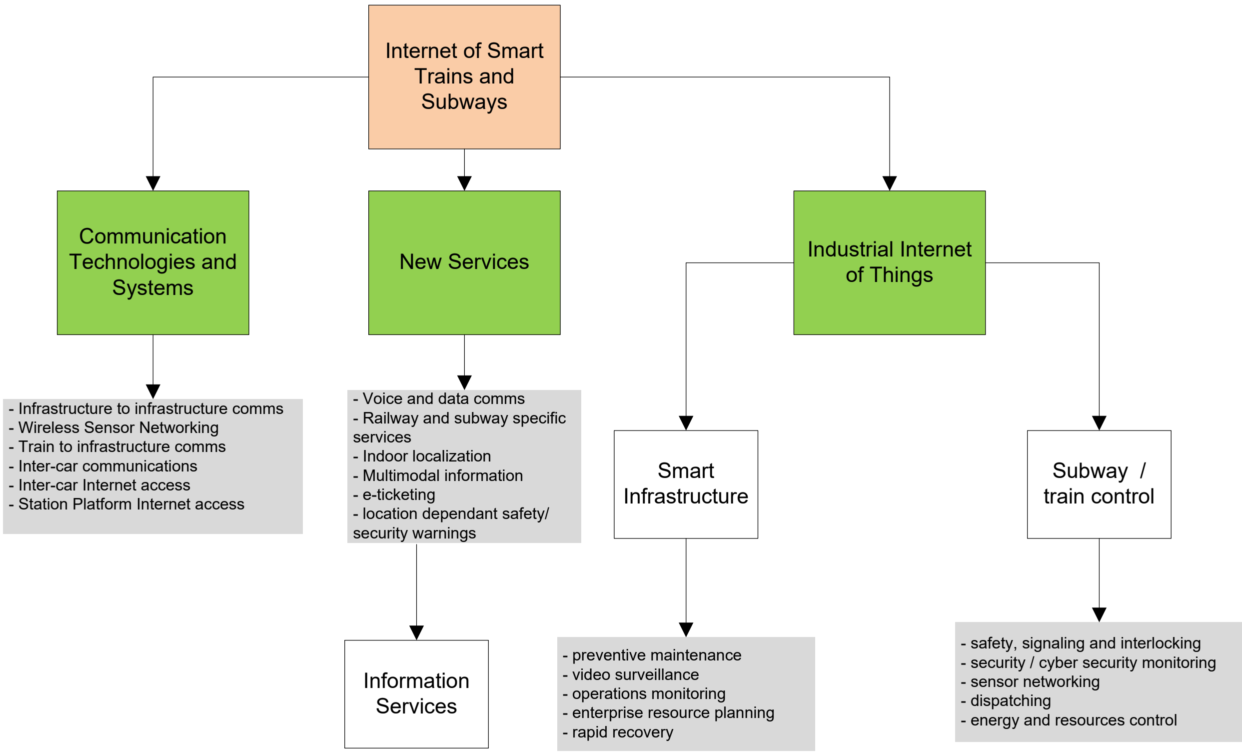

Fig. 1.
Overview of the Internet of Smart Trains applications, services and technologies

Another important aspect is the electromagnetic compatibility. In the context of a continuous development of wireless communication technologies, it is critical to also study the impact of multiplying the communicating devices in a relatively closed environment, such as the subway tunnels and stations. Will the technologies be able to work together, with maximized number of users (both humans and machines) and to deliver information with a reasonable delay and quality of service? Therefore, we consider that performing tests with all communication technologies is important for the successful implementation of the smart features in the subway transportation. On the other hand, new, promising technologies are already in development or testing, such as Wireless Gigabit (WiGig – IEEE 802.11ad), Light-Fidelity (Li-Fi, IEEE 802.15, or Visible Light Communication - VLC) on medium term, operating on non-licensed 60 GHz band (57-66 GHz), offering high-speed, low latency, large throughput, on point-to-point transmissions up to 10 meters.

4. IEEE 802.11 Experiments in Subway Environment

4.1. Coverage of Radio Signals in Tunnels for Quasi-Free vs. Disturbed Electromagnetic Environment Conditions

Transmission of radio signals into the tunnel is affected by multiple reflections that appear on the walls of the tunnel and on the surface of the mobile (typical case – subway train), generating a complex pattern of random waves. Propagation in these conditions can be modeled by assimilating the environment as a dense one, with many reflections and multiple points of transmission or repetition. However, for a correct evaluation of the propagation conditions, in order to have a good start in modeling the signals propagation process, it would be useful to firstly perform field tests in a quasi-free of interferences environment, that is, in a tunnel with all signaling equipment, but not yet operational.
For these tests, a Wi-Fi access point (AP) has been established at one end of a 550 meters long subway tunnel on Bucharest M4 mainline, near a subway station. Signal strength measurements have been performed each 3 or 6 meters from the AP, determining the maximum communication range, evolution of signal received strength and influence of metallic cabinets on the walls. The test bed set up is presented in Figure 2. The catenary equipment for this type of metro line is installed on the ceiling as an additional power supply support (usually not in operation) and as the 3-rd rail, normally employed for subway power supplying, were not connected, but still present as metallic objects along the path. Also, a series of metallic cabinets were present in the tunnel (not represented in Figure 2), separated at around 50 meters each other. The only system powered in the tunnel was the lighting one. For the measurement of signal strength, Wi-Fi Analyzer application was installed on a mobile phone to determine signal loss along the tunnel.

Distance was measured employing a laser meter, working for the first 100 meters from radio source. Afterwards, a metallic tape of 5 meters was used for making distance measurements.

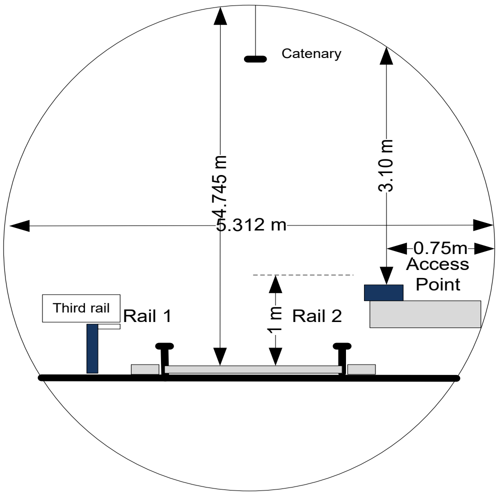

Fig. 2.
The test bed setup for tunnel propagation (M4 line, Bucharest, Laminorului Station)

The measurement was performed in the conditions described above. Results are presented in Figure 3. It can be seen from this diagram that the coverage is longer than in open space, and there can be observed the two typical zones: near field, extending to approximately 30 meters from the AP, where the field decreases significantly, and the far field, beyond 30 meters, where a relatively slow variation of RSSI has been recorded.

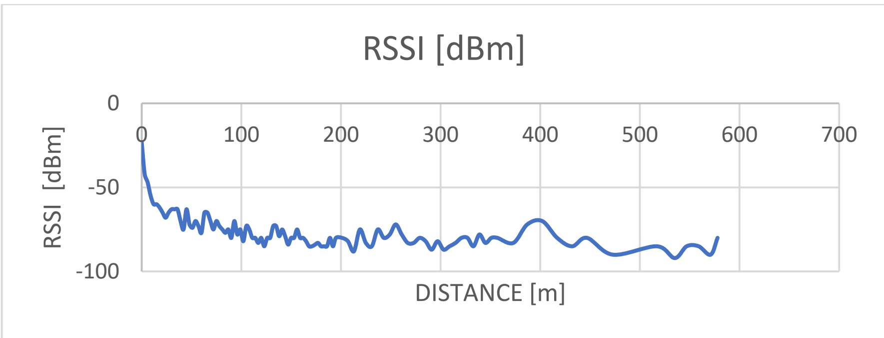

Fig. 3.
RSSI measurement in free electromagnetic environment (tunnel, M4 line, Bucharest, Străulești-Laminorului Stations)

As it can be noticed in figure 3, the variation of the received signal strength indicator stretches within approximately 25 dBm, being most likely caused also by the presence in the tunnel of some metallic cabinets. On the other hand, a clear connection could be established between the two ends of the tunnel, at the distance of approximately 550 meters. The devices connected, and Internet could be accessed.
The same measurements have been performed with congested electromagnetic environment, in the *Unirii* subway station, to determine if the distance the two devices could connect suffers from traffic on all Wi-Fi channels (except channel 14, which is not employed in Romania).

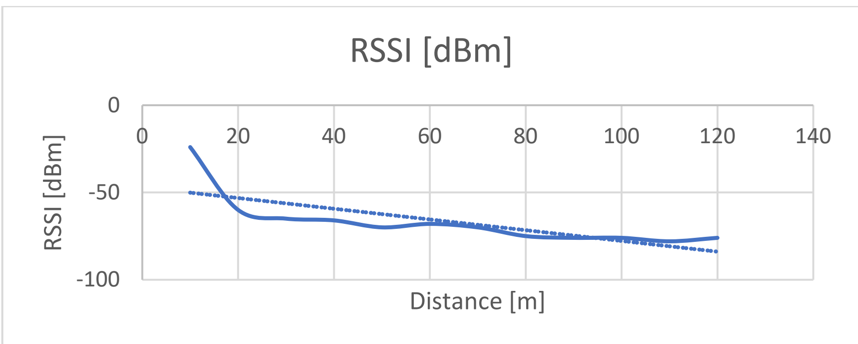

Fig. 4.
RSSI measurement in disturbed e.m. environment (subway station, M1 line, Bucharest, Unirii 1 Station)

As it can be observed in figure 4, the near field distance drops in this case to approximately 20 meters and the maximum connection distance also shortens to around 130 meters. The geometrical conditions for this measurement were also different: instead of a train tunnel, the measurements were performed in a rectangular shaped, larger space, with central concrete pillars. Considering the electromagnetic environment, almost all Wi-Fi channels from 1 to 13 were fitted with different devices communicating during the tests.

4.2. Distance Measurement based on RSSI for Indoor Wi-Fi based Localization

Subway applications for indoor mobile devices localization may have a lot of benefits, including: adaptive travel information regarding the pedestrian segment between successive subway boarding (when moving between different platforms or multi-modal stations), location dependent - adaptive travel information, location dependent emergency warnings etc. Open space localization techniques, such as GPS or GSM cell trilateration are less applicable, due to the weak degree of penetration of GPS signals inside subway environment on one side, and the necessity to involve supplementary services from a third part operator, in the case of GSM pico or nano cell trilateration, on the other side. Instead, installing and knowing position of different APs in the subway environment and using them as reference points for mobile applications and indoor localization could prove beneficial for both subway transport users and planners. The indoor localization employing Wi-Fi may be performed via analyzing the RSSI or the strength of the radio signals received from three or more APs with known position, by trilateration. The received signal strength by the mobile device can be used for distance estimation between APs and the connected mobile device(s). Of course, there are a lot of variables that could influence the strength of the received signals, such as the shape, dimensions and pattern of the indoor spaces, number of mobile devices active at a moment, local propagation conditions etc. However, for the above-mentioned applications, precise indoor localization might not prove necessary. Therefore, performing some tests regarding the precision of this method has been considered useful.
In the triangulation process, the RSSI measurement according to three APs is necessary to obtain mobile device location:

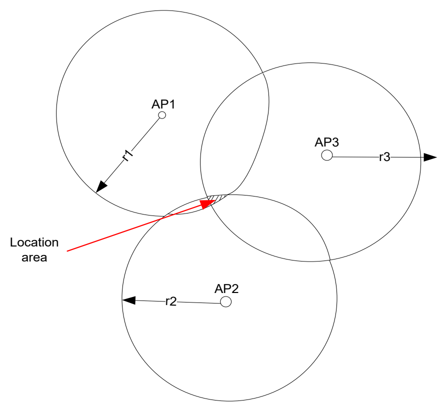

Fig. 5.
RSSI-based location measurement by triangulation

The location area is provided by the intersecting volume between the three spheres (or the intersecting surface from the three circles in plane, for a 2-dimensional location). Thus, considering the coordinates in a XoY reference system, the distances r_1, r_2, r_3, representing the geometrical places of points with equal RSSI corresponding to the three APs can be obtained from the following equations:

$$
\begin{aligned}
r_1^2 &= (x - x_1)^2 + (y - y_1)^2 \\
r_2^2 &= (x - x_2)^2 + (y - y_2)^2 \\
r_3^2 &= (x - x_3)^2 + (y - y_3)^2
\end{aligned} \tag{4}
$$

where x_1, x_2, x_3 and y_1, y_2, y_3 are the coordinates of the three APs, x, y – the coordinates of the located mobile and r_1, r_2, r_3 the measured distances to the three radio transmitters.
A field measurement has been performed in *Politehnica* subway station, to determine what are the errors in RSSI measurement. The Wi-Fi Strength Meter application was employed to determine by direct measurement the distance to the AP, in order to compare precision with the direct (field) distance measurement. The results are presented in the table below:

Table 2
Field measurements values for one link with AP, Politehnica subway station

Crt.no.	Real distance [m]	RSSI-based distance measurement [m]
1	2	2.17
2	10	10.87

3	20	12.2
4	30	13.98
5	40	30.63
6	50	61.12
7	60	68.58
8	70	96.88
9	80	153.54
10	90	108.7
11	100	172.27
12	110	172.27
13	120	199.29

The graphical representation of the measured values is presented in figure 6.

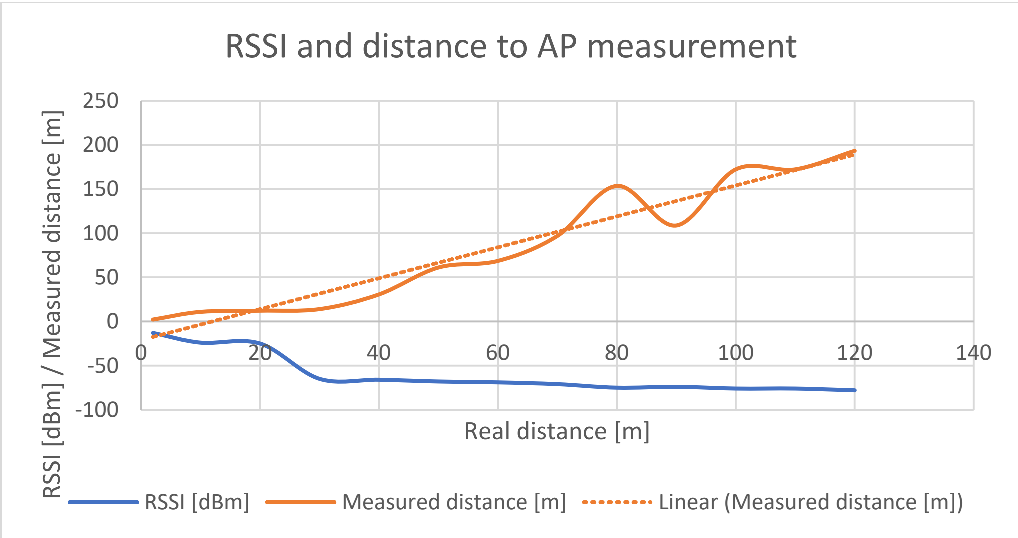

Fig. 6.
RSSI-based distance measurement in Politehnica subway station

In Figure 6 it can be noticed that the precision of the distance measurement decreases with distance from the access point, reaching sometimes around 50%. The most precise direct RSSI distance measurements were obtained below 70 meters from the radio source. The real distance is represented with dot line (measured in the field with a metallic band). To determine the RSSI stability in time, several samples of RSSI and RSSI measured distances were taken from the same location, at different moments in time. Results are presented in table 3:

Table 2
Static field measurements values for one link with AP, Politehnica subway station (same location, different moments)

Time [s]	RSSI based distance measurement [m]	RSSI [dBm]	Time [s]	RSSI based distance measurement [m]	RSSI [dBm]
0	11	-61	80	7.79	-58
5	9.81	-59	85	11	-62
10	8.74	-58	90	11	-62
15	9.81	-59	95	12.35	-61
20	12.35	-60	100	11	-61
25	11	-61	105	9.81	-60
30	11	-61	110	9.81	-60
35	9.81	-60	115	9.81	-60
40	8.74	-59	120	11	-61
45	11	-60	125	9.81	-60
50	8.74	-59	130	11	-61
55	9.81	-60	135	11	-61
60	8.74	-59	140	11	-61
65	9.81	-60	145	11	-61
70	11	-61	150	11	-61

75	9.81	-60	155	9.81	-60

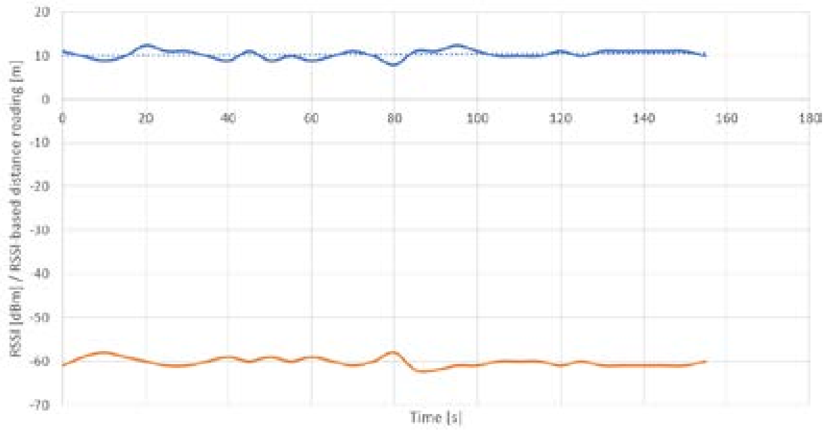

Fig. 7.
RSSI-based distance measurement. Variation in time – same location point, 10 meters from AP

As it can be observed from Figure 7, the RSS level varies in time, so for a more precise location determination it is necessary to perform an averaging of the measured values. In this particular case, the measured variation reached 24% error rate at 2432 MHz, dual channel link (channels 5+9), 72 Mbps speed of the connection. The average RSSI measured value reached 10.2925 meters, with approximately 3% error in distance measurement for 32 signal acquisitions taken from the same location. According to (Bobescu, 2015), the observational error in dBm, denoted by Δ, can be determined with the following formula:

$$\Delta = \sqrt{\sigma \cdot t + \varepsilon^2} \quad (5)$$

where σ represents the standard deviation divided by the square root of number of measurements and ε is the error of the mobile device.

4.3. Considerations Regarding the Effects of Communicating Devices Density on the Quality of Service

With the increasing number of communicating devices on the 2.4 GHz and 5 GHz bands the problems that might arise include delays in data delivery, low access to services, reduced data throughput etc. Some of these disadvantages may affect a series of envisaged services that strongly depend on correct time delivery of messages and are not tolerant to delays. These services include: dynamic route guidance, presentation of trains' schedule, emergency messages delivery etc. In order to avoid such drawbacks, considering the subway environment is a relatively isolated medium from the e.m. field point of view, a solution would be to pre-program the APs to employ only some Wi-Fi channels for usual messaging and to reserve dedicated channels to special requirements messages, such as those being delay non-tolerant. Of course, as IEEE 802.11 is an open communication standard, there might be found at a time some private (mobile) devices owned by travelers, that employ the reserved channels for their communications needs, but this would be only a temporary disturbance. However, the 5 GHz band is recommended for such special communications, being less used.
Another solution would be to give a certain degree of (configurable) priority to delay non-tolerant messages. The problem of congested channels is more acute in the subway stations, where travelers waiting for trains on the platforms, and the temporary stopped trains that also contain connected users might overload the Wi-Fi channels. In the connecting corridors, this effect might be less significant, due to the reduced number of mobile users. An example of most used channels for fixed Wi-Fi communications in the presented case study is shown in Figure 8.

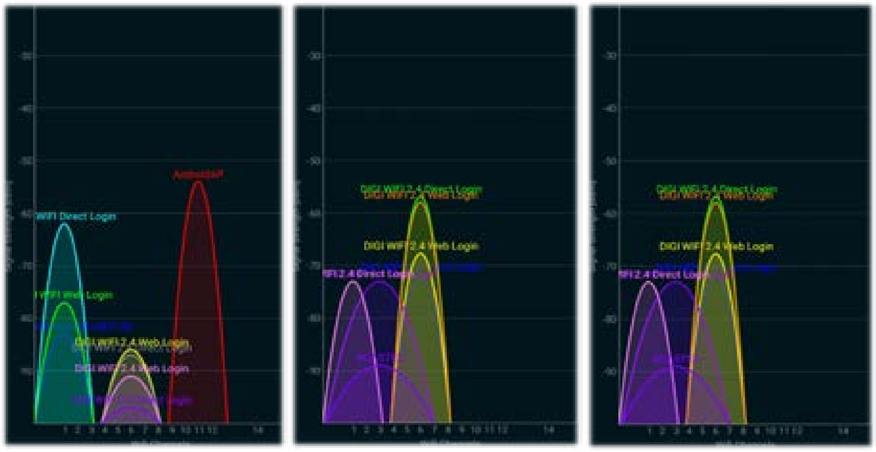

Fig. 8.
Example of permanently employed Wi-Fi channels in a M4 station from Bucharest subway (no private users with mobile hotspots). Channels 1 and 6 are the most crowded (Wi-Fi Analyzer app on Android 7.1.1 device used for measurement)

5. Development of Wi-Fi-based Services Towards Smart Subways

The future implementation of smart services in subway transportation is strongly relying on the efficiency of the indoor communication technologies. IEEE 802.11 is a mature technology, well developed and tested and, moreover, widely spread on all mobile devices present nowadays in the hands of all travelers. By employing location technologies, location-dependent information services, both transport stakeholders and travelers can benefit from the implementation of new services. From the tests performed on the M4 subway mainline in Bucharest, it resulted that:
- Wi-Fi-based location can be employed to determine relative position of travelers in the subway environment. Estimated precision is 10% to 30% from the distance to APs, dependent on:
    - the subway infrastructure element configuration (connecting pedestrian tunnel, station etc.);
    - the degree of Wi-Fi channels congestion;
    - type of application determining the RSSI, convertor to distance etc.
- emergency messaging with a high QoS applicable only if dedicate channels, or message prioritization technique is developed;
- multimedia sharing, internet access in halls, connecting tunnels and subway platforms with speed dependent on the number of users and number of APs;
- the QoS for multimedia sharing and internet access in subway cars and between cars not yet tested.

An overview of the envisaged Wi-Fi-based smart services for subways is presented in Figure 9. In the diagram the delay non-tolerant, prioritized channels are depicted with thicker line.

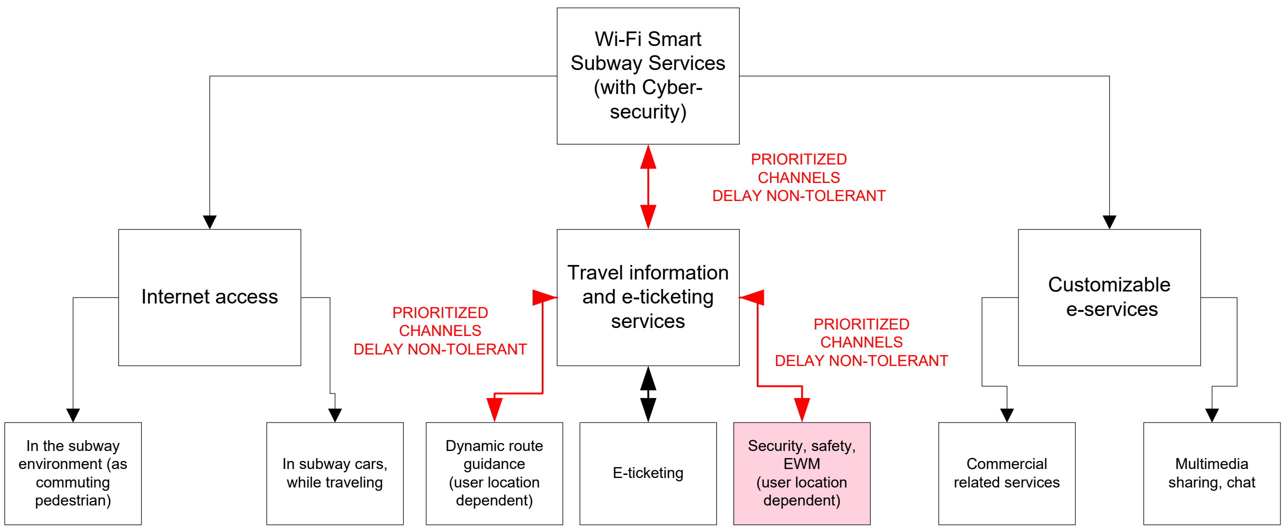

Fig. 9.
Overview of possible Wi-Fi-based smart services to be developed for the subway transport

Conclusion

The tests conducted for this research are considered preliminary. In this phase, these tests were performed in a quasi-free of electromagnetic interference environment. The purpose was to determine, in best conditions (no electromagnetic disturbances and LOS) the maximum range that a Wi-Fi based communication can be established in a subway tunnel. The results were promising, as compared to the open field, the subway tunnel environment behaves similarly with a waveguide, prolonging the range of Wi-Fi signals. A 550 meters stable link could be established between an access point connected to Internet and the mobile device, allowing for information exchange. However, the purpose of these tests was to determine how far a Wi-Fi mobile device, boarded on a subway train, could become in direct link with an access point installed, for example, at the next station. This could help employing this communication technology for additional safety services that are not embedded in the normal interlocking features, such as the early warning announcement of a fallen object on the lines near the platforms (in the subway station). As mentioned before, such an event is not detected normally by the track circuits or other technology for sensing the train presence on a certain track sector. Varying in a certain domain the conditions of the communication tests, additional information could be drawn, such as the behavior of communication distance and message delaying, depending on the number of Wi-Fi channel users. As experiments shown, with the increasing number of users, the message delaying also increased. The solutions would be to employ prioritized messages or dedicated warning message channels.
A third series of tests was conducted to determine the precision in distance measurement between a fixed access point and a mobile device, for obtaining information relative to the usability of Wi-Fi communication for indoor localization. No triangulation has been performed in this phase of testing, solely direct RSSI-based distance measurement. The experiments revealed that the precision of this technology is relatively low, but still enough good for specific smart-subway applications, such as route guidance, location dependent warning and messaging etc., contributing significantly, yet still economically to the evolution of the subway transportation system towards "smart" features. It is in the intention of the author to continue in the future these tests in more specific conditions, such as performing triangulation and also employing different Wi-Fi communication standards, to determine the most from the applicability of this communication technology in the development of smart subways and Internet of smart trains.

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EXPLOITING ITS TECHNOLOGIES THROUGH A TRAFFIC SUPERVISOR SYSTEM TO SUPPORT STRATEGIES AND ACTIONS PROMOTING SUSTAINABLE MOBILITY

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Abstract: In the last decade, a big European effort has been made in terms of research, strategies and initiatives to boost new forms of sustainable urban mobility, in order to reduce the externalities associated with the transport sector. Among the other instruments identified to achieve this goal, the European Commission (EC) emphasizes integrated planning at all mobility levels, to be realized through Sustainable Urban Mobility Plan (PUMS) and its management and also through Intelligent Transport Systems (ITS). In fact, although the EC considers that urban planning is the result of a joint effort on several fronts, on the other hand it is equally important to make technologically modern mobility system, in order to maximize its efficiency. With regard to this technological modernization, the introduction of ITS systems, based on interaction between computer technology and telecommunications, makes it possible to tackle mobility problems in an innovative way, with a systemic approach, considering transports as an "integrated system", in which information, management and control synergistically work, optimizing the use of infrastructures, vehicles and logistics platforms. Based on this premise, this work provides a discussion about the introduction of ITS as a tool to be exploited for the promotion of sustainable urban mobility with ITS technologies' support, particularly referring to the case of a municipality of the metropolitan area of Catania (Italy). Sensors traffic data are obtained through the implementation of a real-time traffic monitoring system with related infomobility services, and through heedful analysis and interpretation, they will constitute the basis for monitoring actions with before-and after- analysis and making the users more informed. Furthermore, these data can be profited to assist traffic planners and managers in their decision-making procedures and improve the support traffic management system.

Keywords: intelligent transport systems (ITS); real-time traffic monitoring system; traffic management; sustainable mobility.

1. Introduction

In every country, mobility is a major value to the people because economic activities and social welfare depend on it, and people consider it a major asset of their life, as they can move freely, safely, quickly and at a reasonable expense (Boltze and Tuan, 2016). However, the constantly-growing transport demand is reflected in critical issues characterized by reduced or insufficient capacity, safety, environmental compatibility, and economic efficiency. These problems are significant for both passenger and freight transport (Zawieska and Pierigud, 2018).
Many European cities suffer from traffic congestion, with annual costs estimated at 80 billion euro. European urban areas, as well as being responsible for a very large part (about 23%) of all CO_2 emissions from the transport sector, also have a high number of fatal accidents. An estimated 28,000 in 2012 around 40% takes place in the urban centres (Mastretta & Burlando, 2007).
To deal with the transport problems, the first question is always that sufficient infrastructure is important. But providing infrastructure alone cannot solve the problems completely because transport infrastructure can't be endlessly extended to catch up with demand growths. Furthermore, it is important to highlight the aspects related to measures to increase the capacity. "Capacity" should not be defined by traffic flow characteristics only; instead it must consider other aspects, such as acceptable levels of noise and air pollutions along the infrastructure (Boltze and Tuan, 2016).
In the light of this considerations, it is necessary to implement actions and measures able to promote sustainable mobility, characterized on the three dimensions/pillars/vectors: environmental, social and economic. Ensure transport system sustainability requires developing transport system control procedures as well as strong measurement and decision-making tools.
The gradual integration of technology into roadside infrastructure has contributed to substantial savings from environmental and socio-economic perspectives (Kolosz and Grant-Muller, 2015). In this way, innovative transport systems, better mobility planning and smart urban transport solutions might promote a more sustainable mobility.
Based on this premise, this work provides a discussion about the introduction of Intelligent Transportation Systems (ITS) as a tool to be exploited for the promotion sustainable urban mobility with ITS technologies' support, particularly referring to the case of a municipality of the metropolitan area of Catania (Italy).
The remainder of the paper is divided into five sections. After an introduction about mobility issues and the application of telematics in the transport sector, Section 2 discusses about the PUMS (Piani Urbani della Mobilità Sostenibile) concept and the role of ITS to support strategies and actions promoting sustainable mobility. Section 3 describes the research methodology and data collection. Section 4 presents the case study with first results about the relevant data collected. Section 5 concludes the paper by summarizing the main findings and directions for further development of the research.

2. The Role of Telematics in Traffic Management

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As urban mobility is a key societal challenge (Jeekel, 2016), it is addressed in a number of the European Commission's (EC) documents, including *Green Paper on Urban Mobility* (EC, 2007) and *Action Plan on Urban Mobility* (EC, 2009a, EC, 2009b). The most comprehensive document directly concerning the governance of sustainable transport in cities is the *Urban Mobility Package* adopted in December 2013, which again, proposes fundamental changes in the way urban mobility is designed and managed (EC, 2013). It emphasizes the efficiency and hence the need for implementation of Sustainable Urban Mobility Plans (SUMPs) prepared following the EC's guidelines (Wefering et al., 2014).
The EC also issued recommendations regarding the main areas of urban transport management, emphasizing the role of smart solutions (Zawieska and Pieriegud, 2018). In particular, according to the new ministerial decree (MIT, 2017), which aims to promote the homogeneous and coordinated application of guidelines for the drafting of PUMS, throughout the national territory, ITS play a key role in the integration of transport systems.
The PUMS is a strategic planning tool that, over a medium-long term (10 years). It develops a systemic vision of urban mobility, proposing the achievement of environmental, social and economic sustainability through the definition of actions aimed at improving the efficiency of the mobility system and its integration with urban and regional planning and development. Among the procedural steps that are necessary for drafting and approval of PUMS, there are the predisposition of the cognitive framework and the monitoring.
In this context, the introduction of ITS systems, based on interaction between computer technology and telecommunications, makes it possible to tackle mobility problems in an innovative way, with a systemic approach, considering transports as an "integrated system", in which information, management and control synergistically work, optimizing the use of infrastructures, vehicles and logistics platforms (Torrisi, 2017).
As mentioned, since infrastructure extension alone cannot handle the traffic problems, Traffic Management seems to be an effective strategy to deal with the problems and contributes to achieve sustainable development.
Therefore, ITS technologies are capable to influence both transport supply and demand, and to balance them as to maximize the positive impacts (i.e., benefits) and to minimize the negative impacts (i.e., costs). The balancing of supply and demand brings about the concept of traffic management with a consequent reduction of impacts on the external environment (Figure 1).

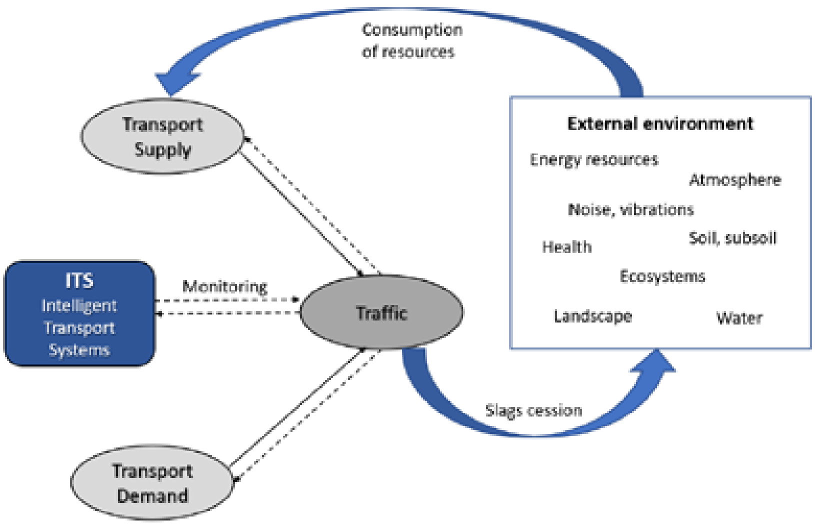

Fig. 1.
The role of ITS within the transport demand and supply and their interactions with energy and the external environment

3. Research Methodology and Data Collection

To achieve the objective mentioned in previous section, the methodological approach for this study has been designed and presented in the form of flow chart as shown in Figure 2.
As can be seen from this figure, this study combines a theoretical review with empirical investigation, based on the integration of PUMS and ITS technologies' contribution in the field of transport planning and management.
A recognition on the state of affairs was made to realize a conceptualization of the case study.
Subsequently, the data collection was carried out considering classified traffic volume counts, coming from a real-time traffic monitoring system. Then, a heedful analysis and interpretation was realized for the predisposition of the cognitive framework.

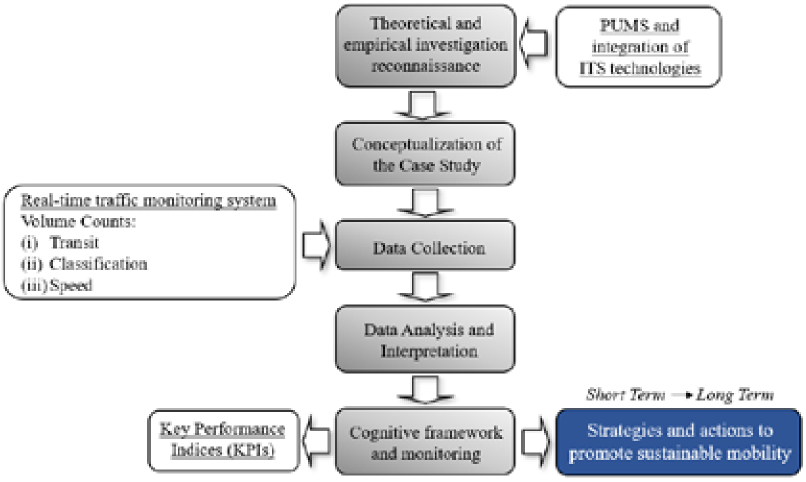

Fig. 2.
Devised methodology for the study

In particular, the basic variables used are hourly average traffic flows referred to the monitored links that belongs to the analyzed network. The monitoring system aggregates collected traffic data in 5-min intervals, and thus 288 time intervals *i-j* correspond to each day, with *i* indicating the beginning of the time interval and *j* as the end of the same time interval. Further, $f^{c}_{k,d,i-j}$ is defined as the average flow for the vehicular category *c*, at link *k* on day *d* during time interval *i-j*. Thus, the computation of the average flow associated with each monitored section of the traffic network for a consistent period of analysis is derived by a mathematical aggregation using the arithmetic mean method. From this remark, the dataset of traffic measures, symbolized by $F^{c}_{p,k,i-j}$, is constructed at link *k* and vehicular category *c,* for the period p (including all analyzed days d) and time intervals i-j, through the average calculation of all these link-traffic flows $f^{c}_{k,d,i-j}$, as shown in the Eq. (1):

$$F^{c}_{p,k,i-j} = \frac{\sum_{d=1}^{n} f^{c}_{k,d,i-j}}{n} \tag{1}$$

where: $F^{c}_{p,k,i-j}$ hourly average traffic flow of the monitored section and n is the total number of monitoring days considered for the analysis.

Through processed data and measures obtained with this system it will be possible to define composite performance indices (KPIs) for monitoring actions with before-and after analysis, in order to develop and assert an evaluation framework for transport planning and management according to the strategies contained in the Guidelines of PUMs and its management through ITS. Moreover, these results will be profitable to propose and implement application procedures to put in place some improvement strategies relating to short-term actions which aim towards long-term actions.

4. Case Study

4.1. Territorial Framework and the Study Area

The study area coincides with the Metropolitan Area of Catania, which is located in the eastern part of Sicily (Italy), on the coast facing the Ionian Sea (see Figure 3). It has an area of about 939 km^2 and it is the most densely populated in Sicily with a population density of 805,15 inhabitants/km^2 (Ignaccolo et al., 2017). It includes the main municipality of Catania and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania (Ignaccolo et al., 2016).

The various municipalities part of this metropolitan area have very omnifarious characteristics as regards the area (variable between more than 150 km^2 and less than about ten km^2) and the population (among fifty thousand and three thousand inhabitants) and their combination in terms of population density.

However, for the majority they are municipalities characterized by medium-sized cities that share similar problems related to a mobility strongly constrained by traffic and inefficient (private and/or public) transport. The historical and commercial center of these cities is primarily attainable through city's principal streets (see Figure 4), which often that are not compatible at all (not only in terms of road section) with required characteristics of a primary or secondary "collector" and consequently with the high traffic flows that instead pass through them. Moreover, these cities do not frequently have an adequate public transport supply able to provide the requested services and to act as a feeder for soft mobility and this entails a considerable motorized mobility demand in a central portion of the city. This heightened inclination to private mobility has favored the rise of high car ownership rates, greatly affecting on congestion phenomenon, pollution and energy consumption (Torrisi et al. 2016). According to this vision, the conditions of urban mobility of these cities could benefit from the valuable contribution given by the application of ITS technologies.

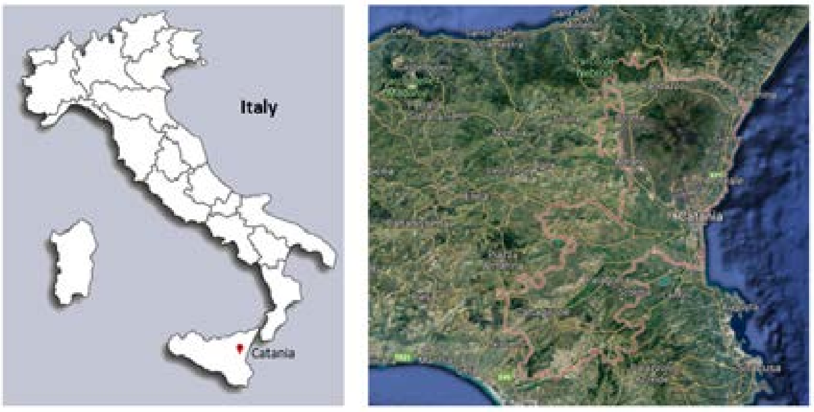

Fig. 3.
Catania - Satellite Images of Metropolitan Area of Catania
Source: (available at http://satellites.pro/Catania.Italy)

In this case, the key concept is to divert the traffic flow on arterial thoroughfares of the city enabling the fruition of some authorized parking zones (perhaps with low-cost fee for residents and workers) which allow to leave the own vehicle and go walking to the city center, thus decongesting the main streets. This certainly increases the livability of the city itself, as well as reducing all the externalities connected to the motorized mobility demand, from three points of view of sustainability: social, economic and environmental.
Hence, the described methodology is applied to several of these municipalities of the Metropolitan Area of Catania and the implementation of the supervisor system and the obtained results are provided as follow in the next sessions.

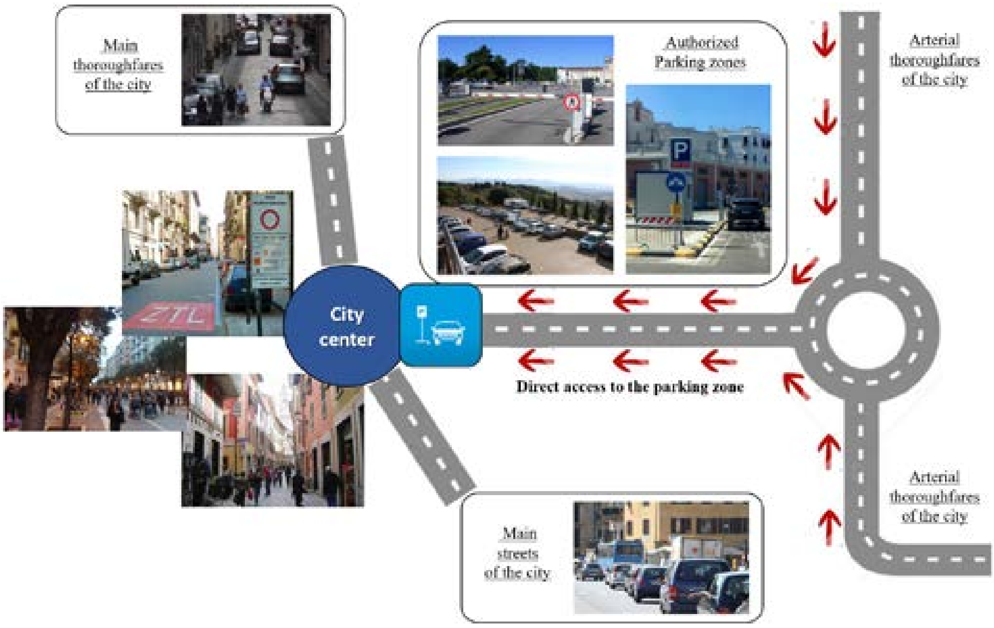

Fig. 4.
Alternative city center car parking idea

4.2. The Traffic Supervisor System and Implementation Description

In the urban area of Catania, the Department of Civil and Architecture Engineering of Catania's University has implemented a mobile ITS laboratory, which allows to know in real-time the traffic flows circulating on the network and simulate the occurrence of anomalous events, i.e. road maintenance, queues and accidents (Torrisi et al., 2018).
The architecture of this system consists of three levels:

- a *peripheral level* realized with traffic radar sensor installed on the road infrastructure and Variable Message Signs (VMSs) able to provide real-time users' information.
- a communication level characterized by a GPRS wireless network to connect the devices, i.e. radar sensors and VMSs with the central system.
- a central level made up of a monitoring and managing software and a simulation and elaboration software which respectively allow to remotely control and manage in real time the devices and to process collected data in order to

do traffic flows estimation and forecasting on the network (more detail can be found in Torrisi et al., 2017a, Torrisi et al., 2017b).

In the details of this study, it has been realized an extension of the traffic monitoring and management system, through the installation of additional devices on the infrastructure and the displacement of the two VMSs in several municipalities of the Metropolitan Area of Catania (as stated in previous section 4.1).
The detection and control units consist of a detection and storage unit of traffic data named Mobiltraf 300 Compact (MT300), with integrated a charge controller and a rechargeable battery through the connection with a photovoltaic panel power system. Moreover, they are equipped with an integrated detector of Bluetooth devices, a GPS tracking module and a communication module for data transfer to the control center via GPRS network.
The functioning of these traffic sensors MT300 is stand-alone, based on the latest technologies available in the field of 24 GHz radar frequency microwave, local signal analysis and remote communication, while offering great flexibility of utilization, low power consumption and high accuracy. They are able to detect the following data related to the transit of each vehicle: the date and the time of the single transit, the direction of travel and the transit lane, the speed (km/h), the vehicular classification (based on the length of the vehicle in cm), the gap and the headway (temporal distances in hundredths of a second respectively between the tails/the heads of 2 consecutive vehicles).
The images below (Figure 5) show the main features of MT300 used for the implementation of the traffic monitoring system and the technical installation scheme which provides the use of an infrastructure to hold up the radar detector sensor, positioned at about 1 meter from the road level, anchoring on it a small photovoltaic panel to guarantee the continuous power supply of the device.
Several site inspections were carried out for the identification of the monitoring sections, besides to taking into account the conditions of mobility related to the analyzed area, according to the characteristics related to the vehicle tracking radar detection of MT300.
The operating experimentation implemented provides a semi-permanent installation for a medium-long detection campaign. The devices have been set up in the GPRS communication network, in order to remotely transmitting collected data to the processing and control center in a completely automatic way: therefore, the acquired data are stored on site, recorded on files with a configured interruption of 5 minutes interval, and transmitted to the remote operations center each 5 minutes.

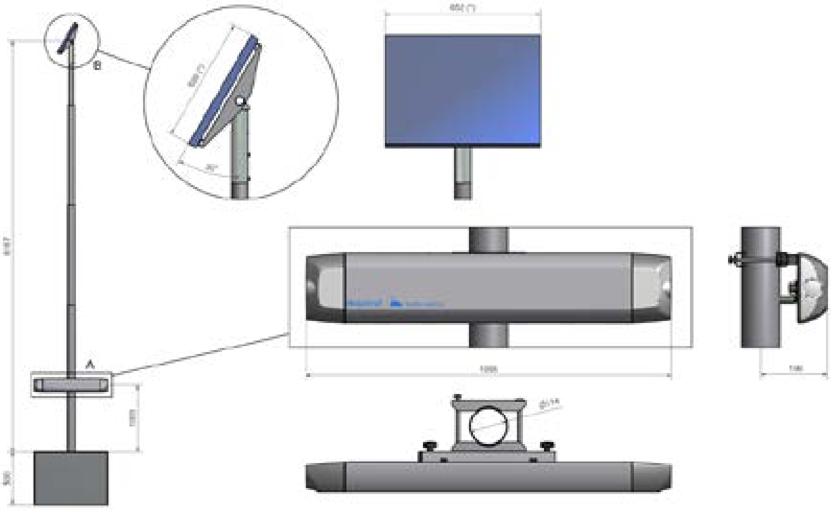

Fig. 5.
Technical installation scheme of MT300

4.3. Data Analysis and First Results

The initial basis of traffic data is essentially represented by the continuous records from detected flows by MT300 installed on the transport infrastructure, which have been configured by using *MobilTrafManager* software during the implementation of the traffic monitoring system and remotely managed via the *MMobility* software, whose graphical interfaces are shown in Figure 6.
As stated in section 3, the basic variables used are hourly average traffic flows referred to the monitored sections of the analyzed transport network. Because the employed variables are referred to time intervals of one-hour, transmitted traffic data of each 5-min are aggregated, and the time intervals i-j must be intended corresponding to one-hour lapse.
Moreover, in the Eq. (1), it is indicated the vehicular category c. In this case, the MT300 devices accomplish a classification on different 8 vehicular classes based on the length: motorcycles, cars, light and heavy commercial vehicles, buses, articled vehicle, road train and exceptional transport. To streamline the complexity of computation and provide out rightness of data analysis' significance, these classes are aggregated into two ones.
Hence, the Eq (1) is modified with according these following formulations (Eq. (2,3)):

$$F^{lv}_{p,k,h} = \frac{\sum_{d=1}^{n} f^{lv}_{k,d,h}}{n} \tag{2}$$

$$F^{hv}_{p,k,h} = \frac{\sum_{d=1}^{n} f^{hv}_{k,d,h}}{n} \tag{3}$$

where: h represents a single one-hour time interval during the day, lv indicates the light duty vehicular category (motorcycles and cars) and hv stands for heavy duty vehicle category (others).

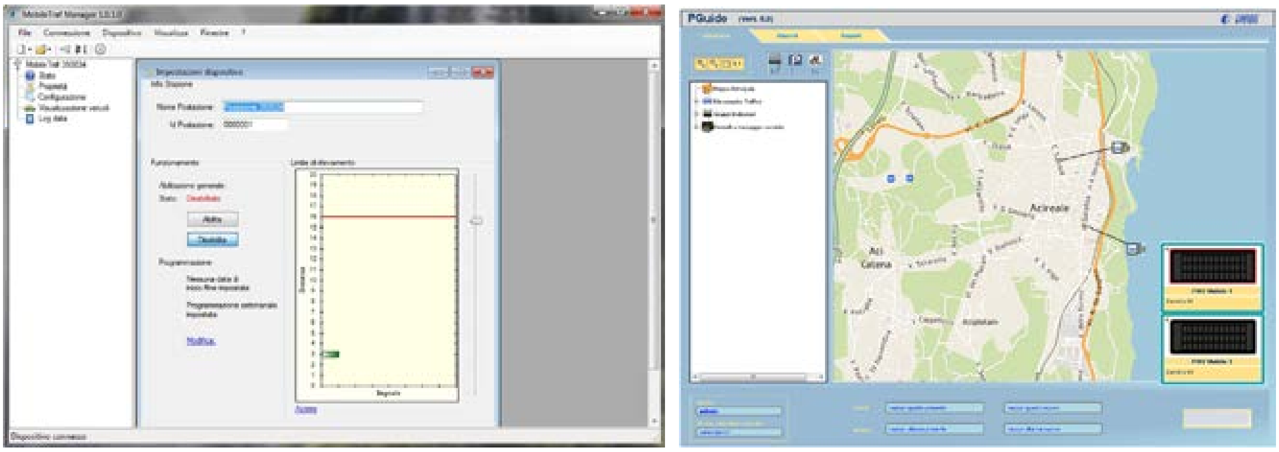

Fig. 6.
MobilTrafManager and MMobility graphical interfaces

These computations refer to real-time traffic data of two months, considering both working days and non-working day. It was also carried out an analysis on day-to-day traffic flow variations and on with-in day variations.
In this context, some explanatory results are analyzed and synthetized for two selected monitoring section: the first represented by a congested road axis to access to the city and the second one also characterized by the presence of some commercial activities, following named *MT_S1* and *MT_S2*. Table 1 shows the aggregated data for the two sections, deriving from the elaboration of collected data in field for the period of analysis.

Table 1
With-in day variation of average traffic flows of monitoring sections

Time Interval [h]	*MT_S1*				*MT_S2*			
	$F^{lv}_{p,k,h}$ [veic/h]	$F^{hv}_{p,k,h}$ [veic/h]	Total [veic/h]	%hv/tot [%]	$F^{lv}_{p,k,h}$ [veic/h]	$F^{hv}_{p,k,h}$ [veic/h]	Total [veic/h]	%hv/tot [%]
00:00	57	120	67	14.93	35	8	43	18.60
01:00	40	5	45	11.11	17	3	20	15.00
02:00	18	3	21	14.29	11	1	12	8.33
03:00	14	3	17	17.65	4	1	5	20.00
04:00	24	6	30	20.00	6	3	9	33.33
05:00	47	23	70	32.86	10	4	14	28.57
06:00	114	23	137	16.79	28	20	48	41.67
07:00	191	28	219	12.79	112	45	158	78.95
08:00	267	57	325	17.59	239	88	327	26.91
09:00	321	60	381	15.75	247	97	344	28.20
10:00	346	59	405	14.57	230	124	354	35.03
11:00	281	56	336	16.62	236	115	352	32.76
12:00	335	57	392	14.54	256	84	340	24.71
13:00	274	46	320	14.38	182	51	233	21.89
14:00	228	26	254	10.24	125	47	172	27.33
15:00	305	45	350	12.86	188	55	243	22.63
16:00	326	52	378	13.76	249	56	305	18.36
17:00	299	62	361	17.17	253	64	317	20.19
18:00	325	61	385	15.80	276	60	336	17.86
19:00	314	56	370	15.14	288	65	353	18.41
20:00	287	44	331	13.29	209	90	300	30.10
21:00	152	26	178	14.61	144	53	197	26.90
22:00	95	15	110	13.64	90	23	113	20.35
23:00	84	10	94	10.64	64	14	78	17.95

It is noticeable that for both monitoring sections there is a high variability of traffic flows, comparing the values reached during peak hours (even higher 400 veic/h in *MT_S1*) and off-peak hours. The most congested timeslots are substantially one in the morning from 10:00 a.m. to 13:00 a.m. and one in the afternoon from 5:00 p.m. and 7:00 p.m; specifically, in the case of *MT_S2*, it extends until 8:00 p.m., likely due to the fact that this road is substantially characterized by a high presence of commercial activities and so the decrease in traffic flows coincides with the closing time of the shops.
This observation has also repercussions on heavy traffic component. In fact, heavy duty vehicles of *MT_S1* constitute a percentage of the total flow varying between 10% to 30%; while in the case of *MT_S2* this range is represented by a wider interval - from around 8% to 78% reached in the early hours of the morning (7:00-8:00 a.m.), which would suggest the urban logistic aspect of delivering goods to commercial activities.
These findings are much more evident from a graphical point of view in Figure 7, which represents the with-in day variation of average traffic flows. By referring to a day-to-day analysis of hourly traffic flows, it is evident from the performed elaborations and highlighted in Figure 8 that there isn't a high weekly variability of traffic flows. However, in the case of *MT_S1* it emerged that, distinguishing between working and non-working days, the number of vehicles decreases for these last ones during the afternoon hours.

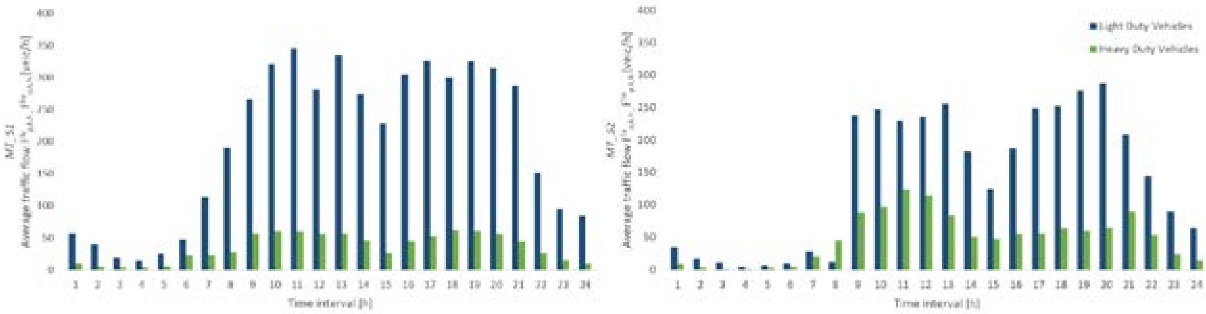

Fig. 7.
With-in day variation of average traffic flows: MT_S1 (left) and MT_S2 (right)

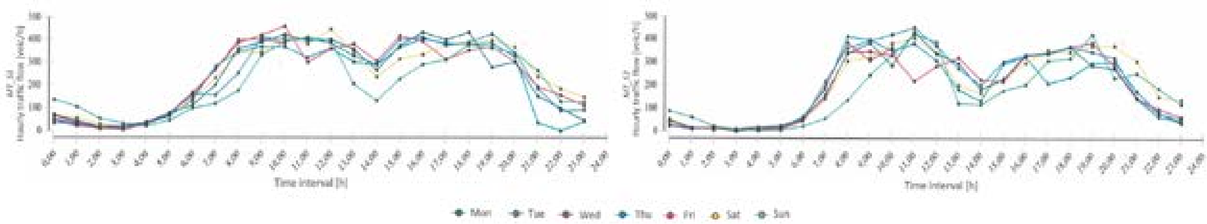

Fig. 8.
Typical day-to-day variation of hourly traffic flows in MT_S1 (left) and MT_S2 (right)

5. Summary and Conclusion

Cities are becoming major areas of human activities worldwide. Yet, they are facing increased traffic problems, including congestions, pollutions and accidents, which strongly call for a sustainable traffic management.
To face contemporary challenges, governments and local authorities are constantly looking for more effective and smarter solutions to problems, and they realize that new, innovative technologies offer enormous possibilities.
In the light of these considerations, innovative transport systems, better mobility planning and smart urban transport solutions might promote a more sustainable mobility.
One of the main conclusion of this study is that reliable transport statistics are indispensable in effective transport governance, and, indeed, for the review of initiatives to promote sustainable mobility. A solution is offered by implementing a coordinated deployment of ITS technologies, which provides access to serviceable mobility information through new methodologies of data collection, resulting in a broader understanding of how urban transport works by lending itself to the creation of effective and efficient transport systems.
In this context, this work provided a discussion about the introduction of ITS as a tool to be exploited for the promotion of sustainable urban mobility with such technologies' support. Afterwards, it was applied the described research methodology to several municipalities of the Metropolitan Area of Catania (Italy), through the implementation of a real-time traffic monitoring system and related infomobility services.
Traffic data of two selected monitoring sections have been subjected to a heedful analysis and for a comprehensive yet simple interpretation, in addition to the numerical elaborations, graphs were utilized to reassume the obtained outcomes.
Results showed a high variability of traffic flows for both monitoring sections, with hourly reach even the 400 veic/hour. In addition, the hourly flows during a day exceed the value of the average hourly flow for more than half of the duration of the day (13 hours/24hours). It is an evidence that these traffic volumes are not acceptable for the analyzed sections, as they are adjacent to the historical center and they have specific road section characteristics that are

not compatible with these flow rates. Accordingly, it will be necessary to put in place corrective actions to managing traffic, by directly acting to the motorized mobility demand, focusing on strengthening public transport and vehicle technological innovation. However, the timing of realization is long, even for economic and infrastructural problems. Instead, in the short-medium term, information and telecommunications technologies can give a significant contribution to better management of public and private mobility. These data will constitute the basis for monitoring actions with before-and after- analysis and making the users more informed. Furthermore, they can be profited to assist traffic planners and managers in their decision-making procedures and improve the support traffic management system.
In conclusion, the above findings may be considered as quite satisfactory, especially for the ability to know what happens in real time in the monitored link, even when the external conditions change, and at the same time they allow to reconstruct the cognitive framework and monitoring the results' evolution of implemented actions and strategies to promote sustainable mobility. However, there is still a wide margin to be filled regarding the implementation of these strategies and actions and their monitoring, which will be represent the object of the further research prosecution and deepening.

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THE PERIODIC TIMETABLE INFLUENCE ON LINE CAPACITY

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Abstract: This paper deals with the influence of timetable periodicity on line capacity. First, there is created a simulation in the simulation program SimuT, and then they are for individual train branches formed and subsequently simulated periodic schedules. The output of the simulation is always a number of train routes (quantitative parameter), the average delay increments (qualitative parameters).

Keywords: timetable, periodic, line capacity, simulation, train.

1. Introduction

Determining the timetable periodicity influence on line capacity is one of the research topics, which can optimize the rail operation and rail transport operation without the implementation of costly building measures.
As part of this research, it is necessary to consider both qualitative and quantitative aspects of the issue. The main interest of the railway infrastructure manager is the realization of quantity (the highest number of train routes) generating revenues in the form of a fee for the allocation of capacity and fee for the use of railway infrastructure, the main concern of individual carriers is mainly the realization of quality, respectively maximally stable train routes in sufficient number (Gašparík *et al*., 2017).

2. The list of Used Methods

Due to the complexity of the problem are the most effective means and methods for its solving modelling and simulation. They are based on multiple repetitions of examined phenomenon with the requirement for high accuracy due to subsequent use in real operation. Since it is a dynamic stochastic model, computer support is necessary – it was chosen a simulation program SimuT (Abramovič *at el*, 2017).
SimuT – it means program Simulation of Tracks, whose primary purpose is verification of operational concepts (including timetables (TT)) according to transport infrastructure (TI). This simulation tool was created and is still improved by Ing. Pavel Krýže, Ph.D. and Ing. René Amcha from Czech Railway Infrastructure Administration (CRIA). As input data are required TI data, examined range of rail traffic data and the definition of alternative solutions. The overall output of the simulation program SimuT is then created TT sheet with all of the attributes, as well as capacity indicators, including an overall average delay increment. Through this indicator is evaluated the TT stability and the train routes quality..

3. Problems Solving

Solving the periodic timetable (PTT) influence on line capacity was done by means of simulations implemented in the simulation program SimuT. They were implemented following simulations:

- current operating range (TT 2016),
- created PTT, maximizing periodicity,
- created periodic freight train paths in network (PFTP).

The TT periodicity influence on line capacity was solved by calculating permeability characteristics according to the prescription SŽDC (ČD) D24, according to the UIC 406 leaflet and due to average delay increment calculation for each simulation scenario (UIC Code 406, 2016). Results for simulation scenarios were compared and on this basis it was created a flowchart of the optimum utilization of train routes in terms of quantity and quality in relation to the implementation of PTT.
The simulation scenarios are characterized by periodicity rate, which is designed by the author of this article like the share of trains kept within PTT or PFTP and all the trains contained in the TT (1).

$$R_P = \frac{N_P}{N_C} \cdot 100\ [\%] \qquad (1)$$

R_P	the periodicity rate
N_P	the number of trains in PTT/PFTP
N_C	the whole number of trains

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As a TT stability indicator is calculated average delay increment ADI (2), which is calculated by dividing the difference between total output and total input delay and the total number of trains. If the increment is positive, the resulting delay isn't eliminated and TI is not able to compensate the extraordinary generated within the established operation range (Gašparík *et al*., 2014).
Average delay increment (ADI) is calculated for all simulation runs as the difference between total output and total input delay and the total number of trains (2).

$$\mathrm{ADI} = \frac{\mathrm{D\ output} - \mathrm{D\ input}}{\mathrm{N}} \text{ [min/train]} \tag{2}$$

D output the total output delay [min]
D input the total input delay [min]
N the number of trains

Within all simulation scenarios there was in the simulation program SimuT set for all simulation runs random input delay based on the exponential probability distribution, freight trains were allowed to go with a lead and for each simulation scenario was done a total amount of 365 runs (for each day of the TT).
In this paper there were calculated capacity indicators according to the SŽDC (ČD) D24 methodology and according to the UIC 406 leaflet – for selected area in terms of current operation, in terms of created PTT and in terms of PTT with PFTP (Directive No 104, 2014). In the selected area there was impossible to construct ITTT because it was not possible without significant interference to the selected operational concept to meet all the conditions for the ITTT creation (Hansen *et al*., 2018).

4. Results

On the basis of problems solving, which is mentioned in the previous chapter, the results have been summarized so that they can be compared the different types of TT with each other.
Table 1 shows the number of trains on five defined sections for each type of TT, where the upper number in a cell represents the total number of trains in the TT, numbers at the bottom of each cell then the number of trains long-distance passenger transport/regional passenger transport/freight transport. If there is an X, it means the kind of traffic doesn't occur on the section.

Table 1
Number of Trains in the TT

Section/TT	TT 2016	PTT	PFTP
Kolín - Choceň	384 171/62/151	336 104/83/149	336 104/83/149
Choceň – HK – VO	174 30/106/38	108 50/40/18	114 50/40/24
Pardubice hl. n. – HK hl. n.	137 19/105/13	179 118/40/21	179 118/40/21
Kolín – VO	213 16/78/119	221 38/40/143	221 38/40/143
Moravany - Borohrádek	48 X/42/6	57 X/38/19	57 X/38/19
The whole amount	956 236/393/327	901 310/241/350	907 310/241/356

Source: Authors

In PTT and PFTP was routed generally lower number of trains than in TT 2016 – it was caused by the formation of comprehensive train routes within PTT and PFTP, when one train number (in SimuT it means one train) covers on average longer distance than in TT 2016 (Šrámek *et al*., 2016). Especially in regional passenger transport was used only one train number, which replaces in a few cases up to 4 numbers (the train was in the TT 2016 three times renumbered).
For all three mentioned variants (TT 2016, PTT and PFTP) are calculated parameters for the closed rail network – the total delay in a closed network, both for all trains and various types of transport. The total delay over a closed network is calculated as a scalar product of the total number of trains (number of trains in the segment) and related average delay increments. Furthermore, for each TT is calculated average delay increment in a closed network, both overall and for different types of transport (Bontekoning *et al*., 2014). Average delay increment is calculated by dividing the total delay over a closed network and the total number of trains on the network. For each TT is also calculated total periodicity rate, as a share of trains routed on the network periodically and all trains on the network.
Furthermore, they are compared average delay increments in the TT versions, here for the entire closed network – Table 2.

Table 2

ADI, Entire Network

TT	ADI (min/train)	ADIL (min/train)	ADIR (min/train)	ADIF (min/train)
TT 2016	0,21	1,88	-0,43	-0,23
PTT	-0,49	1,02	-1,03	-1,46
PFTP	-0,62	1,07	-1,00	-1,83

Source: Authors

Due to the PTT construction was reduced all average delay increments within the closed network, through PFTP creation was further reduced overall average delay increment.
In the evaluation there has been already mentioned the number of trains, their periodicity and average delay increments. However, it is necessary to compare the capacity indicators (such as decisive methodology was chosen methodology according to the UIC 406). Capacitive indicators must be compared especially for the most occupied interstation departments, of which were selected as a representative sample three departments, namely Pardubice hl. n. - Přelouč, Třebechovice pod Orebem - Hradec Králové – Slezské předměstí and Pardubice - Rosice nad Labem - Stéblová.
To formulate generally valid conclusions, it is necessary to analyse various aspects of the results. The quantity parameter is defined primarily by the amount of realized train routes, which is unfortunately partially distorted by the creation of integrated routing in PTT, when one train route means only one train number (Dollevoet *et al*., 2017). Despite this fact, it was found the quantity is similar in TT 2016, PTT and in PFTP.
The basic parameter determining the quality is the overall average delay increment, which is the lowest in the PFTP, then in the PTT and the highest values reaches in the TT 2016. The fundamental research task was to relate the indicators to the TT periodicity – for this purpose was counted for each TT the indicator periodicity rate (Dias *et al*., 2016). Railway lines capacity utilization verifiers are then UIC 406 capacity indicators, primarily total consumed capacity indicator C. All these indicators for closed network there are shown in Table 3; the total consumed capacity indicator is displayed for most capacitive loaded TT section.

Table 3
Indicators for Entire Closed Network

TT	Number of routes	ADI (min/train)	Periodicity (%)	C (%)
TT 2016	956	0,21	44,04	93,42
PTT	901	-0,49	98,34	115,39
PFTP	907	-0,62	98,57	115,39

Source: Authors

Based on the Table 3 is possible to confirm, with appropriate periodic routes construction within PTT is possible under comparable routes quantity conditions to increase the routes quality (decreasing the overall average delay increment on a closed network), despite high capacity utilization of some infrastructure facilities. As the subject of further research it offers methodology UIC 406 revision to extend the capacity indicators calculations not only for day period and rush hours, but also for defined ranges within the periodicity rate. For standard calculation according to the current methodology it was in fact expected that at high capacity utilization of infrastructure facilities will worsen TT stability (overall average delay increment increasing). But if all the trains are kept in PTT, including freight trains (assumption just in time delivery), it is possible through effective bundling to achieve higher train routes quality with increasing periodicity. The whole process of PTT implementation on defined rail infrastructure is clearly shown in flow chart form in Fig. 1.
The PTT construction is within the defined infrastructure divided according to the number of line tracks, when on multi-track lines there should be monitored especially trains bundling and on single-track lines the edge times and crossing possibilities. In terms of comparable quantity and increasing TT periodicity within the entire closed network is created a model like the basis of a simulation (Stojadinovic *et al*., 2016). If there is no decrease of overall average delay increment, it is essential to change the concept (heterogeneity, number of stops, etc.) or to modify the infrastructure and then continue again from the beginning. If the ADI decreases, it is possible to undertake further measures, such as the ITTT or PFTP construction or other possible tracing change – and then create a new simulation. If the ADI doesn't decrease, this procedure could be repeated iteratively, if there is a downturn, it is possible to evaluate the control parameter – the UIC 406 total consumed capacity indicator C. If this indicator is higher than 100%, the constructed TT can be considered functional operational concept with infrastructure capacitating recommendations, if this indicator is lower than 100%, the constructed TT can be considered functional operational concept with the option of inserting additional routes (Weiszer *et al*., 2014).
Since the key parameter of this research is the quality of the rail operation and rail transport operation, respectively reducing the total average delay increment on a closed network, there is shown in Figure 2 the Ishikawa diagram as one of the tools for quality assurance.

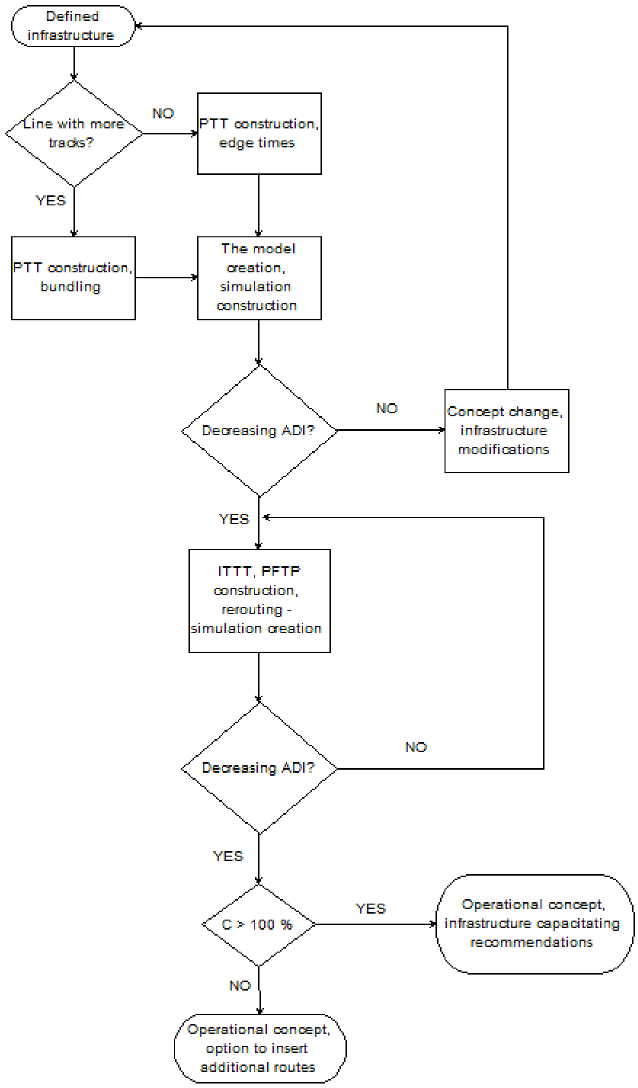

Fig. 1.
The PTT Implementation on Defined Rail Infrastructure
Source: Authors

According to Fig. 2 may be a cause of failure of the desired PTT quality achievement inadequate TI, wrong selected operational concept or inadequate operational train priority. The cause of inadequate TI can be long distances between railway stations or low line speed, leading to the failure of edge times (Široký *et al*., 2014). Lacking railway station tracks can also be problematic.
Selected operational concept can be wrong in terms of train composition (inadequate to demography, not using double track sections), inadequate number of trains, inadequate number of stops (at capacitating may arise Braes paradox) or in terms of incorrect train routing (waiting for crossing, too tight sequence). Within inadequate operational train priority could be mentioned low freight trains priority, which then causes the improper utilization of available capacity due to frequent freight expresses overtaking by passenger transport trains and the associated delay generation (starting, stopping), or incurrent implementation of the operational priorities in peak periods (e.g. increasing freight trains priority during passenger traffic peak). As a further research subject on the quality field it offers compiling of FMEA analysis on the Ishikawa diagram basis (Kampf *et al*., 2016).

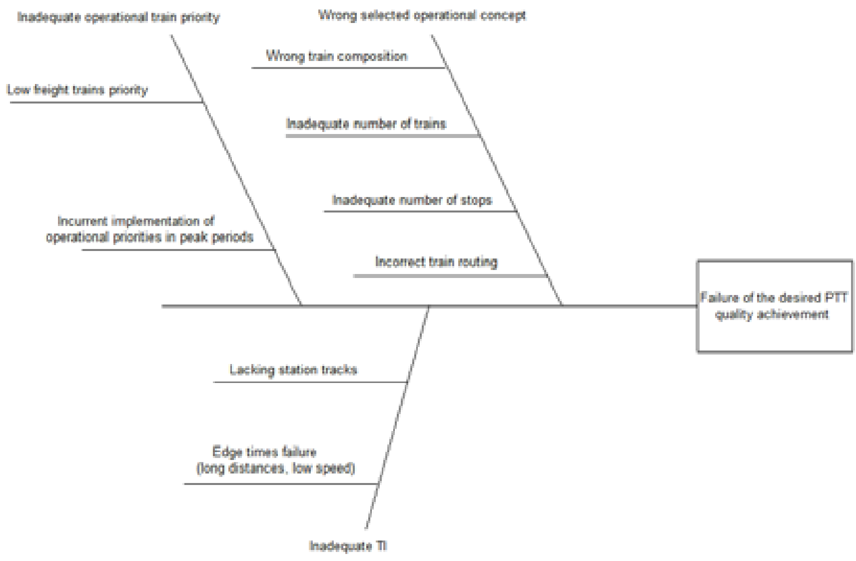

Fig. 1.
The Ishikawa Diagram of Failure of the Desired PTT Quality Achievement
Source: Authors

5. Conclusion

Despite all expectations it was demonstrated increasing TT periodicity does not cause deterioration of the optimum utilization of train routes - under the terms of comparable quantity improve the network quality parameters with the increasing TT periodicity. Since a closed network, on which there were done simulations in the simulation program SimuT, was chosen to include single-and multi-track lines (single track lines suitable for different operational concepts) can be the research considered universally valid. It can be said with increasing TT periodicity and PTT (PFTP) implementation in freight transport it is possible to satisfy infrastructure manager in terms of routes quantity and at the same time it is possible to satisfy carriers by improving the quality of routes.

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A MODELLING METHOD TO ANALYSE ITS BUSINESS ECOSYSTEMS

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Abstract: Social acceptability of new technology is an open issue that arises sometimes at the end of the innovation process jeopardizing R&D efforts. Early engagement of the different stakeholders with end-users and customers to support the design of new technological solutions seems to provide a robust approach to enhance the right collaboration mechanism to mitigate market barriers and strengthen business sustainability. Intelligent Transport Systems (ITS) is an attractive sector that benefits from excellent results achieved by new ICT technologies that are extended to solve transport problems in the area of efficiency, safety, intermodally and comfortability among others. Despite the high expectations of ITS benefit by long-time horizon technologies to be deployed in the market, and the lack of proper mechanisms to predict its acceptability, the ITS markets generate several business hurdles. To understand such difficulties, in EU-funded project NEWBITS (www.newbits-project.eu) the modelling framework established analyses ITS business ecosystems from a socio-technological perspective, in which the autonomous behavior of ecosystem members can be formalized as agents. This is to predict the ecosystem's dynamic behavior in a result of actors' decisions (end-users, customers, stakeholders), each following their behavioral rules, living together in the same environment and formalizing the communication mechanism between each other and with the environment. Among these dynamic modelling approaches, in NEWBITS it is proposed to discretize the ecosystem dynamics in a sequence of milestones by considering the data that can be acquired. The benefits of discretizing the dynamic behavior of the business to the right milestones is that it avoids the analysis of hidden interactions while focusing on a better understanding of key relationships to provide visibility to the intangible values that sustain the ecosystem behavior.

Keywords: business ecosystems, value network analysis, ITS, agent based modelling.

1. Introduction

Individual firms cannot cope by their own competences, the risk and challenges of innovation in multidisciplinary fields such as ITS and C-ITS. Thus, companies are looking for new collaboration mechanisms with other firms to share risks, reduce costs and complement their competences to fit an identified market need. Besides the economic agreements between partners regarding the exploitation of the new product/service and how to support the costs of the development, there are several social dynamics that can affect the mechanism of such a collaboration leading to a failure. Note for example the value of intangible flows between stakeholders such as trust or knowledge sharing between stakeholders at early stages of the collaboration process.

Apart from the social dynamics between stakeholders in a collaboration, there are also technological dynamics to properly identify the right partners with the competences required for the technology developments considering the capacity to adapt and evolve the competences during market evolution.

Regarding the innovation process, there are several positive facts for individual companies being part of a collaborative network, among which it is well recognized that the incremental changes in one partner's technologies or systems or products/services can have radical innovative effects in the network as a whole. Additionally, the level of innovation with a networked based business model can be potentially higher as the number and variety of available technologies, ideas, markets is much higher.

Despite the advantages of collaborative networks for individual companies, lacking competencies that can access innovation with strategic partnerships, a word of caution should be considered since the rate of successful innovation success in certain sectors is quite low. Consider for example the Intelligent Transport Systems (ITS) sector, which is an area of particular interest to get a better understanding of the network innovation processes to increase the successful deployment of services to tackle transport problems with relatively small amounts of investment.

Among the different definitions of ITS, in this paper it is considered the definition elaborated in the NEWBITS project (NEWBITS, D2.1 2017) in which the main function of ITS is to increase the efficiency in the transport system, with special focus on the service and information provision for the full spectrum of users (drivers, passengers, vehicle owners, network operators, etc.) which involves a diversity of stakeholders (network operators, public authorities, OEMs, service providers, technology developers).

Although it was expected in the past years that ITS in general would provide a revolutionary change in the efficiency and safety of transport, the truth is that many of the most promising C-ITS applications have failed to make it beyond trial phases. In order to support increased commercially sustainable C-ITS deployments, the NEWBITS project has been working on an adaptive and innovative business models for the actors along the C-ITS value chain, identifying potential incentives to accelerate deployment and limit the impact of a "last mover advantage" approach.

1.1. Business Ecosystem Dynamics

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The coexistence of social and technological dynamics in the different stages of a collaborative network of stakeholder in the ITS domain and the lack of a deep understanding of the interdependences between the stakeholders leads to a lack of mechanisms to drive the right evolution of the socio-technological dynamics fostering the enablers of the network while mitigating the barriers to introduce the new product/service in the market. Thus, for example, at early stages of the collaborative network a lack of trust in one of the key partners together with a huge pressure on solving hardware integration problems can generate some social dynamics that influence the technological dynamics blocking the right evolution of the product to fit market need at the right time.
There is abundant literature about different business models to describe collaborative networks, among which: network business models, smart service systems, industrial symbiosis, cyber physical systems and service dominant logic (NEWBITS D4.1, 2018), however the approach of Business Ecosystems (BE) rely on the analysis of how companies co-evolve their skills and roles in the ecosystem. The idea of business ecosystems is rooted in the value networks theory and is seen as explaining how a group of companies can simultaneously create value by putting together their assets and skills. (Rong et al., 2015) sum up the existing literature as studying business ecosystems either as networks of interdependent stakeholders who evolve together and share the same fate, or as established value networks with fixed interconnected roles. In this work, two strands of research have been identified: the first focuses on the roles that construct the ecosystem (Constructive elements) while the second focuses on the interconnection of these roles (Configuration).
The interaction and feedback mechanisms between the strategic thinking and the entrepreneurial operations in BE determine the success or failure of a firm in the ecosystem. The interactions differ significantly among different types of identified ecosystems. (Clarysse et al., 2014) provide evidence that business ecosystems are a non-linear value creation process (often informal horizontal links) as groups of firms that delivers integrated solutions to the end-users. The non-linearity properties emerge from the complexity of the ecosystem.
There are theoretical works that support that BE could be studied as complex adaptive systems (CAS). These systems typically include multiple loops and multiple feedback paths between many interacting entities, as well as inhibitory connections and preferential reactions (Battistella et al, 2013). Business ecosystems as paradigms of CAS, change and evolve over time as a result of the interactions between the members of the BE and the interaction between the ecosystem and its everchanging business environment. The complexity of business ecosystems suggests that the emergence and success of ecosystems is a dynamic process requiring a multifaceted responsiveness. As the ecosystem evolves during its life time, and interacts to the external environment, its capabilities define the level of services and the impacts to the society in an adaptive way. This process, leads to adaptations of the cooperative behaviour of the stakeholders too, as the ecosystem reaches higher levels of maturity over time. It is imperative that companies establish a sound measurement approach based on quantitative data, to allow monitoring and assessing the performance of the ecosystem, both from a static and dynamic point of view.
Simulation techniques provides an excellent framework to obtain a better understanding of complex system dynamics, a quantitative approach to predict the evolution of the system and a "try-and-error" approach to validate control mechanisms that could allow to enhance those flows between stakeholders that create value while mitigate flows that could lead to BE failure.
In this paper, it is presented the application of an Agent Based Model (Klusch et al. 2007) to validate the use of socio-technological dynamics for a better understanding of business ecosystem at different phases of the innovation process. Section 2 describes an ITS case study which has been analyzed in section 3 as a business ecosystem. Section 4 provides value network analysis of the BE. Further research and some concluding marks are given in Section 5.

2. ITS Case Study: Intelligent Car Pooling Service

The main objective of VaoPoint (case study name) is to increase the average occupation and achieving a rational use of cars in a university environment with high levels of daily influx of private vehicles. It offers an intelligent carpooling service for daily mobility to the campus, where members of the university community can access numerous carpooling offers. In addition to traditional cost savings on sharing transportation expenses, VaoPoint, promotes the reduction of users' carbon footprint and decrease traffic congestion by promoting high-occupancy vehicles. The acceptability of the app relies on:

1. Efficiency: Matching users to vehicles and minimizing as much as possible main route deviations.
2. Comfort: Encourage social preferences matching of users, avoid campus pathway bottlenecks and guarantee access to parking area.
3. Environmental issues: Reduce the carbon footprint (CO_2) and pollution as a result of the reduction in the number of cars used.

This ITS case study proposes a differential innovation, since it introduces a new service in an existing market that can reduce the flow of vehicles into the university campus, but also can be applied to other transit scenarios with similar problems outside of the University such as interurban mobility and industrial parks. In order to implement a model formalizing the dynamic evolution of the ecosystem, it has been identified 7 roles which are represented graphically in Figure 1:

1. Cities: In the context of VAOPoint, cities refer to university governing bodies that make decisions regarding the territorial management of the infrastructure, facilities, and services within the campus. They are responsible for facilitating the deployment of the ITS service by promoting policies to foster carpooling to reduce number of vehicles. A typical university campus shows the same logistic problems as small cities.
2. Transport authority: In the same context as (1), they act at the same level as a public transport authority within the area of architecture and urban planning charged with the territorial mobility management of the university campus. They promote mobility management within the campus, ensuring the readiness of the campus infrastructure to support effective deployment.
3. Academia: They act as a catalyst for the exchange of knowledge and innovative research among industry partners, in order to enable technology transfer of research activities in innovative transport solutions to the industry.
4. ITS service providers: They are considered the enabler of IT solutions in the field of transport, addressing the development and deployment of decision support systems aimed to improve and optimise the performance of transport systems.
5. Funding body: Funders provide financial support to develop smart mobility applications, and help accelerate new research and prototypes into market-ready technologies.
6. Social media marketing companies: They raise awareness through the social media to engage end users in the pre- and post-deployment in terms of assessment of incentivizing schemes and increase the acceptability of the solutions proposed.
7. End users: These are citizens or businesses that are consumers of the ITS service. On the one hand, the role of end-users in the innovation process is considered paramount, and the importance in tailoring their preferences to the service offering, as well as determining users' acceptability level to facilitate adoption. On the other hand, end users can derive maximum benefit from the exploitation of the service for cost reduction purposes and sustainable mobility.

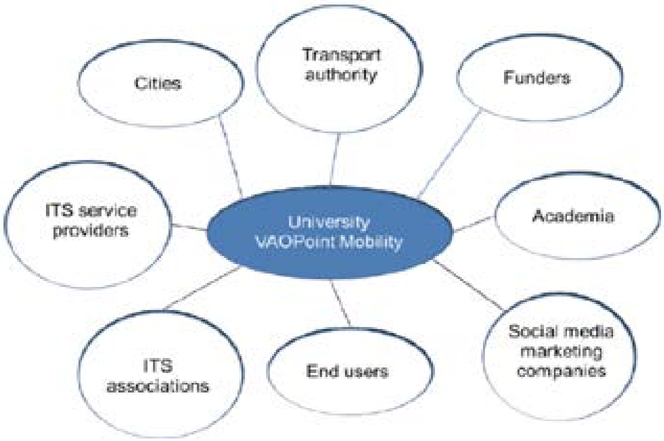

Fig. 1.
Main roles defining ecosystem dynamics in VAOPOINT

For each of the stakeholders' groups, the specific stakeholders have been identified as follows:

- Cities: Universitat Autònoma de Barcelona (UAB) Management;
- Transport authority: UAB Mobility Unit;
- Academia: UAB Living Lab CORE, UAB Logistics and Aeronautics Unit;
- ITS service providers: Aslogic S.L.;
- Funding body: FrontierCities;
- Social media marketing companies: Websays;
- End users: Members of the university community (students, administrative staff, academic staff).

FrontierCities does not only provide funds, but also offers technical support and business advice for the acceleration of new research and prototypes into market-ready technologies. Its ambitious services vary a great deal of and offerings include: a widened Smart Cities scope, a strengthened Grantee Acceleration Programme, an Outreach Service to FI-PPP P2 & P3 research results, a dedicated Financing and Partnerships Acceleration Service, a new Cities Programme dedicated to supporting and developing the network of cities trialling and deploying FIWARE-enabled solutions

As one of the primary stakeholders, the UAB Mobility Unit provides technical support to the UAB management (governing) body on the design of UAB mobility policies, as well as the appropriate planning and management tools to maximise accessibility to the campus in the most sustainable, efficient and integrative way possible. The unit is also responsible for parking management and maintenance of public space.

Aslogic provides ITS/data services, and the research and transfer of new technologies. The other function includes the provision of IT support to UAB Mobility Unit by identifying transport needs and market opportunities.

The UAB Management facilitates the acquisition of licence for deployment and infrastructure readiness together with the mobility unit for service provision. The UAB Living Lab CORE facilitates the deployment of the service in the university. They act as intermediary between the IT Services Unit and UAB management.
The UAB Logistics and Aeronautics Unit role is to design and develop innovative decision support algorithms for both tactical and operational planning problems on the application (e.g. matching) according to the policies defined by other stakeholders. Websays engage end-users through a constant analysis of their opinions and feelings regarding VAOPoint services and the acceptability of incentives.

3. Value Flows in the ITS Car Pooling Service

The successful execution and deployment of ITS innovations involving multiple stakeholders requires efficient cooperation, interacting with each other and feeding each other with knowledge as parts of an interconnected ecosystem. In other words, the deployment of ITS initiatives should be analyzed from a business ecosystem viewpoint, rather than an individual organization perspective.
The relationships between stakeholders can be structured according to different tangible and intangible resources possessed by their stakeholders. Traditional business deals mainly with physical assets and people, while new business modelling approaches such as business ecosystems, recognizes the importance of handling the intangible assets in a network such as knowledge, relationships, other people's assets.
In business ecosystems the intellectual capital and intangibles as a form of value are equally important to tangible assets/deliverables if not more. "Tangible assets" are resources that can be converted to financial merits and other capital-based resources (goods, services, revenue) that are owned by the firm. "Intangible assets" include relationships, employees' know-how and competencies, the effectiveness of the organization's work groups and structure, the efficiency of the organization's production and service processes, and the level of trust between the people or organizations forming the relationships. These intangible assets represent value that is not accounted in traditional financial records, such as the sense of community, loyalty of customers, enhancement of the brand - image, or co-branding opportunities.
Thus, a stakeholder in a collaborative network try to activate and exploit for more value and better performance, creating "knowledge flows" for the production of new services and applications. These relations are making them gain competitive advantages, and create an opportunity for the financial sustainability of them.
In order to support a better understanding of the BE dynamics, instead of focusing on each particular stakeholder, it is more important to identify for each value exchange the mechanism or medium which enables the transaction that takes place. Mechanisms creating knowledge value include: exchanges of strategic information, planning knowledge, technical know-how, collaborative design, policy development, etc., which flow around and support the core product and service value chain. (Allee, 2000).
The concept of Value Networks was introduced in the innovation management literature. [De Reuver, 2009] defines a value network as "a dynamic network of actors working together to generate customer value and network value by means of a specific service offering, in which tangible and intangible value is exchanged between the actors involved"'.
A field work analysis with all the stakeholders of the case study has been performed through different workshops and questionnaires to identify the values that each stakeholder can generate and the values each stakeholder needs from other members of the network. As a result, five main flows have been identified:

1. Knowledge & information flows: Early phases of the innovation process requires knowledge sharing mechanisms that could spark new ideas relying on the integration and evolution of some technologies.
2. Monetary flows: While some stakeholders have enough capacity to support innovation tasks, some others require a minimum economical support to be engaged in the design of a new product/service.
3. Policy flows: In the field of ITS, the capacity to participate in the elaboration of future transport policies is an important asset to drive the right evolution of firm competencies.
4. Data, technology &service flows: It is well acknowledged the value of data in the transport field to identify the end-user preferences and design services to fit market needs.
5. Skilled workforce & public benefits flows: As a result of successful innovative products/services, stakeholders generate new demand of skilled profiles to support the evolution of the product.

Figure 2 represents the knowledge and information flows that move among the case study's stakeholders.

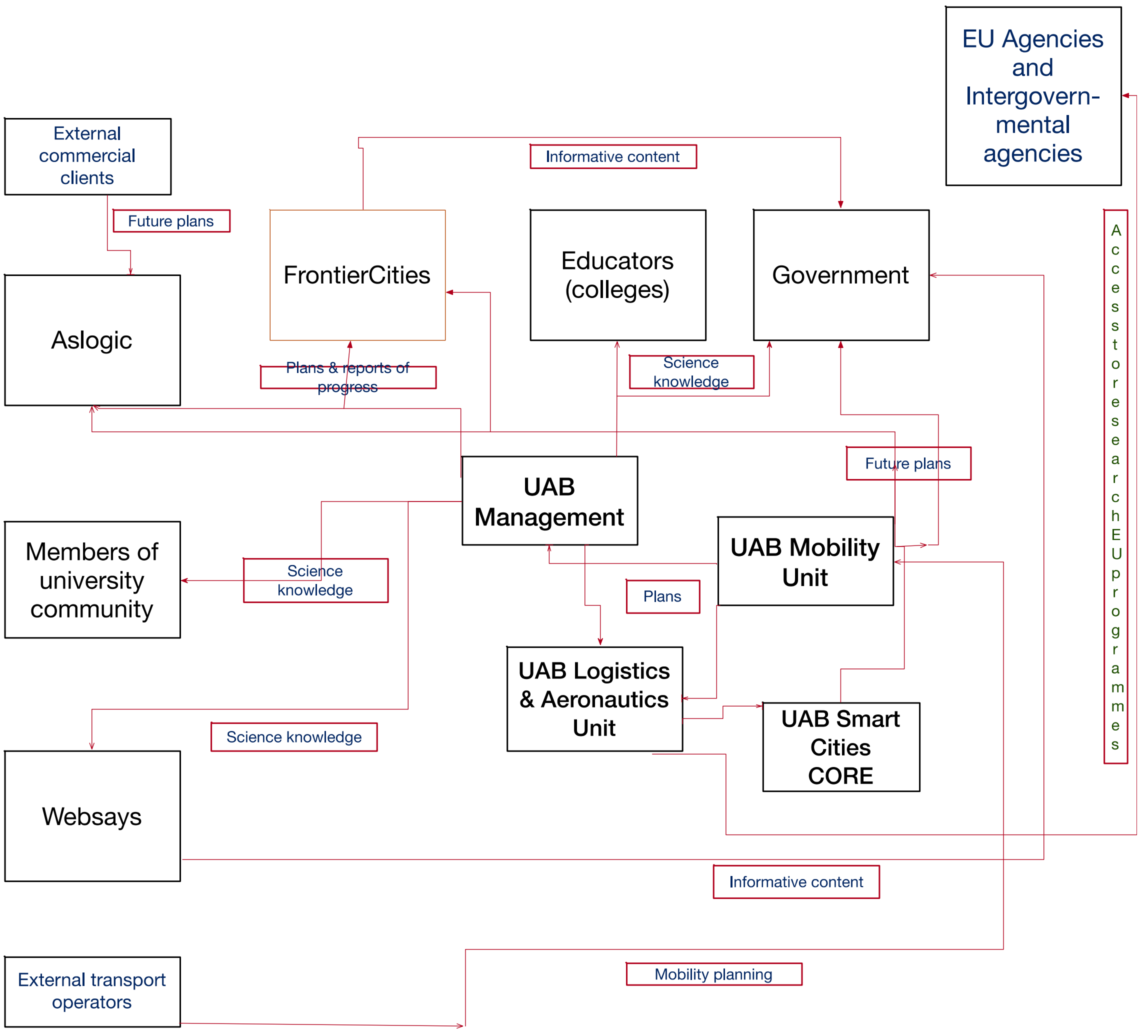

Fig. 2.
Knowledge and information (planning) flows

As it can be observed, there is an outflow of scientific knowledge (ITS, transport-related) from the university (UAB) to the other stakeholders. There is also a separate circle of informative content that begins from Websays, then goes to FrontierCities and the governmental institutions. There is also a third individual flow of "planning reports" moves between the external transport operators, the UAB mobility unit and then it is redistributed among the university's units, advanced and moved forward to FrontierCities, Aslogic.
In Figure 3, it is represented the 5 value flows among the stakeholders identified in the case study. The quantitative analysis of the different flows can be obtained by means of the Value Network Analysis (VNA) (Sutherland, 2009) in order to identify the highest value-producing interactions among stakeholders in the network.

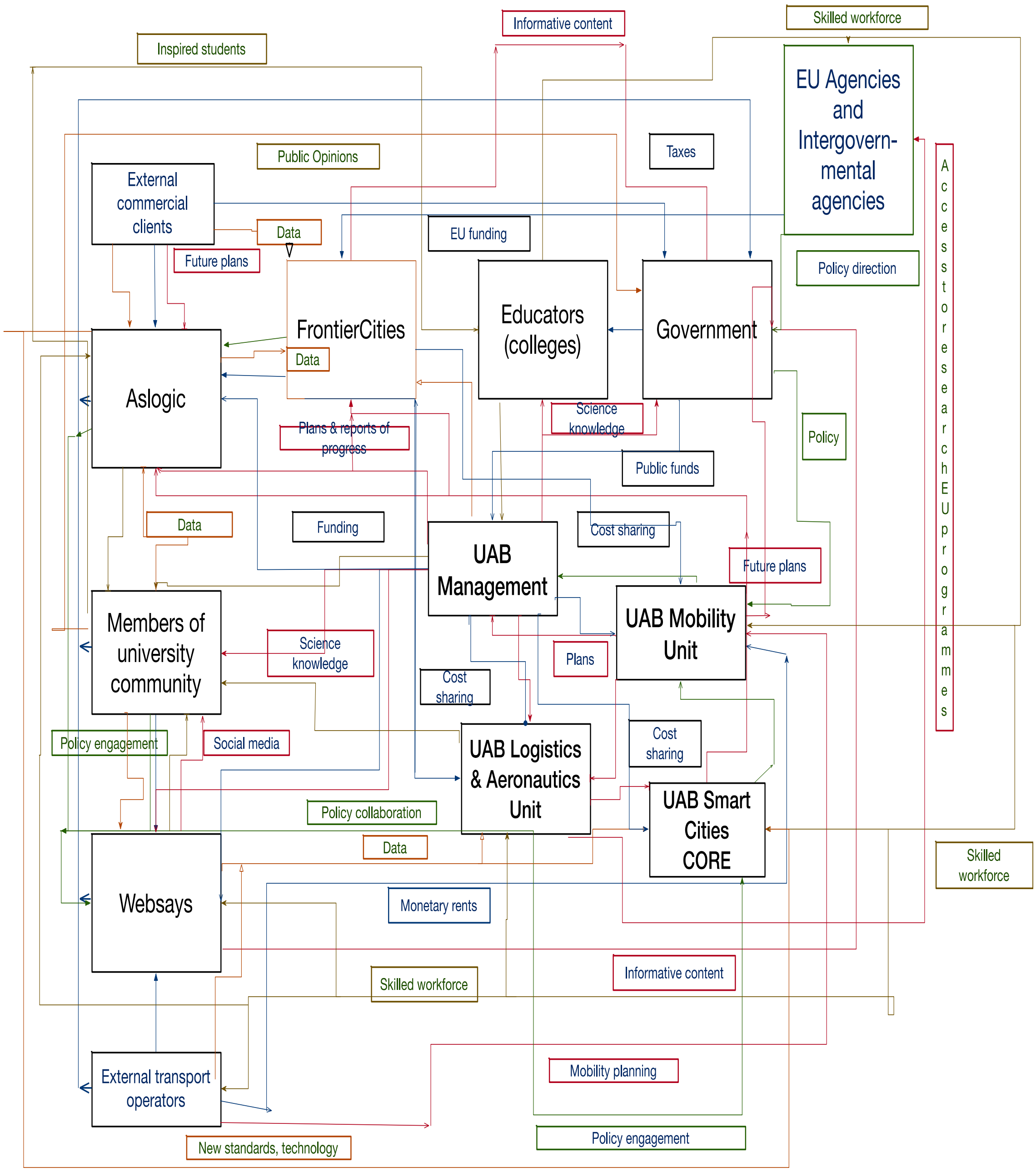

Fig. 3.

Monetary, knowledge & informative, policy & opinions, data, technology & services and skilled workforce value flows in VaoPoint Network

As a result of several questionnaires and workshops in which the subjective value for each stakeholder regarding the rest of stakeholders in the network, the value loops were ranked (see Table 1) and the most relevant direct value flows were also identified (see Table 2).

Value loops show how value is created and delivered throughout the network. They also illustrate interactions between the actors that are not immediately obvious. The calculation of value loop scores involves a multiplication of each value flow score within the loop. Usually "larger value loops" are likely to score lower numbers than the shorter value loops, since logically it is more difficult to deliver value by engaging four or five stakeholders than via two or three stakeholders.

Table 1

Ranking of Value Loops in the Case study

Rank	Score	FROM	TO	Value Flow Type
1.	**0.13**	UAB Management	UAB Mobility unit	Knowledge, Funding
2.	**0.078** **Cycle 1**	UAB Management	Members of community, UAB Mobility unit, UAB Group	Science knowledge, Policy collaboration, Future plans

3.	**0.073**	UAB Management	ASLOGIC, UAB CORE, UAB Mobility unit and UAB Management	Science knowledge, standards, technology, policy collaboration and mobility planning
4.	**0.06**	UAB Mobility Unit	Government, Educators, and UAB	Future plans, funding, skilled workforce
5.	**0.04** **Cycle 2**	UAB Management	Members of community, UAB Mobility unit, UAB Group	Science knowledge, Policy collaboration, Future plans
6.	**0.027** **Cycle 3**	UAB Management	Members of community, UAB Mobility unit, UAB Group	Science knowledge, Policy collaboration, Future plans
7.	**0.01**	UAB Group / Management	Members of community, WEBSAYS, UAB LOGA and UAB Group	Employment, Information content Data, Cost sharing

As it can be observed, the UAB group is one of the main stakeholders that drives the dynamic of the full network by sharing knowledge and providing funding and it obtains as a main benefit transport policy collaboration to elaborate its future plans.

Table 2
Stakeholder's most important direct value flows

Stakeholder	***Value Flow***	***Combined SCORES***
1. ASLOGIC	Acquired Mobility Data	0.80
2. UAB LOGA	Access to existing EU Research programmes	0.78
3. UAB CORE	Technology transfers	0.73
4. UAB Management	Policy Collaboration	0.62
5. UAB Mobility unit	Policy Collaboration engaging Members of university community	0.59
6. FrontierCities	EU funding	0.49
7. Websays	Informative & entertaining content (social media)	0.73
8. Members of Community	1. Collaborative platform on sustainable mobility options 2. Rewards	0.49
9. Government (indirect role)	1. Public opinions 2. Compliance with EU policy directions 3. Compliance with intergovernmental policy directions	0.75 0.60 0.60
10. Educators (indirect role)	Educational material	0.61

4. Ecosystem Dynamics

The members of a Business Ecosystem need to watch and foresee what will happen in the near future considering the volatile and changeable context. Understanding the ecosystem means not only identifying the stakeholders and its relationships in a certain moment in time, but understanding how it evolves by monitoring evolutionary trends. In order to react on changes quickly and efficiently, a keystone member of the ecosystem must be able to foresee what will happen considering present member ITS competencies, and the very fact that ITS field is being performed in a changeable environment, introducing in this way uncertainties in the ecosystem dynamic evolution, and unfortunately introducing more difficulties in the decisions to be taken cooperatively by the ecosystem members.
The dynamic nature of BE is considered as one of the pillars for adaptation not only to environmental and market uncertainties but also to the internal configuration to reach a stable structure with the right number of stakeholders necessary to be competitive with respect to other business ecosystems. By supporting and enhancing business ecosystem adaptation mechanisms it will be possible to identify those ecosystem parameter configurations under which the business ecosystem could be maintained and in consequence be sustainable.

The analysis of the dynamic value flows between BE stakeholders would support the better understanding of the evolution of the business model dynamics, which following can contribute to the identification at early stages of business shortages that would lead to a poor acceptability of the proposed ITS service/product or the failure of the full innovation process. In fact, the nature and effect of the dynamic interactions in a BE can have profound implications for organizational success and determines the speed of the ecosystem's evolution to keep it sparkling, offering plenty of opportunities for its members.

The change, adaptation, and evolution dynamic mechanisms inherent to business ecosystems can cause uncertain ecosystem outcomes which are hard to predict and take time to materialize. Thus, a model supporting ecosystem dynamics would contribute to design control policies and mitigation mechanisms to properly drive the ecosystem to successful scenarios, overcoming gaps in knowledge/ skills and gaining access to critical resources, including financial capital.

Consider for example the high importance of "science knowledge" in ITS at early phases of the VaoPoint business ecosystem in which the knowledge sharing between stakeholders allows to design a new service fitting the end-users demands. At prototyping and validation pilot exercises the "science knowledge" is less important while the importance is very low once the service is implemented and commercialized.

4.1. Agent Based Modelling to Formalize Ecosystem Dynamics

The modelling target of a systemic ecosystem business dynamic in NEWBITS project has been the identification and description of the ecosystem stakeholders, its relationships together with decision rules and actions of the keystone (UAB Group) in order to obtain a global view of the ecosystem behavior.

In (Ramos et al. 2018) it is illustrated the benefits of an Agent based model to identify some ecosystem behaviors by means of simulation MAS tool (Repast has been used), in which agents are formalized to describe the ecosystem members by means of behavioral rules:

- Each agent has a set of decision rules.
- agents' behaviour is described by rules with which it can be computed the effects of receiving tangible or intangible values.
- In these rules, the positive or negative network externalities they experience can be incorporated. This means that an agent will look at other agents' status in making its own decisions.

In Figure 4 it is represented the interfaces implemented in the ABM simulation for the business ecosystem which takes place as intangible or tangible flows between stakeholders.

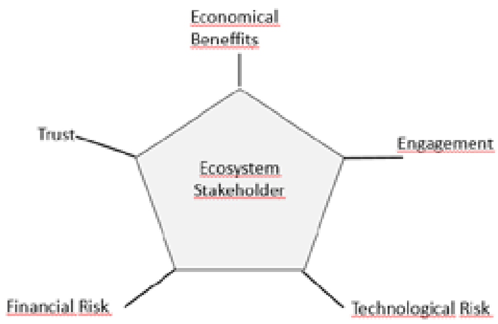

Fig. 4.
Agent Interfaces in a Business Ecosystem

Each agent updates his trust considering his own trust on the task to be implemented according to his competences, the lowest trust and the highest trust of the agents with it has a dependency and the technological risk of the tasks to be implemented by his own company. Thus, if a consortium member fails in the technological task assigned, all the stakeholders that depend on his technology are affected by a reduction of this trust which somehow propagates to the rest of the stakeholders.

Unfortunately, this type of models cannot be easily validated since intangible values such as "trust" has an important impact of the ecosystem evolution but there are no sensors to monitor its dynamics. Thus, the ABM can be used as a testbed platform where different value flow evolutions can be forced by introducing control mechanisms such as end-users contributing to the transport policies of the UAB Group.

6. Conclusions

This paper describes an approach to explore relationships between stakeholders in a cooperative environment to implement an innovative product/service in the ITS arena. Most innovations in the ITS sector rely on the adaptation of validated technologies which reduces the technological risk, however are subject of constant market changes in which the acceptability of a new product/service is influenced by several social aspects besides the technology developed.

The importance of intellectual capital and intangibles as a form of value in collaborative network multi-stakeholder structures has been described by means of an Intelligent Car Pooling Service case study, in which all the stakeholders have been identified and the intangible value flows have been obtained and validated through questionnaires and workshops. A quantitative analysis to identify the most relevant value loop values and flows has been implemented through a modified version of the value network analysis method.
Although Agent Based Modeling provides an excellent modelling framework to specify socio-technological dynamics, there are several shortages when used to predict ecosystem behavior relying on intangible flows due to validation difficulties. In NEWBITS project, the VNA approach has been discretized at 3 different milestones to check the evolution of value flows, while the ABM model will be completed to test control mechanisms.

Acknowledgements

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CHANGES IN THE TRAFFIC SITUATION ON CITY ROADS AFTER TRAFFIC DIVERSION OUTSIDE THE CITY

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Abstract: Road bypasses are constructed to mitigate traffic congestions in city areas. City roads are released and used by city and target traffic (with origin or destination in the city) primary. Travel time can be shortened for all. Question is how journeys within the city area will employ the infrastructure (city roads) originally used for diverted transit traffic. The aim of the article is to find out and to describe the impacts of traffic diversion in dependence on city size and importance of the city. Individual as well as public transport will be assessed, because bypassing has a different impact on each of them. Rerouting of a part of target journeys can be caused by bypassing in individual transport as well. Public transport service can be reduced with the aim to make connections (buses) transiting here faster. Research will be based on evaluation of a set of specific locations (bypassed cities).

Keywords: city bypass, road transport, traffic diversion, traffic flow.

1. Introduction

The article is focused on factors influencing the change in traffic volume on roads within city areas that are bypassed. Effects will be examined in relation to opening of city bypasses. The question is what factors determinate future traffic volume. There can be found examples of empty calmed roads (city roads) as well as of roads with significant traffic volume remaining there. Another important effect is that bus operators sometimes reroute their bus lines to faster or shorter bypass out of the city. Supply of public transport can be reduced in this way. The aim of the article is to find out and describe the impacts of traffic diversion in both modes in dependence on city size and importance of the city.
This article is a part of dissertation thesis, which is actually in process. The set of factors descripted in the article may not be final, but it can be extended in dissertation thesis. Topic of this article belongs to the soft systems. In spite of all attempts to maximize objectivity by the consideration of all factors and conditions in some cases may be quite opposite effects (e.g. small municipality is able to negotiate a full range of long-distance public transport). The aim of the article is to find common and expected effects in general and to learn from both positive and negative examples.

2. Literature Review

This chapter provides an overview about some of published methods and approaches. This analysis creates a background for appraisal of changes in the traffic situation on city roads after traffic diversion outside the city. The increasing automobilization of society is accompanied by negative impacts on society, which also includes increased noise disturbances to which inhabitants are exposed. The paper (Prekop et al., 2016) is focused on the ex-ante and ex-post evaluations of noise loads to inhabitants of the centre living along the former arterial route. The effort is to give a true picture of changes in noise loads to which inhabitants are exposed.
The locational shift in traffic can cause some existing businesses to close up or relocate, but it can also create some new business opportunities. The positive benefits of bypassing city centres commonly include the removal of heavy truck traffic from city centre and the opening up of additional industrial sites along the new route, thus attracting new investments from outside of the region. The negative impacts include increases in sprawled, low density commercial and residential development entailing high environmental and infrastructure costs. Economic impacts of freeway bypasses are presented in the paper Collins et al., (2000) for the cases of medium size cities (e.g. Danville (IL, USA), Richmond (VA, USA)).
Model for the analysis of traffic networks is provided by Peter et al., (2013). There is presented a domain level of optimal control for traffic networks applying Lyapunov function, and applying two level domain control on a realized network model of city Győr (Hungary). This model defines a unique structure of network elements and can be described map-graph independent by a special hyper matrix structure. Its main strength is the computing rapidity. The model can help by identification, where it will be effective to realize possible measures.
The paper Dzebo, (2018) presents a simplified model of traffic assignment to the planned bypass road. The purpose of such model is to provide to the planners a tool for simple, fast and inexpensive way to estimate the expected traffic volume on the planned bypass road by using data that can be obtained relatively quickly. Inputs of the model of traffic assignment are annual average daily traffic on the planned bypass and on the existing routes. Feasibility traffic studies of eight cities in Bosnia and Herzegovina were utilized as source of data.

3. Causes and Effects of Bypasses Construction

The basic question is simply – Why have been the bypasses built? The answer to the question can be found in the difficulties caused by the traffic in the city centre. The most common problems are increased travel times, exhausted capacities for inner city roads development, heavy traffic passing through the city centre and increased pollution, noise,

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number of accidents etc. Aiming to resolve above mentioned problems is necessary for proper planning of city development providing optimal solution.
Effectiveness of city bypass can be assessed in two points of view. The first is about utilization of a newly constructed bypass itself. It is related especially to transit traffic passing in city. The appraisal is possible to be done by directional traffic census. The second question is what will be the change of traffic volume in the city. This second question is more complex. It is not about traffic volume only. Rerouting of traffic as well as trip generation problem causing induction of new traffic is taking a part in solution of this question as well.
Several hypotheses have been stated on the base of literature review. These hypotheses create the scope of the article:

- Bypasses do not necessarily result in a total reduction of total traffic volume in the city centre. Effectiveness of each individual bypass can be quite different in this point of view.
- Bypasses can have a significant impact on the development and location of retailing and local services.
- Public transport service in the bypassed city can be reduced with the aim to make connections (buses) transiting here faster.

4. Structure of Traffic Flows within the City Area

According to Ortúzar et al., (2001) there are 4 basic types of traffic flows in the city areas:

- transit flows passing the city,
- flows originating in the city and going to outlying areas (out of the city),
- flows coming from outlying areas with destination in the city,
- flows realized within the city area only.

Division transit flows can be added in the frame of discussion to this:

- transit in the main direction,
- transit between the main direction and other directions,
- transit in other directions.

This structure of traffic flows can be the base for estimation of city bypass importance and effectivity in general point of view. This analysis consisted of main positive and negative impacts in each type of flows is presented by following Table 1.

Table 1
Analysis of positive and negative impacts

Transit in the main direction	
+ bypass is usually in this direction + the most of transit will use diverted route	- calming of the city when this transit is dominant (economic viewpoint)
Transit between the main direction and other direction	
+ clamed roads within the city centre + possibility to minimize routes passing the city (by using of a part of bypass)	- bypass could be ineffective for this traffic volume - using of other roads in the city (in the case of “new” approach to bypass)
Transit in other directions and journeys within the city	
+ clamed roads within the city centre + bypass can be used only in some specific cases when it is copying part of the route	- using of the same roads as before
Journeys with origin or destination in the city, but going out or coming from out	
+ clamed roads within the city centre + possibility to minimize route through the city (by using of a part of bypass)	- bypass could be ineffective for this traffic volume - using of other roads in the city (in the case of “new” approach to bypass)

Source: authors

The result is that the bypass is attractive for driving in the main transit direction. Other drives can be more attractive due to traffic calming in city centre as well. This can be a problem, calming of transit routes can prepare possibility for traffic induction on other relations able to replace the diverted part of traffic flow.

5. Expected Factors in the Field of Road Traffic

This chapter is focused on introduction of a set of factors that are expected to impact traffic situation. Expected effects will be characterized. It is presupposed that these factors will be researched by mentioned dissertation theses.
City population (number of inhabitants)
The effect is related to the volume of originating traffic generated by city inhabitants. This can affect volume of origin traffic (production) and destination traffic (traffic attraction) as well. It is related to 2 facts:

- inhabitants start and finish their journeys in the city,
- volume of destination traffic should be related to the size of city as well.

Volume of transit traffic
It is important what is the share and volume of transit traffic in the area. The most of this traffic should be rerouted to city bypass (usually smoother drive, higher speed, minimal congestions). This traffic usually disappears within the city. On the other hand, in the case of small ratio of transit traffic it can cause ineffectivity of bypass. This relative small volume will represent prospected traffic volume on bypass.
Attractiveness of the city
This is subjective impact, but necessary to be considered. It is related to the fact if it is useful to come to the city itself or not. Tourism is typical example. On the other hand it should be related also e.g. to shopping possibilities etc. In short, this includes all reasons for travelling into city area.
Location of important objects in the city
This can affect selection of route in general way. It should be highlighted especially if there are objects generating high volumes of traffic like airports, large shopping or industrial areas. Specific is that these objects are usually connected directly to backbone network (motorway, bypass). This interconnection of objects to transport network is the main difference in comparison with the attractiveness of the city, because these objects are often strictly related to existence of this network. Attractiveness is especially related to traffic volume and location to traffic routing.
Attractiveness of bypass for trips within the city area
It may be effective to go between some places located within the city by bypass, especially when it is more quickly, shorter, more comfortable etc.
Comfort on bypass and bypassed route
Quality and comfort on both routes can be also important. This evaluation of routes is almost subjective. On the other hand, felling more safe and comfortable can sometimes cause change of selected route although selected route cannot be the shortest, the most quickly or the most effective. It can have impact in both cases – that the rout through the city will remain attractive as well as that the bypass will become attractive also for drives where it is not presupposed (it should lead to Braess paradox). Comfort can be also a problem in the case when bypass is not fully finished, during construction (reconstruction) works etc.
Extension of route in the case of bypass
The route using bypass can be sometimes longer in comparison with route within the city area. It could be illustrated by the case of Czech city of Mladá Boleslav, it was more effective to enter the city in Bezděčín then to use motorway D10 and its exit closer to the city centre.
Administrative measurements for traffic routing (traffic calming)
Powerful tool can be also administrative measurements supporting "expected" routing of traffic. Measurements can be divided into these 3 groups:
- interdiction of entry (incl. one-way street operation and interdiction of some types of vehicles),
- reduction of speed (effort to extent travel times = to decrease effectivity of route to be selected and used),
- supporting measures – like interdiction of parking.

Access fees
This includes parking fees and restricted city entrance with the aim to reduce number of vehicles in city centre. On the other hand also bypasses can be subject to a toll. This is negative to road users, which do not use regularly other tolled motorways. That is why the use of bypasses should not be favourable for all.
Spatial effects
Effect of road ascents and descents – should be important e.g. in mountainous areas. Possibilities of manoeuvres (dimensions of infrastructure) are second spatial effect – e.g. if road is suitable for freight vehicles etc.
Other possibilities to travel
Different impact should be in the city with quality public transport system, where volume of car trips should be lower than in the city with limited possibilities to travel in different way.

6. Possible factors in the field of public transport

Transport demand
- numbers of passengers travelling to/from the city,
- destination target of passengers is in one/multiple place,
- numbers of passengers transiting (continuing by the same bus),
- numbers of passengers interchanging to other public transport services in the city,
- time loss related to access of bus terminal in the city → possible to be modelled by using of system equilibrium (min. of average travel time).

Other effects
- Priority of line or of served relation (e.g. to connect important cities with no effort to serve bypassed).

- Concept of the transport system (possible effort to create hub in the city or not).
- Existence of other lines providing transport service for the city (e.g. in regional transport).
- Possibilities to create stops on bypasses (to save travel time for transiting passengers with possibility to serve the city).
- Existence of P+R concept (using multiple transport means).

7. Introduction of the Case Study

There were taken 8 cities located in the Czech Republic and 6 in the Slovak Republic into pilot consideration of mentioned effects. First of all, transport conditions are similar in both countries. For that reason, it is possible to put these data together for evaluation.

City categories

This article is focused on medium-sized cities. For application and appraisal of the factors is necessary to divide cities to three categories. Cities are divided from the point of view of regional importance (Table 2).

First category is composed of cities with transregional significance. These cities generate much origin (availability) and destination (attractiveness) routes as well as many routes have transit character. The cities in this category are operated by long-distance and regional public transport.

Table 2

City division to categories

Cat.	City	Bypass open	Bypass type	City type	City population	Long-distance lines service
1	Plzeň (CZ)	2006	motorway	transregional	170 936	all
	Olomouc (CZ)	2007	motorway	transregional	100 494	all
	Nitra (SK)	2011	motorway	transregional	77 048	all
2	Jihlava (CZ)	2008	1st class	regional	50 724	all
	Mladá Boleslav (CZ)	2015	1st class	regional	44 167	partly outside
	Kolín (CZ)	2012	1st class	regional	31 355	all
	Martin (SK)	2015	motorway	regional	62 738	partly outside
	Poprad (SK)	2009	1st class	regional	51 486	all
3	Chrudim (CZ)	2015	1st class	municipal	23 133	all
	Nymburk (CZ)	2010	1st class	municipal	15 062	all
	Vamberk (CZ)	2010	1st class	municipal	4 536	all
	Levoča (SK)	2015	motorway	municipal	14 803	partly outside
	Svidník (SK)	2010	motorway (half profile)	municipal	11 096	all
	Tornaľa (SK)	2006	motorway (half profile)	municipal	7 252	all

Source: authors on the base ČSÚ, (2018); ŠÚ SR, (2018)

Second category includes cities with regional importance. These cities are mostly attractive for citizens from nearby and satellite city areas. Cities are operated mainly by regional public transport and also with most long-distance public transport. Only some long-distance buses (e.g. international connections) have higher significance and the cities are not served by them.

Cities with municipal importance are included in the last third category. There are cities with no attractiveness and the most of transport is composed of transit transport. For these cities is bypass the solution, which ensure transport calming in city centre and calming of the city in others viewpoint. Long-distance lines of public transport are not serving these cities, because they do not generate origin and destination routes for this transport mean. If the long-distance buses serve these cities, the reason is location of the city (and his bus terminal) directly on the route passing the city or the existence of major transport interchanges. If not, this service is lost.

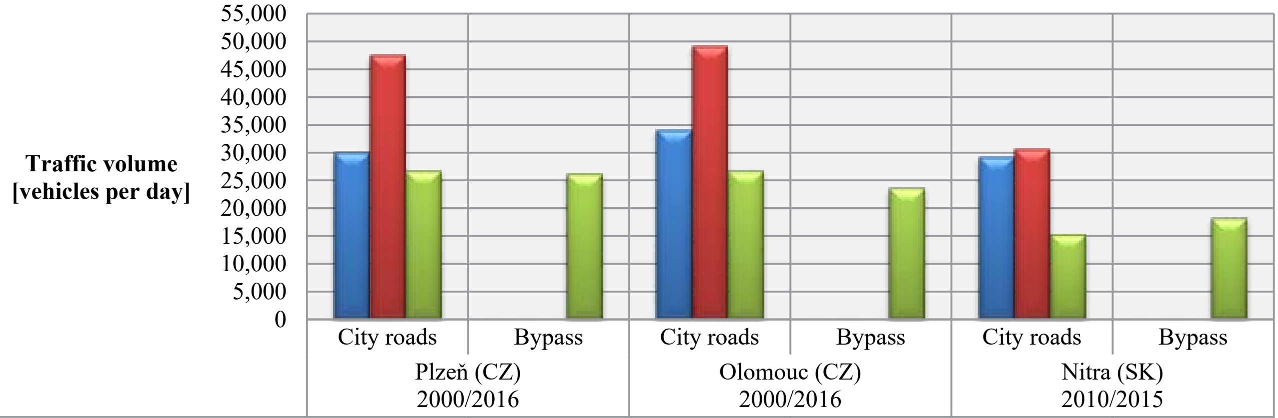
These categories are represented by several Czech and Slovak cities. To comparison was chosen the cities, in which have built bypass in last 15 years. In the table are basic data about cities (number of inhabitants and city type). For categorization of the cities is necessary to analyse attractiveness of the city. It is subjective impact and as well it is specified by location of important objects in the city. The analysis was found, that in case of chosen cities is attractiveness proportionate to number of inhabitants. Finally, the cities were categorized based on presented data about cities and bypasses.

8. Impacts of Bypasses

This chapter describes impacts of bypasses on selected set of cities. First pursued factor is volume of transit traffic. In all three city categories are observed similar results. After built the road bypasses are coming decrease traffic volume in city roads.

Specifically, in the cities from first category traffic volume was fallen by 50%. Current traffic volume is divided to city roads and bypass in a ratio of 1:1 (in typical case). City roads would be overloaded without bypasses as follows from this analysis. Growth of traffic volume in city roads (without bypass) would probably not be so great. The analysis confirms that bypasses do not necessarily result in a total reduction in total traffic volume in the city centre.

Fig. 1 confirms previous paragraph for first category cities. The data presents total traffic volume (all vehicles) in three levels. First is real traffic volume before bypass built. Second is estimated traffic volume (prognosis) on city roads after bypass built, based in prognosis published by national road authority (ŘSD, SSC). It is visible that the increase of traffic is more significant than it was presupposed. Third is real data after bypass built, which show decrease of traffic volume in city roads, but increase traffic volume on road bypass.

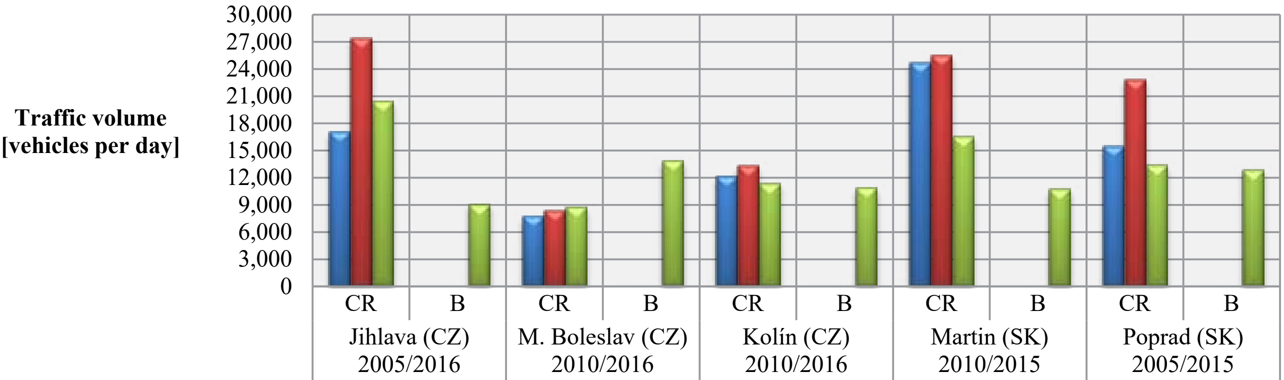


	Plzeň (CZ) 2000/2016 City roads	Plzeň (CZ) 2000/2016 Bypass	Olomouc (CZ) 2000/2016 City roads	Olomouc (CZ) 2000/2016 Bypass	Nitra (SK) 2010/2015 City roads	Nitra (SK) 2010/2015 Bypass
Before bypass; Real data	30,107	0	34,217	0	29,355	0
After bypass; Estimated data	47,659	0	49,240	0	30,731	0
After bypass; Real data	26,815	26,274	26,677	23,681	15,331	18,272

Fig. 1.
First category cities traffic volume
Source: authors on the base ŘSD, (2001); ŘSD, (2017); SSC, (2011); SSC, (2016)

In terms of public transport there have been no changes. These cities are significant from the point of view of regional importance and they generate passengers traffic flows, thus it is not suitable to bypass them.

In the cities from second category is different situation between Czech and Slovak cities. Factually, in Poprad and Martin has come to decrease of traffic volume in city roads (CR) after bypass (B) built. In these cities were traffic volume fall by 40%. Total traffic volume in bypass and city roads is on the level of estimated data (Fig. 2).



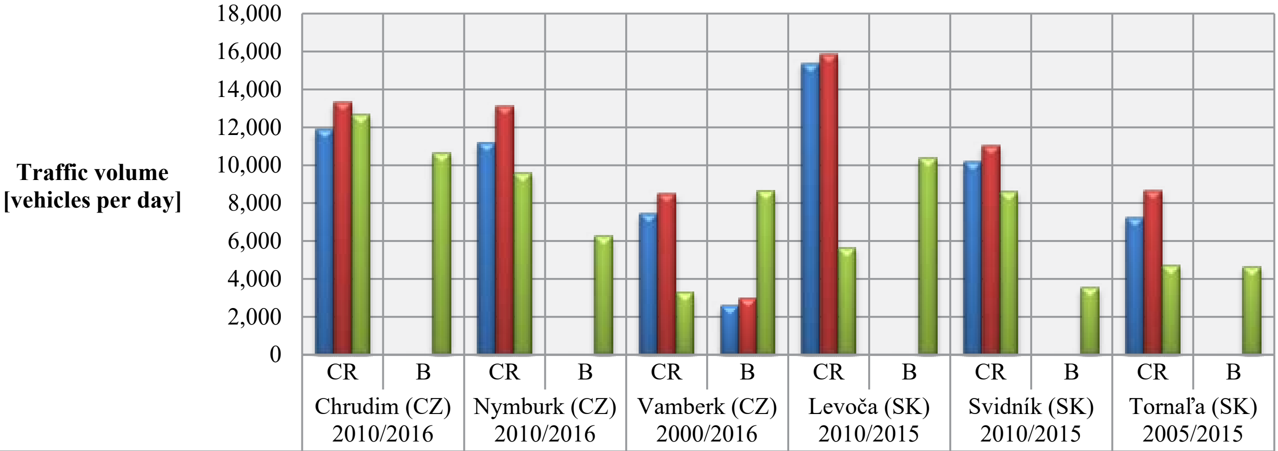
	Jihlava (CZ) 2005/2016 CR	Jihlava (CZ) 2005/2016 B	M. Boleslav (CZ) 2010/2016 CR	M. Boleslav (CZ) 2010/2016 B	Kolín (CZ) 2010/2016 CR	Kolín (CZ) 2010/2016 B	Martin (SK) 2010/2015 CR	Martin (SK) 2010/2015 B	Poprad (SK) 2005/2015 CR	Poprad (SK) 2005/2015 B
Before bypass; Real data	17,099	0	7,762	0	12,194	0	24,756	0	15,526	0
After bypass; Estimated data	27,477	0	8,406	0	13,373	0	25,534	0	22,909	0
After bypass; Real data	20,450	9,085	8,778	13,873	11,410	10,922	16,598	10,765	13,413	12,880

Fig. 2.
Second category cities traffic volume
Source: authors on the base ŘSD, (2006); ŘSD, (2011); ŘSD, (2017); SSC, (2006); SSC, (2011); SSC, (2016)

In Czech cities were increase of traffic volume. In Mladá Boleslav and Kolín remained traffic volume in city roads on the level of estimated data. In addition to this is used road bypass by additional users. Total traffic volume increased more as twice. In Jihlava is situation similar to first category cities.

Changes in long-distance public transport occurred after building the bypasses. Some cities are not served by all lines, because servicing the cities is depended on character of bus lines. If bypassed second category city is located between higher cities, it is high probability to not serving the city by these buses. For example, Slovak city Martin is not served by long-distance buses, because more important is connection between Košice and Žilina in Slovakia. The same is valid for Mladá Boleslav, which is located between cities Praha and Liberec in Czech Republic.

In Slovak cities from third category after building the bypasses have been to traffic volume distribution to city roads (CR) and bypass (B). Traffic volume in these cities was not significantly increased. In Czech cities is different situation. The bypasses, alternatively empty city roads, attracted new road users to use the city roads. It did not cause expected decrease of traffic volume in city roads, but volume was decreased only slightly. Fig. 3 confirms this situation. Note to city Vamberk: This city has had built a part of bypass before 2000 and full bypass was open in 2010. From this reason are for this part of bypass mentioned real and estimated data before the full bypass was opened (Fig. 3).



	Chrudim (CZ) 2010/2016 CR	Chrudim (CZ) 2010/2016 B	Nymburk (CZ) 2010/2016 CR	Nymburk (CZ) 2010/2016 B	Vamberk (CZ) 2000/2016 CR	Vamberk (CZ) 2000/2016 B	Levoča (SK) 2010/2015 CR	Levoča (SK) 2010/2015 B	Svidník (SK) 2010/2015 CR	Svidník (SK) 2010/2015 B	Tornaľa (SK) 2005/2015 CR	Tornaľa (SK) 2005/2015 B
Before bypass; Real data	11,889	0	11,191	0	7,468	2,606	15,397	0	10,198	0	7,255	0
After bypass; Estimated data	13,347	0	13,138	0	8,513	2,970	15,881	0	11,045	0	8,678	0
After bypass; Real data	12,683	10,662	9,604	6,274	3,292	8,663	5,644	10,401	8,631	3,567	4,726	4,650

Fig. 3.
Third category cities traffic volume
Source: authors on the base ŘSD, (2001); ŘSD, (2011); ŘSD, (2017); SSC, (2006); SSC, (2011); SSC, (2016)

Increase of traffic volume is most probably brought by higher attractiveness of city routes because diverted transit traffic cleared the city roads after bypass built. Second factor of increase of traffic volume is bypass attractiveness, which was attracting road users from other lower category roads.

Selected cities have not high regional importance, but they are not located between higher cities (exception Levoča). From this reason they are served by long-distance bus lines in spite of bypass built. For example, there are two nearby cities in Czechia (Mirotice and Čimelice). City Mirotice (1 231 inhabitants) has bypass and many long-distance bus lines (27 from 28 between) are diverted outside the city. By contrast smaller city Čimelice (967 inhabitants) does not have bypass and it is served by 35% long-distance buses (10 from 28 per day). This suggests that the bus service of the city is dependent on more factors, not only on regional impact and bypass.

9. Distribution of Traffic Flows after Bypass Opening

It can be seen that 50.2% of traffic flows use city bypasses in average. Median value of 49.24% is close as well. It is in comparison with segments in city centres used for transit traffic in the past.

Basic overview is provided by Fig. 4 expressing relation between number of city inhabitants and ratio of traffic flows using bypass.

There is no significant relation between number of inhabitants and ratio of traffic using bypass. There is interesting fact that the maximally and minimally utilized bypasses are in the cities of the 3rd category. Maximally effective bypass is located in Vamberk (4 536 inhabitants) where 72.47% of vehicles using the bypass. Minimal ratio of traffic flow using bypass is registered in Svidník (11 096 inhabitants). It is the value of 29.24%.

Maximum ratio of 61.25% is registered in Mladá Boleslav (44 167 inhabitants) and minimal of 30.76% in Jihlava (50 724 inhabitants) in the case of 2nd category cities. Paradox is that both cities are very similar in the point of view of numbers of inhabitants to make such difference in result. It could be stated that structure of the city and regional area as well are very important for this. Mladá Boleslav is industrial centre. Connection of industrial plants to backbone communications (motorway) is relatively suitable that the vehicles coming here can use bypass as well. In the point of view of destination traffic the city of Mladá Boleslav has competition in the capital Prague (ca. 65 km far by motorway) and Liberec (ca. 51 km).

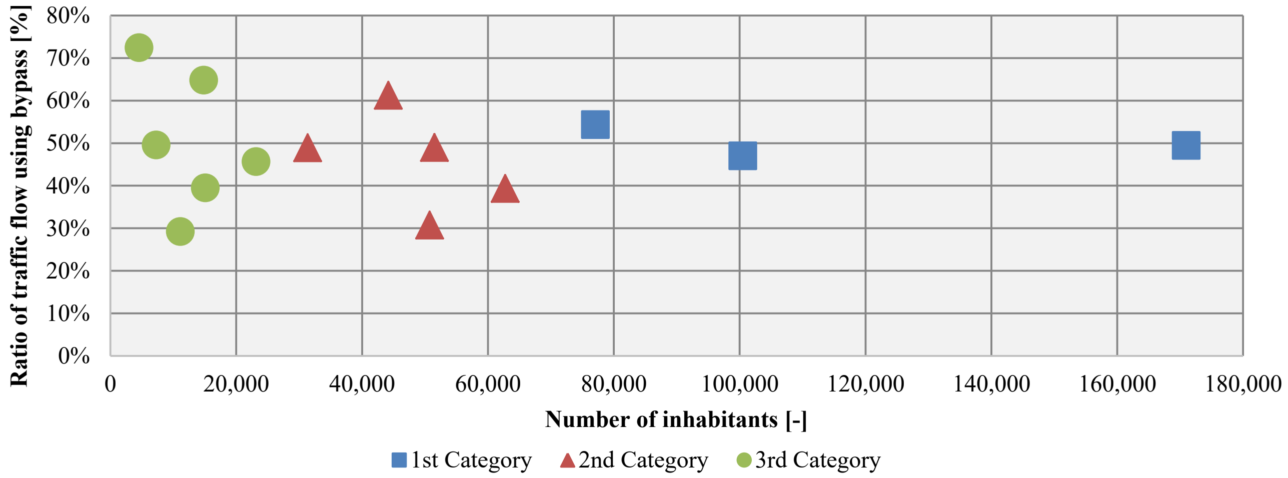


Fig. 4.
Relation between number of city inhabitants and ratio of traffic flows
Source: authors on the base ČSÚ, (2018); ŘSD, (2001); ŘSD, (2006); ŘSD, (2011); ŘSD, (2017); SSC, (2006); SSC, (2011); SSC, (2016); ŠÚ SR, (2018)

Jihlava is typical regional centre attractive to be a destination for traffic from surroundings. The distances are ca. 130 km to Prague and 90 km to Brno by motorway. Transit of passenger cars in direction south-north (along solved bypass) is presupposed to be not so significant due to these relatively longer distances. The places of possible destination can be distributed more evenly within the city area in comparison with the large industrial zone located in Mladá Boleslav. These facts can be explanation for this.
There are 3 cities examined in the first category. The result is that 47.03%–54.37% of vehicles use bypasses. The situation can be characterized as "average" in these cases.

10. Increase of Traffic Volume in Time

Development of traffic volume is measured in different time horizons in the most of cases. Identified difference in two measurements before and after bypass opening is averaged by time frame of 1 year and expressed as a percentage (ratio) of current volume of traffic flow.
The most important increase is registered in Mladá Boleslav. It is the value of 10.96% per year. There is about ca. 15 000 vehicles per day more in comparison of years 2016 and 2010. On contrary, minimal increase is registered in Levoča 0.81% per year. Average increase is 4.10%, median value of 2.99%. Median value is more illustrative because of relative high value in Mladá Boleslav.
Based on this case study, it could be simply quantified that it will take less than 25 years when the 50% of vehicles diverted to bypass (in average) will be substituted by newly occurred traffic (3% per year) in city centres. Naturally, this is a model case only. This process can be sometimes more quickly, sometimes more slowly according to local conditions. Traffic volume in city centre of Mladá Boleslav and Chrudim are higher than before bypassing after 6 years only. In the case of Jihlava after 11 years. Volume of traffic flows in Plzeň and in Kolín are about 90% of values before bypassing. In Plzeň after 16 years, in Kolín after 6 years.

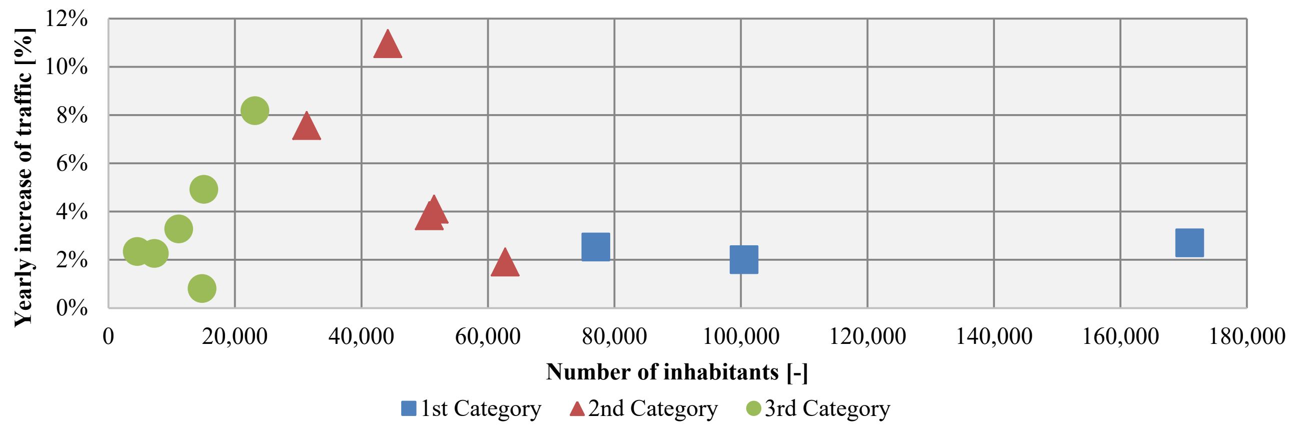


Fig. 5.
Relation between numbers of inhabitants and increase of traffic

Source: authors on the base ČSÚ, (2018); ŘSD, (2001); ŘSD, (2006); ŘSD, (2011); ŘSD, (2017); SSC, (2006); SSC, (2011); SSC, (2016); ŠÚ SR, (2018)

There is no significant relation between numbers of inhabitants and increase of traffic as it is illustrated by the Fig. 5. The reasons can be possibly caused by some socio-economic facts or by other effects.
On the other hand, it is correct to mention that traffic volume within city centres will be more and increased and serious without bypassing. Bypass can significantly slowdown the increase of traffic, this presumption is valid. Problem is with presumption that bypass will calm the traffic. This effect can occur in limited time only, because diverted traffic will be substituted if the volume of traffic will be still increasing like in time period of the beginning of 21st century evaluated in this article.

11. Following Research – Discussion

Results published in this article are based on a pilot study. It was shown by this case study that a lot questions are remaining in this filed. For example, effect of so called traffic induction was not evaluated separately within this study (it is considered within applied general numbers). Relations to some socio-economy data were not estimated. Common presumption (partial hypothesis) that number of inhabitants will have significant impact can be rejected now, after this basic study only.
There is a lot of space for future research what can be realized within elaboration of mentioned dissertation thesis.

12. Conclusion

The article confirms validity of all of the hypotheses stated in the chapter 4 of this article. In any case the building of bypasses help traffic situation in city centres. Traffic volume in city centres has not been totally reduced. A part of traffic was diverted outside the city by bypass, but it makes the possibility for new transport users to use the city roads. Only in some cities (e.g. Vamberk, Tornaľa) the traffic volume decreased and diverted transit traffic was not been replaced by new traffic.
Service of cities by long-distance public transport is partially dependent on road bypasses. It was confirmed that public transport service in bypassed cities can be reduced with aim to make bus connection faster between higher cities. Servicing the cities is also dependent on character of bus lines. It is a difference between cities in the same category, because some is located between higher cities (e.g. Mladá Boleslav) and some is itself the higher cities (e.g. Poprad).

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MARKOV MODELS IN THE ANALYSIS OF THE OPERATION PROCESS OF TRANSPORT MEANS

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Abstract: Operating systems of technical facilities require proper organization of logistic management processes and reliable logistics infrastructure, ensuring efficient and effective task implementation. Such systems are characterized by great diversity, but they correspond to a certain generalization, thus can be described by a mathematical model. This article proposes using Markov model to analyse the transport process. The study was conducted in a discrete time and in a continuous physical time. The analysis was based on data obtained from the company, regarding two different business periods. In the first stage, the choice of suppliers was chaotic and random. Next, an in-depth analysis was conducted and the best contractors were selected. The article presents how undertaken actions have translated into readiness of vehicles, and consequently, the system as a whole, using Markov processes. The aim was to present a method of describing system of technical facilities that effectively supports its diagnostics by forecasting logistic operational indicators. The proposed models are universal and allow for testing of any homogeneous and not-modernized operating systems. Most effectively they can be used in systems where readiness is the most important parameter, i.e. in military, police, health service, fire brigade and civil transport systems. The best results will be obtained for systems that allow accurate recording of the starting and completing tasks. Effective management of the operating processes is important for the management bodies and logistic component responsible for securing implemented activities. This ensures continuity of supply, its quality, reliability and systematic stock recovery. The model presented in this article has a great practical value, allowing identification and description of functioning systems, their evaluation and correction, and design of new operating systems.

Keywords: Markov models, vehicles readiness, supplier management.

1. Introduction

Management of transport means is particularly important in civil transport systems, which are characterized by strict delivery schedules, such as food and fuel supply systems, as well as passenger transport. Their readiness and efficiency guaranteeing punctuality and high quality of services is extremely important, and therefore alongside processes of carrying out transports, efforts must be made to maintain the fleet at a high level of reliability. Proper logistic management of the base not only ensures availability of vehicles in required time, but also guarantees their longer durability and reduces failures. However, often entrepreneurs focused on the core business of the company, treat processes related to restoration of the technical capacity of vehicles superficially, not paying enough attention to the way they are carried out. This was the case in analyzed transport company. Until this problem was identified, the issues of maintaining required level of vehicles technical condition were carried out chaotically and on an ad hoc basis. Only the growing problems forced seeking new solutions and introduction of a comprehensive vehicle management system. The effectiveness of taken decisions can be best confirmed by comparing two periods: before and after changes were implemented, which mathematically has been carried out in this article using the Markov processes. The study was conducted both in discrete time (for abstract time of subsequent state changes) and in continuous physical time. The obtained results allowed not only for description of the analyzed phenomenon, but also for its prediction and conclusion concerning the future.

2. Characteristics of the Research Problem

The research subject is an enterprise providing public transport services based on motor vehicles designed for transport, for more than 7 and not more than 9 persons, including the driver (Law on the road traffic, 1997), i.e. so-called minibuses. The collected data concerned two six-month periods of the company's activity. Services are provided only on one single route section, in both directions. On average, journeys are taken every hour in each direction. The driver sets off with passengers from point A to point B, without stops. In point B, after the customers who have arrived from point A get off, more people get on. The route is 62 km long and takes on average about one hour. The fleet consists of 15 vehicles, which are of Mercedes Vito diesel model with a capacity of 2143 cm3 and a power of 100 kW.
Until recently, the company's owner did not pay due attention to the issue of repairing his vehicles. They were carried out completely accidentally, in a situation where a defect occurred. A motor vehicle workshop was then selected at random basis or on the recommendation of driver, if just was available. Since there were not many failures at first, due to the relatively new fleet, no attention was paid to how to keep it in working order. However, there have gradually been complaints from drivers about the need to increase daily pre-departure maintenance activities, who had to additionally deal with issues such as controlling and replenishing operating fluids, including engine oil and coolant, remedying minor electrical faults such as the lack of external lighting in the vehicle due to improper maintenance of connectors and contacts that were tarnished and required cleaning or checking the battery charge or tire pressure level. As a result of such circumstances, the management decided to take a look at this problem. Firstly, the market was identified, it turned out that there are many workshops in the immediate vicinity, and these are mainly small local companies. However, their closer analysis has shown that only those where the quality of services is low have available dates, but those which

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have the best reputation among customers often require even several weeks of waiting time. Therefore, when repair was required in an emergency situation, it was highly likely that the vehicle would reach one of the less reputable locations. That is why a thorough analysis of the available services was carried out, along with their cost, as well as possibility of guaranteeing the availability of dates for occurrence of an emergency. Two companies were finally selected with whom long-term contracts had been signed. Their task was to carry out short-term repairs and renovations, as well as service inspections ensuring the maintenance of proper technical condition and reducing the risk of serious damage thanks to early diagnosis. The comparison results of these two periods and their impact on exploitation of transport means are presented below.

3. Research Methods – Characteristics of Markov Processes

Modelling of many phenomena from everyday life is possible thanks to the analysis of random processes, among which the chains methods and Markov processes, as well as semi-Markov are popular, which the usefulness is visible especially when it is not possible to make an assumption about the independence of events and random variables.
The advantages of forecasting based on Markov chains include (Filipowicz, 1996; Kałuski, 2007):

- possibility of prediction, when the reasons for occurrence of studied phenomenon are not known or when there are too many of them to be included in the analysis,
- possibility of constructing forecasts for measurable and non-measurable (qualitative) phenomena,
- possibility of constructing short, medium and even long-term forecasts,
- possibility of forecasting the phenomena of mutually dependent components in time.

Markov processes differ from other stochastic processes with a discreet set of states in that they meet the Markov condition for the equality of conditional distributors (Koźniewska and Włodarczyk, 1978; Decewicz, 2010) (1).

$$P\left(X_{t_{n+1}} = j \middle| X_{t_n} = i, X_{t_{n-1}} = i_{n-1}, \dots, X_{t_1} = i_1, X_{t_0} = i_0\right) = P(X_{t_{n+1}} = j | X_{t_n} = i) \tag{1}$$

It is a condition of memory lack (history) of stochastic process: conditional distributor at moment of t_{n+1} depends only on previous state X_n of the process, and previous states X_{tn-1} do not influence its value. Markov processes with discrete time are called Markov chains and they are described mathematically using a stochastic matrix *P* with elements p_{ij} that are transition probabilities from the state $X_n = i$ to the state $X_{n+1} = j$, which fully describe the chain process. The values of their estimators from the sample are the frequency w_{ij} of transitions from the state S_i to the state S_j. In the continuous period, in addition to the probability matrix *P*, the process is characterized by matrix Λ: the intensity of transitions λ_{ij} from the state S_i to the state S_j. The intensity of transitions $\lambda_{ij} \geq 0$ for $i \neq j$ is defined as the right handed derivative probability of transitions relative to time, and the intensity $\lambda_{ij} \leq 0$ for $i = j$ is defined as completing the sum of transitions intensity from the state S_i for $i \neq j$ to 0 and is referred to as the intensity of exits from the state S_i. These are not the intensity of returns from the state S_i to S_i – as the notation suggests, as logistics processes assume no returns. An important role in the study of processes using Markov chains have its limit properties, especially the probability limits $p_i(n)$ with $n \to \infty$, which describe the probabilistic behavior of the process after a long period of time. They will be used to describe the phenomenon evolution in the future.

4. Markov Model in Discreet Time

Chains methods and Markov processes are also called the state space methods. They are based on the characteristics of object in space by means of distinguishable, separable states, the collection of which creates so-called exploitation repertoire, which enables to describe the exploitation process of technical object in a clear and exhaustive way (Będkowski and Dąbrowski, 2000). Therefore, the first stage of construction of Markov model is to identify possible exploitation states in which the analyzed transport means are located. A minimum of five states were distinguished, sufficient to diagnose the system before and after implemented changes. They are presented together along with their characterization in Table 1.

Table 1
Exploitation states distinguished for technical objects under research

Exploitation state No.	State name	Characteristics of the exploitation function of object
S1	Repair	Service to restore the performance of vehicles. It consists of a set of activities restoring technical efficiency by removing malfunctions caused by wear and tear or damage. This is achieved by repairing or replacing worn parts (Orzełowski, 2009).
S2	Carrying out the task – transport	Provision of passenger transport services along the analyzed route. takes place in cyclic, two-way journeys without planned stops.
S3	Garaging	Vehicle stops in the garage while waiting for the next tasks.

Exploitation state No.	State name	Characteristics of the exploitation function of object
S4	Getting on and getting off passengers	It takes place at designated points. Passengers get on at stop A and get off at stop B and inversely.
S5	Vehicle operation	Set of activities carried out on the vehicle aimed to prevent malfunctions and premature wear and tear of components in service (Orzełowski, 2009). It also includes preparation of the vehicle for service. It usually takes place in the morning – as required, but also on an ad hoc basis during the day, as a result of unforeseen events.

Source: own study

The correct characterization of exploitation system still requires defining the relation between its elements, and therefore it was necessary to determine the possible transitions of the object from the previous state to the next state, which is presented in a form of matrix (Table 2) and by means of a graph (Fig. 1).

Table 2
Transitions matrix between states

↓Si→Sj	S1	S2	S3	S4	S5
S1	0	0	1	1	0
S2	0	0	0	1	1
S3	1	0	0	1	1
S4	1	1	1	0	1
S5	1	1	1	1	0

Source: own study

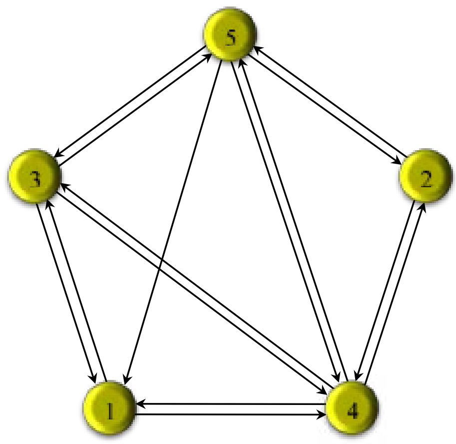

Fig. 1.
Graph of transitions between states
Source: own study

According to the theory mentioned above, the condition of applying Markov processes is fulfillment of the assumption about the lack of analyzed phenomenon history. Evaluation of this criterion is possible by analysis of the autocorrelation function ACF and partial autocorrelation function PACF (StatSoft, 2006). The lack of significant values of the above functions enables to make an assumption about the lack of memory and at the same time enables to determine the value of matrix P estimators of transitions probabilities on the basis of collected data on the phase trajectory of objects. This lack was checked for all states and presented in Figures 2 and 3 for an example of the state S2.

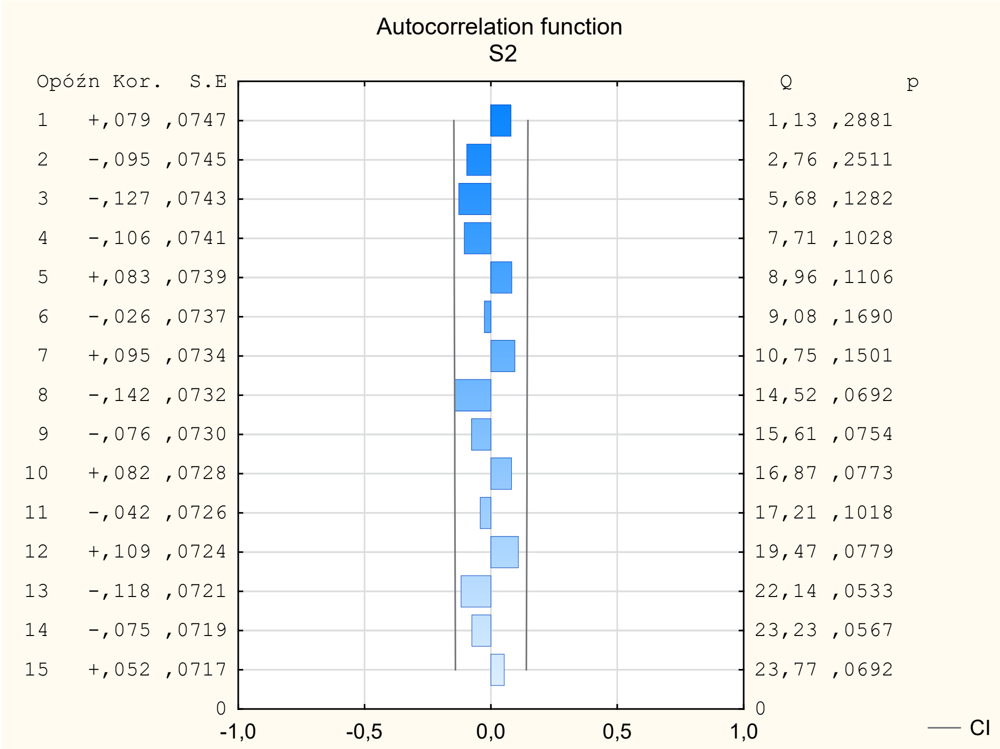

Fig. 2.
Autocorrelation function of the duration of S2 state
Source: own study

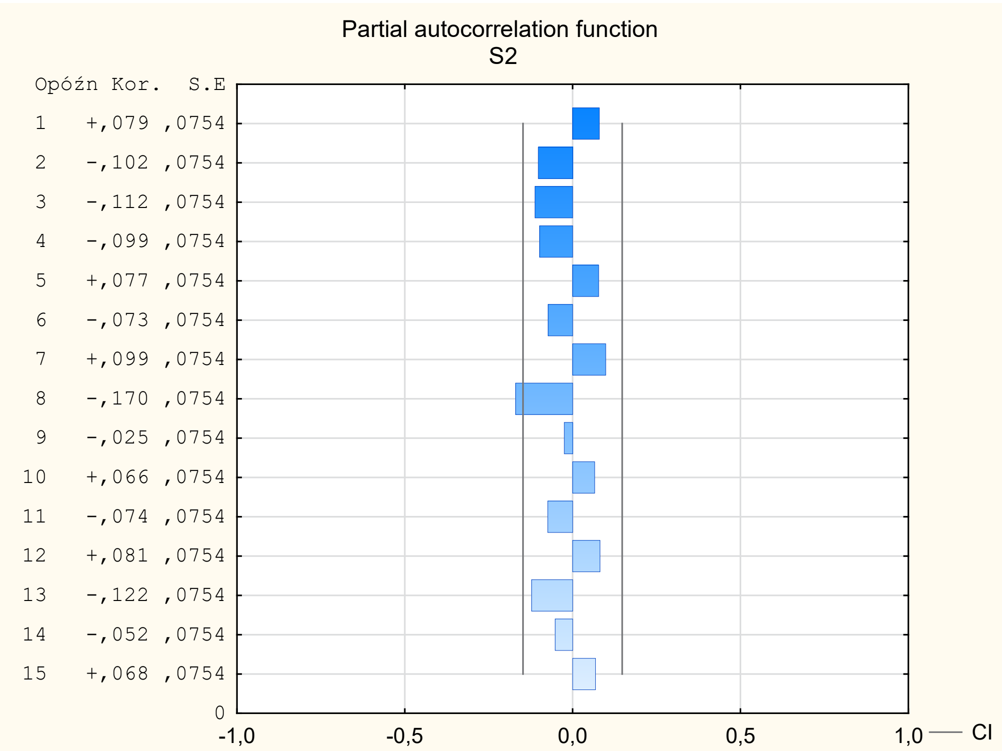

Fig. 3.
Partial autocorrelation function of the duration of S2 state
Source: own study

Estimated elements p_{ij} of matrix *P* for two analyzed stages are described below. Table 3 presents the values of estimators for the process before implemented change in the way of performing vehicle repairs and Table 4 after implemented new method of managing them.

Table 3
Element values p_{ij} of matrix P before implemented change

before	S1	S2	S3	S4	S5
S1	0	0	0.090909	0.909091	0
S2	0	0	0.000873	0.981659	0.017467
S3	0.022346	0	0	0.357542	0.620112
S4	0.014423	0.914263	0.068109	0	0.003205
S5	0.025	0.05	0.025	0.9	0

Source: own study

Table 4
Element values p_{ij} of matrix P after implemented change

after	S1	S2	S3	S4	S5
S1	0	0	0.2	0.8	0
S2	0	0.00085	0.00085	0.994048	0.004252
S3	0.017341	0	0	0.49711	0.485549
S4	0.005934	0.928006	0.065665	0	0.000396
S5	0.020833	0.041667	0.010417	0.927083	0

Source: own study

Estimation errors were calculated for the estimated parameters. Their satisfactory value allowed for continuation of the study, which was a comparison of transitions probabilities for two periods. The percentage changes are shown in Table 5.

Table 5
Probabilities value ratio for transitions of two process stages

% p_{ij}	S1	S2	S3	S4	S5
S1			120.00	-12.00	
S2			-2.64	1.26	-75.66
S3	-22.40			39.04	-21.70
S4	-58.86	1.50	-3.59		-87.66
S5	-16.67	-16.67	-58.33	3.01	

Source: own study

Obtained results are very satisfactory and indicate a positive direction of undertaken activities. A radical change, noting a significant decrease, was the transition from the state S3 of stops in garage (22%), S4 of getting on and getting off (59%) and S5 of service (17%) to the state S1 of repair, which means that there were far fewer situations in which as a result of noticed failure it was necessary to transfer the vehicle to the mechanic. This is due to the fact that maintenance services offered in the second stage were at a higher level. Workshop owners, for which long-term contracts became an attractive and reliable source of income, tried to take care of the quality and professionalism of their work so as not to lose a profitable customer. The use of better quality spare parts, professionalism of the service, supported by experience and long-term practice, as well as systematic inspections of the technical condition resulted in fewer repairs, and therefore a decrease in the frequency of changes between the state of S1 and remaining states (S3, S4, S5). The number of transitions between the state S2 and the state S5 was also reduced. The situation, which after the performed task (transport) was followed the service, was up to 75% less. Previously, the need to take such measures resulted from minor faults found during the journey and caused a necessary to remove them quickly. These were e.g. sudden increases in coolant temperature caused by leaks in the system and requiring refilling, or a broken drive belt causing the alternator to be replaced or in some cases even leading to a complete discharge of the battery. As a result, the next trip was delayed or the vehicle had to be replaced with another, if the malfunction was more serious. The frequency of transitions in the opposite direction from S5 to S2 was also reduced by 17% due to a decrease in the number of morning maintenance operations. Excellent technical condition of vehicle caused that it was often unnecessary to carry out treatments before the journey. It also affected the change in attitude of drivers, whose behavior after modifications in fleet management became an element of the company's policy increasing care for possessed resources. They began to treat the vehicle with greater care, and they also easily repaired a few small defects resulting from the use of e.g.

lighting or other electrical equipment in the vehicle. It was also one of objectives of the company's strategy to make all employees jointly responsible for technical condition and appearance of vehicles, and thus the company's image. The decrease (58%) in frequency of transitions from S5 to S3 (stops in garage) was also significant. Therefore, there were fewer situations when during the service it was found that there were irregularities preventing driving, and because it was not possible to park the vehicle in a mechanical workshop – usually due to lack of free time, it returned to the garage. After implemented changes, such situations were much fewer, and if at all, it was not because of the lack of free repair dates, but because of the fact that the fault occurred outside the workshop hours and the car had to wait for its opening. There were no initial problems with distant dates of handling services in the second stage. The most spectacular change was from the state S4 (getting on and getting off) to the state S5 (service), where a decrease of 88% was recorded. This was again the result of good condition of the vehicles and a reduced number of necessary services between daily transports. It is also worth emphasizing the increase in mutual relations between the states S2 – performing the journey and S4 – getting on and getting off, which means that the total effectiveness of using possessed means of transport increased, as there were carried out more transport cycles. In order to fully show the existing changes, the average process times in two analyzed periods were also compared. The results are presented in Table 6.

Table 6
Comparison of average durations of S1 – S5 states

State	S1	S2	S3	S4	S5
before	189.17	64.1	412.71	8.32	22.57
after	78	64.1	419.691	8.69	16.42
change %	-58.95	-0.08	1.69	4.51	-27.24

Source: own study

In accordance with the above table, we can see a satisfactory difference, especially between the average duration of states S1 and S5, which significantly decreased the duration of maintenance, which was caused by the impeccable level of their carrying out. Better materials and high quality of service caused that the time spent on average by vehicles in the mechanical workshop was shortened by almost 60%. This also affected the average service time, which decreased by 30%. The average durations of remaining states result from the specific nature of implemented tasks and differences between them were only of a random nature and were not related to implemented changes. All the relations are shown in Fig. 2.

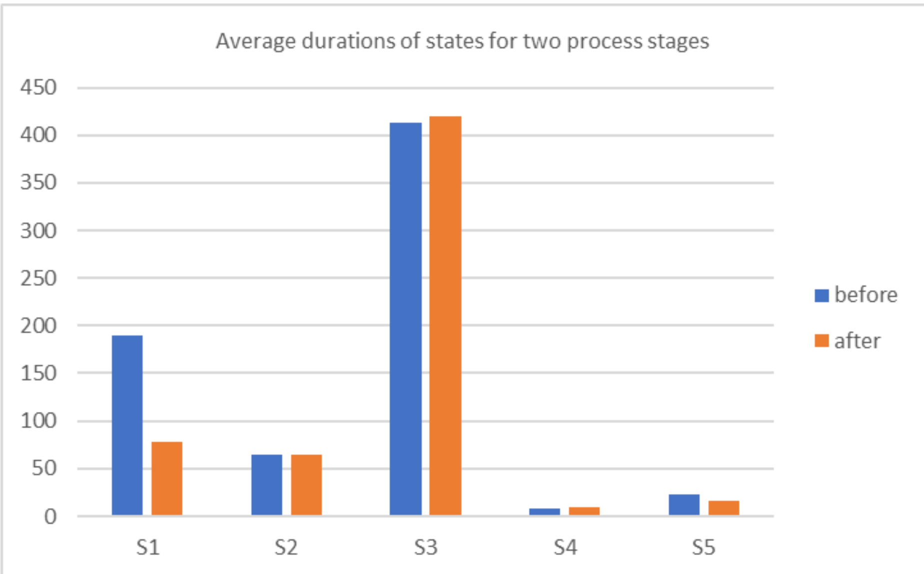

Fig. 4.
Comparison of average durations of states before and after implemented change
Source: own study

The next step was to study the limit properties of the process. Estimated models of Markov chain turned out to be ergodic for both analyzed stages, which enabled to describe probabilistic behavior of the process after a long time with the use of limit probabilities p_j. Their values were calculated using Solver addition of Microsoft Excel program and confirmed in Mathematica program, which allows a wide range of numerical studies to be conducted on stochastic processes. The obtained ergodic probabilities for two studied stages are presented in Table 7 and compared in Fig. 3.

Table 7

Ergodic probability p_j for two process stages

p_j		S1	S2	S3	S4	S5
before	p_j	0.008514	0.442971	0.034817	0.482823	0.030876
	$p_j\%$	0.85	44.30	3.48	48.28	3.09
after	p_j	0.003866	0.455108	0.033473	0.489172	0.018381
	$p_j\%$	0.39	45.51	3.35	48.92	1.84
change %		-54.59	2.74	-3.86	1.32	-40.47

Source: own study

It should be noted that according to the Markov model, in discrete time the analyzed processes in both stages aim to maintain in two states: in the state S2, which is performing passenger transport, and in the state S4, which includes activities related to getting on and getting off of people at stops. The limit values for these states do not differ much, but their increase in the second stage is noticeable. The more interesting turned out to be decrease of probability limits for states related to restoration of transport means, i.e. S1 and S5. Ergodic values decreased by almost 55% for performed repairs and by 40% for maintenance, which means that in the future the analyzed technical objects of system will maintain mainly in states related to conducted business. Long-term forecasts for Markov chain are therefore very satisfactory for the entrepreneur.

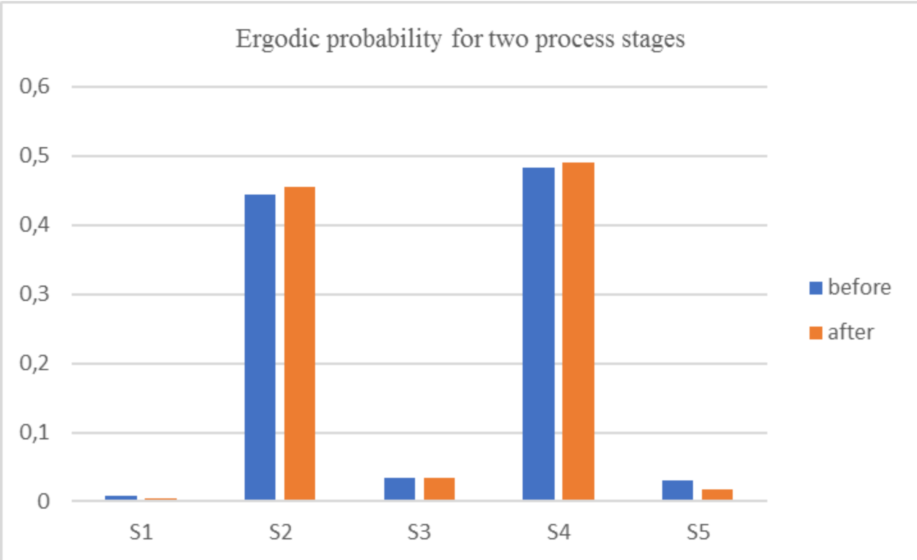

Fig. 5.
Comparison of ergodic probability pj for two process stages
Source: own study

In order to determine whether the forecasted evolution is far from real time, it was checked whether during data collection the process was far from the limit steady-state. For this purpose, differences in ergodic frequencies and probabilities were calculated for data collected in the second stage of study, which are presented in Table 8.

Table 8
Percentage deviations of frequency from ergodic probability of the process after changes

Deviations [%]	S1	S2	S3	S4	S5
after changes	0.07	-0.04	-0.03	0.05	1.02

Source: own study

According to the results presented above, all percentage deviations from the hypothetical balance are very small, and therefore the system at the time of data collection was very close to the asymptotic balance for Markov chain. This proves the usefulness of forecast for the chain.

5. Markov Model in Continuous Physical Time

Satisfactory results obtained for the Markov chain decided to continue the study of Markov models in a continuous physical time. As mentioned earlier, it requires defining not only the matrix P of transitions probability, but also the intensity matrix of changes in states Λ. Therefore, values of elements λ_{ij} of matrix Λ of the transition intensity for each stage of the process have been estimated. The obtained results are presented in Table 9 for the process before changes and Table 10 after changes.

Table 9
Element values λ_{ij} of matrix Λ of the first research stage

λ_{ij}	S1	S2	S3	S4	S5
S1	-0.0099	0	0.0045	0.0054	0
S2	0	-0.0474	0.0159	0.0156	0.0160
S3	0.0028	0	-0.0075	0.0021	0.0026
S4	0.1248	0.1211	0.1087	-0.4690	0.1144
S5	0.0516	0.0511	0.0475	0.0407	-0.1909

Source: own study

Table 10
Element values λ_{ij} of matrix Λ of the second research stage

λ_{ij}	S1	S2	S3	S4	S5
S1	-0.0273	0	0.0148	0.0125	0
S2	0	-0.0477	0.0159	0.0156	0.0162
S3	0.0029	0	-0.0077	0.0022	0.0026
S4	0.1158	0.1155	0.1083	-0.4154	0.0758
S5	0.0667	0.0930	0.0500	0.0600	-0.2696

Source: own study

The intensity of change is expressed in the number of transitions per hour. They are interpreted by reference to the time of lasting the initial state and not to the time of process. E.g. λ_{42} = 0.1211/h means that during the hour of lasting state S4 the vehicle transits to the state S2 on average 0.1211 times, i.e. during the day there were about 3 such changes on average. Since the intensity of transitions for Markov process was calculated as the reversal of expected value (average population) of the duration of state S_i before the state S_j, those states which had higher mean times have lower values λ_{ij}. Therefore, the highest increase in the value of elements of the transition intensity matrix was recorded in relations S1→S3 and S1→S4, due to lower average duration in the process after changes. The average time of state S3 under condition of maintaining in the state S1 was 220 minutes before the change and only 67 minutes after the change, while the average time of maintaining in the state S4 under condition of maintaining in the state S1 was initially 186 minutes and then only 80 minutes. On the basis of estimated values of transition intensity, ergodic probabilities for each stage of the process were also calculated, obtaining results presented in Table 11.

Table 11
Ergodic probability p_j for two process stages in continuous physical time

p_j		S1	S2	S3	S4	S5
before	p_j	0.368744	0.043156	0.561317	0.00969	0.017093
	p_j %	36.87	4.32	56.13	0.97	1.71
after	p_j	0.172442	0.060926	0.738649	0.013502	0.014482
	p_j %	17.24	6.09	73.86	1.35	1.45
change %		-53.24	41.17	31.59	39.33	-15.28

Source: own study

Calculated ergodic probabilities show that the system in continuous physical time tends primarily to maintain in states S1 and S3 both in the first and second stage, which is an obvious result, as these are states with the highest mean times. However, probability values differ. In the first stage, the system aimed to maintain in a state of repair for 37% of the time and after the change only for 17%, which means a decrease by more than 50%. The probability limit for maintaining in the state S5 has also been reduced by 15%, which is also a satisfactory result. The indications for other states are similarly positive. An increase was recorded for S2 and S4 by 41% and 39%, respectively, i.e. for transport states and for S3, which was caused by a reduction in the time spent in repair. Therefore, the obtained forecasts can be considered as satisfactory.

In the last stage, the results for Markov process were visualized by graphical presentation of times determining ergodic probabilities. The determination of characteristic times of the object's reaching the stationary state after a given set of initial states requires solving the set of Chapman-Kołmogorov-Smoluchowski equations, which general matrix form for the studied process is a form of (2):

$$\begin{bmatrix} p_1(t) \\ p_2(t) \\ p_3(t) \\ p_4(t) \\ p_5(t) \end{bmatrix} \cdot \begin{bmatrix} -\lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} & \lambda_{15} \\ \lambda_{21} & -\lambda_{22} & \lambda_{23} & \lambda_{24} & \lambda_{25} \\ \lambda_{31} & \lambda_{32} & -\lambda_{33} & \lambda_{34} & \lambda_{35} \\ \lambda_{41} & \lambda_{42} & \lambda_{43} & -\lambda_{44} & \lambda_{45} \\ \lambda_{51} & \lambda_{52} & \lambda_{53} & \lambda_{54} & -\lambda_{55} \end{bmatrix} = \begin{bmatrix} p_1'(t) \\ p_2'(t) \\ p_3'(t) \\ p_4'(t) \\ p_5'(t) \end{bmatrix} \tag{2}$$

The above set of CH-K-S equations with the restrictions which are a condition of normalization was solved with the use of Mathematica Markov continuous module, assuming that at the initial moment $t = 0$ the process $X(t)$ is in the state $S1$. In this way, a function illustrating the process of object's reaching the limit state was outlined. Fig. 4 shows its course for the state S1 with the highest limit probability, then Fig. 5 and Fig. 6 shows the courses for states S2 and S4, related to the core business of enterprise.

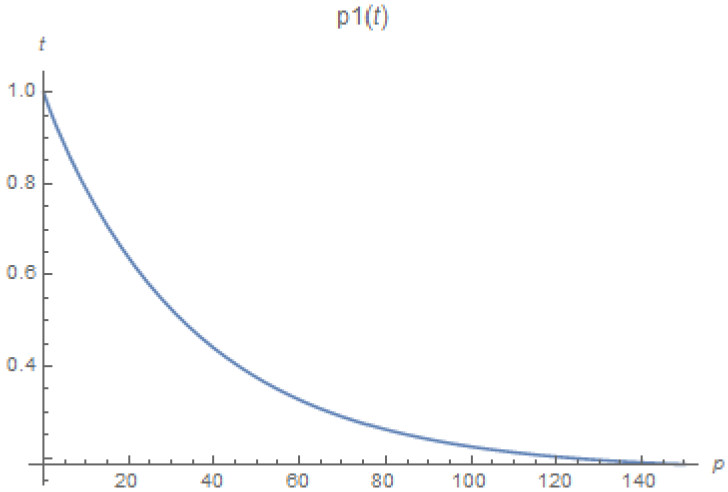

Fig. 6.
Evolution of probability of maintaining system in S1 state
Source: own study

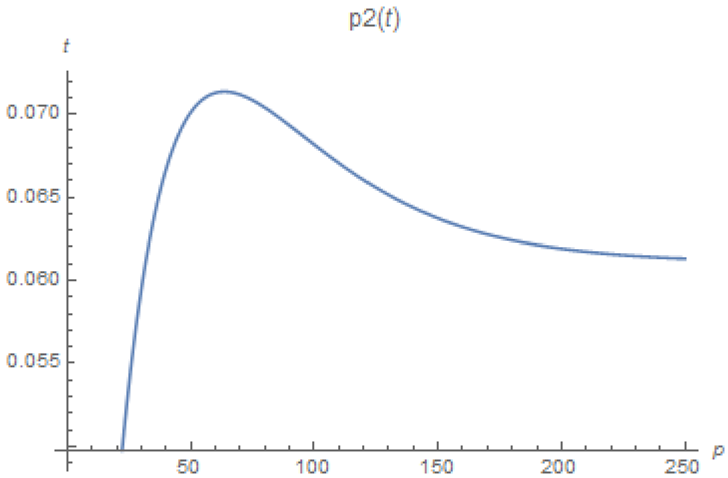

Fig. 7
Evolution of probability of maintaining system in S2 state
Source: own study

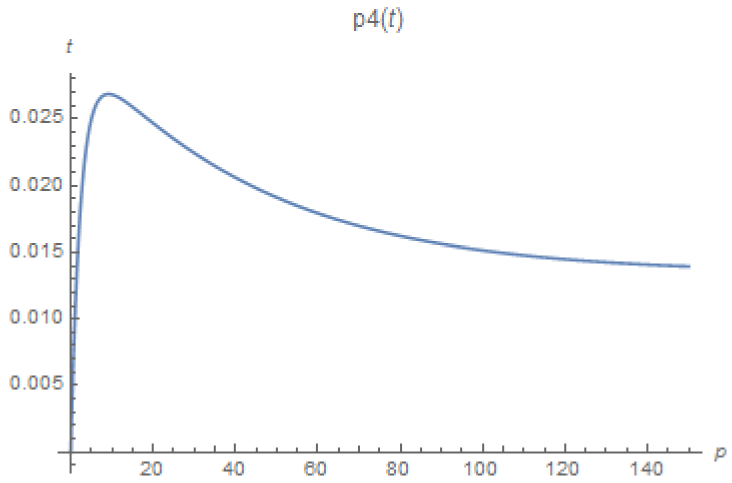

Fig. 8.
Evolution of probability of maintaining system in S1 state
Source: own study

The probability of states S2 (performing the transport) and S4 (getting on and off) having the greatest limit probability is determined most slowly – Fig. 7 and 8. The probability of state S1 (repair) is determined more quickly, but also within a few hundred hours. The study shows that the analyzed system of operation is in steady-state after about 200 hours from forcing the state S1.

6. Summary and Conclusions

The main aim of this study was to show how proper management of the restoration processes of technical objects affects the process of their exploitation. The comparison of two periods of the company's activity, differing in the way the suppliers of repair services were selected, showed significant differences in exploiting the potential of possessed transport means. In the first phase, the random choice of workshops resulted in more repairs and carried out services, as well as longer maintenance. This translated into lower use of the base and obviously not only increased costs, but also reduced profits on operations. In the second stage, a thorough market analysis and selection of the best suppliers resulted in greater readiness of transporting means, as well as increased efficiency of transport. The proposed Markov models described the analyzed system satisfactorily, indicating its imperfection and potential for improvement in the first stage, as well as highlighting the success of actions taken in the second stage. Forecasts in the field of time and for the chain of experience differ, which results from the mutual relations between states. This is caused by relatively long night-time stoppages in the garage in comparison to frequent but much shorter transports and related handling activities. Therefore, according to the chain, the system tends to maintain mainly in states S2 and S4, due to the fact that they are short and frequent, and in continuous time – in states S1 and S3, because they are the longest and not as intensive.
To sum up, it should be emphasized that presented models effectively indicated changes that had taken place in the analyzed system by comparing the results before and after modifications, proving the importance of proper market analysis and effective selection of service providers also in the aspect of fleet management.

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FORMING INITIAL DATA ARRAYS TO CONSTRUCT MATHEMATICAL MODELS OF FUNCTIONING TECHNICAL PARTS OF VEHICLES

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Abstract: Mathematical modeling of functioning process is an important stage in the design and development of complicated technical devices. Based on the quality models it could be defined the parameters of such devices providing the optimum modes of functioning: reliability, cost, etc. One of the most common approaches to modeling is to use a physical model describing the basis of physical principles of object functioning. Usually these principles are described by complicated nonlinear systems of differential equations, the use of which in control and optimization problems is difficult due to high computational costs. In this case, based on the original model it is possible to create a more suitable for further usage model from another class. The approach to constructing a model based on an existing one is called remodeling. One of the ways to carry out remodeling is the following: based on the original model, an array of data on the input and output values is formed a model on the resulting array of approximation algorithms. The quality of such model (accuracy, stability) largely depends on the complete set of initial data. The paper proposes an approach to form initial data in the remodeling of inertial torque transformer, which is an automatic stepless transmission. The initial model of its functioning is the composite systems of nonlinear nonstationary systems of differential equations. As the remodeling class, neural network model is used.

Keywords: inertial torque transformer, design of experiment, remodeling, mathematical modeling.

1. Introduction

Mechanisms being parts of modern vehicles have a complicated structure and their functioning laws are also described by complex functional dependencies. Mathematical modeling of such devices (Tarasik, 2013) can significantly reduce the time and financial resources in determining their optimal parameters on the stage of their design. Models of dynamic devices are often described by systems of differential equations, and the complexity of these systems does not always allow obtaining an accurate analytical solution. In such cases, approximate numerical methods are used. The most common numerical method to solve ordinary differential equations is the discretization, and for partial differential equations are methods of finite differences and finite elements (Samarsky, 1989). Specifying different partitions of the modeling area, one can obtain a solution with the accuracy required for the simulation procedure. However, obtained numerical solutions are not always possible to use studying the device using its mathematical model. In particular, choosing parameters of such devices, optimization algorithms are used, where it is necessary to calculate derivatives according to these parameters. For adequate numerical calculation by the method of finite-difference approximation, a large number of numerical solutions of the mathematical model at different values of these parameters are required. This requires significant computational costs.

Another approach to study the device is to obtain an approximate analytical solution. It can be obtained using such a universal approach as remodeling (Saraev, 2017). Remodeling is the process of formation a model based on an existing model (Blyumin, 2017). Remodeling allows describing objects of different classes by objects from a single unified class. This provide the option of using common approaches to the analysis, optimization and control of the object. But this approach also has a number of disadvantaged, the following of them can be noted:

- in the case of formation the initial model based on laws of functioning, during remodeling procedure it is ignored the physical understanding of the process;
- there is an additional loss of accuracy during the transition from one model to another;
- it is required to develop and implement additional algorithms to transform initial models.

Further there is the basic approach to the remodeling procedure (*Galkin, A.V., 2017*). Let us have the initial model $F(x)$ of the studied object. Then the problem to remodel this object could be formulated as following: for the initial model $F(x)$ it is necessary to find the model from a remodeling class $\widetilde{F}(x,\theta)$, which approximates the initial one in the best way for all x from the set of possible solutions. Parameters θ here uniquely define objects of a remodeling class. A universal approach to remodeling is to form a set of input / output data values based on the existing model $F(x)$, and then to use them for determining a new model from the remodeling class (to define parameters). This process is carried out as follows:

- the first step is to select a set of input values x;
- the second step is using model $F(x)$ to find output values $(x_i, F(x_i))$ which correspond to input values from the first step;
- the third step is to choose a remodel class $\widetilde{F}(x,\theta)$;
- the fourth step is to find parameters θ, uniquely distinguishing the object of remodeling class. Parameters using input / output values $(x_i, F(x_i))$ are defined in such a way to minimize $\left\|F(x)-\widetilde{F}(x,\theta)\right\|$.

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The results of the remodeling, namely the parameters θ of the object from the remodeling class, are determined by choosing the initial data (x_i, $F(x_i)$). Thus, the problem to formalize choosing the set of input data is the point of interest in the paper. We consider the algorithm to solve this problem on the example of an inertial torque transformer, which is an automatic stepless transmission (Bazhenov, 2003).

2. Mathematical Model of Inertial Torque Transformer

Inertial Torque Transformer (ITT) is an automatic stepless transmission. The gear ratio from the motor to the output shaft in such a device is transmitted automatically. The detailed scheme of ITT technical aspects and functioning process is given in (Leonov, 1978). The change in the gear ratio is determined by changing the angular velocity of the output shaft, and also depends on the load of the external resistance. The ITT workflow changes cyclically. At the first stage of the cycle, the reactor and the driven flywheel move separately. The transition to the second stage occurs when the angular velocity of the reactor reaches the angular velocity of the driven flywheel. After that, the reactor and the driven flywheel move together. At the second stage, the reactor accelerates the driven flywheel. After acceleration of the driven link, the reactor starts braking to its stop. This is the third stage of the ITT cycle. The fourth stage begins when the angular velocity of the reactor becomes zero. This stage is called the reactor standoff. Then begins the dispersal of the reactor.

Each stage is described by a system of nonlinear differential equations (Blyumin, 2014). As unknown functions included in these equations, generalized angular coordinates of drive and output shafts rotations, as well as the reactor generalized angular coordinates connecting them. Equations also include the angular velocity of rotation and acceleration.

The model of the first stage is presented by the following system of differential equations (1):

$$\begin{cases} B_1(\psi)\ddot{\varphi}_{21} + B_2(\psi)\ddot{\varphi}_{22} - B_4(\psi)(\dot{\varphi}_{21} - \dot{\varphi}_{22})^2 + \\ + B_6(\psi)\dot{\varphi}_{22}^2 = M_Д; \\ B_2(\psi)\ddot{\varphi}_{21} + B_3\ddot{\varphi}_{22} - B_6(\psi)\dot{\varphi}_{21}^2 = 0; \\ J_П\ddot{\varphi}_1 = -M_C. \end{cases} \tag{1}$$

The transition to the second segment occurs when the angular velocity of the reactor reaches the angular velocity of the slave link, i.e. $\dot{\varphi}_1(t_1) = \dot{\varphi}_{22}(t_1)$.

The model of the second stage is presented by the following system of differential equations (2):

$$\begin{cases} B_1(\psi)\ddot{\varphi}_{21} + B_2(\psi)\ddot{\varphi}_{22} - B_4(\psi)(\dot{\varphi}_{21} - \dot{\varphi}_{22})^2 + \\ + B_6(\psi)\dot{\varphi}_{22}^2 = M_Д; \\ B_2(\psi)\ddot{\varphi}_{21} + B_5\ddot{\varphi}_{22} - B_6(\psi)\dot{\varphi}_{21}^2 = -M_C. \end{cases} \tag{2}$$

Condition of transition is a twist of the satellite in the relative motion at π radians, i.e. $\varphi_{21}(t_2) - \varphi_{22}(t_2) = \dfrac{\pi}{a}$.

The third section has the same equations as the first one (1). Upon reaching the reactor the angular velocity equal to zero the system goes to the fourth part of the work, i.e. $\dot{\varphi}_{22}(t_3) = 0$.

The system of differential equations describing the fourth stage is

$$\begin{cases} B_1(\psi)\ddot{\varphi}_{21} - B_4(\psi)\dot{\varphi}_{21}{}^2 = M_Д; \\ J_П\ddot{\varphi}_1 = -M_C, \end{cases} \tag{3}$$

where $\varphi_i, \dot{\varphi}_i$ are are generalized coordinates and generalized velocities respectively,

$$B_1(\psi) = J_{21} + nme^2 + 2nmed(1+a)\cos\psi + nJ_Г(1+a)^2,$$

$$B_2(\psi) = -anJ_Г(1+a) - nmaed\cos\psi,$$

$$B_3 = J_{22} + nJ_Г a^2, \qquad B_4(\psi) = nmaed(1+a)\sin\psi, \qquad B_5 = B_3 + J_П,$$

$$B_6(\psi) = nmaed\sin\psi, \qquad \psi(t) = a(\varphi_{21} - \varphi_{22}),$$

where a is the inner gearing ratio; n is the number of freight links; m is the mass of the freight link; d is the distance from the axis of the rotation of the freight link to the center of its gravity; e is the distance from the axis of the rotation of ITT to the axis of the rotation of the freight link; J_{21} is a reduced torque of inertia of the leading elements; J_{22} is a reduced torque of inertia of the leading portion of the reactor; $J_П$ is a reduced torque of inertia of slave elements; $J_Г$ is a reduced torque of inertia of the freight link. Initial conditions for the first segment are $\varphi_{21}(0) = \varphi_{210}$, $\dot{\varphi}_{21}(0) = \dot{\varphi}_{210}$, $\varphi_{22}(0) = \varphi_{220}$, $\dot{\varphi}_{22}(0) = \dot{\varphi}_{220}$, $\varphi_1(0) = \varphi_{10}$, $\dot{\varphi}_1(0) = \dot{\varphi}_{10}$. The finite values of the proceeding segments are used as the initial values for subsequent segments, which follows from the continuity of the process.

Figure 1 shows the solution of the Models (1)-(3) obtained by the fourth order Runge-Kutta method with variable integration step.

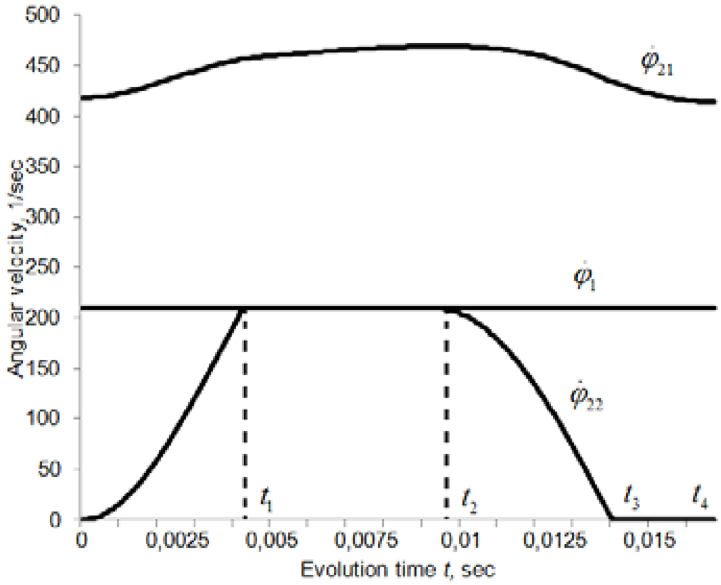

Fig. 1.
Graphs of angular velocities variation

2.1. Remodeling of ITT Workflow

Inertia torque transformer (ITT) is an example of a dynamic object. This dynamics in the remodeling process can be taken into account by using the previous output value (angular velocities) as a new input data. The input data is formed as follows: among the set of arguments, time t is allocated. In the second stage of the remodeling, the output values for the current and a number of previous time values are determined by the given $F(x)$. As a result, for the fourth stage we have the following structure of input / output values set $\{(x_i, t_i, F(x_i, t_{i-1}),\ldots, F(x_i, t_{i-k})), F(x_i, t_i)\}$.
The neural network is used as a modeling structure for Models (1)-(3). Earlier studies (Saraev, 2018) allowed to choose the structure of the neural network:

$$y_k = \sigma_2\left(b_0 + \sum_{j=1}^{100} w_j \cdot \sigma_1\left(b_j + \sum_{m=1}^{6} w_{jm} x_m\right)\right), \quad (4)$$

where $y_k = \{\dot{\varphi}_{21}(t), \dot{\varphi}_{22}(t), \dot{\varphi}_1(t)\}$, $x_m = \{J_{22}, i, t, \dot{\varphi}_{21}(t-1), \dot{\varphi}_{22}(t-1), \dot{\varphi}_1(t-1)\}$, $\sigma_1(net) = \dfrac{1}{1+\exp(-net)}$ is a sigmoid activation function and $\sigma_2(net) = net$ is a linear activation function.
The result of the remodeling is the set of parameters of the neural network model (4), which uniquely determine it. These parameters can vary considerably from one set of source data. A comparison of three models obtained by different input data formation is given.
The following parameters were varied: the reduced moment of momentum of the leading part of the reactor J_{22} and the gear ratio i and time moments t. Three different sets of input-output data were generated, which were then used as training samples during the study of the stability of models obtained during remodeling.
For the construction of the first neural network (Model I), 3251 cases of the process were used, for the construction of the second network (Model II) 3147 cases and for the construction of the third network (Model III) 3408 cases of the process we used respectively. As a test sample, the results of the solution of the analytical model obtained by the Runge-Kutta method were used for the parameters: time $t = \{0.0001, 0.0002, \ldots, 0.0156\}$, i = 0.4, J_{22} = 0.03. A comparison of the results obtained by solving the equations of Models (1)-(3) by the Runge-Kutta method and the results obtained from Models I-III constructed in the remodeling are presented in Figure 2. Analysis of the graphs given allows one to judge the similarity of the obtained results.

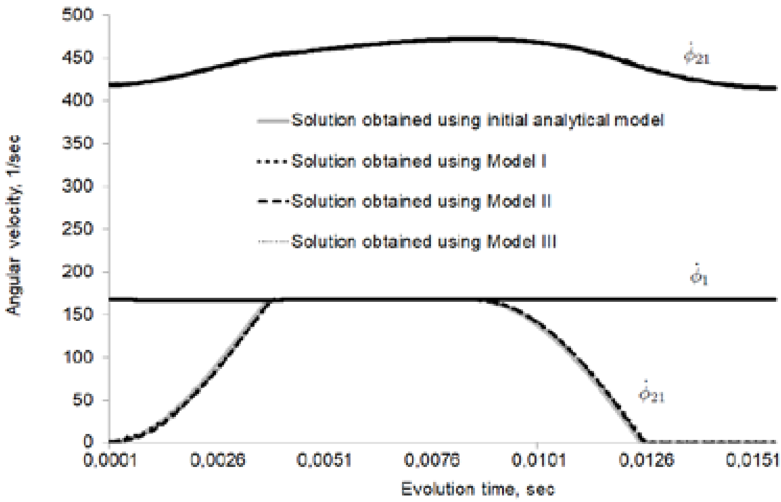

Fig. 2.
Angular velocities obtained using Runge-Kutta method and Models I-III

Further comparison of models to confirm the stability of the method was carried out in several stages. At the first stage, the series of weight coefficients of the obtained models were compared. For one output of each model, 605 weight coefficients were obtained. Figures 3-5 show the sweep curves for pairwise deviation of the model coefficients. The proximity of the median values of the range to zero indicates a high stability of the coefficients obtained.

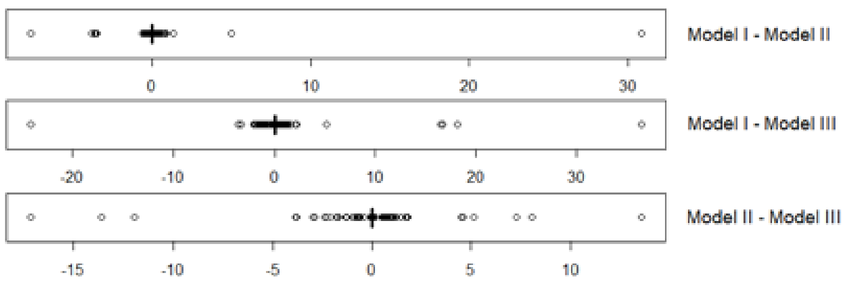

Fig. 3.
Comparing weights for $\dot{\varphi}_{21}$

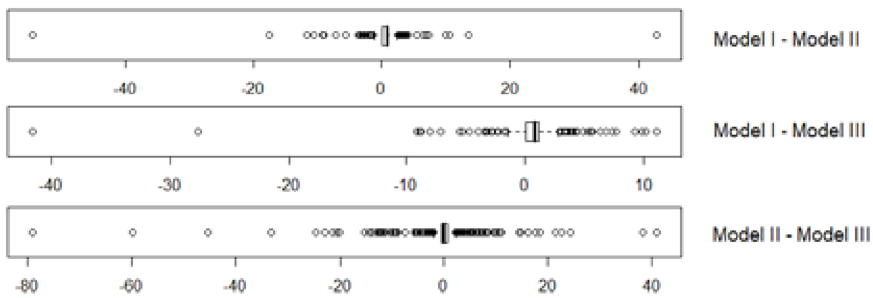

Fig. 4.
Comparing weights for $\dot{\varphi}_{22}$

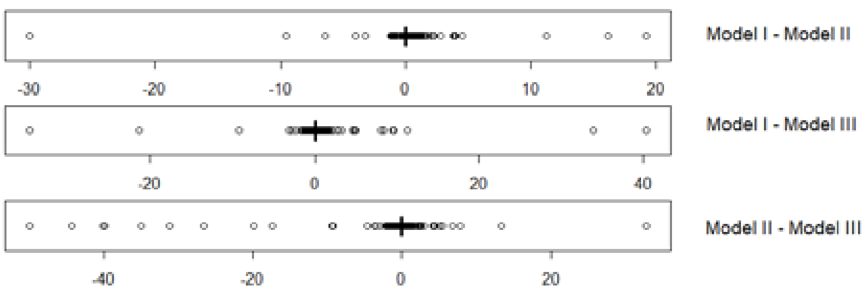

Fig. 5.
Comparing weights for $\dot{\varphi}_1$

Despite the fact that the resulting neural network models are generally stable, the question of the formation of the initial data is still actual.

3. Algorithm to Form Initial Data Array for the Remodeling

The process of forming the initial data for the remodeling is close to problems of selecting the optimal design of experiments (Nalimov, 1971). The difference is that, there is no need to carry out several "experiments" at one point of the design, since the result will be the same when the function $F(x)$ is determined.

For dynamic systems, time t is allocated among many arguments. Having fixed all the argument values, except time, during the experiment we obtain an implementation in the form of a set of values $\{F(x_i, t_1),\ldots, F(x_i, t_j),\ldots, F(x_i, t_{Ni})\}$. It makes no sense to combine certain moments of time with values of other arguments, since for dynamic systems it is not the value of the function at a particular time, but its implementation at a certain time interval that plays a role (Galkin, 2012). Therefore, one can specify in advance the distribution of points (moments of time) on the time interval in which the measurements will be carried out. As a result, time ceases to be an argument, the values of which we control during the experiment (data preparation). In the case of dynamical systems defined by the numerical methods of differential equations, it is convenient to take the grid defined by the integration step (Arushanyan, 2018) as the distribution of points along the time axis. The D-criterion is used as a criterion of design optimality: the minimum value of the determinant of the dispersion matrix of parameters (Chubich, 2013).

The optimal design depends on the class of models in which a particular response function is the object of interest. The most studied are the response functions, which parameters are linear: $\widetilde{F}(x,\theta) = H^*(x)\theta$. In this case, the variance matrix of the parameter estimates is

$$D(\hat{\theta}) = \left(\sum_{i=1}^{N} H^{*T}(x_i) D^{-1}(x_i) H^*(x_i) \right)^{-1} . \qquad (5)$$

The matrix

$$M = \sum_{i=1}^{N} H^{*T}(x_i) D^{-1}(x_i) H^*(x_i) \qquad (6)$$

is an informative matrix. Since responses are formed by a deterministic function, the response variance in the model (6) and, accordingly, are absent in the informative matrix.

In case of nonlinear models with respect to the parameters θ, the function can be linearized by decomposing it into a Taylor series in the neighborhood of initial values of parameters θ. In addition, it is necessary to take into consideration only the first order term components. In this case, the linear component will be the Jacobi matrix $H^*(x,\theta) = \dfrac{\partial \widetilde{F}(x,\theta)}{\partial \theta}$.

Then the algorithm of successive approximation of parameters estimators of the remodeling model is (Gorski, 1978):

1) to build the initial design of the experiment $x_0^{(p)} \in X_P$ in N_0 points;
2) based on the plan from Step 1, to find the initial approximation of parameters estimators $\hat{\theta}_0$ and the informative matrix (6) $M(\hat{\theta}_0, x_0^{(p)})$;
3) to find the new point in the design of the experiment from the condition
$$\max_x sp[M(\hat{\theta}_0, x_0^{(p)}) M^{-1}(\hat{\theta}_0, x)] ;$$
4) to calculate the value of the response $F(x_{N_0+1}, \hat{\theta}_0)$ in the found point x_{N_0+1} and to add it to the initial design.

Then to repeat Steps 2-4.

The criterion to stop calculations applying the algorithm is the achievement of the variance of parameter estimation, a given small value:

$$D(\hat{\theta}_k) < \varepsilon .$$

The variance of the parameter estimation can be calculated using an informative matrix $D(x_k^{(p)}, \hat{\theta}_k) = M^{-1}(x_k^{(p)})$.

Taking into account the fact, that during the calculation a particular point in the design, the response item is not a scalar value, but some dependent on time vector, it is necessary to change the method to calculate the informative matrix (6):

$$M = \sum_{i=1}^{N} \left(\frac{1}{N_{t_i}} \sum_{j=1}^{N_{t_i}} H^{*T}(x_i, t_j) H^*(x_i, t_j) \right) . \qquad (7)$$

3.1. Forming Initial Data Set to Remodel ITT Workflow

Let us consider the selection of the initial data set for remodeling based on the example of the output $\dot{\varphi}_{21}$. Firstly, a data set for the initial determination of the neural network (4) parameters was formed. The values of the reduced moment of

inertia of the reactor leading part J_{22} and the ratio i were uniformly taken from their range of permissible values: i = 0,1; 0,3; 0,5; 0,7; 0,9, J_{22} = 0,028; 0,0315; 0,0343; 0,0363; 0,041.
Combinations of values of these parameters pairs formed the initial design of the experiment. The response was calculated by solving the system of differential equations (1)-(3) by the fourth-order Runge-Kutta method with the integration step t = 0.0001 sec. Then parameters of the neural network were determined based on the obtained array of input data. The gradient of the neural network model (4) was calculated (using its parameters as arguments). The informative matrix (7) was calculated using the obtained gradient. The inverse of the informative matrix allowed us to determine the estimates of parameter variance. The determinant of the matrix is $\det D(\hat{\theta}) = 2{,}47$. To find the new point in the design, an optimization problem $\max\limits_{x} sp[M(\hat{\theta}_0, x_0^{(p)})M^{-1}(\hat{\theta}_0, x)]$ was formed. The solution of this problem was carried out by the Monte Carlo method of random search (Rubinstein, 2008). The solution of the optimization problem were: the values of the moment of inertia of the leading part of the reactor J_{22} = 0.0487 and the ratio i = 0.748. At the next stage for the found new design point, the response was defined as the solution of the system of differential equations (1)-(3). The data obtained in this way were added to the initial data. After that, new values of parameters of the neural network model (4) were determined. At this stage, the determinant of the coefficient variance matrix is $\det D(\hat{\theta}) = 2{,}22$. This process could be continued until the estimates of parameter variances rich a predetermined criterion.

4. Conclusion

The study of technical devices used in vehicles using their mathematical models is an effective tool to improve their functioning quality. Remodeling can be used to simplify and unify research methods. An approach to the simulation of an automatic stepless transmission, which is an inertial torque transformer, is considered. An important issue in remodeling is the forming the input data array. To solve this problem it is proposed to use methods of optimal designing of experiment. As a tool that reflects the effectiveness of the proposed methods, it is suggested using an information matrix, the inverse of which determines the variance of model parameters from the remodeling class. Neural network models with high approximation properties were used as a remodeling class. The proposed methods and algorithms are confirmed by the calculations.

Acknowledgement

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RISK MANAGEMENT IN SUPPLY CHAINS

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Abstract: Risks represent a number of possible unwanted events that require a plan and control activity in case of such events. The need for risk management at present is an essential component of enterprise management. In all industries, as well as in supply chain management, there are many potential risks due to the complexity of the organizational structure of the supply chain. One of the most important reasons for the development of risk management in supply chains is globalization. Globalization coupled the various markets, and the distance between the consumption and production space suddenly increased (unlike before when the places of consumption and production were closer which meant fewer risks). Furthermore, globalization marked the need to engage more participants in the supply chain, which exponentially increased the risks. This paper mentions some of the frameworks for risk management and the methods of risk control and avoidance.

Keywords: Risks; Supply chain; Risk management; Globalization.

1. Introduction

In the past decade, risk management became one of the key logistic activities, but its implementation is not simple, especially in the case of global supply chains which are characterized by transportation of freight over long distances, with long delivery times and a large number of participants with various inter-relationships (Maslarić, Brnjac and Bago, 2016). The last few years have seen significant events around the world that have only heightened the awareness of how detrimental risk can be to the business. As a result, supply chain risk management has become top of mind for many organizations. (www.kinaxis.com)
According to Rao and Goldsby (2009), a risk is defined as the relationship between the range of possible negative outcomes (severity or impact) and the distribution of the corresponding probabilities for each outcome. According to Maslarić (2014), the most common interpretation of risk is connecting it to the probability of an undesirable outcome. Risks incur because the omnipresent uncertainty makes it impossible to predict future outcomes. It is that uncertainty, which is sometimes equated to risk, that creates risk whose very existence demands an appropriate response. Such a response is formalized through risk management. A combination of the appropriate concept of risk (presented with an adequate definition of risk) and defining the methods of risk management (includes both defining the classification of all the relevant factors of risks) form the basis for a successful modeling and utilization of a risk management system (Bemeleit *et al.,* 2005*).* It is essential to identify the connection between the causes of risks and risky occurrences, because such an approach may create a proactive risk management in supply chains.
Norrman and Jansson (2004) define risk management as a decision-making process about the acceptance of familiar or estimated risks and implementation of activities with the aim of minimizing consequences or probability of their occurrence. According to Waters (2007), risk management is a process of systematic identification, analysis, and addressing risk in a business enterprise. In his work, Franck (2007) defines risk management as a process which is a response to the existence of an uncertainty (and thus, a risk) by controlling the deviations from a prespecified aim, specification or standard. Culp (2002) defines risk management as an attempt of organizations to ensure the assessment of all the risks they are exposed to (identification of risk and taking appropriate measures to control potential outcomes of the identified risks). Risk management is or should be, a fundamental issue in the planning process and management of every organization (Finch, 2004).
According to Al Hashim (1980) global supply chains are a source of competitive advantage. Global configurations of firms provide access to cheap labor and raw materials, better financing opportunities, larger product markets, arbitrage opportunities, and additional inducements offered by host governments to attract foreign capital. However, coupled with these benefits that entice firms to go global are the uncertainties and consequent risks that managers face in global supply chains (Manuj and Mentzer, 2008). An enterprise may have the lowest overall costs in a stable world environment, but also the highest level of risk – if any one of the multiple gating factors kink up an elongated global supply chain (Barry, 2004).

2. A framework for Risk Management in Supply Chains

In order for the response to undesirable outcomes to be adequate, there needs to be a structured methodology of the identification of risk probabilities. The identification and the adequate response are an essential aspect of risk management. According to Jüttner, Peck and Christopher (2003) there are four basic principles that enable risk management in a supply chain:
1. Evaluation of the risk source in supply chain management
2. Identification of risk by defining the most relevant consequences
3. Monitoring risk triggers in the supply chain strategy
4. Mitigating risk within the supply chain

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2.1. Evaluation of the Risk Source in Supply Chain Management

Risk classification clarifies the extent of potential interruptions that might occur in an organization within the supply chain and offers a basis for risk evaluation. The risk in the supply chain can be divided into three categories (see Fig. 1):

- Environmental risk sources;
- Network risk sources;
- Organizational risk sources.

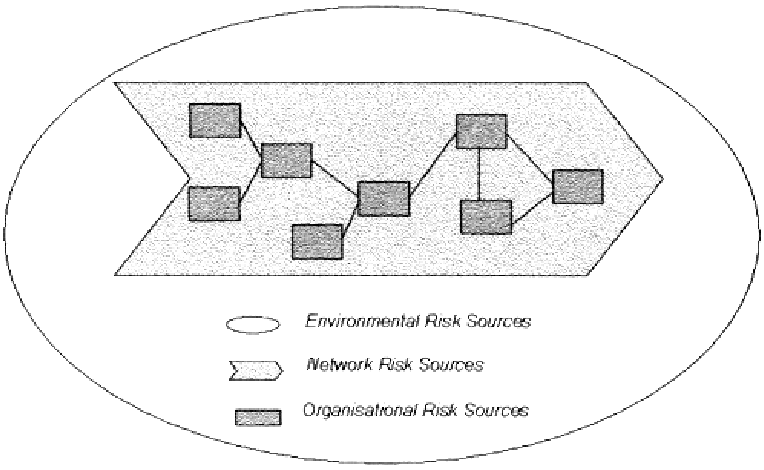

Fig. 1.
Risk Division
Source: Jüttner, Peck and Christopher, 2003

Environmental risk sources comprise any kind of uncertainty arising from the relationship between a supply chain and its environment. They can manifest themselves as accidents (fires), socio-political interactions (protests or terrorist attacks) or other external forces (earthquakes, severe weather).
Organizational risk sources are the risks within certain systems of a supply chain; they can come from the employees (strikes), manufacturing uncertainties (machines), and IT uncertainties.
Network risk sources refer to the interaction between organizations within a supply chain. They are divided into three sources:

- Lack of ownership - circumstances in which such risks occur are the result of unclear boundaries between client companies and supply companies within the chain. These risks are triggered by the trends of outsourcing and focusing on the core competencies of a certain company in the chain. Increased production, distribution, and utilization of logistic partners lead to a complex relationship network between the companies with mixed and unclear responsibilities. These risks often result in increased supply expenses due to outdatedness, and diminished value which is relayed throughout the organization of the supply chain.
- Chaos - the complexity of a supply chain may create chaos effect. This can be the result of an exaggerated reaction, unnecessary intervention, second thoughts, distrust, misinformation in the supply chain, or for the simple reason that there was a misunderstanding among organizations within a supply chain. An example of the chaos effect is the bullwhip effect in a supply chain.
- Inertia - generated by the lack of response and adaptation to market circumstances and market signals. In particular, inertia is found in global supply chains where cost reduction takes priority over flexibility.

Supply chain risks can also be divided as it is shown on Figure 2.

Fig. 2.
Division of Supply Chain Risks
Source: (Business Queensland, Risk Management, 2018)

External risks include:

- Demand risks - caused by an unpredictable or unclear user demand.

- Supply risks - caused by any kind of interruption in the production process, regardless of whether it is raw material or parts in the supply chain.
- Environmental risks - beyond the supply chain, most commonly connected to economic, social, political, climatic factors, as well as a terror risk.
- Business risks - caused by the supplier's financial and operational stability or by the purchase and selling of supplier's companies.
- Physical risks - related to the infrastructure of the supply chain - the condition of the facilities (degree of mechanization, maintenance, etc), and regulatory compliance.

Internal risks in supply chains provide better alleviating opportunities since they occur within the area that is controllable, unlike the external risks. These include:

- Production risks - brought about by the changes in key personnel, management, business processes (e.g. the manner of communication to suppliers and buyers),
- Planning and controlling risks - brought about by inadequate evaluation and planning, which in turn result in inefficient management,
- Risks of unpredictability and alleviation - caused by the habit of a company to conceal or postpone negative information. Such companies react slowly and with more difficulty when an unexpected event occurs.

Supply risks can be considered a separate core risk to which special importance can be attributed. Therefore, this paper aims to examine it in more detail. There are primarily two supply risk sources: the fluctuation of user demands and internal users' demands management. According to Jüttner, Peck and Christopher (2003) typical sources include:

- Wrong specification - A common error is the so-called pumping of product specifications and services of a company. Buyers then become drawn by the number of factors, high-tech options, and logistic benefits that are provided by suppliers. Engineers that make the products argue that it is a special part of the development and a means to an end, whereas human resource managers claim that the service has strategic value. Whatever the case may be, such a service increases risks and limits the possibilities of supply due to the specificity.
- Demand volatility (instability) - In volume industries, where demand is difficult to predict before placing the product, instability might become a greater issue. The development of a supply chain with the help of forecast methods may aid in reducing demand instability. Although new methods are ensuring a more accurate prediction of demand, companies are forced to include the demand instability risk in their supply chain strategy, by opting for suppliers that are able to promptly respond to an increase or decrease in demand, i.e. orders.
- Inadequate internal coordination and communication between the functions - external cooperation is in itself a challenge, and some companies lack a well-developed communication within their own part of the supply chain.

2.2. Identifying Risk by Defining the Most Relevant Consequences

Risk consequences can manifest themselves in every aspect, and the existing literature provides extensive lists which include consequences ranging from damaged reputation to health and safety (Harland and Brenchley, 2001).
End-companies of a supply chain that are focused on a great and fast consumer goods turnover, particularly those that sell products typically in retail (shops), aim to stay competitive with product prices, so the efficiency of operation is a constant pressure. Such companies continuously search for a way to have a lower quantity of supply so as to become agiler and respond more quickly to changes in demand. At the same time, however, they are faced with competitive and commercial risks, such as loss in profit due to the unavailability of a product. Also, managers in consumer goods companies are not concerned with events of low probability with the potential of disastrous outcomes. Instead, they focus on atomistic differences, such as interruptions caused by a direct supplier/buyer (supplier's bankruptcy). Risk management on the level of the entire supply chain as such has not been recognized as a key element in planning business continuity.
Norrman and Lindroth (2011) suggest differentiating between operational accidents, operational catastrophes, and strategic uncertainties, based on the probability and seriousness of risk consequences. There are numerous contributing factors with the potential of developing from operational accidents into operational catastrophes due to the unplanned response to accidents.

2.3. Monitoring Risk Triggers in the Supply Chain Strategy

Risk has always been a part of the process of equalizing supply and demand, but in the last decade, many factors have come forward that have increased the degree of risk. According to Jüttner, Peck and Christopher (2003) these include:

1. Focusing on efficiency, and not effectiveness
2. Globalization of the supply chain
3. Concentrated factories and centralized distribution
4. The trend of outsourcing

5. Reducing the supply base

These sources of risk have a direct influence on the risks related to the network of a supply chain. Globalization and outsourcing have led to an increase in complexity of a supply chain. The supply chain network structure features vertical and horizontal connections, return links and two-way exchanges encompassing both ascending and descending activities in terms of supply chain organization.

2.4 Mitigating Risk Within the Supply Chain

Miller (1992) differentiates between five general strategies that can be implemented to mitigate risk, four of which can be used in managing risks in supply chains. These four strategies are shown in Figure 3.

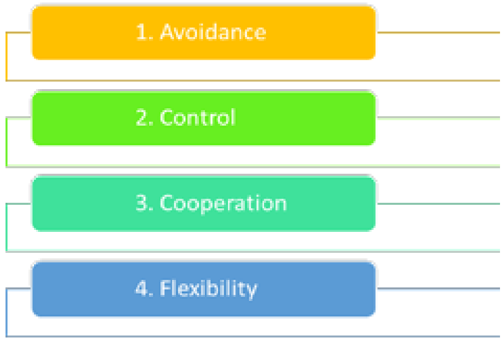

Fig. 3.
General Strategies Used in Managing Risks in Supply Chain
Source: Miller, 1992

Avoidance is resorted to when risks related to the work on the given market are not acceptable for general business. From the standpoint of supply chains, a company may pass over some products, suppliers, or companies, if the offer is unreliable.
Companies may seek to assert control over potential events with various risk sources, rather than to treat uncertainties passively, as restrictions within which they must act (Miller, 1992). The control strategies are among the most widespread within supply chains. Cases within the supply chains include vertical integration, excess supply, maintaining excess capacity in production, storage, manipulations and/or transport, and at asserting contract demands on suppliers.
Cooperation is a response to risks which, unlike controls, stand for associated agreements in order to mitigate a certain risk. From the supply point of view, cooperation ensures transparency and understanding between companies within a supply chain by exchanging information on potential risks, in order to create adequate plans of business continuity. Most commonly, cooperative agreements are signed with key suppliers, depending on the supply chain strategy.
Unlike the control which focuses on risk estimation, flexibility is based on improving the response time to risk using the existing estimation factors (Miller, 1992). An example in supply chains is a postponement, whereby companies put off their decisions on production, configuration, labeling products for specific destinations. A postponement reduces their dependency on forecasts and increases the possibility of a response to a variability or disorder in demand. Another instance is several product sources within the chain which partly mitigate risk or localized sources with short deadlines and potential for quicker responses to undesirable events.

3. Risk Management Techniques in Supply Chains

Managing risks in supply chains refers to risk management within the earlier process (downstream), which includes the processes of suppliers who procure raw materials and create half-products but also the products and services that are focused on outlining and optimization of the design process, and the subsequent upstream processes that refer to the distribution of products and services to end-users at the right place and at the right time time and in demanded quantities. Risk management means reducing financial, operational, reputational, and legal risks, as well as confidential information risk. In an ideal system in which risks were managed ideally, nothing that happened would negatively affect those elements.
According to Supply Chain Management Review (2017) there are numerous techniques that managers deploy in order to manage risks in supply chains, some of which include:

- Innovation and efficiency in contracting management;
- Strategic requirements for supplier insurance, indemnification, and limitations of liability;
- Provider optimization and redundancy;
- Supplier financial stability visibility; and
- Proper diligence in operational supplier assessment reviews.

3.1. Innovation and Efficiency in Contracting Management

The manner in which procurement handles contracts i.e. contracting is what lays the groundwork for risk management. There is currently an upward trend of contract rationalization, which resulted from the understanding of significant costs of creating and renegotiating legal contracts that are extensive, difficult to understand, and made to protect a certain entity. A more recent contracting style enables procurement to create much more successful contracts that extend the contract period and increase procuring efficiency. Procurement departments in many companies rely on short and well-balanced contracts which are easier for suppliers to understand.
Control of contract processes is crucial. One example from Supply Chain Management Review (2017) shows that the umbrella contract of a company covered only the road distribution, whereas a single statement of work (SOW) demanded distribution by helicopter and installation of the key equipment. The lack of air coverage liability in the umbrella contract put the company at great risk.

3.2. Strategic Requirements for Supplier Insurance, Indemnification, and Limitations of Liability

Signing up for any kind of service from an external supplier, in earlier or subsequent processes, demands an estimation of openness to risks. Each contract must cover the limitations of liability, indemnification, and supplier insurance. A supplier must be liable for two reasons. Firstly, they are insured against legal and financial exposure that might impede their ability to support their clients. Secondly, the contracts provide protection for the procurement organization against direct and indirect claims from suppliers or third parties that may be affected by activities, or lack thereof, of suppliers. More often than not, procurement companies do not require a properly issued certificate of insurance which they comply to, from each of the engaged suppliers and sub-suppliers.
A common drawback is time, that is, many supplier's insurance policies will not run out at the same time as the contract. Failure of each policy to be renewed and continue being enforced during the contract time means the cancellation of risk protection without the procurement's knowledge.

3.3. Provider Optimization and Redundancy

In a supply chain, too large a consolidation of supplier associations is to be avoided. Commonly, dominant suppliers will attempt to push their way in, in order to become the only raw material suppliers, which is acceptable unless a disaster takes place, such as a bankruptcy or closing down of the supply factory.
Proper management of sources ensures an even number of suppliers with one or two demands. One demand is more factories or data centers for the supplier which enables the manufacturer to set up production in multiple locations. The second approach is segmentation of provider's relationships towards several suppliers into the primary and secondary contract, which ensures sustainable operations within the supply chain, in case one of the manufacturing locations closes down.

3.4. Supplier Financial Stability Visibility

In 2016, Han Jin Shipping, one of the seven biggest maritime transport companies declared bankruptcy and ceased to operate on the same day. Thousands of containers were stranded on ships anchored in harbours or docks worldwide. The impact was tremendous. Han Jan conducted 10 per cent of the container transport between Asia and America. There were many shipments between other countries as well, and the damage took months to repair.
Many companies fail to - or do not want to - reveal their financial stability to other participants in the supply chain, especially to their key suppliers, who otherwise would not be doing business with them. Some companies demand a financial report of the company they wish to conduct business with, but the problem lies in the fact that the data given freely may raise doubts over their credibility.
The current trend is promising, the only factor indicating financial stability of a company is a global credit rating agency.

3.5. Proper Diligence in Operational Supplier Assessment Reviews

Many organizations, i.e. companies, do not assess their suppliers' performance. In many companies, only a small share of the best suppliers will receive a review on how significant they are for the supply chain. This poses a problem because many suppliers then assume they are doing their job right, even though that might not be the case.
According to Supply Chain Management Review (2017), numerous companies now divide their suppliers into categories, according to their financial expenditures based on the Pareto principle:

- Category A suppliers; 15 percent of suppliers that represent 75 percent of costs,
- Category B suppliers; 25 percent of suppliers that represent 15 percent of costs,
- Category C suppliers; 60 percent of suppliers that represent 5 percent of costs.

Such a categorization makes it possible to provide assessment reviews.

4. Conclusion

Supply chain risks are an aspect that continues to grow and with every new technological implementation the catalogues of risk expand further. Only by adequately identifying risks and responding to them can sustainability and competitiveness be achieved. The current trends of implementation of the blockchain technology suggest that supply chains transparency will increase, which in turn will result in a better cooperation and an easier response to undesirable events. On the other hand, utilization of such technologies poses the question of how big of a risk and expense a wrong shipping creates, which sets in motion a process of distribution which was started automatically and which is not easy to amend, as is the case with current technologies. Moreover, there is an issue with the size of the risk and expense of a wrongly charged order, and processing time. Furthermore, the implementation of the big data technologies in supply chains also opens up possibilities of cooperation with an easier connection between databases of the parties in the supply chain. This, however, may lead to issues regarding risks, such as cyber attacks, the quantity of information available to parties in a supply chain, and others.

The implementation of both technologies ensures great possibilities, but at the same time demands adequate risk management on the level of the entire supply chain, as well as within each party. As the structure of supply chains grows more complex, so does risk management within a supply chain, demanding great attention because, as mentioned earlier, a low probability event with low preliminary impact along with inadequate risk management may lead to a disastrous event with severe consequences.

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HIGH DURABILITY – HIGH RETROREFLECTIVITY SOLUTION FOR A STRUCTURED ROAD MARKING SYSTEM

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Abstract: Horizontal road markings are basic road safety features that provide exceptional cost effectiveness by meaningfully lowering the number of accidents. The markings are effective during night time, when the risk of a severe accident is highest, because of being reflectorized with glass beads. Results from a field test of a road marking system comprising structured cold plastic reflectorized with premium glass beads, which was done at a motorway in Switzerland, are presented. The applied system provided initial retroreflectivity (R_L) of 853 to 1010 mcd/m²/lx, which after four years of usage dropped to 232 to 341 mcd/m²/lx, respectively. Such results were possible, because high quality base material was combined with appropriately matched premium glass beads. Highest financial, safety, and environmental benefits are obtained with road marking systems that are highly durable and the described system was meeting those criteria. Indeed, a brief financial analysis has shown that with the tested system, approximately 25% financial savings were realised in the long term, despite higher initial cost. This state-of-the-art technology should be of particular interest to road administrators seeking a method to maximize the benefits of horizontal road markings using reasonably-priced long-term solutions.

Keywords: horizontal road markings, retroreflectivity, glass beads, road safety, durability, cost analysis, cold plastic.

1. Horizontal Road Markings

1.1. Road Marking and Safety

One of the critical ubiquitous safety features on almost all roads are horizontal markings. They serve as guidelines for the drivers to help them remain in centre of their paths, as was scientifically established (Steyvers and de Waard, 2000). The importance of horizontal markings was reported by to be particularly associated with the conditions of poor visibility, particularly at night (Horberry and coworkers, 2006). Even though the number of vehicles travelling at night is much lower than during daytime, the reported number of accidents and their severity are significantly higher (Plainis et al., 2005). In darkness, when quantity and quality of visual cues accessible to the drivers are limited, retroreflectivity (R_L) of horizontal road markings takes the prominent guiding role. Indeed, it was demonstrated that during night time driving, R_L is a natural focus point for drivers of all ages (Zwahlen and Schnell, 1999), with elderly drivers relaying more on the edge line (Underwood et al., 2005). Hence, improvement in the quality and R_L of horizontal road markings can lead to improvement in the quality of life and mobility of elderly population.

It was calculated that the mean safety benefits 60 times exceed the average costs of installation and maintenance of road markings (Miller, 1992). Majority of the benefit comes from reduction in the number and severity of accidents. Safety benefits associated with maintaining appropriately high R_L were only recently quantified. Based on complicated statistical analyses of single vehicle night time crashes between intersections, excluding inclement weather occurrences, decrease in accidents by up to 23% with increase in R_L by 100 mcd/m²/lx was correlated and later the robustness of the used methodology was confirmed (Carlson et al., 2013; 2015).

1.2. Road Marking Materials

Horizontal road markings have to be considered as systems, comprising the base (colour) layer and the retroreflective layer. The base layer may be a waterborne or a solventborne paint, a thermoplastic mass, or a cold plastic; the retroreflective layer usually consists of glass beads. The base layer provides adhesion to the road surface, gives the desired colour, and holds glass beads while the retroreflective layer furnishes R_L and protects the base layer from abrasion. Only co-operation of these two layers yields a successful road marking system.

The markings can be divided into thin-layer, with the applied thickness below 1 mm, and thick-layer, which are applied at thicknesses reaching even 3 mm or more. Various types of road marking materials, along with their advantages, disadvantages, and key safety considerations were recently reviewed (Babić et al., 2015). Additional detailed discussion regarding paints, with accent on solvents as Volatile Organic Chemicals capable of producing substantial quantities of tropospheric ozone were presented (Burghardt et al., 2016a).

Majority of roads are marked using paints, which are usually applied at ±400 µm (i.e. ±0.6 g/m²). After evaporation of the solvent (either organic or water), a dry film approximately 250 µm thick remains. This thin layer of paint is usually not sufficient to adequately hold glass beads for longer than 1 year, even though evaluations done on high-quality waterborne paints demonstrated that two-year or longer durability can easily be achieved with premium systems under favourable conditions (Burghardt et al., 2016; 2017).

1.2.1. Thick-layer Structural Marking

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On major roads with heavy traffic loads, thick-layer road marking systems are preferred: hot-applied thermoplastic masses, cold plastics that polymerise on the road surface, or solvent-less plural component urethane- or epoxy-based materials. Thick layer markings are most frequently applied as structures, either regular or stochastic, because thus it is possible to achieve a vibroacoustic effect, which warns drivers deviating from the traffic lane. Additionally, the structures facilitate water drainage, which improves retroreflectivity under wet conditions (RW). In addition, some of the glass beads on structural markings are sheltered from the action of passing vehicles and snow ploughs, which augments markings' performance. Typically, structured markings are applied at 2-3 kg/m² and are reflectorized with glass beads dropped-on at 0.4-0.5 kg/m². Providing the applied mass instead of layer thickness is more correct, because of the required irregularity of the structure. Properly applied exemplary dot-structured road marking is shown in Figure 1.

Fig. 1
Exemplary Dot-Structured Road Marking at Night
Source: M. Swarovski Gesellschaft m.b.H. Used with permission.

1.3. Glass Beads

Standard glass beads for road marking, size 100-850 µm, are prepared from milled window glass, in vertical furnaces, where at temperature of approximately 1200 °C irregularly-shaped particles become round. Their refractive index (RI) is 1.5. With standard glass beads, it is possible to achieve R_L in the field of about 350 mcd/m²/lx. Various types of glass beads, their production process and achievable results in the field have recently been reviewed (Burghardt et al., 2017).**Error! Bookmark not defined.** A plethora of types and qualities of standard road marking beads are available worldwide from numerous manufacturers. The produced glass beads are coated to achieve good adhesion to various base layer materials and sieved according to the customer specifications, regional demands, and various normative requirements. When needed, anti-skid particles are intermixed to assure high skid resistance under wet conditions. European norm ISO EN 1423:2013 require the glass beads to be over 80% round, free from air bubbles, and fully transparent. Content of lead, antimony, and arsenic are limited to less than 200 mg/kg.

1.3.1. Premium Glass Beads

Whereas increased R_L can be readily obtained with glass beads of higher RI, their use remains a niche due to high cost and low resistance to scratching. A solution to by-pass those limitations are premium glass beads, with RI of ±1.6 still belonging to Class A according to ISO EN 1423:2013 norm, but prepared from carefully selected virgin raw materials. Chemical composition of such glass beads leads to the mild increase in RI and to simultaneously improved resistance to scratching. Special production process provides exceptional roundness and superior surface quality, which allows R_L in the field to exceed 1000 mcd/m²/lx with white base layer and also very high R_L in yellow and orange markings. Additionally, RW of 100 mcd/m²/lx can readily be achieved. A microscope image of a narrow fraction of this type of glass beads, SOLIDPLUS brand from M. Swarovski GmbH, is provided in Figure 2. Visible is their exceptional roundness; the small ‘bubbles’ and dots are just artefacts of reflecting light.

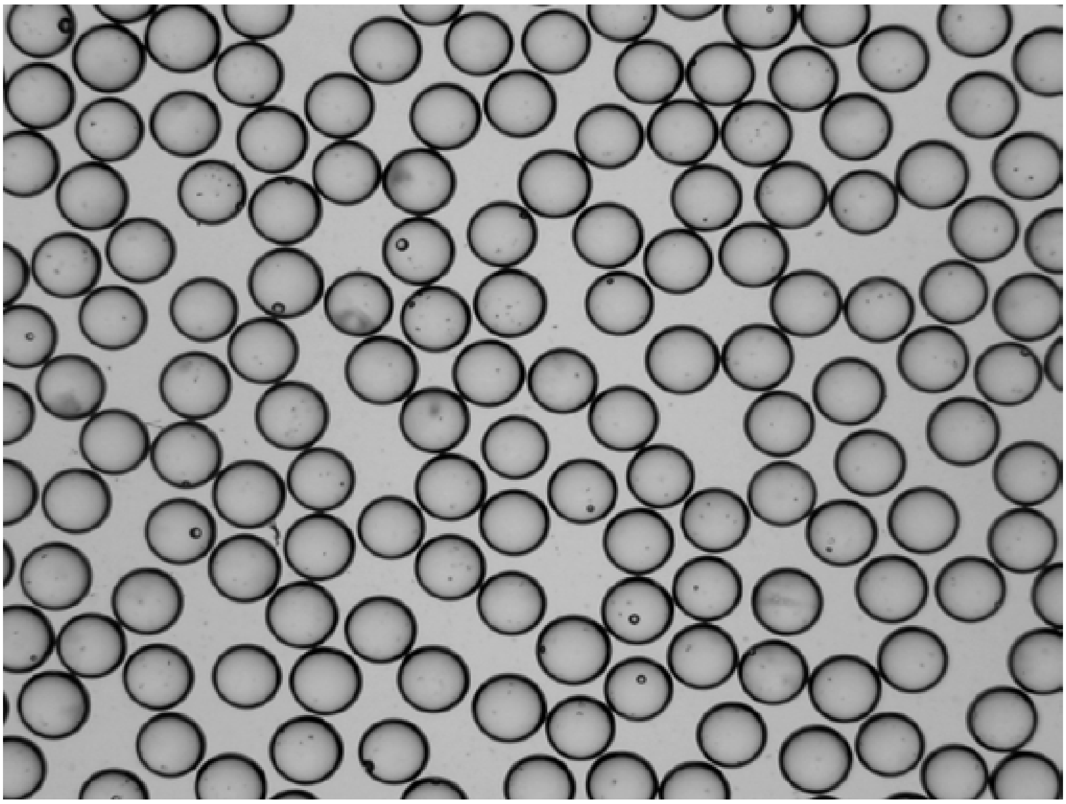

Fig. 2.
SOLIDPLUS glass beads, 630-700 µm fraction
Source: M. Swarovski Gesellschaft m.b.H. Used with permission.

2. Experimental

2.1. Methodology and Materials

Evaluation of road marking systems is quite a difficult task due to a plethora of variables that can affect the outcome. Durability depends not only upon the quality and type of marking materials and their application technique, but also upon the conditions during and after application, vehicular traffic, and numerous other environmental and surroundings factors. The ultimate test always remains the actual application and usage on a specific road stretch, which all parties involved in road marking business must understand.
The test was performed in the field, at a 400-metre stretch of motorway T5 in Switzerland, carrying Annually Averaged Daily Traffic (AADT) of 36,067 vehicles. All markings on one carriageway (edge lines 25 cm wide and a dashed middle line 20 cm wide) were done using randomly structured white cold plastic Luxorit Structura Premium (Roberit AG; Windisch, Switzerland) applied at ±2.20 kg/m², reflectorized with premium glass beads SOLIDPLUS100 300-850 T18 (M. Swarovski GmbH; Amstetten, Austria) dropped-on at ±0.45 kg/m². A brief summary of the results is being described elsewhere (Burghardt, 2018); herein details are provided.
Measurements were done using a dynamic testing method, with retroreflectometer ZDR6020 (Zehntner GmbH; Sissach, Switzerland) attached to a vehicle, which is a method assuring maximum work efficiency and safety for the measuring crew, while obstruction of traffic is minimised. Data was collected by the software every few milliseconds during normal driving and averaged for 50-metre stretches. Validity and consistency of the utilised test method was established (Holzschuher et al., 2010). The measurements were done annually, by an independent external contractor, according to Swiss standards SN 640 877:2012, SN 640 877-1:2012, and SN EN 1436:2001+A1:2008.

2.2. Results

The results are provided in Table 1 and visualised in Figure 3. In parentheses are given standard deviations. Very high R_L achieved initially in all of the lines significantly decreased within the first year of use, by an average loss of 406 mcd/m²/lx or 43%. However, the rate of loss during the next three years was much lower, on average annually only 76 mcd/m²/lx or 16%. The resulting premium systems applied at edge lines, after four years of road exposure, had higher R_L than typically achieved with new road markings reflectorized with standard glass beads. Slightly lower R_L measured the middle line was still surpassing the requirements, even though this line is exposed to much more vehicles encroaching on it and also to much heavier winter maintenance. Unusually small loss of R_L during the second year of usage remains unknown. It might be hypothesised that the measurements during the second year were done on markings that had residual dirt or moisture; another plausible explanation could be exposure of glass beads that were embedded too deeply. Nonetheless, the tested premium road marking system did not require renewal for five years. The edge lines could provide even a six-year durability if the continuing R_L loss rate were to remain constant. Assuming that the rate of R_L loss would be similar for standard glass beads, one could expect that a drop in R_L from the typical initial 350 mcd/m²/lx to the minimum required 200 mcd/m²/lx would occur within three years.

Table 1
Retroreflectivity of the Tested Premium Structured Road Markings

Line	Retroreflectivity [mcd/m²/lx]				
	Initial	**1 year**	**2 years**	**3 years**	**4 years**
Edge right	1010 (153)	567 (127)	547 (163)	446 (93)	341 (52)
Middle (skip line)	853 (96)	374 (67)	374 (92)	335 (46)	232 (20)
Edge left	984 (151)	688 (62)	675 (120)	518 (94)	372 (36)

Source: Author, courtesy of M. Swarovski Gesellschaft m.b.H. and Roberit AG.

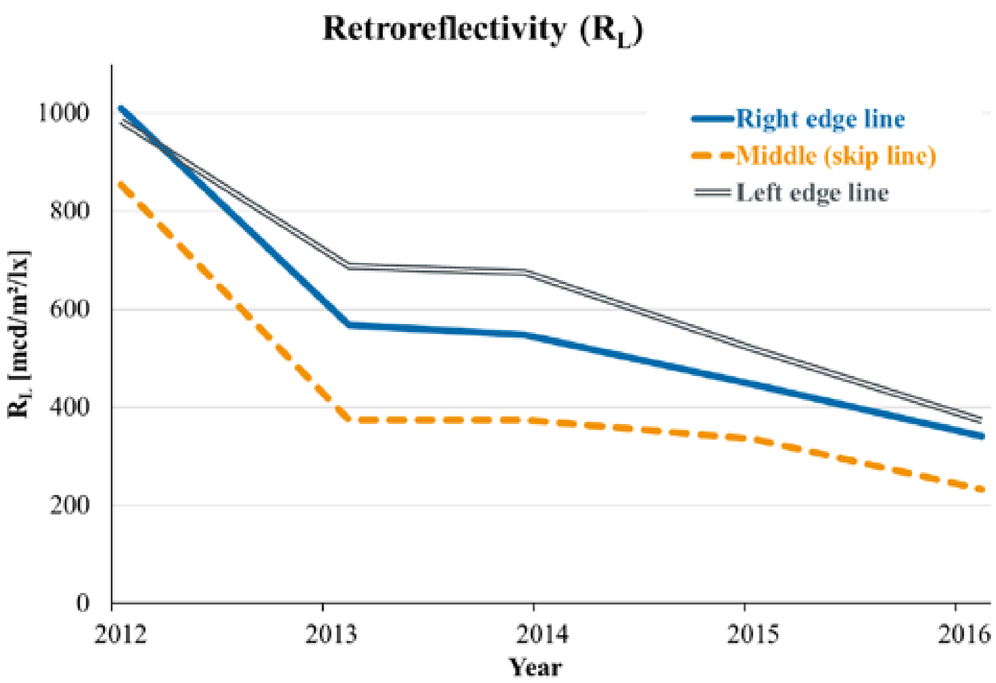

Fig. 3.
Retroreflectivity of the Tested Premium Structured Road Marking System
Source: Author.

2.3. Financial Analysis

For financial analysis, one must make several assumptions related to expense allocation. In a recent analysis (Burghardt et al., 2018) related to thin-layer markings, relative cost for standard system was apportioned into labour that included amortisation, fixed costs, and profit (33%), the paint (45%), and the glass beads (22%). The calculated long-term financial benefit was a result of halving the labour expenses in case of a two-year premium thin-layer road marking system that required more costly paint (50% higher unit price) and premium glass beads (300% higher unit price). Over a ten-year road marking cycle, financial savings of 16% were calculated with the selection of a premium system; inflation and price volatility not included.
In the structured road marking system, assumed apportionment of expenses must be different than with the thin-layer systems, because of required high quantity of the cold plastic. Exemplary allocation of expenses for standard and premium systems is provided in Table 2. The durability of a standard system was taken as three years, which is a maximum expectation for this class of road. With the initial expense of the premium system only 25% higher than of the standard system and almost doubling of the durability, financial savings of 25% can be easily realised over a 10-year cycle. Slightly higher cost of labour was taken for the premium system to give room for the demanded higher quality of work and lower permitted error rate.

Table 2
Financial Calculations

Expense allocation	Standard system	Premium system
Labour, fixed costs, profit	15%	20%
Cold plastic (at 2.20 kg/m²)	80%	85%
Glass beads (at 0.45 kg/m²)	5%	20%
Initial expense	100%	125%
Expected durability [years]	3	5
Relative total cost per 10 years	100%	75%

Source: Author.

3. Discussion

The results from this field test demonstrate the advantage of using premium road marking systems as compared to the standard. Exquisite durability leads to overall long-term financial savings despite higher initial expense. Additional, albeit very difficult to calculate, are indirect benefits associated with accidents that could be prevented due to high R_L. Addition of those benefits always leads to advantage of a road marking system with higher R_L, because of enormous costs caused by road accidents, as was demonstrated (Abboud and Bowman, 2002). Less frequent markings renewal would also lead to reduction of traffic jams caused by the road maintenance, as was recently calculated (Fiolić et al., 2017). The results of this analysis agree with a recently presented comprehensive costing evaluation (Pike and Bommanayakanahalli, 2018), which included also financial losses due to road blocking by marking crews, potential of accidents in the road marking work zone, and the supervisory costs of road administrators.
The premium glass beads are much costlier than standard, but can furnish exceptional R_L, which has a potential for lowering the number and severity of night time accidents. Moreover, drivers do see and appreciate very high R_L, as was recently reported (Pashkevich et al., 2017; Burghardt et al., 2017). A great advantage of using the premium glass beads is the possibility of intermixing them with standard beads to obtain somewhat increased R_L at a moderate price. The importance of appropriate matching of glass beads with the colour layer has to be emphasised, because the main impact on system durability has the paint layer, as was mentioned above (Burghardt et al., 2016; 2017).**Error! Bookmark not defined.Error! Bookmark not defined.**
It was established that durability of road marking systems is the controlling parameter in cradle-to-grave Life Cycle Assessment (LCA) of environmental friendliness (Burghardt et al., 2016b). Similar critical importance of durability can be concluded from LCA results published by a manufacturer of the cold plastic resins (Cruz et al., 2016). Data from field test provided herein confirm exceptional durability of the premium system, which makes it the most environmentally-friendly road marking solution. The longevity results provided herein are in stark contrast with a recent report related to LCA of bicycle paths markings, where cold plastic applied at 3.0 kg/m² was to have durability only thrice that of a solventborne paint applied at 0.6 kg/m² (Trigaux et al., 2017).

4. Conclusions

The reported results from a road test of structured road marking system, comprising high-end cold plastic reflectorized with premium glass beads having RI increased to 1.6 and high resistance to scratching clearly demonstrated that obtaining a five-year road marking system for a motorway with AADT exceeding 35,000 vehicles is feasible, indeed. Even though the exceptionally high R_L obtained initially has faded within the first year, its subsequent loss was very small. The durability was obtained because of very good match between the cold plastic and glass beads. It was calculated that such premium road marking system would be in the long-term less costly than standard system, despite higher initial expense.
Amongst the reasons for using highly durable road marking systems, one must mention the following:

- Financial savings, as one of the key parameters for road administrators.
- Lesser environmental burden, which is a very important factor for the entire society.
- Lower congestion caused by renewal of the markings, which shall be appreciated by drivers.
- High retroreflectivity, leading to improved driving conditions, which is a very valuable benefit for the society in terms of lowering the number of accidents and simultaneous improvement of quality of life and mobility of elderly.
- Improvement of the aesthetics, which was shown to be associated with safer driving (Żakowska, 1997).
- Clearly marked roads are also important for various machine vision technologies that are being developed for the oncoming autonomously driving vehicles' technology (Davies, 2017; Carlson and Poorsartep, 2017; Mosböck and Burghardt, 2018).

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LEGISLATIVE CONDITIONS FOR INTEGRATED TRANSPORT SYSTEMS FORMATION IN THE SLOVAK REPUBLIC

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Abstract: There is practically no functional integrated transport system in Slovak Republic due to the absence of valid legislation for the creation of integrated transport systems (IDS). There is also poor coordination of public passenger transport. Coordination of public passenger transport is necessary condition for the creation of functional integrated transport system. Legislation for the creation of functional integrated transport systems in Slovak Republic should be based on European Union legislation in the segment of public passenger transport. In Slovak Republic, there are two integrated transport systems currently in development: IDS Košice Region and IDS Bratislava Region. Žilina Regional Integrated Transport System (ŽRIDS) is the integration of the public transport of Žilina and railway undertaking Železničná spoločnosť Slovensko. This paper contains a proposal of legislative modifications for the creation of integrated transport systems in Slovak Republic. Successful introduction of functional integrated transport systems can lead to the transfer of passengers from individual car traffic to public passenger transport.

1. Introduction

The need for coordinating individual modes of public transport and subsequent integration of functioning integrated transport systems in the Slovak Republic has been a frequently discussed topic recently. To create functioning integrated transport systems in the Slovak Republic it is necessary to constitute legislation which will support these systems. In order to enact relevant legislation it is appropriate to analyse functioning transport systems in the European Union and to draw from their principles. The transport within ITS is provided by various means of transport: trains, underground, trams, trolley buses, buses, cableways and/or ships (ITS Zürich). Transport by cars and bicycles can be followed up thanks to various systems including P+R (*Park and Ride*), B+R (*Bike and Ride*) and K+R (*Kiss and Ride*). Passengers can be transported by various carriers within ITS. They can use a single (integrated) ticket which is valid regardless of the carrier and used means of transport. However, the integration rate varies (some carriers in territory of ITS are not participating in).

2. Transport Policy of the European Union and the Slovak Republic in the Area of Public Transport Services

Passenger transport is of a big social and political importance in the single economic space of the EU. Some policies dealing with organisation and management of passenger transport are regulated with higher legal rules.

2.1. Principles of National Transport Policy of the Slovak Republic

The goal of a transport policy is to create transparent conditions, minimise risks in the access to a transport market and transport infrastructure, and provide services for constantly growing transport needs of the society (passengers and goods transportation) within required time frame and with required quality, while reducing negative impacts of transport on the environment. In 2000 Principles of National Transport Policy of the Slovak Republic were updated. The update was adopted by the Government of the Slovak Republic as the resolution No. 21/2000, constituting a basic system document of the transport department. The updated national transport policy of the Slovak Republic was interpreted within specific principles, and their subsequent implementation ensured a smooth integration of the Slovak Republic into European structures in the area of transport.
The above mentioned document established a global goal - to ensure a sustainable mobility. The goal includes 8 specific objectives:

- To create transparent and harmonised competition conditions in the transport market;
- To ensure modernisation and development of transport infrastructure;
- To ensure adequate financing in the transport sector;
- To reduce negative impacts of transport on the environment;
- To improve quality and development of transport services;
- To increase the safety of transport and safety protection;
- To support research and development in transport;
- To cope with impacts of transport globalisation.

3. Conditions of Integrating Functioning ITS in Foreign Countries

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For the transport systems integration to be applied it is necessary to get over the difference between the proposal for transport policy and its extension at the national and local level.
The goal of the integrated transport policy is to foster the development of various transport modes in a manner that will lead to implementation of an efficient, sustainable, safe and regionally balanced transport system, where each mode of transport operates in the field of economy and usefulness, features non-discriminatory prices that are adequate to support a progressive development of transport, infrastructure and services. Broad policy objectives of the integrated transport policy could be summarised as follows (Pant, 2001): Meeting the transport demand generated with a higher rate of GDP growth;

- Ensuring transport development which ensures economic effectiveness and pays special attention to transport integration;
- Capacity, quality and productivity improvements through technology gradation and modernisation;
- Higher maintenance standards so as to reduce the need for frequent reconstruction.

3.1. Examples of Functioning ITS in the European Union

Integrated transport system in Paris may set a good example. One of public transport participants is the organisation of all public transport networks of the Paris-Ile de France region that is a responsibility of Syndicat des Transports d'Ile-de-France (STIF). This is a public body bringing together the French government, the regional council and 8 "départements" (counties) making up the region (including the city of Paris, which is both a municipality and a county). Transport services are operated by more than 80 companies chosen and authorised by STIF, out of which two are public monopolies (RATP and SNCF), and the other ones are private companies. Companies have endless rights for the operation of their services, and they receive subsidies from STIF which set the level of fares. STIF is linked with RATP and SNCF companies through service contracts which define the quantity and quality of services that these two companies have to provide, and the public funds that they will be granted by STIF in exchange for that (STiF, 2003).
STIF is managed by a board of 34 directors: 17 of them represent the French national government, out of which 5 represent the Ile-de-France Region, 5 represent the city of Paris, and 7 represent the 7 other counties. It is chaired by a representative of the government in the region ("Préfet").
A committee of public transport users and partners was created in 2001. It brings together representatives of municipalities, passengers, trade unions and economic sector. It is consulted by STIF on several topics including the fare policy (STiF, 2003).
STIF has approx. 120 employees including: 25 employees working on delivering transport services, 20 employees working on new infrastructure projects, 10 employees working on the fare policy, 10 employees working on mobility and other surveys, 4 employees working on contractual and legal issues, 4 employees working on electronic ticketing systems, and 3 employees working on communication issues.

3.1.1. Extended Integration

The term "wider integration" may be interpreted as integration of public transport with other modes of passenger transport. The integration with passenger cars has been a key goal of STIF through its active policy of developing park and ride facilities since the 1970's. STIF gives subsidies to local authorities and transport companies which wish to build park and ride facilities close to important railway stations. The integration of public transport with bicycles is more recent, but some efforts have been made over the past years. First, racks for bikes at railway stations are multiplied with the financial aid of STIF. The number of bikes that can be parked jumped from 1,000 in 1997 to more than 6,000 in 2002. Then all heavy rail services accept bicycles for free outside rush hours during the week, and all the time during the weekend. Lastly, the city of Paris has started a new programme of building protected bus lanes large enough to allow for bikes as well (4.50 m). These new lanes, which have received subsidies from STIF, have already made up more than 40 km. Some recent and still limited initiatives have been launched so as to promote integration between public transport and car rental. Holders of yearly passes now have special price reductions to rent cars. The aim is to enable public transport users to get an easy access to car rental if they do not own a car.
The integration of public transport with specific transport services for people with reduced mobility was significantly improved with setting up a regional centre of information about the accessibility of public transport systems devised and funded by STIF in 2003. This agency provides handicapped people with some accurate information about the level of accessibility of mainstream public transport services, and if necessary, it recommends people to contact organisations providing on-demand services.

3.2. Integrated Transport System in the Canton of Zürich, Switzerland

The highest transport authority in the canton of Zürich and adjacent regions that is functionally linked with the cantonal department for economy is a tariff and public transport association called Zürich Transport Network (ZVV - Zürcher Verkehrsverbund). In 2014 the ZVV company carried approx. 620 million passengers. Nearly 450,000 passengers crossed the borders of Zürich by public transport every day. The rate of return on investments was 65% (ZVV, 2018).

The ZVV is a dependent institution of a public law and a holding company embracing 44 independent companies in total (Swiss Federal Railways, Swiss Post as well as various smaller bus companies, mountain railways and shipping routes, etc.) in the canton of Zürich, which joined their forces in order to offer a nationwide palette of transport services to their customers.
The ZVV ensures typical tasks of an ITS organiser:

- establishment of a single transport offering,
- implementation of a single tariff, processing and information system,
- establishment of single transport conditions,
- central execution of financial relationships with carriers and transport order parties,
- public transport propagation.

The relationship between the ZVV and carriers is based on two agreement types:

- cooperation agreement (time horizon of 10 years),
- transport agreement (period of validity of time table - license for 2 years).

Rate of loss of operational costs is covered with three resources. The state grants a subsidy only for passenger railway transport, the canton and municipalities cover the loss of other modes of transport with the ratio of 50:50. Carriers receive these subsidies through the ZVV which, among other things, also verifies justice of carriers' requirements. Carriers hand the fare proceeds including revenues from all business activities over to the ZVV.

3.3. The Czech Republic - ROPID (Regional Organiser of Prague Integrated Transport)

ROPID, regional organiser of Prague integrated transport, commenced its business on December 1, 1993. The ROPID was established with a resolution of the 33th session of the capital city of Prague Council as an allowance organisation of the capital city of Prague. Its establishment represented a culmination of the city intention to react to ongoing social and economic changes and to build a modern integrated public transport system in the capital city of Prague and its surroundings. The goal of this system is to offer an attractive and respectable public transport for all inhabitants groups and city visitors, and to set up an alternative to a growing intensity of individual motoring (PID, 2018).
Basic competencies of ROPID organisation are as follows:

- preparation of further development of the integrated transport system and its formation,
- processing principles of public transport organisation, establishment of a required volume of transport competencies to ensure transport serviceability of the territory, and relevant dealings with municipalities, the capital city of Prague, Central Bohemia Region, and carriers,
- proposal for transport measures, lines intervals, time tables and connection links,
- cooperation on preferential measures implementation,
- train ordering in territory of Prague,
- proposal for economic provision of PID (Prague Integrated Transport) operation with effective utilisation of available funds,
- proposal for a tariff and fare within PID,
- working out a regional transport plan,
- making contracts in order to provide PID operation with respective municipalities, the capital city of Prague, Central Bohemia Region, and carriers on behalf of the capital city of Prague, and control of their fulfilment,
- organisation of financial flows of proceeds and subsidies within PID,
- selection of carriers of newly established lines through public trade competitions,
- safeguarding a single information system of PID.

While forming the PID system the ROPID organisation has followed up with the previous development which can be characterised with these key factors:

- falling ratio of public transport performances with a growing individual motoring,
- transformation of Dopravní podnik hlavního města Prahy (transport undertaking of the capital city of Prague) to a stock company in the ownership of the city,
- implementation of urban transport into municipalities of Ořech and Hovorčovice, provided by Dopravní podnik hlavního města Prahy in cooperation with ČSAD, based on the agreement with relevant municipalities and counties Prague-East and Prague-West,
- signing "Principles of cooperation of the capital city of Prague and ČD", which, among other things, assumed an accelerated restoration of cooperation between urban transport carriers and ČD and an effective utilisation of passenger transport provided by ČD in the system of urban public transport, and subsequently making contracts on cooperation between the capital city of Prague and ČD, enabling commencement of railway integration,
- discontent of municipalities at the borders of Prague with public transport quality and the interest in solving its problems through integration into Prague urban public transport system,

- implementation of new bus lines of Dopravní podnik hlavního města Prahy, a.s., into municipalities beyond the city boundaries,
- establishment of private bus carriers, who share efforts to assert themselves in the transport market within Prague and its surroundings.

3.4. Integrated Transport Systems in the Slovak Republic

Currently in the Slovak Republic there exists no applicable legislation for integrated transport systems formation. This statement is based on the fact that there is no law on public transport which would establish rules for public transport and territory serviceability (Ľuptak, 2017). Nowadays the transport is financed with public sources on many passages in a duplicate manner in a form of parallel connections of various public transport modes. It is also caused with the fact that in 2009 passenger railway transport should also have become part of self-governing regions competency which, however, has not been put into practice yet.
This is the reason why competency distribution within route ordering and public transport performances has not been clear so far. And a coordinator role is missing here, too. A transformation to a more effective transport is possible only if there is a uniform legislation enacted in this area; that would be represented with a law on public transport. It should definitely specify parameters of railway lines concurrence, whereby rail transport would represent a key system. Bus transport would mainly provide passengers move from railway stations into destination stations and the other way round.

3.4.1. ITS Bratislava

Public transport in Bratislava and its surroundings has joined the integrated transport system in Bratislava Self-Governing Region in order to create an appealing offering. The system includes tram, trolley bus and bus lines of the transport undertaking Dopravný podnik Bratislava, regional bus lines of Slovak Lines and all suburban trains, categories of passenger train and regional express train, of Železničná spoločnosť Slovensko.
Passengers travelling by trains of Železničná spoločnosť Slovensko can decide to:

- use tickets according to actual price lists of ZSSK including one-way tickets, discounted fare with customer offerings (e.g. KLASIK RAILPLUS), free transport for selected groups of inhabitants or railway line prepaid tickets – in the same way as in entire Slovakia. These tickets are applicable only in trains of ZSSK.
- use integrated tickets which are valid not only in involved trains of ZSSK, but also in Bratislava public transport and suburban buses of Slovak Lines.

Railway lines included into the integrated transport system in Bratislava Self-Governing Region (ITS in Bratislava Self-Governing Region):

- S 20 **Bratislava - Malacky - Sekule** (all trains of a passenger and regional express train category) (in the passage Závod - Sekule as a partially integrated line),
- S 50 **Bratislava - Pezinok - Cífer** (all trains of a passenger and regional express train category) (in the passage Báhoň - Cífer as a partially integrated line),
- S 60 **Bratislava - Senec - Reca** (all trains of a passenger and regional express train category),
- S 25 **Zohor - Záhorská Ves** (all trains of a passenger train category),
- T **Zohor - Plavecké Podhradie** (all trains of a passenger train category as a partially integrated line).

In the above mentioned trains it is possible to use tickets of ZSSK as well as tickets of ITS in Bratislava Self-Governing Region.

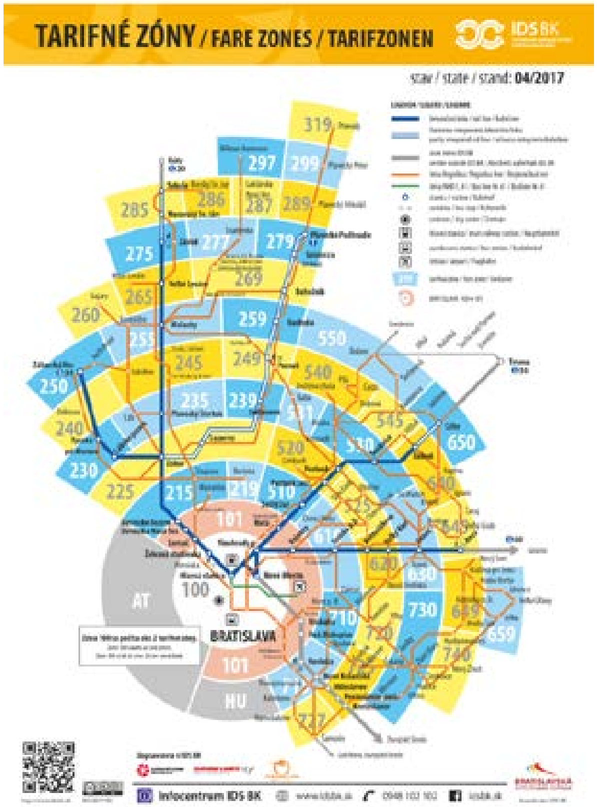

Fig. 1.
Integrated System of Bratislava Self-Governing Region
Source: (Ľuptak, 2017)

3.4.2. Regional Integrated Transport System of Žilina (ŽRIDS)

Today's ŽRIDS began to emerge in 2003 after cancelling passenger transport on the line No. 126 Žilina - Rajec. The city of Žilina, Žilina Self-Governing Region and municipalities near the railway line entered into cooperation with the company Slovenská investičná a realitná spoločnosť, a. s. (SIRS). Since February till April 2003 it was SIRS which provided passenger transport on the railway line; afterwards the transport provision was taken over by Železničná spoločnosť Slovensko thanks to an agreement with SIRS. This railway line was the first out of 26 Slovak lines with a previously stopped passenger transport, where the passenger transport was restored.
Since April 30, 2003 the time table on the railway line has been linked with the time table of line No. 2 of the city of Žilina urban public transport.
Since autumn 2003 machines to mark tickets for urban public transport have been installed into all motor and tow wagons on the line, which in fact put the integrated transport system ŽRIDS into existence. A self-service passenger processing system has been established here. Later a zone tariff has been implemented on the railway line.

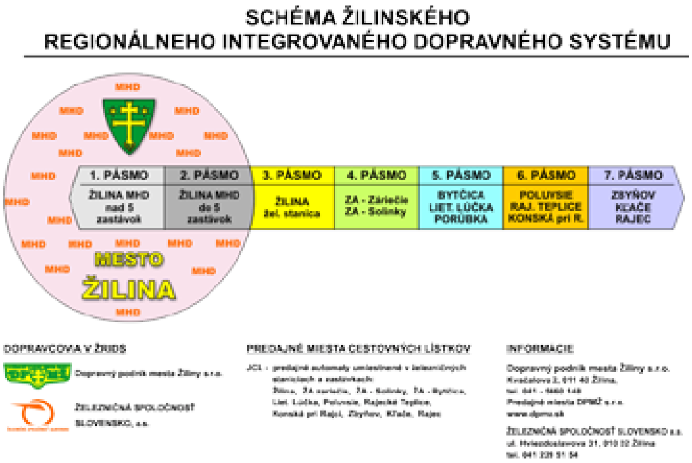

Fig. 2.
A Scheme of Regional Integrated Transport System of Žilina
Source: (Ľuptak, 2017)

3.4.3. Integrated Transport System in Košice

Currently there is a project of integrated transport system in Košice being worked out. On a long term basis the Transport Department of the Košice Self-Governing Region Authority has been developing an initiative for ITS formation through its cooperation with Ministry of Transport and Construction of the Slovak Republic, with the company Železnice Slovenskej republiky, and carriers operating in Košice Self-Governing Region, namely Železničná spoločnosť Slovensko, a. s., eurobus, a. s., ARRIVA Michalovce, a. s., and Dopravný podnik mesta Košice, a. s. In compliance with a worked out study "Institutional and Organisational Analysis of Public Transport System Development at a Regional Level of Košice Self-Governing Region" with regards to economic intensity of operation of the company ORID, s. r. o. (founded on March 1, 2010), unexplained attitudes of public transport order parties to the entry of an organiser, and based on the resolution No. 95/2014 of Košice Self-Governing Region Council to the date of August 31, 2014, the competencies and tasks of the company ORID, s. r. o., were transferred to the Transport Department of the Košice Self-Governing Region Authority, effective as of September 1, 2014. The Transport Department of the Košice Self-Governing Region Authority has been intensively studying and working on formation of the "Eastern Slovak Region" as well as on a sustainable ITS system in compliance with approved strategic documents - "Strategic Plan of Transport Infrastructure Development until 2020" and "Development of Public Transport".
Major tasks of the Transport Department of the Košice Self-Governing Region Authority are as follows:

- Institutional support for ITS formation;
- Coordination of regular public transport time tables;
- Working out of single transport regulations and tariff;
- Support for ITS infrastructure formation;
- Management of ITS operation and its control;
- Development of integrated transport system;
- Establishment of conditions for a sustainable regional and urban mobility;
- Development and improvement of environmentally positive transport systems for the sake of support for a sustainable regional and urban mobility.

Principles of transport system integration in Košice Self-Governing Region:

- Transport optimisation in Košice Self-Governing Region with regards to urban transport and regional railway and bus transport;
- Coordination of bus lines within suburban transport;
- Optimisation of transport operation along major railway routes;
- Creation of connecting lines of the optimised bus transport with utilisation of buses of corresponding capacity;
- Working out of single transport regulations;
- Establishment of a single ticket and tariff;
- Formation of a quality and complex information system for passengers (information panels in interchange nodes and means of transport, network of information and dispatching system of carriers).

4. Proposals for Legislative Implementation Solutions in case of ITS in Slovakia

The major task of integrated transport systems organisation in Slovakia should be a clear distribution of individual authorities' competencies, establishment of a transport authority and then rational operation of subjects within formed integrated transport systems, leading to the easiest realisation of ITS characteristics (Kampf, 2017 and Gapsarik, 2015).
The harmony of concepts while ordering the scope of transport and modernisation of the railway transport passage have been a long-term issue not only from the perspective of preparation, but mostly from the perspective of the follow-up usage (life cycle of some parts is up to 100 years), and therefore they must be prepared with an appropriate responsibility and clear concept of future functions and capabilities (Gnap, 2006). Thus, mutual confirmation of operational and infrastructural concepts as well as their sequential fulfilment is required. First of all it is the coordination of intentions within the order of railway passenger transport (MDV), order of regional bus transport (self-governing regions), urban transport (town councils), and intentions of integrated transport systems, which should finally lead to creating conditions for changing the proportions between individual transport and public transport performances in favour of public transport. To achieve this it is necessary:

- to create and approve mid-term transport concepts (transport operation plans) at the county and national level, including subsequent regular update;
- to create a clear concept for railway infrastructure development, and its observance;
- to ensure harmony in these concepts and development documents including concord with national transport policy and its projection into city plans;
- to establish clear criteria for implementing infrastructural intentions within the area of railway infrastructure into perspective plans, and evaluation of their priority;
- to create a matching operational concept, out of which claims to the scope and parameters of railway infrastructure arise.

4.1. Role of an Organiser

For a functioning integrated transport system in Slovakia it is necessary to create an organiser (coordinator) role, whose major tasks are as follows: establishment of a single transport operation offering, implementation of a single tariff, processing and information system, establishment of single transport conditions, and central execution of transport financing. When conforming to these rules, however, positives of public transport must be utilised to the greatest extent:

- regularity,
- availability,
- mass scale,
- ecology.

The support for an organiser's (coordinator's) legal form must take the form of legislation, i.e. act on public transport. Besides bringing this law into force it is also necessary to fulfil other objectives and measures of transport policy of the Slovak Republic, mainly speaking about:

- optimisation of public services funding,
- development of transport in regions,
- development and formation of integrated transport systems.

These objectives may be accomplished by ITS organisers provided they have specialised skills and have been authorised to do so by order parties.
With respect to the fact that there has been no effective law on public transport, and therefore there exists no precise definition of an integrated transport system or organiser, we can propose two possible legal forms of an organiser which could be defined in a law on public transport. The main prerequisite is that the law on public transport allows for services provision in public transport to be realised by ITS organisers.
The activity of an organiser depends on a contract on public service commitment and is funded with fare proceeds and reimbursements for a documented loss. Processing of ITS development documents may be part of costs included in transport performances reimbursed with contracts on public service commitment or reimbursed with separate contracts for work, but in each case their processing must be guaranteed by the organiser.
Organiser as a **carrier**

- has the role of a carrier,
- performs his activities on the basis of a concession,
- provides the transport on the basis of licenses (is the owner of licenses on links in a given ITS),
- acts as a single carrier in relation to passengers,
- enters into contracts on transport (or on means of transport operation) with individual carriers in ITS and bears the responsibility for their fulfilment,
- is a receiver of fare proceeds, reimbursements for a documented loss, or subsidies from towns and municipalities, and uses these funds to pay for contractual transport performances of carriers,
- is the owner of travel documents and is entitled to perform transport control in the entire ITS,
- operates or owns an information system,
- provides basic ITS development documents in relation to order parties,
- is always a legal entity.

5. Conclusion

The importance and scope of the problem on one side and capacity capabilities on the other side enable to propose basic procedures and establishment options of an organiser in ITS. From the point of view of functioning ITS formation in Slovakia it is necessary to adopt a new legislation in order to enable and define ITS unambiguously (Poliak, 2017).
It would also be appropriate to transfer competencies of a party ordering transport performances to self-governing regions from the perspective of solving transport issues of specific regions. The solution for implementing functioning integrated systems in Slovakia may be easier based on a complex analysis of ITS operated abroad, since mistakes happening at their implementation can be avoided.

Acknowledgements

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MODEL OF IDENTIFICATION MECHANISMS FOR CREATING EFFECTIVE INTEGRATION OF THE RAILWAY MARKET UNDER THE TRANSPORT COMMUNITY TREATY

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Abstract: The European Union's efforts to create a single transport area in the Western Balkans resulted in the Treaty on establishing the Transport Community. Fragmentation of the railway transport market, low density of the national networks, poor conditions of the infrastructure and rolling stocks, resulting in low quality of the services are the main characteristics of the Western Balkans railway sector. Institutionalizing future railway infrastructure development and progressive integration of Western Balkans railway transport markets into European transport market, on the basis of the relevant EU legislative, are main objectives of the Transport Community within the scope of railway sector. Considering the complexity of integrating processes, transition mechanisms should, in non discriminatory manner, provide the right of access to the railway infrastructure for all licensed passenger and freight railway undertakings in EU and Western Balkans countries, with no any restriction on the licenses validity, safety certificates, rail vehicle authorization, the certification documents of train drivers, etc. This paper has aim to develop the model of mechanisms for creating future effective integration of the Western Balkans railway transport market set up under the Treaty on establishing of Transport Community.

Keywords: Transport Community, railway infrastructure, railway transport market, EU legislative, liberalization.

1. Introduction

The main characteristics of the Western Balkans transport network are low quality, low density and high level of fragmentation. These elements have a direct influence the high costs of inputs, production and distribution, and therefore low national competitiveness. Despite an investment volume of 13.5 bn EUR since 2004, the Western Balkans' transport network still requires focused financing (WBIF, 2017).
Regarding the future development of the Western Balkans infrastructure and its integration in EU transport network two important moments are marked as a milestone. First one is concerning the regional Core transport network[3] and an indicative extension of the EU Core Network and Corridors to enhance connectivity within the Western Balkans six countries and further with the EU network agreed by the leaders of the Western Balkans in 2015. The second one is the signing of the Transport Community Treaty in 2017 with the aim to support integration of the Western Balkans network. Two main pillars of the Transport Community are: (1) further development of Western Balkans TEN-T Core and Comprehensive Networks (TEN-T Comprehensive and Core Network to the Western Balkans is a multimodal network which includes road, rail and inland waterway links in the six SEETO regional participants, together with a number of designated seaports, river ports and airport nodes and terminals. The Core Network is a subset of the Comprehensive Network. The Core Road Network comprises 64% of the Comprehensive Road Network and the Railway Core Network comprises 67% of the Comprehensive Rail Network corridors and routes (SEETO, 2018)), and (2) connectivity reform measures implementation.
In this paper is will be addressed the transport infrastructure background, Transport Community Treaty main scope and objectives and mechanism of financial support throughout synergic model which presented the main interfaces between Transport Community and instruments of support.

2. Analysis of Western Balkans Transport Infrastructure Background

Western Balkan countries are characterized by transport infrastructure of poor development, low density and poor quality of services, far below the European average. Such a situation significantly affects the reduction of the overall economic development of the region and the low competitiveness of the Western Balkans countries. In the Study of the International Monetary Fund (IMF, 2018) in which are defined the key quantitative criteria that determine the development of infrastructure, it has been determined the gap of infrastructure in the countries of the Western Balkans. In Figure 1a are presented regional infrastructure gaps by sector and regions (CEE = Central Eastern Europe; CIS = Commonwealth of Independent States; SEE-EU = Southeast Europe EU members; SEE-XEU = Southeast Europe non-EU members).

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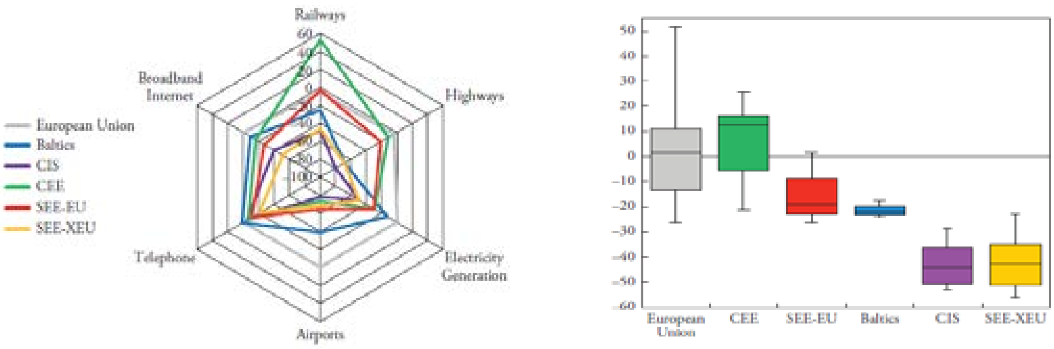

a **b**

Fig. 1.
Regional infrastructure gaps by sector and region and aggregate indicator of infrastructure gaps by regions in 2015
Source: (IMF, 2018)

Considering the aggregate indicator of infrastructure, it is evident that the infrastructure in the Western Balkan country is by 50% less developed than the European average presented in Figure 1b. The evident gap in the financing of transport infrastructure lasting for more decades is primarily a result of the budget deficit of the countries in the Region. It is impossible to expect that overcoming of this gap will be resolved promptly. In the last fifteen years the annual public investment in infrastructure is just 6% of GDP (e.i. 8% of GDP for Bosnia and Herzegovina and 3% for GDP for Serbia). In case of Bosnia and Herzegovina there was no consistent development for all mode of transport networks, what creates the huge inter-modal gaps. For 1500 km of roads in post-war period it has been invested cca 3 bn EUR, and at the same time for almost the same length of railway network it has been invested ten time less, just 385 mil EUR (Ferizović, 2017). Comparing the dynamics of the EU public infrastructure investment and Western Balkans, it will be needed almost 33 years for the countries of this Region to catch up current EU level.
Western Balkans' Core and Comprehensive TEN-T Rail Network characterized an insufficient investment in railway infrastructure (only 15% of total investments), inadequate maintenance, as a result of the financial deficit, obsolete rolling stock and inadequate management position the railway system of the Region to the bottom of the European scale. Comparing with the other types of infrastructure, the condition of the railway infrastructure of the Western Balkans region scores the highest gap in the quality indicators and needs the significant improvements. The Figure 2 shows that majority of the TEN-T railway Corridors in the Region suffering of poor quality of infrastructure. The worst situation is on the Corridor Vc.

Fig. 2.
Railway infrastructure quality on the rail TEN-T Corridors in Western Balkans
Source: (SEETO, 2018)

Consequently, the poor condition of the railway infrastructure is triggering the poor quality of railway services, which leads to a significant drop in railway traffic and contributes to a reduction in market share in the transport market. Considering the indicators in railway freight and passenger traffic, it is noticeable that in the period from 2010 to 2016, are recorded significant fluctuation (Figure 3).
In respected period, the freight transport has decreased in amount of 16%, with the significant decreasing in freight traffic at the railway Corridor X, even that Corridor has the majority of share followed by Corridor Vc (33% and 23%, respectively). Regarding the railway passenger traffic the situation is worse. Namely, almost an all Corridors and routes it has detected a decreasing in pkm in period 2010-2016.

Fig. 3.
TEN-T Comprehensive and Core Rail Network freight traffic (mil. tkm) and passenger (mil.pkm) in 2010-2016
Source: (SEETO, 2018)

Only on Corridor X with the highest share of 32% and Corridor Xb recorded the increasing in passenger traffic volume. The reasons are multiple, and are primarily the consequence of the market un-competitiveness of the railways in the region. If the practice of inadequate and deferred maintenance would continue, the costs will increase and decrease the productivity, which will negatively impact the further decline in railway traffic causing un-efficiency of the whole system. In the presence of mature competitive transportation modes, railways can no longer ignore the needs of consumers in designing of services, nor to determine prices regardless of their costs.

3. Transport Community as a Core Pillar of the Single Open Railway Market

Intensification of regional integration process of Western Balkans countries with the European internal transport market is a focal point of EU diplomacy efforts holding Summits in: Berlin (28 August, 2014), Vienna (27 August, 2015) and Paris (4 July, 2016). With the vision to develop the competitive transport system and high quality and safe services, transposing EU legislation in order to strength the economic development, the Transport Community Treaty (TCT) has been signed on Trieste Western Balkans Summit (12 July, 2017).
The objectives of TCT are in line with the Connectivity Agenda. Western Balkan Region is committed in railway market opening by 2020 through implementation of railway reform strategy. Establishment of the competitive, reliable and safe railway system and increasing effectiveness of border-crossing procedures (already signed Border-crossing bilateral Arguments between Western Balkans countries have an important role in market opening) shortening delays in railway service providing are the main objectives of Connectivity Agenda soft measures. The opening of the rail market will contribute significant benefits to users of rail services to create a significant polygon for attracting investors, including private capital, as well.
Establishment of the single open market requires common and integrated approach in railway infrastructure development and reforms of the railway sector. The Figure 5 presents synergistic model of Transport Community management structure its scope and financial support instruments. The key elements of the model will be presented in following subchapters.

3.1. Transport Community Objectives, Operating Scope and Management Structure

The main objective of the Treaty is the establishment of the Transport Community (TC) in the field of road, rail, maritime transport, inland waterways and the development of the transport network between the European Union and the SEE countries. Main principle of the Transport Community is based on the progressive integration of transport markets of the SEE countries into the European Union transport market on the basis of the relevant *acquis* (Regulatory rules applicable to different modes of transport covering specific regulatory areas are presented in Annex I of the Treaty), for all modes of transport excluding the air transport in the following areas: technical standards, safety, interoperability, traffic management, security, social policy, public procurement, and environment.
The scope of the TCT is the operating area of different transport modes: road, railway, inland waterway and maritime concerning the both, infrastructure development and regulatory framework reforms. For the purpose of operating international rail passenger or freight services providing the right of access to the infrastructure in all EU member states and Western Balkans countries to all railway undertakings licensed in an EU or by a Western Balkans country are obliged. Also, the TCT will not allow any restrictions on the validity of licenses of railway undertakings, safety certificates, the certification documents of train drivers and rail vehicle authorizations granted by the relevant authority of EU Member State or Western Balkans country.
Management structure of TCT is assembled by five bodies as presented in Figure 4. (1) Ministerial Council should provide general policy guidelines, review progress on the implementation of Treaty, give opinions on the appointment of the Director of the Permanent Secretariat and decide on the seat of the Permanent Secretariat. (2) Regional Steering Committee is responsible for the administration and its proper implementation of Treaty and adopts the budget every year. It makes recommendations and takes decisions binding upon the Contracting Parties and prepares the work of the Ministerial Council. (3) Technical Committees will be established in the form of *ad hoc* working groups, and each

Technical Committee may make proposals in its sphere of responsibility to the Regional Steering Committee. (4) Social Forum focusing attention on social matters in following key areas: workers' fundamental rights, labour law, health and safety at work, as well as equal opportunities. (5) Permanent Secretariat provides an administrative support to the Ministerial Council, Regional Steering Committee, Technical Committees and Social Forum, act as a Transport Observatory to monitor the performance of the indicative TEN-T extension of the comprehensive and core networks to the Western Balkans and support the implementation of the Western Balkans Six (WB6) Connectivity Agenda.

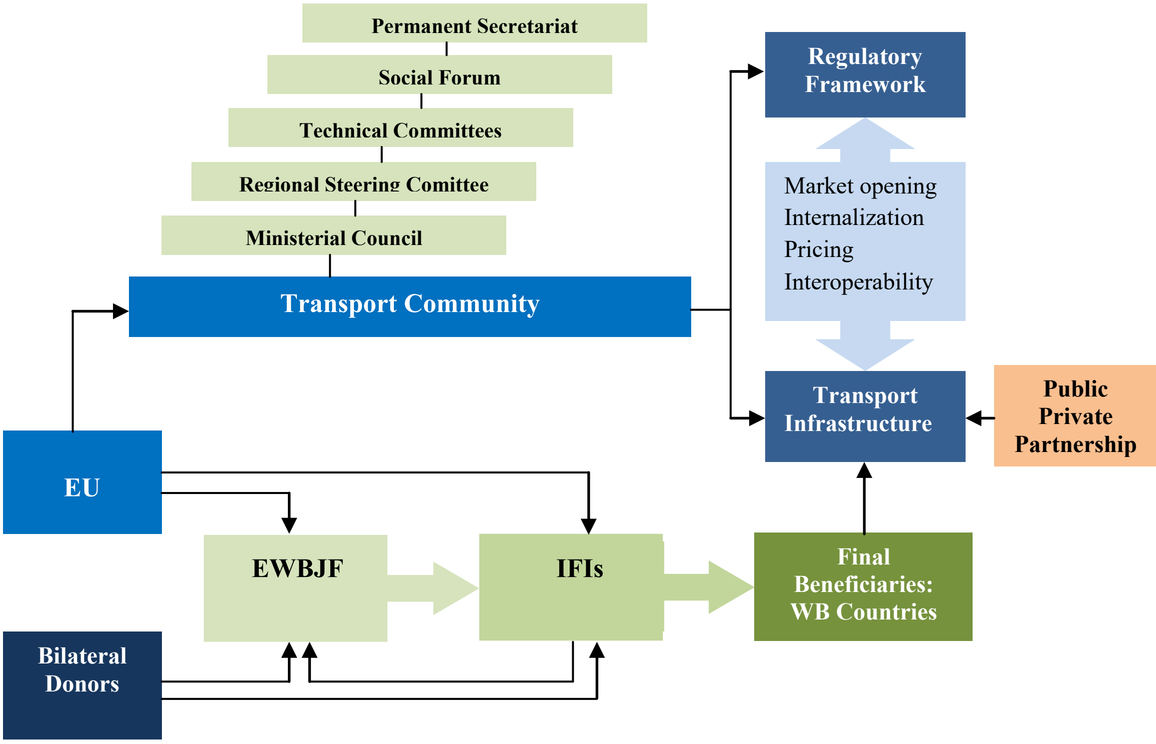

Fig. 4.
Synergistic model of Transport Community structure and scope and financial support entities
Source: (Elaborated by Authors based on Čaušević et al., 2018 and EIF&EIB, 2018)

Transport Community budget is defined by the contributions of the EU and Western Balkans countries (Annex V) in order to cover the operational expenses for functioning of its bodies. The level of contributions may be reviewed every three years, on request of any Contracting Party, by a decision of the Regional Steering Committee. The budget contribution is divided into two parts: 80 % for the EU and 20 % for the six Western Balkans countries. The 20 % for the South East European Parties will also be broken down according to the following scheme: each country contributes with 2% to the budget and the remaining 8 % will be distributed among the six South Eastern European parties depending on their share in the total GDP (in billion EUR per Western Balkans countries are presented in Table 2) of the Western Balkans parties' (Annex V).

3.2. Railway Sector Regulatory Reforms

Transport Community Treaty has given the main focus on railway sector regulatory reforms in order to become compatible with the EU regulatory framework. Table 1 summarize the railway regulatory areas that should be implemented in two transitional periods. These reforms should be in line with the implementation of legislative regarding the TEN-T development process and railway network as its part. The main regulatory areas of railway sector in Western Balkans countries are liberalization and railway market opening. In that sense the issues of full internalization of external costs and fair pricing system in the function of creating a fair pricing system should be given special attention.
According to the Treaty's transitional measures, in order to avoid discrimination, progressive adjustment of any state monopolies is required, and the Regional Steering Committee shall monitor the measures adopted to attain this objective. In that respect, approximation of the existing legislation on state aid and competition of the Western Balkans countries to that of the EU is needed, in order to ensure that their existing and future laws on state aid and competition are gradually compatible with the *acquis* by the end of the Treaty's second transitional period.

Table 1
Railway sector regulation transposing dynamics

Infrastructure regulatory area	Railway regulatory area	I TRANSITIONAL PERIOD

(Annex I)	(Annex I)	
TEN-T development	1. Market access 2. Train driver licensing 3. Interoperability 4. Railway safety 5. Social field – working time 6. Passenger rights EU Agency for Railways 7. Inland transport of dangerous goods 8. Transportable pressure equipment	Have to implement all railway legislation as provided for in Annex I
		Have to make sufficient progress in implementing the rules on State aid and competition included in an agreement referred to in Article 17 of the Main Treaty or in Annex III, whichever is applicable.
		Railway undertakings licensed in B&H shall be granted access to railway infrastructure in B&H
		II TRANSITIONAL PERIOD
		By the end of the second transitional period B&H shall apply this Treaty, including all railway legislation and the rules on State aid and competition
		Railway undertakings licensed in B&H shall be permitted to exercise the traffic rights provided for in the railway legislation referred to in Annex I on railway infrastructure of any other South East European Party

Source: (Elaborated by Authors based on Čaušević et al., 2018)

In order to create single open market in Western Balkans area TCT is focusing on the issues regarding the competition rules and other economic provisions (Rules on competition and state aid referred to Article 17 of the main Treaty are stated in ANNEX III). Western Balkans countries should ensure that an operationally independent public body entrusted with the powers necessary regarding private and public undertakings and undertakings to which special rights have been granted, in order to disable: (a) all agreements between undertakings, decisions by associations of undertakings and concerted practices between undertakings which have as their object or effect the prevention, restriction or distortion of competition; and (b) abuse by one or more undertakings of a dominant position in the territories of the as a whole or in a substantial part thereof. The issue of state aid should be scope of an operationally independent authority which is entrusted with the powers necessary for the fully disabling any state aid which distorts or threatens to distort competition by favoring certain undertakings or certain products. This authority shall have the powers to authorize state aid schemes and individual aid grants as well as the powers to order the recovery of state aid that has been unlawfully granted. A mechanism for ensuring full transparency in the area of state aid, the regular annual report should be provided in accordance with the methodology of the EU survey on state aid.

3.3. Instruments for Supporting TCT Implementation

From the model presented in Figure 4 are visible stakeholders and instruments for supporting the functioning of the Transport Community and achieving its goals in the function of creating a single liberalized transport market and railway market as its sub-segment.

Western Balkans Investment Framework has been organized as a joint imitative of European Commission, European Investment Bank, European Bank for Reconstruction and Development and Council of Europe Development Bank on 2009, which now include and KfW, with the aim to streamline the conditions for assistance provided by various donors. The European Western Balkan Joint Fund (EWBJF), co-managed by the EIB and EBRD, has a central role in the WBIF legal structure and is the main pooling pot for the majority of grant donors (EIF&EIB, 2018).

The WBIF is a joint blending facility of the European Commission, participating International Financial Institutions (IFIs), bilateral donors and Western Balkans countries to deliver funding for strategic investment projects in beneficiary countries. Eligible sectors include infrastructure development within the environment, energy, transport and social sectors as well as private sector development WBIF Technical Assistance instrument via IPFs - Infrastructure Project Facilities to Support Projects in European Regions amounts total value of 205 mil.EUR. (EC, 2107). Complementary regional technical assistance instruments includes: JASPERS - Joint Assistance to Support Projects in European Regions Expansion to all IPA II beneficiaries from 1st of January 2016, with 3 mil. EUR for the Western Balkans and CONNECTA -Technical Assistance to Connectivity in the Western Balkans Support to achieve the connectivity targets Bring high priority energy and transport infrastructure, projects to maturity for investment co-financing. Assist the preparation and implementation of short and medium terms regional transport reform measures 9.354 mil. EUR, potentially up to 25 mil. EUR (EC, 2017).

Western Balkans International Financial Institution financing in 2017, including the lending and grants presented as a percentage of GDP is shared, as follows: 0,856 EIB and EBRD, 0,326Word Bank and EU grants 0,253 (IMF, 2018).

WBIF provides technical assistance in the implementation of the infrastructure development projects on Core Network and the regional projects are its core objective. For the period 2015-2020 for the key connectivity investment is allocated 1bn EUR. The highest share is regarding the transport infrastructure 46 project in total value 412,6 mil EUR, of which 74% for railways Figure 5. In 2017 WBIF has allocated fourteen technical assistance grants an two investment grants in amount of 26,1 mil. EUR and 98,4 mil. EUR, respectively (WBIF, 2017). Regarding the grants allocations per countries there are well- balanced amounts per countries in range of from 15% to 19 % (Figure 5).

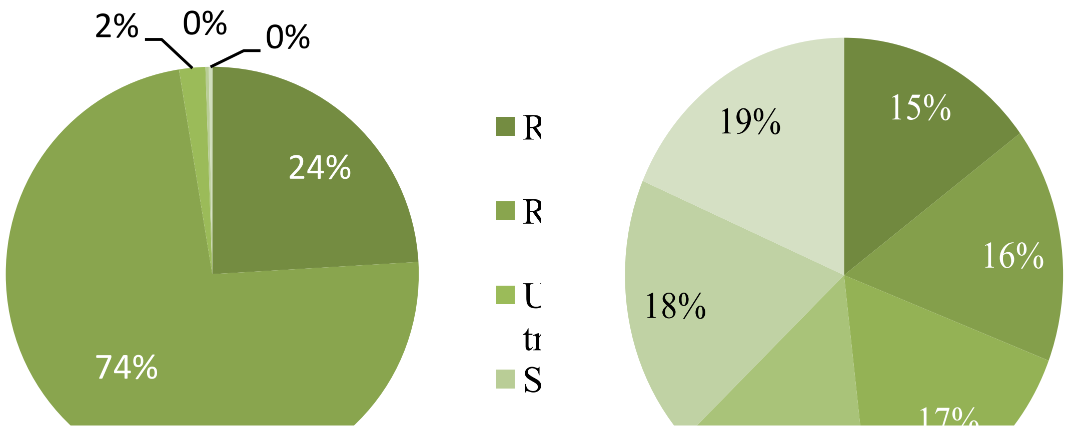

Fig. 5.
WBIF financial support by sector and Western Balkans countries
Source: (WBIF, 2017)

In the Table 2 is presented allocation of WBIF grants in transport infrastructure area by countries in Region in the range of 43.9 mil.EUR to 101.9 mil. EUR for Bosnia and Herzegovina and Serbia, respectively. For the projects regarding environmental area it was granted 0.4 mil.EUR for Macedonia and 31.7mil.EUR for Bosnia and Herzegovina.
In order to facilitate regional cooperation, WBIF has supported transport and environmental projects benefiting more than one country, in amounts 4,6 mil. EUR and 4,3 mil EUR, respectively (WBIF, 2017). In Bosnia and Herzegovina case, six grants in total value of 9.1 million EUR for technical assistance to transport and environment projects were approved in 2017 (WBIF, 2017).

Table 2
Distribution of WBIF grants in transport and environment area

Western Balkan Country	Transport (mil. EUR)	Environment (mil. EUR)	GDP (bn.EUR)	Logistics Performance Index	Environmental Performance Index
Albania	61.9	18.7	10.8	2.41/117th	74.3/61st
Bosnia and Herzegovina	43.9	31.7	15	2.60/97th	63.2/120th
Kosovo	70	16	6	n/a	n/a
Macedonia	85.4	0.4	9.8	2.51/106th	78.0/50th
Montenegro	44.9	19.2	3.8	2.38/123rd	78.8/47th
Serbia	101.9	14.4	34.1	2.76/76th	78.6/48th

Source: (WBIF, 2017)

The Trieste Summit provided 144.5 mil. EUR for six transport infrastructure projects (three road projects, two railway projects and one IWW port project (SEETO, 2018).
The South-East Europe Transport Observatory (SEETO) estimated a total of €13.9 billion priority projects in the region. Current investment needs are thus significant and require effective prioritisation in times of limited fiscal flexibility. In addition, a set of connectivity reform measures, which was agreed together with the Core Network, is being implemented to maximise the benefits of this investment effort (WBIF, 2017).

3.4. Public Private Partnership as a Sustainable Financing Mechanism of the Railways

The Western Balkans' governments are facing an increasing demand for public infrastructure services. The fact is, however, that the management of services by the public sector does not lead to the fulfilment of the requirements of the users for a quality service, and that the budgets of these governments for financing transport infrastructure, almost regularly in deficit, indicates the necessity of involving the private sector in the field of financing and management of

transport infrastructure and developing a new form of public-private cooperation, known as Public-Private Partnership (PPP).
In that sense it should be considered an option regarding the involving private investing in the Western Balkans Region railway infrastructure projects, as a valuable mechanism for its sustainable financing and long-lasting efficiency of further development (Figure 4). It should be noted that even PPP in transport infrastructure is not a new financing practice, railways are, traditionally, more conservative than road sector in its implementation. Nevertheless, positive practise of leading EU railways should be considered in case of PPP investment projects implementation in the Western Balkans.

4. Conclusion

The Western Balkan countries have been in the process of the railway sector reform for two decades, which is a consequence of the indolence of the main stakeholders, primarily sector's political structures and the management of the railways companies. Although the improvement of the Western Balkans railway network is under way and some slight improvements are evident, significant engagement of key stakeholders at the national and regional levels is needed in connections with the TEN-T core and comprehensive network in order to empower all the potentials that the railway sector has.
Presented synergic model envisage Transport Community as a focal point in creating the single railway transport market and creating mature conditions for its integration in the EU liberalized transport market. Establishing the Transport Community in its full capacity, through its operational scope and management structures, will eliminate non-physical obstacles that affect current regional trade and railway traffic, resulting in providing more efficient and high quality services. Only with the provision of continuous and sustainable financing of the railway infrastructure supported by various EU mechanisms and public- private partnership, as well, what will be a subject for faster progress of overall Western Balkans countries economy.

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DEVELOPMENT OF THE TEN-T CORRIDORS AND THEIR IMPACT ON THE TRANSPORT AND LOGISTICS SYSTEMS OF THE EU COUNTRIES

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Abstract: The main research objective of the study is to identify and analyse basic factors influencing the efficiency and effectiveness of functioning and further development of the transport and logistics macro-systems in the EU countries. Nowadays, among the various factors determining the smooth transfer of people and goods within the logistics systems, transport infrastructure is of special importance. It is seen from the point of view of such its components like these existing within the EU TEN-T corridors. They play a decisive role in enhancing efficient material and information flows in logistics macro-systems, being able to generate relatively high value added (European added value - EAV). Author focuses on the issues concerning creating EAV which is seen in form of selected direct and indirect effects generated by the development of TEN-T corridors. These effects are considered in terms of logistics efficiency, regarded as an increase of logistics macro-systems' quality standards. It has been pointed out, that much more research activity should be oriented towards analyzing the market processes determining the creation and distribution of the EAV across the logistics value chains. For this purpose, meta-analyses are to be used. Therefore, it has been applied three main indicators presented periodically in reports of international organizations, i.e. logistics performance, trade facilitation and competitiveness indices which give the basis for assessing and comparing transport and logistics systems efficiency of individual countries. They have been used to measure EAV in indirect way. The results of the study indicate that the TEN-T core transport infrastructure will play soon crucial role in determining the quality of both transport and logistics environment of the EU countries, affecting the efficiency of global logistics supply chains as well as the whole logistics mega (global) system.

Keywords: TEN-T corridor, core network, transport system, logistics system, logistics performance indices.

1. Introduction

The logistics macro-system constitutes one of the categories of the logistics systems existing on a macro scale. It is a spacious economic structure comprising means of production and consumption, with terminals of dispatch and delivery of the volume of goods, namely the sources of generating the flow of goods and their suppliers which comprises various flows including the flow of information, financial means and goods. Consequently, the logistics macro-system is an existing, organized and integrated within the national economy, system of flows of raw materials, materials and products and the related information and financial transfers, ensuring optimization of supply chain and network management through e.g. automatic identification of products, computer simulation, controlling, electronic exchange of data and comprehensive cost account (Grzelakowski, 2010). In the practical and cognitive aspect, in turn, it is assumed as a system (set) of interconnected material flows of companies as well as supply and sales markets, both domestic and international, taking into account indispensable, in terms of transport and logistics, relations between them based on information and cash flows. Hence, its reliability, efficiency and effectiveness have to be estimated in form of performed both transport and logistics goals.

Goods flows are performed in their physical aspect, by the transport system. The said system integrates, in the technical, organizational, economic, functional and spatial aspects, particular elements of the logistics macro-system – its sub-systems and as such, integrates the transport system with the logistics systems of other countries. Consequently, the transport system facilitates the implementation of the logistics tasks defined by the supply chains and networks operators constituting the integral part of the logistics macro-system (Fig. 1). From such perspective, the transport system, typical for the concept of supply chains and networks management based on the idea of optimizing functions and operations of transport in the logistics, in its functional, spatial, technical and organizational meaning, should be designed and shaped to provide effective and efficient completion of both transport and logistics processes).

It means that the effectiveness and efficiency of the transport system operations, including the issue of security and reliability of the completion of transport processes, must be perceived in the logistics meaning, i.e. on the logistics macro-system scale. Since the transport system constitutes only the technical and material base for the efficient and effective services of the goods' flows which actually always depends on the scale and rationality of the transport tasks created by the domestic logistics system constituting in fact the demand area for any transport system. Therefore, the tasks set for the transport sector, resulting from the occurring transport needs, defined by the character and manufacturing structure of the logistics macro-system translate finally into the specific volume and structure of the demand for transport services. Consequently, in real terms, the logistics macro-system is the main area of economic activity which determines: 1/ the intensity of the flow of effective demand for network and carriage services of transport and, as a result, 2// possibility of rational – in categories assigned to the standard of multimodality, interoperability and co-modality – use of available at a particular time, forms and types of transport, and therefore, the effectiveness of meeting the demand (Mangan et al., 2009).

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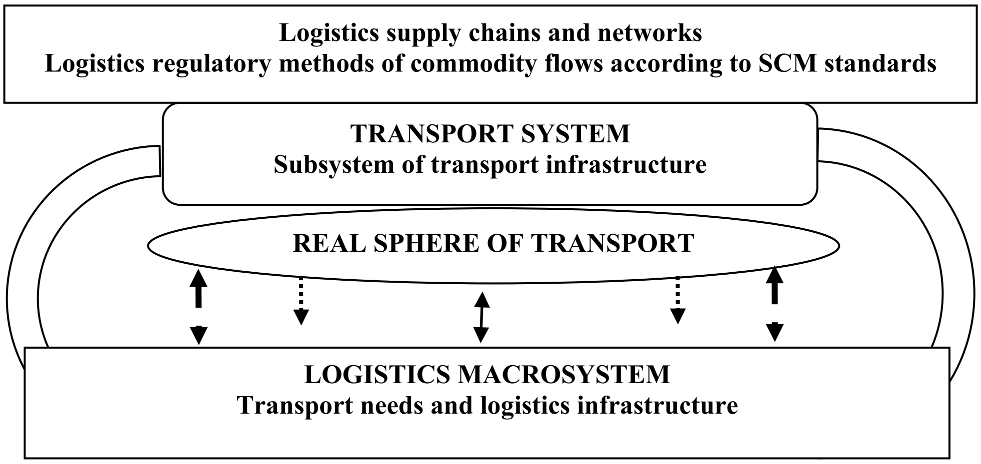

Fig. 1.
Transport system as a component of logistics macro-system
Source: A. S. Grzelakowski, own development

Given that transport macro-system constitutes an integral part of both macro and mega logistics systems (Fig. 1), the quantity and quality of carried out tasks within the said system, depends in real terms mainly on technical and organizational effectiveness of transport and logistics processes performed within logistics system. It means that these processes are predominantly determined by appropriate technical standards and operational quality of transport infrastructure. As a result, the growing requirements for providing the smart transport infrastructure can be met only by implementing its highest quality network which fulfils the standards, applied currently to the EU core and complementary infrastructure situated within the TEN-T green corridors (White Paper, 2011).

2. EU TEN-T Corridors and the European added Value – its Creation and Transfer

In pursuing its strategic goal in the area of transport policy, i.e. implementing sustainable mobility in transport sectors, the EU undertakes to build the Single European Transport Area (SETA). (White Paper, 2011). Striving for achieving it in the next decades, the EC has adopted since 2011a new, innovative in its nature concept for the further development of TEN-T corridors. Their significance as fundamental elements providing cohesion of transport networks able, at the same time, to ensure integrity of the EU members' transport systems and to form grounds for SETA, was currently fully recognized both within the EU transport and cohesion policy. (Regulation EU, 2013) For the purpose of planning and programming as well as providing financial support for developing TEN-T, regarded as networks of primary importance, the EU began to apply a division of their infrastructure components based on the so-called two-level approach. The two-level approach means that the network of priority importance for the EU will be constructed gradually through developing the so-called comprehensive and core networks. Accepting such solution – TEN-T system construction model – in its final version by 2050 means that in the structure of the said network there are the following elements:

- basic comprehensive network which constitutes the basic level of TEN-T and comprises the existing and planned infrastructure satisfying the minimal requirements defined in the Commission guidelines, and
- core network comprising the strategically most important components of comprehensive network which shall constitute „backbone of multi-modal mobility network" of the EU, including mainly those elements of TEN-T system which generate the highest value added for Europe (Regulation EU, 2013).

The comprehensive network should be constructed by 31.12.2050 and the core network by 31.12.2030 at the latest.
The core network consists of those elements of the comprehensive network which indicate the greatest strategic importance for meeting the objectives of the EU Trans-European policy related to the development of priority transport network. The core network should contribute in particular to handling the increased mobility and to developing low-emission transport system. The said network must be integrated in the so-called main transport nodes and should ensure efficient connections with the networks of neighbouring countries transport infrastructure. (White Paper, 2011)
Therefore, the core network, by definition, should carry out the following transport and logistics tasks, vital for achieving high standard of security and reliability of the European transport and macro-logistics systems, as well as in the future SETA, aiming at:

- facilitating in the possibly most effective manner the low-emission transport of goods and people,
- making it possible to use more effectively the existing network of the transport infrastructure,
- supplementing missing links in the TEN-T network system,
- eliminating the so-called bottlenecks in the EU transport network system,
- providing new possibilities within more effective services concerning the so-called multi-branch combinations.

On the other hand, the comprehensive networks shall meet the requirements related to ITS. The system shall also ensure the management of traffic and exchange of information within particular branches of transport and between them in relation to multi-modal transport operations and transport-related services of value added, improving both security standards and possibilities to satisfy the determined ecological requirements. ITS should ensure smooth connection of the comprehensive network infrastructure with the infrastructure of the regional and local traffic operating in the EU logistics macro-systems. Therefore, the core and comprehensive network which jointly form the TEN-T system, constituting key component of the EU logistics networks, are covered by the interactive system of geographic and technical information developed for trans-European network (TENtec). The system is used by particular EU Member States to notify on progress in the implementation of their projects and investments being the subject of common interest within the area of transport and logistics. At the same time, the system supports the construction of the integrated transport and logistics system on the EU level.
One of the basic instruments for successful implementing the said solution and ensuring effective construction of the core network system in the EU is the concept of building the so-called core network corridors based mainly on railway freight corridors. The corridors constitute the key framework system being an indispensable instrument for effective coordination of processes aimed at implementing the core network. Their construction is based on modal integration, inter-operability and coordinated development of infrastructure and its management leading to building the resource-effective multi-modal transport. The core network corridors should constitute the main platform necessary for the purpose of managing the traffic capacity, investment planning, building and coordination of the development of multi-modal reloading nodes and implementation of inter-operational intelligent traffic management systems.
Such model of the development of transport infrastructure within the core network in which the main transport and logistics nodes play the significant role, will undoubtedly contribute to the more precise and effective planning and completion of investment in the EU Member States' transport and logistics systems, too (White Paper, 2011). The core network will be developed within 10 main transport corridors (Fig. 2) which should ensure the construction of the key, secure and reliable transport structure indispensable for smooth SETA building and enhancement the single market as well as maintaining the constant economic growth in the EU.

Fig. 2.
The main EU core network TEN-T transport corridors
Source :(Regulation EU, 2013)

In line with the CEF Regulation, the EC being in charge of developing TEN-T core network corridors will give priority to projects of high EU added value. This means in particular projects building or upgrading cross-border sections, removing bottlenecks on the main European traffic routes, and prioritizing the realization of links currently missing in the EU transport network. Only such projects, covering transport infrastructure of high quality standards, enabling to build so-called intelligent core networks and carrying out the strategy of sustainable mobility, efficiently built and effectively managed, are able to generate high added value reflected in the increase in social mobility and consequently, improvement in the quality of life and level of social welfare.
The European added value referring to the investment projects within the area of transport infrastructure of the highest quality standards is understood as value resulting from the EU intervention which is additional to that one which would be generated as a result of actions of a member state itself (Regulation, 2013). Accordingly to the official documents it may result from different factors, e.g. coordination gains, legal certainty, greater effectiveness or complementarities. In this meaning it reflects broader European relevance and significance of the action with a view to presenting models and mechanisms which can be applied not only regionally or nationally but also EU widely. In practice, however, for a better understanding of the EAV concept, and a whole conceptual framework it is necessary to operationalize EAV, clearly explaining what elements contribute to this economic category and constitute EAV. For the sake of necessity of further EAV research, and above all, its measurement, a conceptual development of a so-called 'EAV database ' in which data and information are collected on a selection of actions that have been taken at EU, EU-MS and MS levels needs to be completed.
EAV generated by the high quality infrastructure built within TEN-T core network corridors, regarded as an additional value for Europe requires better recognizing and examining the mechanisms of both creating and distributing it within the supply value chains (EC Mobility and Transport, 2011). Furthermore, it is necessary to analyze the market

processes, which determine the distribution of EAV. The distribution process of EAV refers to three basic dimensions: spatial and network oriented as well as functional (transport & logistics) ones. Recognizing these mechanisms and the ability to measure EAV requires in turn the use of appropriate research methods and tools. The existing toolbox, which could be used for this purpose, is relatively quite rich. However, during the preliminary stage of research it turned out that the possibilities to adopt well-known macro- and micro-economic models applied to assess the effectiveness of the implementation of transport infrastructure large projects and construction of sustainable mobility plans, like: CBA, and RAEM, Trans-Tools, LMS, ASTRA, SASI, NEAC, REMI, Mobilec, VACLAV, World Container Model and CGEurope, and also LMS (NL), RHOMOLO (BE), RegFIN (Regional Finish CGE model) has been verified negative (Grzelakowski, 2014). As a result, at this stage of examining the methodological issues, research concerning above mentioned theoretical challenges can be done using mainly the deductive method, supported by the following research techniques and tools, like: analysis of EAV database and documents as well as development of logical structures based on the analytical approach, methods for measuring the quality and value, statistical technique, individual case studies and moreover surveys and interviews (Project I-C-EU, 2015).
It means that aiming at examining the impact of core network corridors on the transport and logistics macro-systems it can be used indirect methods, based on the assessment of the impact of transport infrastructure classified as a core network on the improvement of transport accessibility and country competitiveness supported by trade facilitation indices and logistics performance indices.

3. The Impact of Transport Infrastructure of TEN-T Corridors on Accessibility and Connectivity of EU Countries

Transport infrastructure investments located in TEN-T corridors imply additional transport capacity, increased efficiency and better reliability and service quality in logistics sector. This in turn, usually leads to lower transport costs and time savings in providing logistics services and consequently, to higher productivity as well as increase of competitiveness and business expansion what stimulates economic growth (Newbery, 2004). Their impact on the transport system and the economy as well as economic growth is presented in synthetic form in in Fig. 3.

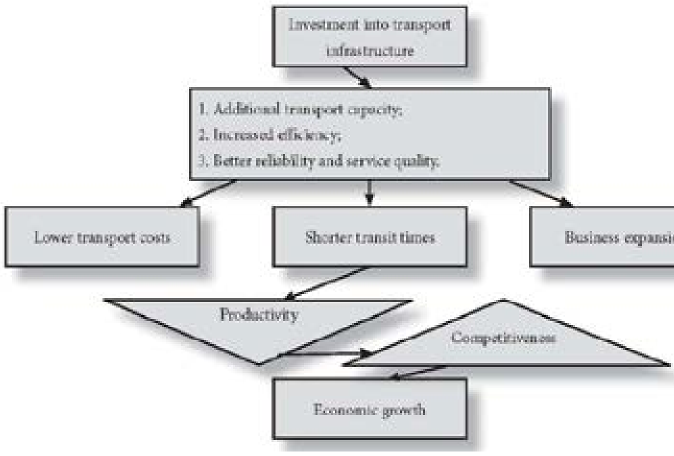

Fig. 3.
The impact of transport infrastructure investments on transport system and economic growth
*Source:(*Mačiulis *et al.,* 2009)

Considering these issues, it is worth mentioning, referring to the research of Branch and Chopra, that the role of transport costs on total production costs has been historically declining and this tendency appears to be continuing (Branch, 2009; and Chopra, Meindl, 2010). Hence, the effects perceived in this respect, i.e. the savings in transport and production costs, have the character of macroeconomic benefits generated by the development of transport infrastructure.
Considering this, the role of transport high quality infrastructure, which significantly affect national and regional competitiveness, should be viewed in close relation to questions of accessibility and connectivity. Thus, some accessibility and connectivity indices should be analyzed in this type of research. Usually, they prove to be helpful in competitiveness research both on sectoral (transport, logistics) and national levels.
Authors focusing on a review of accessibility indices, distinguish five major theoretical approaches for measuring accessibility indicators: 1. the travel cost approach, 2. the gravity or opportunities approach, 3. the constraints-based approach, 4 the utility-based surplus approach, and 5. the composite approach (Project I-C-EU, 2015). Each of them can be used to measure and assess the level of countries' transport accessibility and connectivity, which is a derivative of the already achieved quality standards of their transport infrastructure, simultaneously allowing them to evaluate its impact on the efficiency of the transport and logistics macro-systems.
Bearing in mind, that the high quality transport infrastructure is closely related to the questions of accessibility and connectivity, which are currently becoming the main indicators of the assessment of the efficiency of the transport and

logistics systems, some accessibility and connectivity indices can be used as a supporting tools to analyze the impact of this kind of transport infrastructure on national competitiveness and logistics performance of the EU countries. Hence, trying to clarify the set of relations between high quality transport infrastructure and its wider economic impacts on transport and logistics macro-systems as well as the whole economy, in particular its competitiveness and economic growth, the main indicators of competitiveness focusing on the role that transport infrastructure plays in are adopted. The most reliable and up to date data in this field are contained in the *IMD's World Competitiveness Yearbook* and in the *World Economic Forum (WEF)'s Global Competitiveness Report (GCR)*. Both studies use composite indicators to integrate large amounts of information into easily understood formats. However, the WEF's indicator, i.e. the *Global Competitiveness Index* (*GCI*), as a much credible source of wider information concerning transport infrastructure is more often used. It relays on evidence-based *hard* data and opinion-based *soft* data, and in both data sets transport infrastructure is considered as an important variable to measure national competitiveness. Covering 137 economies, the *GCI* 2017–2018 measures national competitiveness defined as the set of institutions, policies and factors that determine the level of productivity (The WEF, 2018). The *GCI* combines 114 indicators that capture concepts that matter for productivity and long-term prosperity. These indicators are grouped into 12 pillars among which is also infrastructure. These pillars are in turn organized into three subindexes and the first of them referred to the category *basic requirements*, regarded as a key for factor driven economy includes four pillars. The three subindexes are given different weights in the calculation of the overall index, depending mainly on each economy's stage of development. Transport infrastructure is contained in pillar 2 and is weighted 50% of the total score that pillar 2 has in the *basic requirements subindex.* In the *GCI* transport infrastructure is measured through the following variables: quality of overall infrastructure, quality of roads, quality of railroad infrastructure, quality of port infrastructure, quality of air transport infrastructure

The *WEF*'s *GCR* highlights the importance of transport investment stating that extensive and efficient infrastructure is critical for ensuring the effective functioning of the transport and logistics sectors and of entire economy. Well-developed infrastructure reduces the effect of distance between regions and countries, integrating their transport and logistics markets and connecting them at low cost to markets in other countries outside the EU. It means that TEN-T core network corridors are able to impact not only Europe's transport and logistics space but also global one. (Branch, 2009)

Presented in *WEF*'s *GCR* 2017-2018 results at the competitiveness frontier in the global scale indicate, that among the top 10 ranked economies are five EU countries: the Netherlands (4), Germany (5), Sweden (7), the United Kingdom (8), and Finland (10). They scored 5,7 - 5,5 points in country's overall GCI which takes values from 1 to 7. The other EU countries, with the exception of Austria (18) are far beyond the top 10 world leading countries. However, in some of them, subindexes A expressing the strength of infrastructural factors on country's competitiveness takes values equal or even higher to those received by countries included in the top 10 (on average, between 5,4 – 6,4), e.g. Austria (18) – 5,7, Belgium (20) – 5,4, Spain (34) – 5,9, France (22) – 6,1. It means that accordingly to the *WEF*'s *GCR,* transport infrastructure, even this of highest quality standards, regarding as a *basic requirement* does not play key role as compared with many other pillars determining country's competitiveness.

Its role, however, cannot be overestimated in terms of its impact on transport and logistics systems, which facilitate smooth transfer of people, and goods, enabling at the same time meeting of the highest standards set by global logistics operators in international trade. To measure its impact on the examined research area, two indicators can be used: 1. Enabling Trade Index (ETI) and Logistics Performance Index (LPI). These indicators are contained in the *WEF*'s and *Supply Chain & Transport Industry Partnership's* Global Enabling Trade Report (GETR-ETI) and *IBRD/World Bank's report* on *Connecting to Compete. 2016 Trade Logistics in the Global Economy*. The ETI as a composite indicator, assesses the extent to which economies have in place institutions, policies, infrastructures and services facilitating the free flow of goods over borders and to their destination.. It consists of an aggregation of individual indicators measuring various trade-enabling factors. These factors are organized into seven pillars, which are, in turn, organized, into four larger, umbrella groupings, called subindexes. The subindex C concerning infrastructure consists of three pillars assessing the availability and quality of transport infrastructure of a country (pillar 4 containing 7 indicators), its associated transport services (pillar 5; 6 indicators), and availability and use of ICTs (pillar 6; 7 indicators). (WEF and GAfTF, 2018) Figures of the last year's *WEF's GETR* indicate that among the top 10 countries in the global ranking there are as many as 8 EU countries, i.e. the Netherlands, Luxembourg, Sweden, Finland, Austria. UK, Germany and Belgium. Analyzing the overall indices (ETI) of the GETR, it should be emphasized that such a high position of these countries in the world ranking in terms of facilitating trade is the result of their contribution to the development of transport infrastructure and ICT. They obtained some of the highest rates in the world in all three pillars of the subindex C. (WEF, 2017) They leading role as high quality transport services providers in the global economy is confirmed by data contained in the World Bank's report on LPI.

The LPI is an interactive benchmarking tool created to help countries identify the challenges and opportunities they face in their performance on trade logistics and what they can do to improve their performance. The World Bank's LPI as a synthetic indicator analyzes countries in six components among which special attention is paid to the quality of trade and transport infrastructure (The World bank/IBRD, 2017). This component have been chosen based on theoretical and empirical research and on the practical experience of logistics professionals (LPI questionnaire, 2016). It is regarded as an area of policy regulations giving the opportunity to evaluate the quality of country's logistics services from the point of view of the existing quality standards of its transport and ICT infrastructure The world's top performers remain at the logistics frontier four EU countries, with seven EU countries in the top 10, i.e. Germany (1), Luxembourg (2), Sweden

(3), Netherlands(4), Belgium (6), Austria (7) and UK (8). They scored such high positions in the global LPI ranking due to already reached high quality transport infrastructure generated added value satisfying both transport and logistics operators providing wide spectrum of services within their logistics systems.

4. Conclusion

Gauging the role of the high quality transport infrastructure in creating added value generated within the TEN-T corridors, it has been analyzed the leading indicators of national competitiveness as well as trade facilitation and logistics performance indices. The results of the study indicate that each of these three dimensions of efficiency of the transport and logistics system of the EU countries is closely related to transport infrastructure able to create high added value (EAV) expressed in form of increasing accessibility and connectivity. Being aware of this, the EC strongly supports the development of the core network TEN-T corridors regarded as the EU priority transport axes containing green intelligent infrastructure.

It has been also shown, how meta-analysis as the statistical procedure for combining data from multiple international reports, gather information from these sources with varying research subjects and methodologies. It turned out, that the treatment effect as well as its size is consistent from one report to the next. Therefore, it was sufficient basis for recognition that meta-analyses can be used in this case to identify the common effects seen as EAV. However, predictions from a meta-analysis give only a rough guess of such effects that are to be expected as it is a case of EAV of TEN-T corridors. Moreover, results from such meta-analysis can in turn be used to make predictions on new situations. These can be of use in practical decision making concerning transport infrastructure development, when up to date data is not available e.g. for Cost-Benefit Analysis (CBA/BCA). Still, in setting acceptable parameters in CBA, meta-analyses are often the most reliable and precise source of information.

The reliability and security of both transport and logistics macro-systems of each country depend to a large extent on the development of high quality transport and IT infrastructure. It determines the transport service quality as well as the efficiency and effectiveness of transport operations in the logistics macro-system. Therefore, building the transport infrastructure network of the highest standard, proper for TEN-T corridors, it is important to meet within the logistics macro-system the requirements of the logistics supply chains and networks' operators. Only such infrastructure network will create the highest quality technical base needed to build the SETA regarded as the key component of the future EU logistics area based on the sustainable mobility along with its security, reliability and flexibility.

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CHANGES IN EU LEGISLATION AND NEW OPERATIONAL REQUIREMENTS ON INFRASTRUCTURE MANAGERS IN THE CZECH REPUBLIC IN RELATION TO PUBLIC SIDINGS

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Abstract: This paper deals with railway legislation with respect to railway transport in the Czech Republic and EU. It describes certain changes in legislation and their impact on infrastructure managers. It mainly focuses on the tasks infrastructure managers have to take on in relation to a new railway category – public sidings. The authors also deal with recent experience with the process of allocating rail capacity on public sidings.

Keywords: infrastructure manager, legislation, public siding, railway undertaking, railway transport.

1. Introduction

The Czech Republic is bound by the EU legislation (regulations, directives, and decisions). The requirements of these legal regulations are reflected e.g. in the Act on Rail Systems (Directive No 266/1994 Coll.), the regulations to implement the law and subsequently in the regulations of railway operators as well. This paper presents selected requirements on railway undertakings, their implementation and the role of the Faculty of Transport Engineering of the University of Pardubice (hereinafter referred to as "FTE") in this process.

2. New Legislation – New Requirements

One of the recent changes imposed by the EU legislation – Directive 2012/34/EU of the European Parliament and of the Council establishing a single European railway area – was the introduction of a new railway category: public siding (hereinafter referred to as "PS"). These are sidings on which freight transport can be operated by more than one railway undertaking and the main purpose of which is the connection of a service facility to national and regional rail systems. Rails on premises used in mining, processing and energy industries are not considered as PSs.
Another change having an impact on the railway market was the definition of a service facility (hereinafter referred to as "SF"). Service facilities include storage sidings, refuelling facilities, vehicle washes, faeces suction systems for toilets of passenger trains and water refilling systems or train repair and maintenance halls. They can also include other technical facilities providing services directly related to the operation of railway transport on national and regional rail systems or public sidings (Gašparík *et al*., 2017).
Both changes imposed new requirements on railway undertakings for both passenger and freight service, but also on infrastructure managers (rail system operators). From 01 May 2018, PSs must be available to any potential users (passenger and freight railway undertakings, firms providing maintenance and building railway infrastructure, etc.) where possible considering the capacity, technical or operational conditions of the PS. The Czech railway undertaking *České dráhy a.s.* (Czech Railways, hereinafter referred to as "CR"), the owner of the most sidings with refuelling facilities, washes, repair halls and other SFs, had to do the following in reaction to the change:

1. Specify a group of public sidings within its sidings,
2. Establish and publish non-discriminatory rules for the use of PSs,
3. Ensure the allocation of capacity to applicants for the use of SFs at the specified sidings, in a non-discriminatory fashion.

In light of the requirements of the Directive (Directive 2012/34/EU), Access Office to Transport Infrastructure was established in the Czech Republic. Among other things, the Office ensures and oversees the non-discriminatory nature of the conditions for access to the railway market.
Following the requirements of the Directive (Directive 2012/34/EU), CR entrusted FTE as an independent body to implement the above mentioned points 2 and 3. A capacity allocator department was established at the FTE and a team of experts was appointed from the Department of Transport Technology and Control and Department of Transport Management, Marketing and Logistics, who first drew up a Network Statement. It is a fundamental document defining the rules for the allocation of capacity to all applicants for the use of PSs and the SFs thereon (Gašparík *et al*., 2014). Among other things, the document contains technical specifications of the rail systems, the process and ways of submitting a request for capacity allocation, the price of capacity allocation, and penalties for actions which disrupt the operation of the sidings (delays caused, etc.).

3. Capacity Allocation Information System

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To implement point 3, i.e. the non-discriminatory allocation of capacity on PSs, a software tool was developed at the capacity allocator department – the capacity allocation information system (IS PROK). Its purpose is to register record and process online requests for capacity (Abramovič *et al.*, 2017). Fig. 1 shows the capacity allocation diagram using this IS. After logging in using their login name and password, the applicants specify, among other things, the requested infrastructure capacity, type of railway transport (passenger service, freight service, etc.), time interval they want to use the siding in, tractor unit series and train (unit) length, and mainly what services they want to use (wash, refuelling facility, repair/maintenance, etc.). After that, they save the request and send it to the allocator (to the Department of Transport Technology and Control of the FTE). Subsequently it is assessed whether formal requirements of the request have been met (mandatory fields, etc.). Where possible considering the capacity of the siding within the time interval required, the request is approved and the capacity is allocated (Hansen *et al*., 2008).

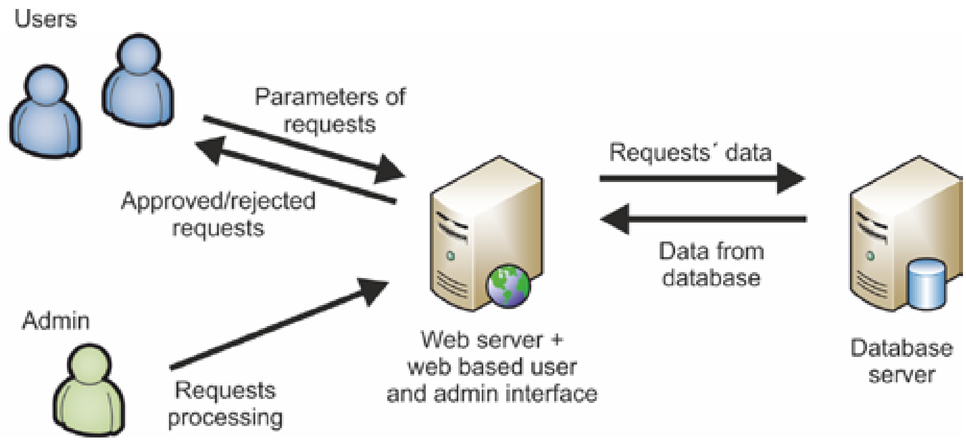

Fig. 1.
IS PROK diagram
Source: Authors

Where there are two or more requests to use the same SF within one time interval, the allocator decides about the priority of the individual requests and gives priority to individual applicants. The Network Statement sets out the priorities of individual trains as follows:

a) Regular public railway transport trains providing transport services on national level,
b) Regular public railway transport trains providing transport services on regional level,
c) Combined transport trains,
d) Trains of railway undertakings with a framework agreement,
e) Regular international passenger service trains,
f) Regular international freight service trains,
g) Regular national passenger service trains,
h) Regular national freight service trains,
i) Other trains.

Possible positions of SFs (e.g. refuelling facilities or washes) are shown in Fig. 2. The specific position of the SF in relation to other facilities and buildings on the siding and the number of service lines (service facilities) has an impact on the possibilities of practical use of the SF by several railway undertakings (applicants). Of key importance is for instance the number of fuel dispensers of the refuelling facility and the possibility of their parallel use by two entities (railway undertakings). Significant is also the railway lay-out (number and length of tracks) at the PS entrance, at the facility and at the PS exit (Directive No 104/2014).

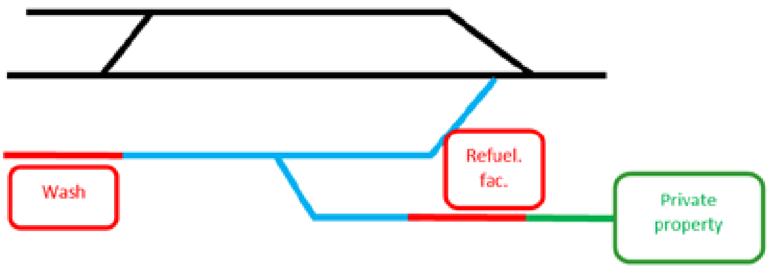

Fig. 2.
Example of siding arrangement
Source: Authors

Problematic can be another private property on the siding premises where this property can only be accessed using the track at the SF. Maintaining access to this property can have a negative impact on the SF's capacity. Another limiting factor for the parallel use of several SFs on one siding is the technological time standards for the use of the individual SFs in combination with the train unit parameters, mainly its length (Dollevoet *et al*., 2008).
Fig. 3 shows the original and current conditions. A railway undertaking wanting to use a siding had to sign an agreement with the siding operator (owner). In addition to that, it currently has to request service facility capacity, to which purpose an independent body has been established – the allocator allocating capacity to applicants (Široký *et al*., 2014).

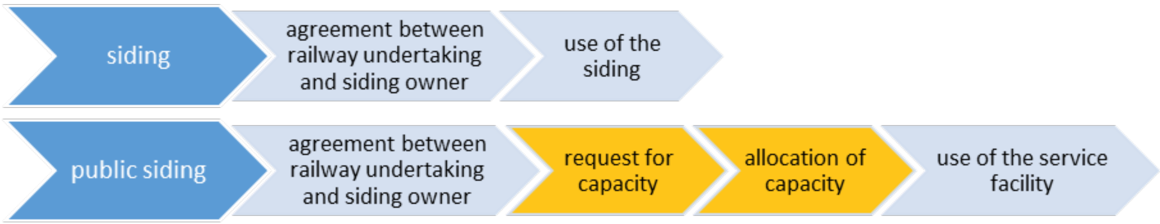

Fig. 3.
Use of sidings and public sidings
Source: Authors

4. Process of Rail Capacity Allocation

Only an authorised applicant can submit a request for rail capacity allocation to the allocator, the authorised applicant being a person with a valid licence for the particular rail or, in accordance with the Act on Rail Systems, a person who doesn't hold a valid licence, but presents the allocator before the rail capacity allocation with a written statement of the licence holder stipulating that they would actually use the capacity allocated (Stojadinovic *et al*., 2016).
The request for rail capacity allocation is to clearly define the required capacity and services, including information on the time of its use. The request is to be supported by a valid licence to operate railway transport, authorising the applicant to operate the required type of railway transport in the time period for which the rail capacity allocation is requested, or the applicant is to prove the submission of a statement in accordance with Article 4(1), point (b) of the Statement, where allowed by the applicable Act on Rail Systems.
Requests for rail capacity allocation, for introduction of a train of the railway undertaking, for shunting a vehicle or processing a working timetable of a train are submitted by the applicant electronically using the allocator's information system. When requesting ad hoc capacity allocation in accordance with Article 7, points (b)-(d), it is recommended to contact the respective service facility before submitting the request and verify its free capacity.
In allocating capacity, the allocator proceeds in a way so as not to give preferential treatment to an applicant.
Where the rails to which the statement applies meet with another rail, the capacity allocator is the capacity allocator on such another rail (Cempírek *et al*., 2017).
Capacity is allocated using four key processes. At the same time, the allocator allows for submitting a request in a format defined by the allocator. A detailed description of this option is provided for on the allocator's website (pridelce.upce.cz):

a) Long-term allocation, which is taken into account in creating the annual working timetable and implementing the planned changes thereof. Regular requests and late requests for capacity fall within this category as well. Requests to be taken into account when creating the annual working timetable are to be submitted by 15 August 2018. Late requests to be taken into account when creating the annual working timetable are to be submitted by 31 October 2018. Changes of the working timetable are then carried out in accordance with the National and Regional Rail Statement applicable to the preparation of working timetable for the respective period issued by the *Správa železniční dopravní cesty* (Railway Infrastructure Administration; hereinafter referred to as the "Railway Infrastructure Administration Statement"). The infrastructure manager provides the railway undertaking with working timetable aids, upon request and for consideration. The price for the provision of aids is agreed by the infrastructure manager with the railway undertaking in a railway transport operation agreement. The dates and time periods for the submission of these requests are provided for in §34a of the Act on Rail Systems. The request can be submitted in the allocator's information system at pridelce.upce.cz or www.ceskedrahy.cz/pd. The railway undertaking can include in one request for a specific location (part of a national rail or siding) more trains or shunted vehicles,
b) Ad hoc allocation using the free capacity left after the creation of the annual working timetable and implementation of all the planned changes thereof. Ad hoc requests are submitted no later than 5 calendar days before the requested date of rail capacity allocation electronically in the allocator's information system at pridelce.upce.cz. Where the request is submitted late, its processing cannot be guaranteed. In this case, the applicant can use a process in accordance with points (c) or (d). The maximum period of validity of all types of ad hoc requests is only until the next change of the annual working timetable

c) Urgent ad hoc allocation – where the applicant intends to submit the request later than 5 calendar days, but no later than 24 hours before the requested date of the rail use, it is possible to select the urgent ad hoc allocation option in the allocator's information system at pridelce.upce.cz. Before submitting an urgent ad hoc request, it is recommended to verify the free capacity of the respective service facility (service volume, time interval),
d) In case of an unpredictable event, which the applicant couldn't have foreseen even within the period stated in point (c) and which happened through no fault of their own, it is possible to submit a super-urgent ad hoc request in the allocator's information system. Also in this case the allocator recommends finding out whether the respective service facility has free capacity (service volume, time interval) before submitting the request. Such request is usually processed within 60 minutes. Such request can only be approved where it doesn't affect rail capacity already allocated and the requested time of use of the rail doesn't exceed 120 minutes. This request is subject to a charge in accordance with point (c).

Rail capacity, i.e. its usable capacity within a schedule of required routes of trains / shunted vehicles on a specific rail section in a specific time period, is expressed as a number of trains / shunted vehicles that can be moved on a national rail or to/from sidings in a specific time period given the existing technical, operational and personal capacities and maintaining the necessary transport quality. Should it not be possible to satisfy all requests for capacity allocation to be taken into account in the annual working timetable, the allocator can offer to the applicant free capacity in a different location or different time period (Šrámek *et al*., 2016).
The allocated rail capacity can only be used by the applicant the capacity has been allocated to and who holds the respective licence, or by a licence holder having made a statement in accordance with Article 4(1). Where the licence holder cannot use the allocated rail capacity, or intends to limit the scope or frequency of train journeys on specific days or in a specific time period, they can waive the allocated capacity at the allocator no later than 30 days before the date of the planned train journey or of using the public siding. Where the applicant waives the allocated capacity later than 30 days before the date of the planned train journey outside of the date of the regular working timetable change specified in the Railway Infrastructure Administration Statement, or the allocated rail capacity expires due to a delay in the use of the rail by a train or shunted vehicle longer than 1,200 minutes through fault of the applicant, or where they fail to use the allocated rail capacity, they are obliged to pay a penalty to the infrastructure manager in accordance with the provisions on penalty payments. Capacity freed in such a way can be allocated to another applicant.
In the event of extraordinary situations in railway transport (e.g. delays, track closures, train redirection due to impassable rail sections, introduction of abnormal trains, etc.), the rail system operator allows for the use of the rail according to the order established for railway dispatch control in the Decree No. 173/1995 Coll. issuing the railway transportation rules, as amended, and proceeds according to §23b (5) of the Act on Rail Systems.
During the long-term capacity allocation, it is possible to make changes to the requests in the allocator's information system. Upon making a change, the original number of the request remains the same, but the date of submission is changed. Where this change is made after the end of the time period for submitting regular requests taken into account in the annual working timetable, but before the end of the time period for submitting late requests taken into account in the annual working timetable, also the type of request is changed from regular to late (UIC CODE 406).
The applicant can use the allocated capacity of a rail or public siding within a time interval starting no earlier than 3 hours before the time of arrival stated in the request and ending no later than 21 hours after the time of departure stated in the request for capacity.

5. Conclusion

New EU legal regulations impose new requirements on railway undertakings, infrastructure managers, but also on the Ministry of Transport and other railway transport administrative bodies (Rail Authority, Access Office to Transport Infrastructure). Defining the category of public sidings and service facilities created a need to establish an independent body allocating capacity on PSs and coordinating the use of SFs owned by the Czech Railways. This body is the Faculty of Transport Engineering of the University of Pardubice where the academic staff can thus put their expert knowledge into practice.

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FROM SUSTAINABLE URBAN MOBILITY PLANS TO SUSTAINABLE ISLAND MOBILITY PLANS – SUSTAINABLE MOBILITY POLICIES IN ISLAND CITIES

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Abstract: Transport planning of island cities has set, until recently, as a priority, the service of travelling by private vehicle, so their development was based on this logic. However, the consequences of the dependence on the car use are now evident at all levels: urban, transport, environmental, economic and social. The era of car dominance in island regions must come to a closure. After recognizing the problems that modern island cities have to face, due to the inability of existing infrastructures and networks to respond to the dynamics for more sustainable mobility, new models of transport and urban planning need to be adopted. Sustainable mobility is one of the most contemporary directions of the EU, in terms of organizing the transport system and addressing the main problems of island cities. Sustainable mobility practically describes a transport system that meets transport needs and, at the same time, defends environmental integrity, social equity and economic efficiency. The "Sustainable Island Mobility Plans" (SIMPs) which provide a comprehensive strategy to meet mobility needs through the principles of "integrated planning, participatory effort and evaluation", tend to this direction. The SIMP differs completely from a conventional traffic approach, as it focuses on the human factor (residents and visitors), as well as the change in attitude towards mobility, promoting alternative and friendly means of transport. This paper will present island cities policies that will provide measures and strategies for the enhancement of sustainable island mobility, namely traffic and road network management, equal mobility of vulnerable users, improvement of network service, transport infrastructure, and spatial and urban planning. Future planning should aim to reduce the negative impact of transport on the environment, as well as create efficient and affordable transport in island regions.

Keywords: island cities, small islands, sustainable mobility, transport planning, case studies, Greece.

1. Introduction

As part of the long search for the appropriate urban form (Barbopoulos, Milakis and Vlastos, 2005), two conflicting urban planning models have been proposed (Bakogiannis, et.al., 2017): (a) the model of the "diffused" city, which is based on the policy of expansion and development of uniform urban arrangements with undefined boundaries that extend in the scope of local human activity (Aesopos, 2006), low urbanization and sociability; and (b) the model of the "compact" city, which adopts a design standard for the control of urban sprawl (Rodi, 2012) with compact and flexible allocation of mixed uses, which utilize as a social life center the small surface public space (Klampatsea, 2012).
The current status in Greece regarding the urban organization of space is closer to the first model, since there are many settlements that have been developed illegally. In fact, according to the estimations of the Technical Chamber of Greece (TCG), there are more than one million informal developments in non-planned areas across Greece (Apostolopoulos, et al., 2017; Apostolopoulos, Mittas and Potsiou, 2017). Initially, the majority of informal developments were concentrated around big urban areas. This tendency changed over the years and thus today the phenomenon of diffusion is more prevalent in areas of great environmental value, such as coastal areas, wooded areas and islands (Polyzos and Minetos, 2007).
The intensity of the problem of illegal housing is more intense in the islands, as a result of great pressure from tourism, rambling legislation, absence of control mechanism and lack of planning policies (Syrmalenios and Athimaritis, 2003). Apart from the degradation of the landscape and the environmental characteristics of many islands, the above causes have resulted in the creation of residential areas lacking "character" and specific form. They are hybrid areas with compact settlement cores that have been created historically and circumferential enclaves of houses that are dependent to the settlements' centre. In many cases, the vast majority of the islands tend indeed to resemble a vast urban area that spans across the whole island and is limited exclusively due to the fact that the islands are "body of land cut off from adjacent lands by water" (Verrill, 1922 in Calado, Quintela and Porteiro, 2007). A typical example is the case of Salamina, where a great percentage of its area is occupied by houses or anthropogenic activities, as one can see in Image 1. Such situations, in turn, cause transport problems, since the diffusion of houses away from commercial activities creates mono-functional areas, resulting in the increase of the residents' movements for their daily needs. As a matter of fact, in the case of islands, which constitute closed systems (Calado, Quintela and Porteiro, 2007; Gil, Calado and Bentz, 2011), residents and visitors meet their needs in specific areas, leading to further traffic congestion there, the degradation of these areas and the diminution of the quality of life of their residents (Fasoulas, 1999; Psatha, 2012; Garling, 2018). The problems are even more intense during the summer months, when the population of the Greek islands skyrockets. According to Anagnostopoulos, Spyridonidou and Psarra (2017), the population of the Greek islands in summer is up to 15 times bigger compared to the population during winter. Therefore, tourist travel constitutes a major source of environmental problems, like in the case of Norway, as Hoyer (2010) notes, since the tourism model that prevails in the Greek islands is not combined with sustainable mobility.

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The above matters are just some of the factors that set the framework in which urban planners and transport planners are asked to design sustainable island communities, implementing strategies and policies. Therefore, the following question arises: Which policies can be implemented in the planning of the islands of Greece, in order to promote sustainable mobility? For that reason, this paper examines the existing strategies from a theoretical perspective, through the study of official texts. At the same time, the subject is approached in practical terms, through the examination of case studies of Greek islands where there have been implemented projects aiming to the integration of sustainable mobility policies.

2. Islands and Sustainable Mobility

As mentioned in the above section, the increased use of cars in modern societies has led to the degradation of cities. This fact raised concerns already since 1970 at a global scale (Bakogiannis, et al., 2015). In this context, a series of conferences took place in several cities across the world (Beriatos, 2009; Bakogiannis, et.al., 2014), a typical example being the Global Conference on Human Settlements Habitat II, which took place in Constantinople in 1996 and focused on the need of the transformation of modern cities into more compact cores. The purpose was multiple, but the need to reduce transport costs prevailed (Binde, 2003), with the purpose to make cities more economic.

In this context, in March 2011 the European Commission proposed the implementation of Sustainable Urban Mobility Plans (SUMPs) for cities of a certain size through the White Paper on Transport "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" (COM (2011) 144*final). The present agenda of travel planning, known as "Sustainable Urban Mobility," was designed in accordance with the White Paper. We can consider as "Sustainable Urban Mobility" the public or private mode of travel and transport in the city that has public, natural, motor-driven or combined character. Compared to other European countries, the interest in Greece is relatively recent (Bakogiannis, et al., 2015). Nevertheless, many municipalities of the country invest on sustainable urban mobility, implementing SUMPs with a view to exploit the positive effects on a number of sectors, such as the transportations, the environment, the free urban space, the culture, and the economy.

The beneficial effects on islands may differ from those on urban areas, as a result of the special characteristics of the islands. The question that arises in view of these different characteristics is whether a different planning of the projects of sustainable urban mobility is needed for urban areas and for islands.

Table 1
Differences between a SUMP and a SIMP

	SUMP	SIMP
	Methodology	
General Vision	Car-free city	Car-free tourism
Area	Urban-Suburban-Satellites	Whole island-More islands-Urban areas?
Population	**Residents** + Tourists	Residents + **Tourists**
Need for Infrastructure	Heavy with fixed use	Light and flexible
Gates/External Connections	Numerous means of transport	Limited choices: Ferry-boats (mainly) and airplanes (sometimes)
	Focus	
Trips	Home to work	Leisure
Car	Massive use. Need for permanent solutions	Need for flexible solutions (high VS low season)
Public Transport	Need for heavy, massive and stable PT	Need for light, personalized (on demand) and flexible PT
Rail	Existing or possible	Not possible
Maritime Transport	Not very critical. Ports only in coastal cities	Very important and always existing
Walking at non urban areas	Leisure. Not critical	Very important touristic activity. Always existing
Cycling	Mainly in the urban area	Mainly out of the urban area
Energy	Always integrated with the National Energy Network (On-grid)	Not always integrated. Possible off-grid solutions
Participation Engagement	Mainly residents	Residents + Tourists
Innovation	Difficult, slow and costly development of innovative ideas	Lighter, quicker, cheaper development of innovative ideas

Source: Anagnostopoulos, K. and Spyridonidou, A., 2018. D.2. Year-round Sustainable Island Mobility Planning (SIMP). 5th European Conference on Sustainable Urban Mobility Plans. Nicosia, Cyprus, 14-15 May 2018. Available at: http://www.eltis.org/sites/default/files/d2_spyridonidou.pdf (Accessed on June 2018).

According to Spyridonidou and Anagnostopoulos (2018), there are differences between the Sustainable Island Mobility Plans (SIMPs) and the Sustainable Urban Mobility Plans (SUMPs) regarding both the methodology and the aims on which the planning focuses. Indeed, the main methodological differences concern the delineation of the study region

(Komninos, 2017), the existence of limited external connections and the need for light and flexible infrastructure in the islands, compared to the urban areas in the mainland. At the same time, the trend towards population fluctuation, in yearly base, creates different mobility patterns in winter and summer season. This challenge (Anagnostopoulos, 2017) creates a different objective in the case of SIMPs, since planners focus on the development of car-free tourism and not of car-free cities, as is the case in urban areas. A different approach is apparent as to what is defined as target-group in each case: in the islands the focus of interest is more on tourists than on residents, whereas the reverse is true in the case of most cities. Therefore, a way needs to be found for the tourists to participate as actively as possible in the consultation of planning (Spyridonidou and Anagnostopoulos, 2018). This practice is also applicable in the case of planning in SUMPs. In this case, however, the interest focuses mainly on the residents.

In addition to the above differences, there are also issues regarding the possible means that planners can implement in the case of SIMPs. As presented in Table 1, the focus of interest in the case of SIMPs is not on the massive use of cars for commuting purposes, but for periodic leisure transport. The capability for development of heavy infrastructure, such as the railway and the establishment of frequent itineraries with many transport modes, is limited; therefore, light, personalized and flexible personal transport modes are being sought. The spatial planning of most islands as open cities, characterized by a great dependency between the urban and peri-urban space, creates the need for cycling and walking even in the peri-urban space, which is not a top priority in the case of cities.

In that context, it is concluded that the planning principles of SUMPs and SIMPs do not differ in their substance. Their differences concern exclusively the special morphological and socio-economical characteristics of the islands (Bakogiannis, et al., 2016). Both SUMPs and SIMPs use planning as a tool to achieve the goal of a functional, sustainable, economic and human city, ensuring a minimum level of accessibility to key destinations for all citizens. In that way, the transportation system proposed through the integrated urban and transport planning will contribute to the financial, social and environmental sustainability of the island. These elements constitute two important strategic goals of a SIMP. The Table 2 (Komninos, 2017; Anagnostopoulos, 2017) presents the total of the strategic goals in summary.

Table 2
Strategic goals of a SIMP

1.	A transportation system contributing to the financial, social and environmental sustainability of the island
2.	Ensuring a minimum level of accessibility to key destinations and services for all citizens
3.	Improved safety and security across the whole island road network and overall transportation system
4.	The re-allocation of public space and the restriction of traffic access and parking
5.	Promoting car-sharing, car-pooling, bike sharing and other forms of sharing economy
6.	Significant change in the modal split towards sustainable transport modes: - High quality and more accessible public transport - New ways of using the car - Promoting walking and cycling - Improving air and/or sea transportation - Optimizing the design of multi-modal hubs and terminals - Intelligent transport management and information systems (ITS), on demand service provision, ICT use, etc., integrating the existing and new mobility services
7.	Efficient management of the seasonal peak of travel and parking demand and reduction of the subsequent air and noise pollution
8.	Stimulating car-free vacation destinations.
9.	Stimulating projects at the nexus of mobility and energy, such as electromobility, to promote alternative fuels and the smartening of the island electrical grids
10.	Logistics chain optimization

Source: Anagnostopoulos, K., 2017. Sump and Island Particularities. Available at: https://issuu.com/anakosmas/docs/simp_and_island_particularities (Accessed on June 2018).

3. Case Studies: Three Greek Islands

3.1. Which Islands were Selected?

With the purpose of finding out whether and to what extent the above presented points can be easily applied to the Greek islands, three Greek islands were examined: Milos, Nisyros and Poros (Fig. 1). These islands were selected according to the following criteria:

(a) Small size: Small size facilitates the understanding of island characteristics, compared to islands that have broader settlement network and more transport choices. Furthermore, small islands constitute spatial units with more limitations, due to the small size of the closed system and their socio-spatial organization, and therefore their planning constitutes a great challenge for planners.
(b) Different geography: The islands are located in different complexes (the Cyclades, the Dodecanese and the islands of the Saronic Gulf) and in varying distance from Athens. However, the common parameter is the short distance from each complex's capital. Different geography also translates to a different historical and cultural

tradition, different architecture and different morphological characteristics in the organization of the settlements.

(c) Different transport infrastructure: In this way we can examine islands with different transports. Milos has an airport, while the other two islands have only ports. Even their maritime links are different: Poros and Milos have frequent links to Piraeus, whereas Nisyros has better communication with Kos.

(d) Difference in population and population fluctuations: We aimed to examine islands with settlements of varying size.

It should be noted that for all these three islands, transport studies have been implemented. These studies, despite not being SIMPs, have already posed the question of integrating bicycle and more sustainable transport methods. Worth noting is the fact that, contrarily to the usual practice of selecting areas with different characteristics (Kyriakidis, 2016; Bakogiannis *et al.,* 2015), in this study islands with differences were selected., since the aim of their examination is not to find good practices, in order to implement them in a similar region, but to explore some points that, being common to most of the islands, can be taken into consideration during the implementation of SIMPs.

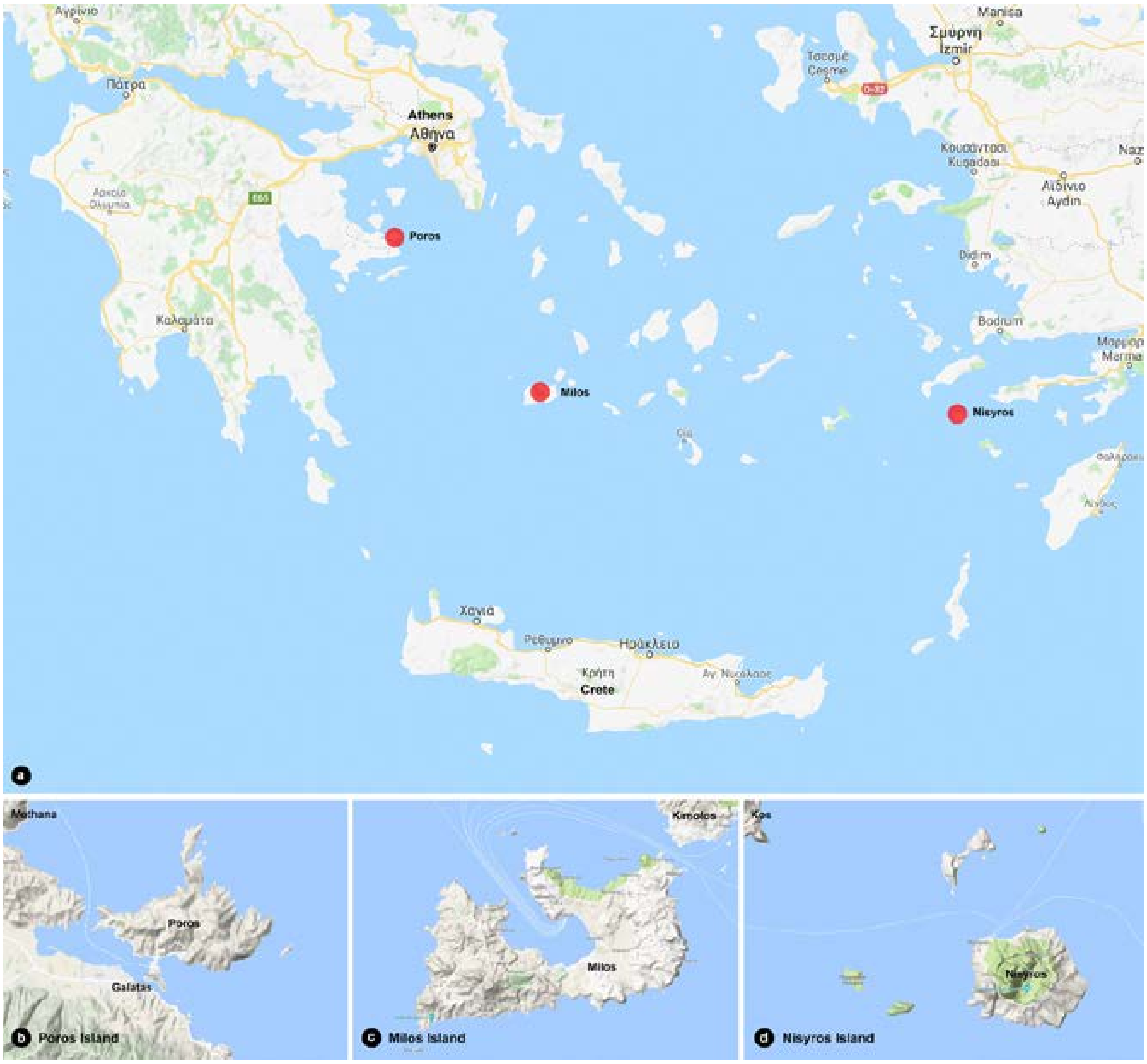

Fig. 1.
Location of the islands studied
Source: Google Maps – Own Elaboration

3.2. Discussion on the Three Islands

The islands in question were examined with regard to their settlement network. Milos has the most settlements. Poros is populated only in its northern part, where there is the settlement of Poros and in small distance also the Kiani Akti. The small settlement network is probably the reason why previous studies focus spatially on the scale of central settlements

(Poros, Mandraki, Adamas and Pala). The present planning approach has resulted in ignoring problems in other parts of the islands. These problems were indeed evident during the summer months, when the increased traffic volumes were located on the roads leading to the beaches. It is nevertheless worth noting that in the case of Poros the related study (Vlastos and Bakogiannis, 2005) mentioned the adjacency and the existing dependencies between Poros and Galatas in the Peloponnese (Fig. 1b; 2c). This point is important, since it proves that in the case of implementing SIMPs in the Greek islands, the dependencies with bordering islands or settlements should be taken into serious consideration due to their direct adjacency. Typical examples are Spetses and Porto Heli; Milos and Kimolos (Fig. 1c); Elafonisos and Neapolis; Paros and Antiparos; Naxos and Koufonisia; Santorini and Thirasia; Kalymnos and Leros, Kos and Nisyros (Fig. 1d), etc.

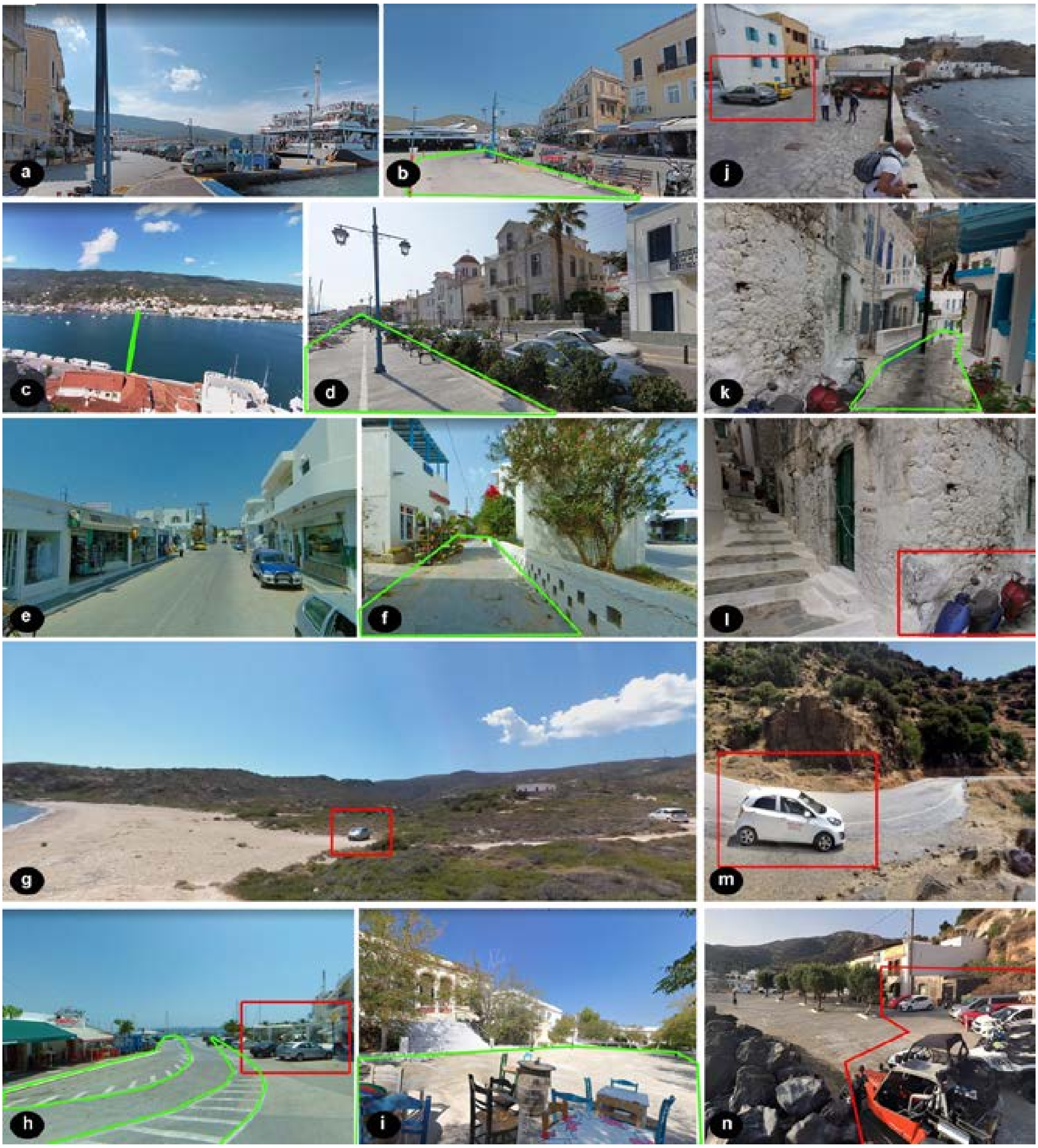

Fig. 2.
a-d: Poros Island; e-i: Milos Island; j-n: Nisyros Island
Source: Google Street View – Own Elaboration

In all these three islands the importance of urban waterfronts was identified. Unlike the case of Nisiros, where the coastal front is pedestrianized and not occupied by the port, since the port is located at a distance of 330 m. from Mandraki (Vassi, 2016), in Poros and Adamas the port occupies part of the coastal zone, and the space required for the movement and parking of cars has reduced the space utilized by pedestrians (Fig. 1a;b; h). In fact, in the case of Poros, where the coastal road is practically the only open public space of the settlement, the limitation of on-street parking is necessary, in order that the pedestrians do not crowd in the narrow sidewalks (Vlastos and Bakogiannis, 2005).

The issue of roadside parking is, however, also evident in the interior of the settlements. Typical example is Mandraki in Nisyros, where, despite the fact that the structure of the settlement (Fig. 3a-c) is such that does not allow the access of cars to many of its areas, the presence of two-wheelers (Fig. 2l) is nonetheless evident in bigger roads. Especially in the platforms, which constitute the core of the settlement's social life, we observe the phenomenon of both car and two-wheeler parking (Vassi, 2016). This situation results in the reduction of the sociality of open spaces (Fig. 3b) and their satisfactory functioning. The need of combining renewal policies and parking policies is therefore evident. It is worth noting that in the context of the demarcation of parking, the issue of demarcating the parking spaces of buses and taxis in the areas close to the terminals should be also discussed (Bakogiannis, 2004).

The narrowness of the roads (Fig. 2 k; j) is characteristic of the other two islands, too. It is indicative that both in Milos and in Poros the average width of rural roads is about 6 m. Widening is not always possible, because of the roadside construction, which in many cases is unauthorized. In fact, in many places there is no sidewalk at all, and the lighting is deficient. Consequently, the development of a network of cycle routes (Fig. 3c) cannot take place without turning some road sections into one-way streets, in order to provide more space for cyclist and pedestrian movement. (Bakogiannis, 2004; Vlastos and Bakogiannis, 2005). Such interventions, however, should take place only after a study that would take into consideration both its movement needs and its geomorphology, examining whether and to what extent the area or the route is suitable for cyclists. It should be noted, however, that in the case of implementation of a bicycle route network, it is necessary to encourage visitors and residents to use it, through bicycle-sharing or bicycle renting systems. The use of electric bicycles (Fig. 3) is a further way to encourage visitors and residents to turn this transport mode and avoid the use of cars.

The issue of connecting the settlements with the islands is indeed an important planning parameter. Satisfactory connections are needed in the case of Milos, where bus routes are significantly increased during the summer months compared to the winter ones (MilosBuses, 2016). Nevertheless, there are accessibility issues in some settlements and destinations of interest. A typical example is the case of the airport's connection with the settlements of the islands, where the routes do not satisfactorily serve the morning flights (MilosBuses, 2016). For that reason, taxis are also used to meet the transport needs of residents and visitors. Frequently, however, the cost makes this mode of transport an uneconomical choice for most visitors. Solutions such as car-sharing and car-pooling can provide an alternative way of using car.

Finally, a point that should be taken into account in the process of planning the islands is the protection and enhancement of the natural environment. It is no rarely that the latter is sidelined in order to exploit every available land for construction purposes, while in other cases regions that should be protected are used for parking purposes. In the case of Milos, characteristic is the presence of a stream that needs to be regulated and then designed for the enhancement of its image and its environmental value.

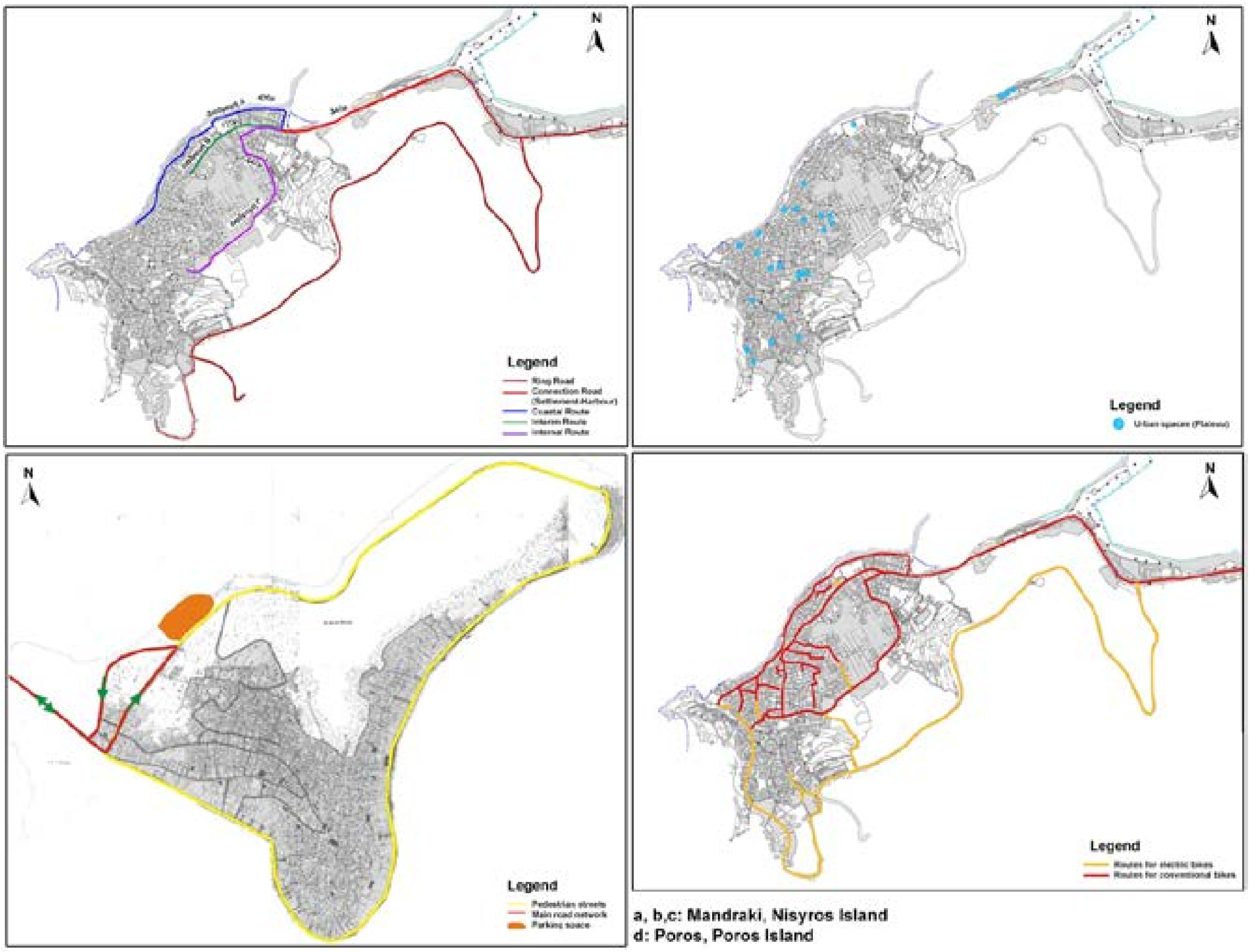

Fig. 3. *Main proposals for Mandraki (a-c) and Poros (d) presented on maps*
Source: Vassi, 2016 ; Vlastos and Bakogiannis, 2005.

4. Conclusions

The planning for sustainable urban mobility is an increasing trend in cities of European Union countries. This trend is now also extended to the islands, most of which receive a great number of tourists during the summer months. In this category are included also the Greek islands, where a model of mass tourism constitutes the core of their economic base.

The present directions for SIMPs concern the selection of the vision for planning, the delineation of the study region and target-groups, and the promotion of sustainable modes of transport through combined transport, walking and cycling.

With the above strategies for the implementation of SIMPs in mind, three small Greek islands were examined. The aim of the examination of the case studies was to assess the implementation of the above strategies in the planning of the Greek islands. The conclusions drawn can be summarized as follows:

- Islands are closed systems and, therefore, constitute a settlement network that should be studied as a whole. The scale of the island constitutes the basis for the delineation of the study region. However, in the cases that strong dependencies to other islands or mainland regions are found, these dependencies should be taken into consideration and the region of study should be delineated in a different way. As in the case of SUMPs, the delineation of the study region should be based on the frequent transports of the residents and visitors of the region to be planned.
- The planning, depending on the scale of the study region and on population changes, should focus on different target-groups. In the case of islands emphasis is usually placed on the transportations of tourists, which are substantially more, and for that reason the planning seems to be more about a car-free tourism than a car-free city or settlement network. Thus, what tends to be most important is the issue of assessing the accessibility of tourist destinations in various ways.
- The lack of heavy infrastructure raises the need of enhancing flexible solutions. New ways of using the car (car-sharing, car-pooling) and the bicycle (bike-sharing) can contribute to the development of a more alternative model of tourism, leading even to a change in the tourist profile and to the expansion of the tourist season. Electromobility is another option that can be promoted, given the small distances and the existing potential for alternative energy sources (wind, wave and solar power), which can be easily exploited.

- For the safety of drivers, cyclists and pedestrians, the existing provisions should be taken into account. Since in many cases their implementation is not possible, due to limited space, making one way roads may be the solution for providing space for pedestrian and cyclist movement. Such interventions should be in line with the parking policy, especially in sections within settlements, urban waterfronts and transport hubs, such as ports and bus terminals.
- Smart applications can contribute to ensuring a minimum level of accessibility to key destinations, reducing the impact from the islands' weaknesses (poor quality road infrastructure, unsatisfactory transport services, distant settlements, the ageing of resident population). At the same time, the strengths of the islands, such as short distances within settlements, pedestrian streets and paths, as well as natural and cultural assets can be exploited for promoting cycling and walking, or even participatory planning practice, through a model that approximates direct democracy.

The above points are just some of the planning pillars of a SIMP. While there are methodological and objective-related differences between SIMPs and SUMPs, nevertheless, many elements remain the same. At any rate, the implementation of the first SIMPs will constitute a safe way of assessing the practices, and will raise further issues for discussion regarding the identification of the best planning approaches.

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TURKEY RAILWAY TRANSPORT HISTORY AND POLICIES

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Abstract: The railways constructed and operated during the Ottoman Empire period were realized with the external capital that foreign entrepreneurs execute. Humanitarian Anatolia was introduced in 1856, 33 years after the first use of steam locomotives in the world. The total length of the railway network transferred to the Republic of Turkey, founded in 1923, it is 4,136 kilometers from the Ottoman Empire. During the period of 1923-1950, when railway transportation was considered as a state policy, a total of 3,764 kilometers of railways were built, average of 139 kilometers per year. Railways in this period were considered as a modernization project with all social aspects surrounding development and reconstruction. Due to seasonal problems, the railway was abandoned from 1950 to 2000. In these years when a recession period experienced, railways were completely neglected and only 945 kilometers of railways were built. Important investment projects to be put into practice after 2000 were planned and investment projects on railways were determined. Between 2004 and 2016, a total of 1,805 kilometers of railways were built an average of 138 kilometers per year. Currently, 4,053 km of railway is under construction. The studies that the country have carried out by focusing on the 2023 goals are now giving positive results. Efforts to increase the length of the railway network are under construction. Integration of the railway network with other transport systems must be ensured. It is aimed to reach the desired levels in railway freight and passenger transportation. Therefore, the study has presented suggestions about the improvement and development of Turkish railways and country policies.

Keywords: railway policy, transportation, Turkey.

1. Introduction

The transport activities are one of the parameters that show the degree of socio-economic development of a country. An advanced transportation system greatly affects all economic activities from production to consumption (Çolak, 2013). The railways, which have an important place among transportation activities, are one of the most important items of civilization history. The humanity has met thanks to the railway with phenomenon called modernization (Atilla, 2002). The first railway in the Ottoman Empire was built in 1856. Most of the railways built after this period were made with the support of foreign state and companies. The length of the railways, taken over from the Ottoman Empire and remained within the national borders, is 4,136 kilometers. After the declaration of the Republic, the new railway construction activities which started in 1924 were the result, and in the period of 1923-1950 approximately 3,764 km new railways were opened. Since 1950, there has been no balanced growth in other modes of transportation in parallel with the development of highway networks and vehicles, which resulted in a new railway of 945 km in the period 1951-2003. As a result of giving priority to railway investments within the transportation system since 2003, 1,805 km of new railway was built in the period of 2004-2016. As a result of the changes in transportation policies since 1950, highway-based transportation is being carried out both in the passenger and freight transportation in the country. After 1950, it has not been able to carry out balanced transport policies. Therefore, the share of passenger transportation of railway among other transport types decrease from 42.2% in 1950 to 1.1% in 2016.The share of freight transportation decrease from 68.2% in 1950 to 3.9% in 2016. Today, the point reached is; all transport subsystems are considered to be a part of a whole in order to achieve a sustainable healthy economic structure and minimize the environmental impacts. The importance given to railways in the world is increasing day by day. Turkey, it has accelerated its railway work to arrive aware of this situation after 2000. Many parameters such as railways within the borders of the country, renewal of old lines, new railway lines, projects made, number of passengers carried are examined and presented in this study. As a result, the history of Turkish railways and the policies applied have been explained and suggestions for railways have been offered. The studies on railways have been examined and presented as literature review.

European Union railway policy, the current situation of the railway sector in Turkey, opening up to competition of the railway sector and the application made and the results worldwide explains. The situation of railway transportation becoming competitive with other types of transport has been examined (Kabasakal and Solak, 2009). In this thesis, the transition from highway to railway passenger transport aims to analyze the high-speed train investments in Turkey. This study additionally includes policies that should be applied to encourage passage from highway to railway based on the results of the analysis (Dalkıç, 2014). Privatizing Ministry of Transport, Maritime Affairs and Communications, the state has enabled to undertake a task as 'regulatory and supervisory'. The railway infrastructure for private companies in the European Union has been through the European Union railway package. In this study, the revenues obtained as a result of the privatization are compared. (Demirelli, 2014). In this study, the situation of the railways built during the National Struggle period is mentioned. Railway policies implemented during the Republican period are explained. The features and routes of the railways built by the state and foreigners are given. During the Atatürk period, it was mentioned what the financial resources of the railway construction (Avcı, 2014). The period of development of railway transportation is explained in this research. An evaluation was made by comparing the policies aimed and realized on railway transportation within the transport policies (Sonar, 2015). The reasons for investing in the railway are

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explained. This study has been given to the case of Turkey's railway transportation. The features of completed and ongoing lines are given. High Speed Train lines were compared. In the case of passenger and cargo transportation of railway lines in Turkey it was examined (Yüce and Öztürk, 2015). Yücel and Taşar (2016) examined the developmental stages of the railroads in the late Ottoman period and in the early days of the Republican period. The period from invention of the wheel to the present has been described and analyzed. In this study, information on the history, politics and recent status of the railways of Japan, Russia, USA, Canada, Latin America countries, Germany France, England, Italy Sweden, Switzerland, Netherlands, Central and Eastern Europe countries are given (European Railways Reform-Experiential Learning). In this study, historical developments and current situation of Turkish railways are presented. In the current situation, many issues such as freight transport, passenger transport, environmental pollution and financial situation are mentioned. The announced strategic plan and objectives explain what high-speed railway lines kilometers, number of wagons, logistics center numbers should be in 2019 (TCDD Strategic Plan 2015-2019). Kızıltaş (2016) examined the basic features of high speed railways and mentioned the importance of these trains in the railway sector. In this study, the contribution of high-speed railways to countries is explained locally. In other study, it was explained that Turkish railways were more active in passenger and freight transportation than other types of transportation until 1950, and after 1950, it was given importance to highway transportation. Furthermore, this study offers information about railway policies in Turkey (Kızıltaş, 2016). According to Hüner et al. (2017), it is mentioned that the passengers used rail systems are less exposed to adverse effects such as traffic stress, noise and air pollution. Rail systems are important both for freight transport and passenger transport. The railway is especially important for mass loads such as fuel and food. The comparison after explaining between Europe and Turkey railway policy is made. In this report presented, the historical development of the Turkish railway is mentioned. The investments and characteristics made in fifteen years have been explained. Applied policies and future goals are explained (Reaching and accessing Turkey, 2017). In this study, the importance of transportation, the situation of the railway in the Ottoman and republican period, the present situation, the situation of the railways in the statistics and the railway policies that should be applied are presented. In the report, it was explained how railways were built in the Ottoman period and how many kilometers were transferred to the Republic period (Railway truth in transport, 2018). In the report of the TCDD's 2018 performance program, general information and performance information consist of two parts under the heading title. The current status of the railway included in the 10th development plan and estimated railway line growths in the future years are presented. The described goals, objectives and policies for the future years (2018 Year Performance Program, 2018).
The history and politics of the Turkish railways have been investigated in this study. It is given features of the railway line made in Ottoman Empire and the Republic of Turkey. The changes in railway passenger and freight transport with applied policies have been presented. The railway transportation consumes less energy than other types of transport. For this reason, railway transportation investments should be given importance. The right railway policies that should be applied in this context are presented in this study.

2. Ottoman Empire Period and Policies

Along with the developing and changing transportation vehicles in the world, important steps have been taken in railway transportation in Europe and America. For the Ottoman Empire, railways played a very important role in economic, political and military direction. For the first-time railway transportation in the world has started in England. The entry of the railway into the Ottoman Empire, whose lands were spread over three continents, occurred much earlier than many other major countries. The railways, considered as the cheapest, fastest and most reliable vehicle of transportation, have a significant advantage over other transportation vehicles and sub-structures. The reasons for giving importance to the railways in the Ottoman Empire;

- The fact that agricultural products will be delivered to domestic and foreign markets more easily, quickly and cheaply,
- The government's dominance over remote provinces will increase,
- Facilitating the dispatch of military troops during war periods.

The Ottoman administrators, who were aware of this, supported the development of the railway. During the reign of Sultan Abdülmecit for the first time in the territory of the Ottoman Empire, a railway with a length of 130 kilometers between İzmir and Aydın was built by a British company in 1856. The construction of this line lasted 10 years and completed in 1866 at the time of Sultan Abdulaziz. In the following periods railways were made by British, French and German companies due to hardware and financial difficulties.
Between 1856 and 1923 years, the following lines were built on the Ottoman Empire (Table 1).

Table 1
The lines built during the Ottoman Empire

Line name	Type	Kilometer(Km)
Rumeli Railways	Normal line	2,383
Anadolu-Bağdat Railways	Normal line	2,424
İzmir -Kasaba and extension	Normal line	695
İzmir -Aydın and branches	Normal line	610

Line name	Type	Kilometer(Km)
Sam-Hama and extension	Narrow and normal line	498
Yafa-Kudüs	Normal line	86
Bursa-Mudanya	Narrow line	42
Ankara-Yahşihan	Narrow line	80

Source: http://www.tcdd.gov.tr/content/31

A total of 8,619 km of railway was constructed in the Ottoman Empire lands as seen in the Table 1. 4,136 km of the railway line of 8,619 km in the Ottoman period is within our national boundaries. 2,404 kilometers of these lines were operated by foreign companies and 1,377 kilometers were operated by the state. The lines built before the Republic and operated by foreign companies were bought and nationalized during the Republic period.

3. Republican of Turkish Period and Policies

With the first and second five-year industrial plans, it was aimed to reduce the problems of passenger and freight transportation. It is proposed that these plans should focus on railway transportation investments. In the early years of the Republican period, the importance of commercial materials was great. It has followed a conscious railway policy in order to transport by railways of basic industrial goods such as iron and steel, coal and machinery in the cheapest manner. The passenger and freight transportation in Turkey until 1950 is mainly done by railway and marine transport. After 1950, highway transport has been emphasized due to changes in transportation policies. Between the years 1950-1970 was the golden age of highway construction. The cost of railway infrastructure and business investments, the cheaper road infrastructure, Marshall aids and the automotive industry, which began to develop after 1970, made highway transport superior to other types of transport in freight and passenger transportation. During this period, investments in highway has the biggest share of transport investments. Although the share of highway investments in the general budget has been decreasing since 1980, increases in road freight and passenger transportation have not slowed down. Table 2 shows the passenger and freight transportation ratios of the transport types by years.

Table 2
Freight and passenger transportation ratios of transport types according to years

	Freight Transportation (nettone-km)				Passenger Transportation (passenger-km)			
Years	Highway	Railway	Maritime	Airway	Highway	Railway	Maritime	Airway
1950	25	68.2	6.8	0	50.3	42.2	7.5	0
1960	45	52.9	2	0.1	72.9	24.3	2	0.8
1970	75.4	24.3	0.2	0.1	91.4	7.6	0.3	0.7
1980	88.0	11.8	0.1	0.1	94.7	4.6	0.2	0.5
1990	81.2	9.8	8.9	0.1	96.6	2.5	0.1	0.9
2000	90.1	5.4	6.4	0.1	96	2.2	0	1.8
2010	89.9	5.3	5	0	97.8	1.6	0.7	-
2015	89.8	3.9	6.3	0	89.2	1.1	0.6	9.1
The civil aviation is not included in the data.								

Source: Railway Sector Report, 2016

In 1950, railway freight transportation was 68.2% and passenger transportation was 42.2%. After this year, the road-aided policy implemented has affected these rates in the negative direction. In 1960, railway freight transport was 52.9% and passenger transport was 24.3%. In the same period, highway freight transport increased from 25% to 45%.

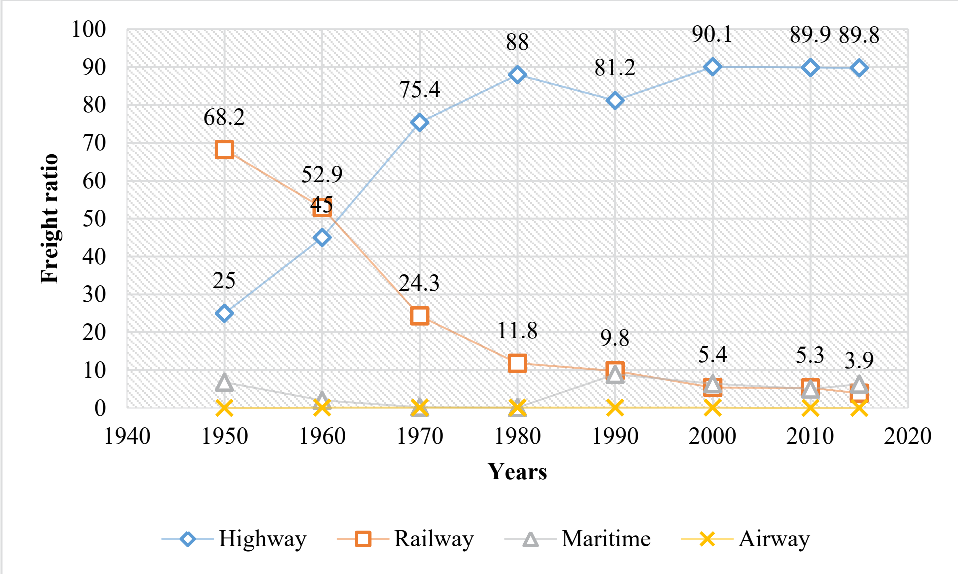

Fig. 1.
Freight transportation according to the type of transport

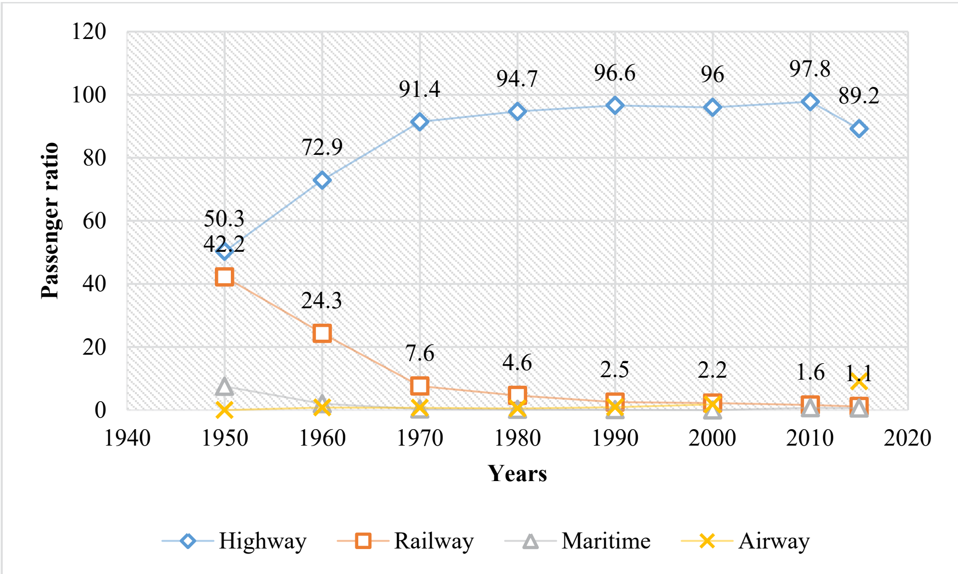

Fig. 2.
Passenger transportation according to the type of transport

Figure 1 and Figure 2 represent how the rates of passenger and freight transportation for the types of transport between 1940 and 2015 have changed. In the first years of the Republican period, the importance of railway transportation was emphasized. The construction of the railways between 1950 and 2000 has entered a period of stagnation. This situation is shown in Figure 1 and Figure 2.

Table 3
The length of railway lines in the Republic of Turkey

Periods	Conventional Line Total (km)	High Speed Train Line Total (km)	Total (km)
Mainline and branch line from the Ottoman Empire	4,559	-	4,559
1923-1931	6,011	-	6,011
1940	8,637	-	8,637
1950	9,204	-	9,204
2001	10,940	-	10,940
2003	10,984	-	10,984
2005	10,984	-	10,984
2007	10,991	-	10,991

Periods	Conventional Line Total (km)	High Speed Train Line Total (km)	Total (km)
2009	11,008	397	11,405
2011	11,112	888	12,000
2012	11,120	888	12,008
2013	11,209	888	12,097
2014	11,272	1,213	12,485
2015	11,319	1,213	12,532
2016	11,319	1,213	12,532
2017	11,319	1,213	12,532

Source: Railway Sector Report 2016

In Table 3, 40% of conventional lines expressing widespread railway network; 37% of Turkey railways were built before the declaration of the Republic. Between 1923 and 1950, a total of 3,193 km of railway was built, with an average of about 139 km per year. After 1950, an average of 52 km of railway was built annually. The total railway line length, which was 9,204 km by 1950, was 12,532 km at the end of 2016, including the high-speed train line. In other words, only 3,328 km of railway was built in 66 years. A total of 1,545 km of railway mainlines were constructed in 2001 and after. According to this, in 2001-2016 period, the mainline construction was 103 km on average of a year.
In Figure 3, the railways within the national borders of the Ottoman Empire and constructed after the Republican of Turkey period were represented with different colors.

Fig. 3.
Turkish railways by period
Source: Reaching and accessing Turkey 2017

The Republic of Turkey has 8,356 km of mainline, 591 km of 2th line and total of these line is 8,947 km. When this length is added to the 2,372 km subsidiary line, the total conventional line length reaches to 11,319 km. The length of the high speed train (HST) line is 1,213 km, and the length of the branch lines is 433 km. The conventional and HST lines have a total length of 12,532 km. 4,350 km of these lines are electricity and 5,462 km are the signal. The electric and signal line rates in total road length were 35% and 44%, respectively (Turkish State Railways Annual Statistics 2012-2016).
The condition of the mainline construction is given in Table 4. When the average railway construction in Table 4 is examined, it is understood that the railway was neglected between 1950 and 2000.

Table 4
Average line lengths built according to periods

Periods	Length of line (Km)	Average annual railway construction (Km)
Ottoman Empire	4,136	53
1923-1950	3,764	139
1951-2003	945	18

Periods	Length of line (Km)	Average annual railway construction (Km)
Conventional mainline length at end 2016	8,950	-
High speed train line length at end 2016	1,181	-
Total mainline length	12,532	-

Source: Reality of Transport Railway 2018

Turkey's facilities and technology between the years 1923-1950 and technology and facilities of today's Turkey is not the same nevertheless, railways have been neglected for nearly fifty years. While an average of 139 km of railway was built between 1923 and 1950, which has limited possibilities as seen in Table 4, an average 18 km railway was built between 1951 and 2003. The reason for this situation is misapplied transportation policies.

In 2003, the railway sector was again recognized as a state policy. The goal is to increase the effectiveness of railway, which are modern faces of developed countries and have been neglected for years in Turkey. In 2003, a radical change was made in transportation policies which lasted for fifty years. The neglected railroads were again considered as state policies and the largest investments were made up to now.

In the last fifteen years:

- HST line length of 1,213 km in Turkey, the number of passengers carried in this line of 34.79 million,
- Electric line length is 4,433 km, signal line length is 5,462 km,
- By the end of September 2017, the total number of passengers transported by railway was 131.8 million,
- The amount of freight carried has reached 1.6 times,
- The Marmaray rail project that transported 217.91 million passengers so far was built,
- The construction of logistics centers, one of the most important pillars of regional development plans, has started and the construction of eight logistics centers has been completed (Reaching and accessing Turkey 2017).

Figure 4 shows location of the eight logistics centers used in the present condition. In addition, it shows the location of logistics centers in the construction phase and other centers that are planned to be built.

Fig. 4.
Logistics centers in Turkey
Source: Railway Sector Report 2016

In a logistics center:

- Container loading and unloading and storage areas,
- Customs territory,
- Customer offices, parking, car park,
- Banks, restaurants, hotels, maintenance and repair facilities, gas stations,
- There are ways to accept and forward trains.

After 2000 years, railway construction has gained momentum and renewal works of existing railways have begun. Within 15 years, 10,236 km of 11,319 km conventional lines were subjected to complete maintenance and renovation. Figure 5 shows the lengths of lines that completed repair and maintenance between 2002 and 2017.

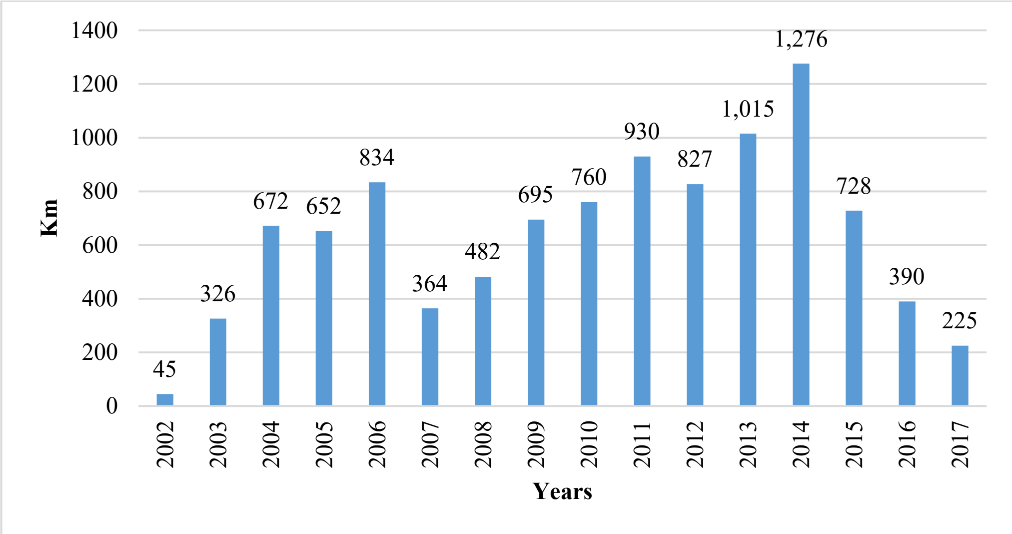

Fig. 5.
Lengths of lines that completed repair and maintenance
Source: Railway Sector Report 2016

With renewed lines; train speeds, line capacity and capability have been increased, making passenger and freight transportation more comfortable, safer and faster. In areas with high freight transport potential, eight logistics center have completed. Thanks to these centers, the organized industrial zones will be connected to the railways. The combined transportation will take place when the railways are connected to the ports. HST lines, which have been important for construction in recent years, have contributed to the development of the country in transportation. The route, line type, length and date of high-speed railway lines constructed after 2000 are shown in Table 5.

Table 5
Length of high speed train lines

Line Section	First Line (Km)	Second Line (Km)	Total Mainline (Km)	Station Track (Km)	Total (Km)
Sincan-Eskişehir	221	221	442	3	445
Eskişehir-Pendik	155	151	306	13	319
Polatlı-Konya	212	213	425	13	438
Triangle	6	5	11	0	11
Total	594	590	1,184	29	1,213

Source: 2016 Annual Report

These lines have relieved the load on the highway between big cities in passenger transportation. The number of passengers carried by HST between 2009 and 2016 is shown in Figure 6. It is very important for intercity passenger transportation of railway projects like high speed train. These projects have many advantages. It is more comfortable and more convenient than the highway. In addition, transportation time is less than the highway.

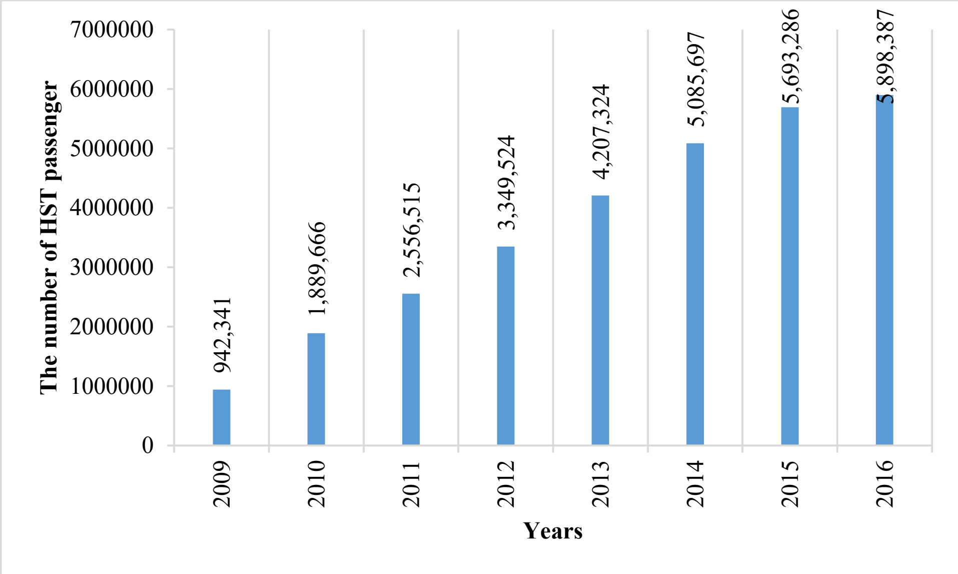

Fig. 6.
Passenger transported by High Speed Train
Source: Railway Sector Report 2016

The important railway construction and renovation projects carried out by the TCDD are to be ordered according to their planned end dates.

Table 6
Projects expected to be completed in 2018-2019 and 2023 years

Important railway construction and renovation projects to be completed in 2018	**Important railway construction and renovation projects to be completed in 2019**
Konya-Karaman Speed Train (ST) line (102 km)	Adana-Mersin 3rd and 4th Line (67 km)
Konya-Karaman ST line (102 km)	Bursa-Bilecik ST line (102 km)
Palu-Genç-Muş railway construction (115 km)	Construction of Bahçe-Nurdağ variant (17 km)
GAZİRAY (27 km) structure construction	
Ankara-Sivas line construction	
Electrification of the 770 km line	
918 km of conventional line signaling is being made.	
Important railway construction and renovation projects to be completed by 2023:	
Kayseri-Yerköy SHT line (142 km)	
Edirne-İstanbul ST line (230 km)	
Gebze-Sabiha Gökçen- Yavuz Sultan Selim Bridge- 3rd Airport- Halkalı line (124 km)	
Sivas-Erzincan-Erzurum-Kars ST line (656 km)	
Karaman-Ulukışla-Yenice-Mersin-Adana-Osmaniye-Gaziantep-Şanlıurfa ST line (661 km)	
Samsun-Çorum-Kırıkkale-Kırşehir-Aksaray-Ulukışla ST line (601 km)	
Sivas-Malatya ST line (125 km)	
Erzincan-Trabzon ST line (192 km)	
Malatya-Elazığ ST line (121 km)	
Nurdağ-Kahramanmaraş ST line (63 km)	
Gaziantep-Şanlıurfa-Mardin ST line (332 km)	
Adıyaman – Gölbaşı – Kahta ST line (100 km)	
Siirt-Kurtalan ST line (25 km)	
Tokat Turhal ST line (42 km)	
Ankara – İstanbul Very High Speed Train Line (Köseköy) (232 km)	
Eskişehir-Kütahya-Isparta/Burdur-Antalya ST line (423 km)	
Kayseri-Nevşehir-Aksaray-Konya Antalya ST line (556 km)	

Source: Railway Sector Report 2016

The railway investments do not only play an important role in the realization of economic development. Thanks to the sectoral adaptation of technology, railway transport, which has increased comfort and speed, has also affected its travel preferences. At present, high speed trains are preferred for travels less than 400-500 km in the world. This rate is 15% in the current situation in Turkey. Over time, this ratio will be increased to 40%. Ankara, Eskişehir, Konya and Istanbul were met with the works carried out in this direction. The speed train networks will be applied to a lot of science in the coming period, including Izmir, Afyon, Usak, Bursa, Yozgat, Sivas, Erzincan and Karaman. The main goal is to increase the effectiveness of railway networks in the most functional way in global integration, international transport, intra-city and inter-city passenger transport, commercial transport, economy, social and cultural life.

HST construction projects were carried out in Turkey. Ankara-Eskişehir-Istanbul, Ankara-Konya and Konya-Eskişehir-Istanbul high-speed railway lines have been completed and opened to service. Turkey is ranks 6th in Europe and 8th in the world in terms of HST lines. In addition to the construction of new railways, the importance of modernization of the existing system has been emphasized and road renewal mobilization has been started. A total of 10,236 km of the existing railway network was maintained and renovated. It should be connected to the ports by railways of production centers, organized industrial areas and the development of combined transport has been prioritized. The law regulating the railway industry was enacted, the legal infrastructure for liberalization in the sector was provided, and the way for the private sector to make railway transportation was opened. In this context, the separation process of as infrastructure and business of railways has been completed.

Between the years 2018-2023:

- In East-West and North-South axis, the goal is to create a double-track railway corridor. For this purpose, 1,213 km of high-speed railway line needs to increase to 12,915 km,
- 11,319 km Conventional railway line should elevate to from 11,319 km to 12,115 km so that a total of 25,030 km railway length is reached in 2023,
- Completion of renewal of all lines by 4,400 km line renewal,
- The share of railway transportation; should raise to 10% on the passenger and to 15% on the freight,
- Ensuring that the transportation activities of the liberalized railway sector are carried out in a fair and sustainable competitive environment.

Between the years 2023-2035:

- Extension of railway network to 31,000 km by 6,000 km extra speed railway,
- The development of intelligent transport infrastructure and systems to ensure integration of the railway network with other transport systems,
- Completion of railway lines and connections in the Straits and Gulf Passes and becoming an important railway corridor between Asia-Europe-Africa continent,
- It is targeted to reach railway freight transport by 20% and passenger transport by 15%.

4. The Recommendations for a Correct Railway Policy

The main factors affecting railway transportation are:

- Inadequacy of infrastructure and low standard,
- Railway infrastructure and superstructure technology cannot be renewed,
- Lack of technical development,
- Inadequacy of technical personnel and inadequate vocational technical training,
- Inadequate allocations to railway projects for many years,
- Due to the long construction times and weather conditions affecting construction quality negatively,
- Low business service quality.

The most suitable policy for railways of Turkey is given in this study. These are:

- Transport plans should be prepared nationwide for all modes of transport,
- Integration of transportation types should be ensured and combined transportation should be provided,
- The usage of logistics centers must be easy and convenient,
- The railway should be a leader in freight and passenger transport and passenger and freight rates should be increased,
- The infrastructure of the old lines should be transformed into speed rail. The kilometers of high-speed train lines should be increased,
- The existing railway lines must be urgently integrated with each other and used more efficiently,
- All major cities, agriculture and trade capitals must be connected to each other by rail,
- It is necessary to reduce the importance and investments given to the highway and to invest in the railway instead of these investments,
- Priority should be given to the railway where energy consumption is lower than in other types of transport and capacity of railways should be increased and used efficiently. Energy consumption shares in transport sector is given in Figure 7.

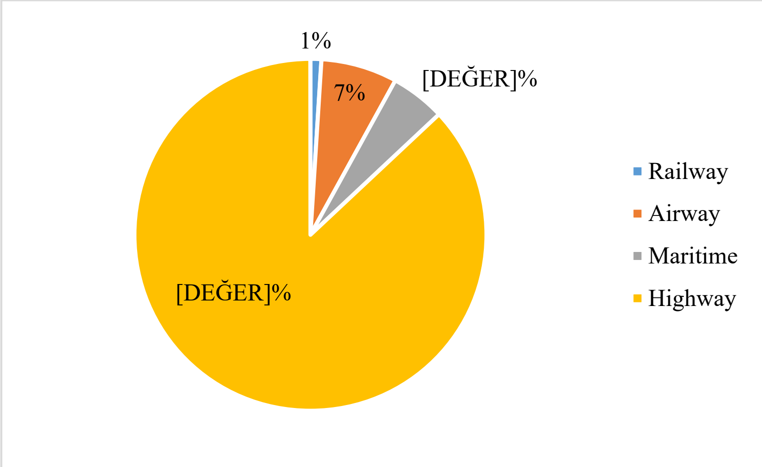

Fig. 7.
Energy consumption shares in transport sector
Source: Environmental Indicators 2016

5. Conclusion

The history and politics of the development of Turkish railways are explained in this study. The railway process that started with the Ottoman Empire continues to develop rapidly its current condition. The 4,136 kilometer railway network remained from the Ottoman Empire to the Republic of Turkey. These lines were mostly made by foreign companies and most of these lines were purchased and nationalized after 1923. From the proclamation of the Republic until 1950, the railway was regarded as the main means of transportation among the transport types. The railway is the most effective way of passengers and freight transportation during these periods. The railway transport has been slowed down with the policies implemented after 1950 and highway transport has been prioritized. After the years of 2000, along with the applied policies have lived the golden age in railway investments. The railway projects made in this period and the projects planned to be made in the future have given in the study. The railway history and applied policies have been presented. In addition, suggestions have been given for the development of railway transport in Turkey.

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WHAT CAN REPUBLIC OF MACEDONIA LEARN FROM SLOVENIAN TRANSPORT PLANNING?

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Abstract: Transport provides many benefits to society and economy, but also creates certain negative effects to human health and environment, so in order to have efficiently working and at the same time as least harmful as possible transport system, governments must set and implement the national transport policy accompanied by many focused strategic documents. Republic of Slovenia and Republic of Macedonia are to some extent similar in terms of the determinants of the national transport policy; e.g. in size, population and position on important European transport corridors. On the other hand, they differ greatly in the state of socio-economic development, the size and condition of existing transport infrastructure and superstructure, the volume and structure of traffic flows, traffic safety records, as well as level of investments into transport infrastructure and related equipment etc. It is impossible to copy national transport policy from one country to another, but it is possible to look for best practice examples on measures taken in different countries in order to provide a good basis for own transport policy. The authors have done the brief overview of Slovenian strategic documents on transport development and the analysis of Slovenian transport system, with the focus on traffic safety and public passenger transport. They isolated positive measures taken in Slovenia in order to create a list of suggestions of measures possibly applicable in the Republic of Macedonia.

Keywords: Transport planning, transport policy, strategic development of transport.

1. Introduction

Transport provides many benefits to society; it gives the individual freedom and independence to travel and facilitates trade (Haq, 1997). In fact, the quality of life depends largely on the degree of development and operation of transport system. Unfortunately, the uncontrolled growth of road transport has started to show first consequences; transport problems have become more severe than ever in both industrialized and developing countries alike (Ortuzar & Willumsen, 2011). The Republic of Slovenia (hereinafter Slovenia) and Republic of Macedonia (hereinafter Macedonia) are not exceptions.

Nowadays transport planning is aiming to achieve sustainable transport system, that is an affordable, safe and environmentally friendly transport systems, that allows the basic access and development needs to individuals, companies and society while it promotes equity within and between successive generations (ECMT, 2004). It is far from easy to achieve this, so good decisions need clear objectives (MCA, 2009), and this is impossible without comprehensive planning. Transportation planning process consists of many steps including (summarized from DOT, 2007):

- assessment of existing transport conditions;
- forecast of future population and employment growth;
- identification of current and projected future transportation problems;
- development of long-range plans and short-range programs as well as operational strategies for moving people and goods;
- estimation of the impact of recommended future improvements to the transportation system on economic, social and environmental features; and
- development of a financial plan for securing sufficient funds to cover the costs of implementing strategies.

The goal of every manmade created system is to achieve the best possible performance indicators. These indicators serve to identify progress over time or to compare with existing comparable systems in other countries. The main purpose of analysing the operation of the transport system is to provide better conditions for users and reduce the negative effects of traffic on the environment. It should be noted that the functioning of the transport system depends on the harmonization of its individual parts, and not only on the operation of the individual segments separately. The efficiency of the transport system operation and its progress can be assessed from various perspectives, and for this reason it is necessary to create many indicators.

The objective of this paper is to link two aspects of Slovenian transport system, namely traffic safety and public passenger transport, to the measures foreseen in the Slovenian transport policy and in the other accompanying strategic documents and to provide the set of suggestion for Macedonian colleagues involved in setting up national transport policy.

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2. The Characteristics of Slovenia and Macedonia

Slovenia and Macedonia, the successors of former Yugoslavia, gained the independency in 1991, but their development since then has been rather different. Slovenia is European Union (EU) member state since 1st of May 2004, member of Eurozone since the beginning of 2007 and member of Schengen zone since the end of 2007, while Macedonia submitted the formal membership request in 2004, got a candidate status by the end of 2005, and is now in the process of negotiations. Among others, this has also affected the way in which transport system is planned and financed.
Slovenia and Macedonia are similar in size, population and they are both positioned on important European transport corridors; Slovenia was firstly crossed by two Pan-European Corridors V and X, and now, with new TEN-T programme it is crossed by Mediterranean and Baltic Adriatic core corridors, while Pan-European corridors VIII and X pass over Macedonia territory. On the other hand, they differ greatly in the state of socio-economic development, the size and condition of existing transport infrastructure and superstructure, the volume and structure of traffic flows, traffic safety records, as well as level of investments into transport infrastructure and related equipment etc. as can be seen from the following table. Yet, we can observe rather unsustainable trend of transport development in both countries; in general, public transport has marginal role and the importance of railway transport is small and decreasing, especially in the segment of passenger transport, while the number of road freight vehicles is increasing in both countries.

Table 1
Some similarities and differences between Slovenia and Macedonia (2017, if not otherwise stated)

	Slovenia	**Macedonia**
Area	20,273 sq km	25,713 sq km
Population	1,972,126	2,103,721
Population 65+	384,684 (19.51 %)	282,140 (13.41 %)
Median age	44.5	37.9
Human development index	0.892 (2015)	0.728 (2011)
GDP (PPP)	71.04 billion $	31.55 billion $
GDP – real growth rate	5 %	2.5 %
GDPc (PPP)	34,100 $	15,200 $
Unemployment rate	6.6 %	23.4 %
Public debt	73.6 % of GDP	47.4 % of GDP
Airports	16 (7 with paved runways)	10 (8 with paved runways)
Roadways	38,985 km	14,182 km
Expressways	769 km	
Railways	1,229 km (503 km electrified)	925 km (313 km electrified)
Motorization rate (passenger cars)	531; 487 (2006)	190; 119 (2006)
Average age of passenger cars	9.9 (2016); 7.6 (2006)	12 (2015)
Buses	2,679; 2,277 (2006)	3,230; 2,200 (2006)
Buses, number of seats	114,000; 98,000 (2006)	n.a.
Number of passenger railway vehicles	347 (2015); 395 (2006)	24 (2015); 67 (2006)
Capacity of passenger railway vehicles (seats)	22,000 (2015); 24,300 (2006)	3,800 (2015); 6,700 (2006)
Passenger cars (mio pkm)	29,632 (2010); 26,932 (2006)	9,344 (2016); 5,492 (2006)
Buses (mio pkm)	3,183 (2010); 3,062 (2006)	2,069 (2016); 1,581 (2006)
Railways (mio pkm)	680 (2016); 793 (2006)	83 (2016); 105 (2006)
Passenger train movements (thousand train kilometers)	11,830; 11,816 (2006)	1,512; 1,604 (2006)
Railways – number of passengers (thousand)	13,650; 15,750 (2006)	663; 1,524 (2009)
Motorization rate of lorries and road tractors	41 (2012)	19 (2015)
Number of lorries	75,096 (2012); 62,964 (2006)	26,524 (2012); 13,545 (2006)
Number of semitrailers	7,370 (2012); 6,260 (2006)	4,588 (2005)
Number of trailers	17,048 (2012); 12,937 (2006)	5,442 (2012); 4,627 (2006)
Goods road tr. enterprises	4,846 (2012): 5,696 (2006)	193 (2006)
Freight train movements (thousand train kilometers)	19,359; 19,524 (2006)	1,962; 2,788 (2006)
Railway tr. – goods (1,000 t)	18,595; 17,052 (2006)	1,358; 2,929 (2009)
Railway tr. – tkm (mio tkm)	4,360; 3,373 (2006)	222; 497 (2009)
Railway tr. – containers/swap bodies (1,000 t)	3,707; 1,704 (2006)	244; 355 (2006)
Number of injury road accidents	6,491 (2016); 11,223 (2006)	3,854 (2015); 3,313 (2006)
Road accidents fatalities per million inhabitants	65 (2016); 131 (2006)	74 (2015); 70 (2006)

Source: Authors, based on (CIA Factbook, 2018), (Eurostat, 2017), (Eurostat, 2018), (Policija, 2018), (OECD, 2018)

3. Selected Positive Achievements of Slovenian Transport Planning

The planning of Slovenian transport system has always been in line with the EU guidelines; almost all important transport issues detected on EU level have been included in Slovenian strategic documents for the development of transport. However, some of these documents, although meant as strategic, are rather superficial (for example Resolution on Slovenian transport policy), while some of them are more comprehensive (for example Resolution on national programme for traffic safety in Slovenia). Further problem is the realisation of foreseen measures; in certain occasions, the realisation has been delayed, postponed or cancelled, mainly due to financial reasons or poor definition of goals and measures in the strategic documents. Nevertheless, in short, Slovenia like EU, wants to achieve better mobility and accessibility, improved service for the economy, improved traffic safety, reduced energy consumption and lower environmental impacts as well as lower transport costs for the users. This is by no means easy and just preparing the documents and taking no or little number of actions is not enough.

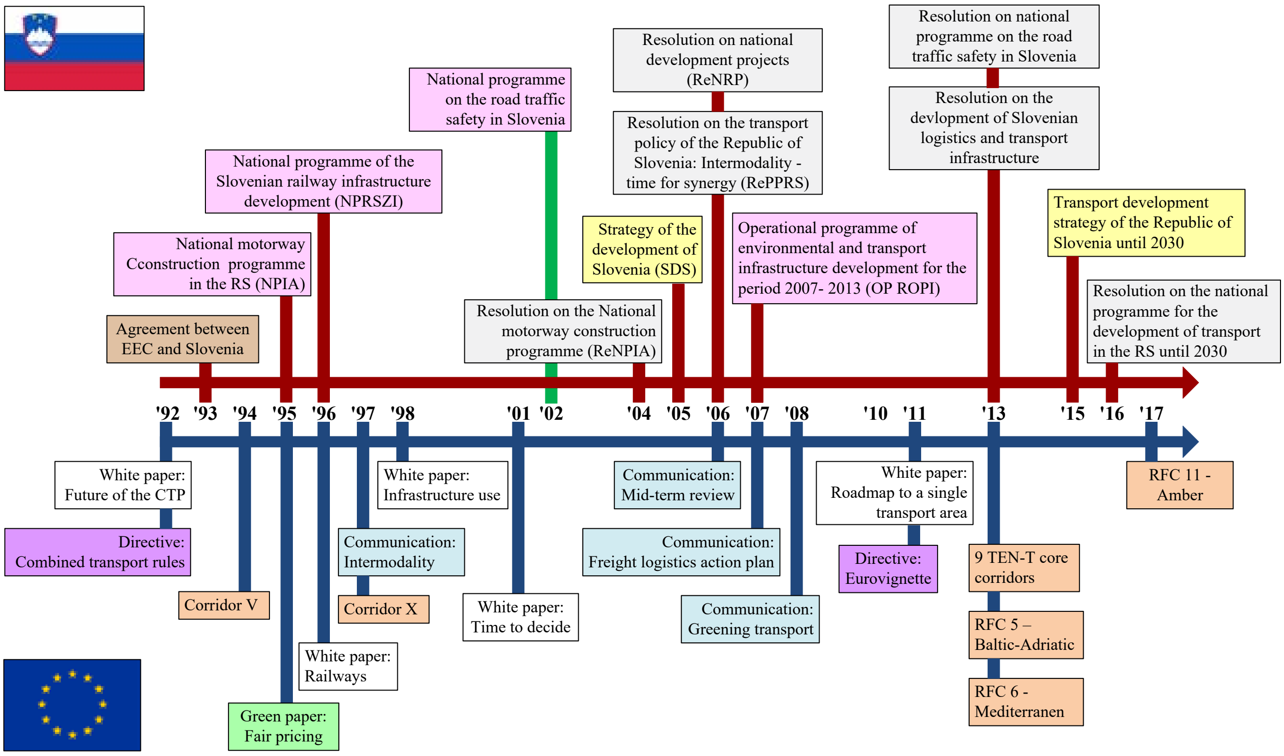

Fig. 1.
Important Slovenian and European transport development documents
Source: Authors

Although Slovenia tackled many issues of transport sustainability since its independence, the achievement in traffic safety is worth a closer look, as it represents a long-lasting and comprehensive approach towards achieving the vision 0, and because traffic safety records in Macedonia are not showing almost any improvement in last decade as can be seen from the following figure.

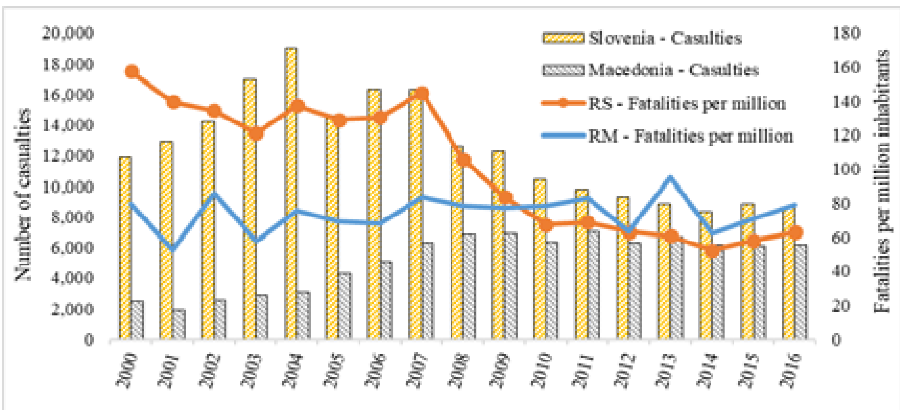

Fig. 2.
Road safety records in Slovenia and Macedonia
Source: Authors, based on (OECD, 2018)

The other important success in Slovenia is the finalization of the project on integral public passenger transport. Although there are many elements yet to be accomplished and the results in terms of increased number of intercity passengers are so far not very visible, this project promises a lot. Again, as can be noted from the statistics, the use of public passenger transport in Macedonia is quickly declining, thus the presentation of Slovenian experience makes sense.

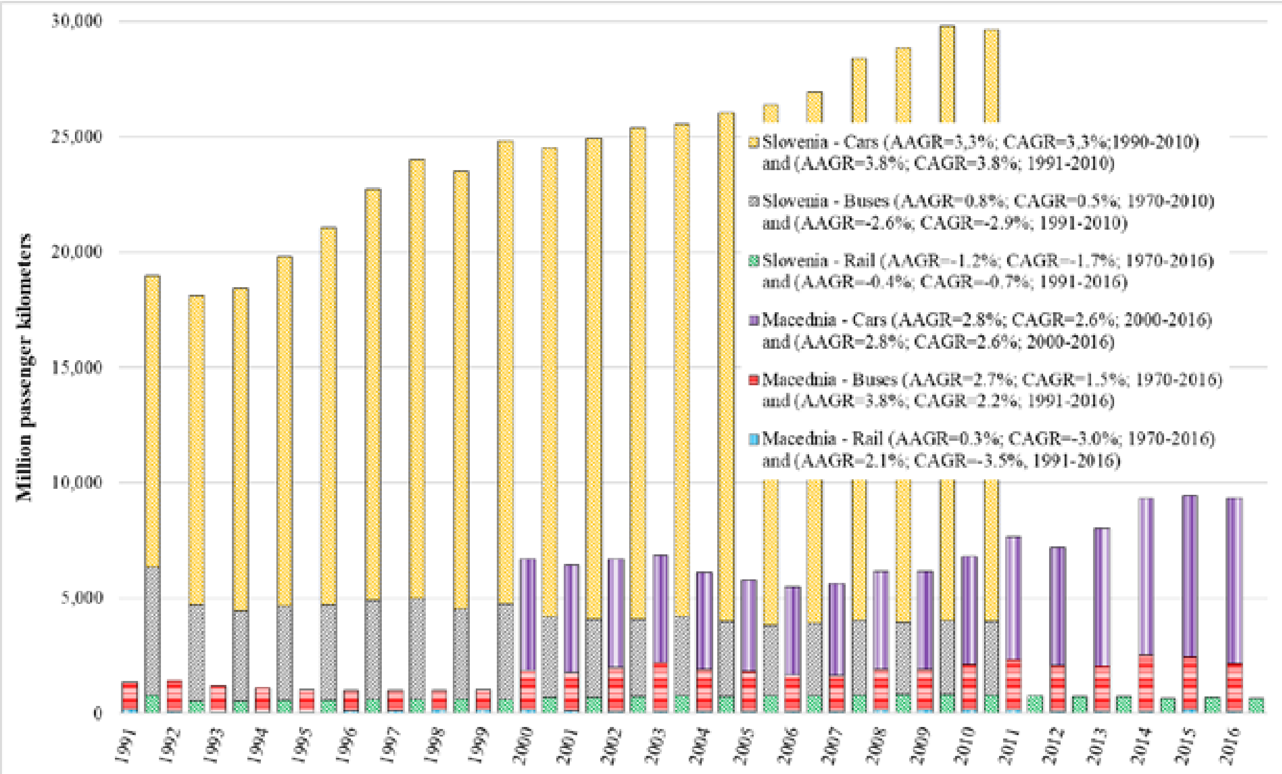

Fig. 3.
Passenger transport in Slovenia and Macedonia since the independence (in million passenger-kilometres)
Source: Authors, based on (OECD, 2018)

3.1. Road Traffic Safety

One of the basic qualities describing the functioning of transport system is traffic safety. Traffic safety is commonly measured in terms of number of accidents and severity of their consequences. Road traffic injuries are currently estimated to be the eighth leading cause of death globally (WHO, 2013). Apart from the human suffering caused by traffic injuries, the socio-economic costs incurred are estimated at around 2% of annual EU GDP (EC, 2013). It is thus clear that countries will (at least try to) resolutely address this problem.
Countries confront the issue of road traffic safety in different ways, usually depending on the transport demand, general development of national transport system and obtainable financial resources. The fact is that the availability of adequate road infrastructure deeply influences traffic safety records and motorways are considered the safest roads (ETSC, 2008). The construction of Slovenian motorways system started in the 1970s. Slovenian government gave the priority to the further construction of motorways network after the independence, as some segments of Slovenian motorway system were already constructed, and considering the broader social and economic importance of motorways in regards to the railways. Slovenian residents have largely approved this decision (Toš, Kos et al., 1995). Nowadays with the Slovenian motorways system being completed in the directions of Pan-European corridors V and X, we can state that besides supporting Slovenian economy and integration into European traffic flows as well as being beneficial for majority of Slovenian citizens by providing comfortable long-distance transport, the construction of motorways greatly impacted the traffic safety, especially after the introduction of vignette tolling system for vehicles with maximum authorised mass not exceeding 3 500 kilograms. Although initially considered as inappropriate by the creators of Slovenian transport policy who emphasized the need to charge the use of infrastructure in a dynamic way based on marginal social costs, the vignette tolling system moved a lot of traffic from regional roads to motorways (the introduction of vignette tolling system coincided with the construction of almost 100 kilometres of new motorways in the year 2008; this also influenced the increased of total traffic work on motorways).

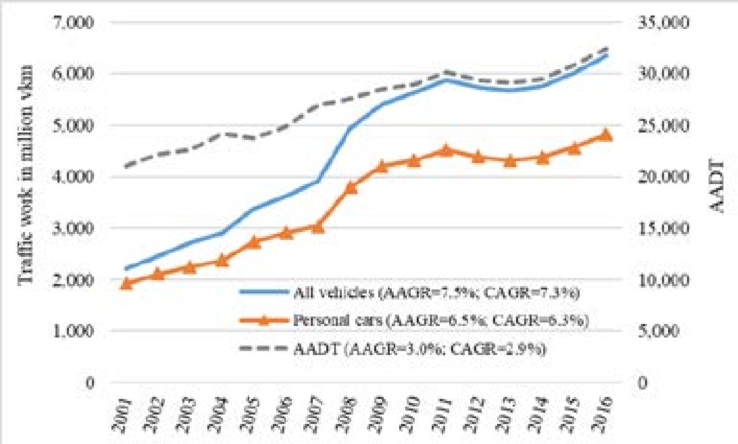

Fig. 4.
Traffic work and annual average daily traffic (AADT) and motorways
Source: Authors, based on (DRSI, 2018)

Table 2
Traffic accidents on main and regional roads

	Main roads		Regional roads	
	2007	**2008**	**2007**	**2008**
Material damage	1.844	1.391	2.543	1.692
Severe injury acc.	142	130	250	218
Light injury acc.	1.174	927	1.908	1.519
Fatal injury acc.	46	44	87	68
	3.206	2.492	4.788	3.497

Source: *Authors, based on (Policija, 2018)*

Traffic work on motorways almost tripled in the period from 2001 to 2016 resulting in accommodation of 47.7% of all traffic work done on Slovenian roads, while this percent was 22.8 in 2001. Regardless of the increase of motorways length, AADT increased for almost 55% in the same period, and the structure of traffic changed significantly. Safety prediction function suggests deterioration of traffic safety on motorways arising from increased traffic and heterogenization of traffic flows. Zanne, Groznik, & Twrdy (2016) determined the following safety prediction function on traffic accidents data for the period from 2001 to 2012 (SPF): $E(\lambda) = AADT^{0.7577}$ where $E(\lambda)$ indicates the predicted number of accidents. With the extension of time series, we can determine a new SPF, $E(\lambda) = AADT^{0.7370}$ which indicates improvement in safety on motorways resulting from additional measures taken, like improvement of traffic management with real time coordination between centres, application of dynamic signalization and installation of various physical safety elements like rugged lines or shock absorbers, as well as the introduction of additional training programme for novice drivers. The most recent safety measure on motorways is the introduction of stop-free electronic tolling system for vehicles with the maximum authorized mass exceeding 3,500 kilograms. This system is in operation since April the 1st 2018, and its impact on traffic safety cannot be assessed at this point.

Fig. 5.
Measures to improve road safety on Slovenian roads
Source: Various web pages

The mandatory training programme for novice drivers was introduced in 2010. This programme includes a theoretical part and a practical part and as well as group workshop on road safety and psychosocial relationships between road users. A novice driver must enrol for the programme in the period of two years since the attainment of the licence. The citizens of Slovenia believe that this measure will have the positive effect on traffic safety ($n=715$; $\bar{x}=3.65$; $\sigma=1.319$; $min=1$; $max=5$); however, by their opinion the cost of this additional training (currently 125 EUR) is too high ($n=743$; $\bar{x}=4.42$; $\sigma=1,095$; $min=1$; $max=5$) (Zanne, 2013).

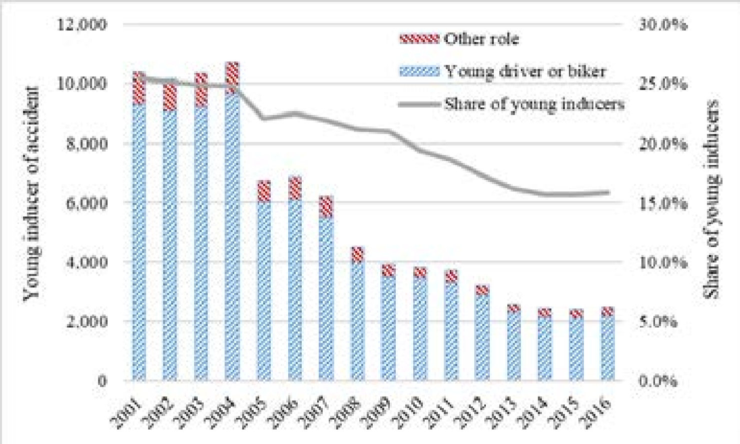

Fig. 6.
Young inducers (aged 18 to 24) of traffic accidents
Source: Authors, based on (Policija, 2018)

Table 3
Type of accident and main reason for accidents by young inducers

	2001	2006	2011	2016
Fatal acc.	63	56	21	11
Severe injury acc.	600	242	151	45
Speeding	2861	2075	1054	791
Share	27.6%	30.2%	28.5%	31.9%

Source: Authors, based on (Policija, 2018)

Rehabilitation programmes exists for those drivers who have lost their drivers' licence due to traffic offences including alcohol use. Slovenian Traffic Safety Agency is very active in performing different activities rergarding traffic safety; besides general informing of the citizens, they do targeted campaigns on speeding, cell phone use and alchohol as well as targeted activities directed towards specific participants in tranport, like pedestrians, bikers or truckers or senior drivers. However, studies show that the campanigns have positive effect on traffic safety only if supported by adeqaute for of police in terms of more present raffic control (Elvik et al., 2009). The opinion of majority of Slovenian citizens (92.2%) is that more frequent road traffic control would affect traffic same more than increasing level of penalties for offenders (Zanne, 2013). In addition, as a EU Member State, Slovenia is committed to Directive EU 2015/413 on facilitating cross-border exchange of information on road-safety-related traffic offences which grants mutual right to access vehicle registration data in order to improve the exchange of information and to speed up the procedures in force. Consequently Slovenian roads are no longer the speeding polygon of foreign drivers.
Also insurance companies in Slovenia play active role in improving safety on Slovenian roads; for example, the Triglav insurance company has so far financed the installation of about 80 smart signs in dangerous areas to help reduce traffic accidents in settlements with and without a street system (these roads are statistically considered the most dangerous) and at level crossings. Furthermore, the number of level crossings has been reduced by almost a quarter by implementation of modifications on transport infrastructure in the period from 2006 to 2018.
Nevertheless, the estimation of total socio-economic costs of traffic accidents reached from 1.3 to 2.8 percent of Slovenian GDP in 2016, depending on the methodology used (AVP-RS, 2017). This means that there is still room for improvement and one of the ways how to achieve the long-lasting improvement is also the establishment of well-organized and convenient public transport.

3.2. Public Passengers Transport

The prolongation of life expectancy and the shift of many activities into the older age in life. The elderly population is often characterized by a decrease in physical ability and thus a longer response time, worsening vision and hearing, confusion and lack of concentration. As a result, with the increasing volume of traffic flows and changes in transport infrastructure, they increasingly find themselves in road accidents. The proportion of elderly citizens in Slovenia is increasing, Slovenian population is aging. In addition, around 12-13% of people living in Slovenia have certain disabilities or special needs. Both of these groups deserve to have equal or at least similar mobility possibilities as the rest of population. Furthermore, there are around 437,500 daily inter-municipal migrants (SURS, 2018a), among which more than 160.000 inter-regional daily migrants in Slovenia (SURS, 2018b). As a rule they use personal car to accommodate their travelling needs. All this suggests that an adequate passenger transport system needs to be established.
The efficiency of interurban public road transportation was deteriorating quickly until 2011; regardless of the fact that the number of buses serving interurban connections almost halved since the 1990, the utilization of urban buses dropped from 73.6% in 1990 to 32.2% in 2001 and finally to 21.1 % in 2011 (Zanne, 2013). While interurban bus transport shows recovery in last years, the utilization level of passenger trains is low and still decreasing; according to the information obtained from the Slovenian railways, the average occupancy of passenger trains was 24.6% in 2015 (SŽ, 2015). In rail transport delays are common due to old and poorly maintened rail infrastructure, while the users also criticise the condition and comfort of trains. In addition not all trains can accommodate disabled people.
The reasons why Slovenia citizens hesitate to more frequently use public transport are provided in Table 4. As can be noted the price is not the most important factor for not using public transport, instead it is the quality of provided service.

Table 4
Reasons for not using public transportation

	Price	Trip duration	Schedule and frequency	Comfort and cleanliness	Distance to the station
Big city	3.02	3.67	3.44	2.71	2.68
Small city	2.71	3.89	3.93	2.46	2.88
Suburb	2.76	3.96	4.25	2.74	3.58
Rural area	2.49	3.90	4.51	2.35	3.72
Average	2.68	3.87	4.12	2.49	3.25

Note: 1 – doesn't agree, 3 – partially agree, 5 – totally agree
Source: (Zanne, 2013)

Due to disperse settlement pattern in Slovenia it difficult to organize efficient public transport system or a public transport system that would fit the needs of all inhabitants. Nevertheless, a good attempt is done with the project Integral public passenger transport (IJPP). The work on project lasted for several years, almost a decade. It introduced the single chip card ticket which is valid for various forms of public transport and will integrate the use of long distance and urban transport into a single system. The project links 35 public carriers in Slovenia, which operate long-distance regular bus and rail transport as well as urban transport of passengers in Ljubljana and Maribor. In practice, this means that the passenger can choose which mode of transport to use on a selected route. The result of the project is also a IJPP portal (usable also on mobile devices) which publishes all valid timetables for intercity line bus and rail transport for all 6,485 stations in Slovenia, as well as the timetable for urban traffic in Ljubljana. Through it the user gets the information how to reach desired destination with a detailed description and time evaluation. The IJPP portal is linked to Google Transit.

The IJPP ticket can be time determined (monthly, yearly, half-yearly) or quantity determined (single use ticket or ticket for 10 journeys per month) and is issued (all but a single use ticket) in the form of a registered electronic ticket which is non-transferable.

Subsidy plays a vital role in the operation of transport markets, possibly more so than in any other industry. This is because transport markets are made up of a combination of market forces and the actions of transport planning authorities, with subsidy playing a pivotal role in reconciling these two "forces" in the actual market place (Cowie, 2010). Subsidies are currently available for high school and college students as well as the participants in education programmes for adults. These theree categories of users are the most common users of public transport services in Slovenia. Later on, the subsidies will be arranged for other categories of passengers.

Although this system has been only recently introduced, some positive effects in terms of number of passengers can be observed on buses, while the drop of rail passengers is continuing. Nevertheless, Slovenian railways – Passenger transport has ordered

4. Conclusion

Transport system cannot develop into desired direction without the definition of many strategic documents, and the implementation of measures set in these documents is at least as important as their definition. Learning from the (mistakes of) others is a good approach although it can be time consuming and can lead to unrealistic expectations as countries differ among each other and consequently also do the determinants for transport planning.

The main objectives of transport is to provide safe and unconstrained daily travel for citizens and to provide the basis for the development of economy. In doing so, the organization of public transport and the level of traffic safety are very important. They can both affect the performance of transport separately or in connection, as well organized, accessible and convenient public transport can reduce the intensity of traffic flows and thus contribute to traffic safety.

Improving traffic safety is a challenging and time-consuming process. Slovenia has approached it holistically - with the combination of various hard measures (eg. infrastructure construction, physical equipment on infrastructure) and soft measures (eg. campaigns for rising awareness of citizens, preventive action and police control, traffic management tolling system or procedure for obtaining a driving license). Positive results are visible, but could be jeopardized if no or wrong measures are taken in future (eg. the re-introduction of distance based tolling for personal cars or other push measures if not accompanied by pull measures).

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RESEARCH CHALLENGES IN IMPLEMENTING AND OPERATING HIGHER TRAIN OPERATING SPEEDS

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Abstract: Railways enjoy public support at national and international level to improve their performances taking into the consideration higher train operating speeds. In this paper, we firstly discuss High Speed Railways (HSR) and Medium Speed Railways (MSR) experiences around the world. We provide current state analysis trying to identify best practices referring development and operating models. Moreover, we describe research challenges in the fields of planning and managing railways with higher operating speeds. A range of complex problems arises at different levels of planning hierarchy. Finally, we analyse strategic plans from Central and Eastern European countries. This review of knowledge and experiences is useful for understanding upcoming challenges in introducing higher operating speeds and assessing potential impacts on the development of Serbia, as well as other Central and Eastern European countries.

Keywords: High speed rail, Medium speed rail, high performance rail networks, regional development.

1. Introduction

Around the globe, railways enjoy public support at national and international level to improve their performances taking into the consideration higher train operating speeds through concepts of High Speed Railways (HSR) and Medium Speed Railways (MSR). Specifically, Europe Union has encouraged member and candidate countries to take into the consideration the construction of new lines dedicated to high speed trains or to reconstruct existing conventional lines upgrading their technical performances for running either high speed or medium speed trains. The further railway infrastructure development has to be directed on improving performances of the European rail system and creating interoperable Trans-European high-speed rail network.

Several reasons can motivate the construction of new HSR lines or upgrading conventional railways for operating high speed and medium speed trains. Among others, capacity congestions on railway corridors are leading factor accounting for investments. Additionally, congestions and traffic accidents in roads, delays and discomfort in air traffic, but also intention to develop coherent transport networks can influence political decisions on establishing high performance railway networks.

European Commission within the series of White papers on transport (see e.g. European Commission (2011)) promoted HSR services as a successful alternative to both air and road transport over medium distances of 300–600 km. The main benefits from establishing HSR services directly refers to the capacity realized on conventional lines, sustainable modal shift contributions, increase in time savings, comfort and safety issues for passengers, as well as stimulants for economic and regional development. As an HSR service enters a given corridor, its performance attracts new passengers, but also those that had previously used other transportation modes. For the purpose of illustration, we present data on transport modal shift following the introduction of HSR services on the Paris-Lyon (France) and Madrid-Seville (Spain) lines (see Albalate D. et al. (2015)). Concerning the Paris-Lyon line, the modal share of railways increased from 40 to 72% in the first 5 years of service (between 1981 and 1984), reducing the number of air and road passengers for 24% and 8%, respectively. Similar modal shift was captured ten years later on the introduction of service of the Madrid-Seville line. The modal share of railways was increased from 16 to 51% reducing air and road for 27% and 8%, respectively.

HSR and MSR services offer a punctual, comfortable and rapid transport of passengers. However, these services involve huge investments and expenditures varying with network designs and their functions. HSR and MSR services involve three major types of costs: the costs of building infrastructure, the costs of operating rail services and external costs. It is valuable to map the way in which network designs and their functions affect these costs, as well as the circumstances under which these huge investments are socially profitable. Therefore, it is required to identify and quantify the costs and benefits during the life of project in order to provide decisions for the undertaking projects or not.

HSR and MSR services are more environmentally oriented than other modes in medium-distance transportation. However, the construction and operation of these services, especially HSR services, also imply some environmental impacts. Common types of environmental impacts from HSR refer lend taking, noise and vibration affects, barrier effects, visual impacts of elevated structures, sound walls and other elements.

The HSR and MSR expansions bring benefits in economic and regional development. Cities along the same lines are linked together into integrated regions that can then function as a single stronger economy. Benefits could be seen in the revitalization of these cities by encouraging real estate development and improving accessibility around railway stations. Building of new lines or reconstructing existing conventional lines open labor markets offering job positions for a wider network of workers. Finally in addition to the regular passenger service, business and conference tourism benefit from HSR and MSR also.

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In this paper, we firstly provide definitions of HSR services and relationship of HSR with existing conventional services. Moreover, we discuss and analyze HSR and MSR experiences around the world. We review and analyze several countries that have successfully implemented HSR and MSR services to reduce rail travel time between their main cities. Secondary, we describe research challenges in the fields of planning and managing HSR systems. A range of complex problems arises at different levels of planning hierarchy. Finally, we analyse strategic plans from Central and Eastern European countries for developing railway transport and increasing train operating speeds.

2. Higher Train Operating Speeds Definitions

Following European Council Directive and International Union of Railways (UIC) (see e.g. European Council (1996) and International Union of Railways (2015)) high operating speed railways involve electric passenger train units using steel wheels on steel rails. Higher operating speed railways encompass three different types of infrastructure:

1) High speed lines of first category;
2) High speed lines of second category; and
3) Medium speed lines.

High speed lines of first category refers to specially built high-speed lines equipped for speeds equal to or greater than 250 km/h. High speed lines of second category refers to specially upgraded conventional lines, equipped for speeds in range 200-250 km/h or lines with some sections that have special features as a result of topographical, relief or town-planning constraints, on which the speed is reduced below 200km/h and is adapted for each case individually. Medium speed lines refers to upgraded conventional lines which have maximum operating speed of the order of 160 km/h. Based on survey provided by Michell et al. (2014) at least 11 countries operate high speed lines of first category, including China, Japan, South Korea, Taiwan, Spain, France, Germany, Italy, Britain, Turkey and Russia. The Table 1. presents the number of kilometers of high-speed tracks of first category in the world. A number of other countries (e.g. United States, Finland and Austria) operates HSR services with maximum speeds below 250km/h. Although many countries around the globe have plans to build HSR lines in near future, the most of them currently are implementing MSR concept where medium speed trains (e.g. countries in Central and Eastern Europe) are operated with the maximum speed of the order of 160 km/h, optionally up to 200km/h (e.g. Switzerland, Sweden etc.).

Table 1
HSR networks of first category in operation

Country	HSR lines of first category [km]
China	25000
Spain	2888
France	2696
Japan	2464
Germany	1136
Italy	981
South Korea	657
Turkey	632
Others	888

Although HSR and MSR shares the same basic engineering principles with conventional railways they also have technical differences. HSR and MSR lines generally characterize special dedicated infrastructure, purpose-built rolling stock and in-cab signalling. From a point of view of technical features, special dedicated infrastructure is required because horizontal and vertical alignments as well as other track parameters must be designed so as to make high operational speeds sustainable. Conventional lines, even with major up-grades, are unable to allow speeds above 200-220 km/h.
Beside the speed, it is valuable to analyze the relationship of HSR with existing conventional services and the way in which their use of infrastructure is organized. Following Campos and de Rus (2009), four different exploitation models can be identified (see Figure 2):

1) The exclusive exploitation model is characterized by a complete separation between high-speed and conventional services, each one with its own infrastructure. One of the major advantages of this model is that the market organization of both HSR and conventional services is fully independent.
2) In the mixed high-speed model, high-speed trains run either on specifically built new lines, or on upgraded segments of conventional lines. This reduces building costs, which is one of the main advantages of this model.
3) The mixed conventional model, where some conventional trains run on high-speed lines. The main advantage of this model is the saving of rolling stock costs and the flexibility for providing ‘intermediate passenger services’ on certain routes.

4) The fully mixed model allows for the maximum flexibility, since this is the case where both high-speed and conventional services can run (at their corresponding speeds) on each type of infrastructure. The price for this wider use of the infrastructure is a significant increase in maintenance costs.

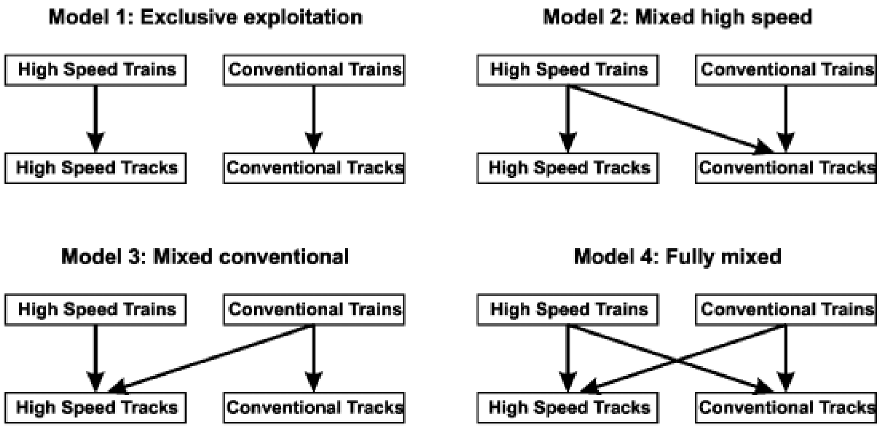

Fig. 1.
HSR exploitation models
Source: Campos and de Rus (2009)

3. HSR and MSR Experiences and Development

In this section we provide a survey of HSR and MSR projects around the globe, focusing on HSR projects in Asia and Europe. We focus our attention on the main issues involved in the undertaking projects: the motivation for adoption and development of HSR and MSR services, their impacts on mobility and economy development.

3.1. HSR in Japan

Japan presets the first country that built and started to operate a national high speed railway system, called Shinkansen. Initially, Shinkansen railways are defined as railway lines that could attain speeds of 200 km/h. As Shinkansen expanded, maximum operating speeds also increased step by step and currently reach 320 km/h. The purpose of establishing HSR services was to connect the major urban areas and to provide transport capacity necessary for the rapid growth of the Japanese economy. The key motivation of the project was the need to exceed heavy congestions on both the rail and highway corridors. The first HSR service started in 1964 on the corridor between Tokyo and Osaka, named the Tokaido Shinkansen line with the length of 515 km. The Tokaido line was the first, and is still the busiest, HSR line in the world. The line was designed to operate exclusive HSR service at 210 km/h, while later the speed was increased to 285 km/h. The HSR service initially reduced the six hour and forty minute conventional rail trip time to four hours, while future upgrades reduced the travel time between Tokyo and Osaka to less than three hours.
The first expansion was in 1975 with the Sanyo Shinkansen which extended the Osaka end southwestward in the length of 622 km to Hakata. Next in 1985, the Tokyo end was expanded 536 km northward to Morioka as the Tohuku Shinkansen. In the same year, the Shinkansen system was extended with the Joetsu line from Tokyo to Niigata in the length of 320 km. Further expansions followed in the period 1997-2016 referring not only to the extension of these four existing lines but also referring to the introduction of new high speed lines, such as Kyushu Shinkansen (257 km), Hokuriku Shinkansen (450km) and Hokkaido Shinkansen (149km). Today, Japan has the fourth HSR network in the world reaching almost 2500 km and serving more than 300 million passengers each year. The current maximum operating speed amount 320km/h on the Tohuku Shinkansen, while further research on development anticipates increase in speeds up to 360 km/h. The whole Shinkansen system has a very high level of reliability with average delay of 0.6 minutes per train over the entire time-table period of validity.

3.2. HSR in China

Although China began planning its HSR network late in the 1990s, the first HSR service was introduced in 2008 on the line Beijing–Tianjin with the length of 120 km and a maximum operating speed of 350 km/h. When the line opened, it set the record for the fastest conventional train service in the world by top speed, and reduced travel time between Beijing and Tianjin to 30 minutes. Main motivation for developing HSR services for China were to bust and reshape its economy, as well as to solve problem of capacity restrictions and congestion in densely populated corridors. In following five years, the HSR operating length reached about 9300 km, while in 2017 even exceeded 19000 km in total length, accounting for about two-thirds of the world's HSR tracks in commercial service. Note that HSR service keeps few additional world’s records concerning the maximum train speed. Specifically, the max speed on Beijing–Shanghai corridor reached 380 km/h exceeding previous China record of 350 km/h and competitive max speeds of 320km/h on

other HSR networks, such as in Japan and Europe. Furthermore, Shanghai Maglev presents the first high-speed commercial magnetic levitation line whose trains run on non-conventional track and reach a max speed of 430 km/h.
Figure 3 presents the HSR network that is planned to be consist of 8 vertical and 8 horizontal corridors. In contrast to other HSR networks (like in Japan and Europe), the HSR network in China, is designed on the base of long-scale corridors, such as Chengdu–Shanghai (2066 km) and Beijing–Hong Kong (2383 km). China has chosen to apply exclusive exploitation model for main HSR lines building most of them only for high speed passenger services. The station density of the HSR lines varies by different corridors. Referencing to Fu et al. (2015), the Beijing–Guangzhou corridor has 43 stations (average station spacing 52 km) while the Beijing–Shanghai corridor has 23 stations (average station spacing 60 km).

Fig. 2.
HSR network in China
Source: Rail_map_of_PRC.svg

3.3. HSR in Europe

The first European HSR lines were opened in West Europe countries in the 1980s and 1990s. Since then, the European HSR networks continually expanded based on the development plans of building and upgrading national and international corridors compatible with existing railways. The concept of interoperability and compatibility with conventional railways differentiates the European HSR networks from other HSR networks, such as Shinkansen network in Japan. In the same time, the experiences vary among countries, so in this section we will present and analyze HSR systems individually instead of generalizing them as an unique European concept.
The first HSR service in Europe was introduced in 1981 on the line Paris - Lyon (France) with the length of 409 km and a maximum operating speed of 260 km/h. Since then, France has continued to build HSR system, called TGV lines. The TGV lines constitute radial network with 4 routes connecting Paris with other high populated French cities, even spreading into other countries such as Switzerland, Belgium, the Netherlands, Germany, and the UK. The development policy was to invest only in profitable lines serving corridors with sufficient passenger demand. Passenger demands and time savings on one side against investments and operating costs on other side were equally considered in French HSR projects. Therefore, France created a mixed HST infrastructure system building high speed tracks along sections with higher passenger demands and using some segments of conventional tracks along less crowded lines and for accessing city centers. The newest high-speed lines allow maximum speeds up to 320 km/h at dedicated high speed track sections

and up to 220 km/h on mixed sections. France has the second largest high-speed network in Europe and the third in the world with 2,696 km of operative HSR lines.
The HSR system in Spain, called AVE, was introduced in 1992 opening in service the 472 km long Madrid–Sevilla line for speeds up to 300 km/h. The main motivation for establishing AVE lines was to provide for almost all regions HSR connections to Madrid in less than 3 hours and to Barcelona within 6 hours. Today, the AVE network consists of 11 lines, including the 621-kilometre long Madrid–Barcelona line. The total length of the network amount 2,888 km making it the longest in Europe. Although the Spanish conventional and HSR lines differentiate in several technical characteristics including track gauges, it did not presented a barrier for implementing the interoperable passenger service mixing the new AVE lines and the older Iberian gauge network. This network design enables the third exploitation model where some conventional trains provide intermediate services on certain HSR lines.
In Germany, the main goal for establishing HSR service, called ICE trains, was to solve capacity problems in certain corridors and to improve north-south freight traffic. Therefore, differing to France and Spain, Germany chose the concept of upgrading existing lines instead of building a separate HSR rail network. Specifically, based on the fourth exploitation model, ICE network was developed more tightly integrated with existing conventional lines with attention to serve long distance trains, regional trains and freight trains too. Pricing in much higher upgrading and operating costs, this developing policy provided great benefits for regions and industrial centers, especially in Southern Germany. One of the consequences of this concept is that ICE trains can reach a higher spectrum of high speeds (250 - 300 km/h) only on some stretches of lines, although the latest generation of ICE trains reached up test speeds of 360 km/h and is licensed for speeds up to 330km/h. Today, beyond intra-national destinations, ICE trains serve destinations in Austria, Switzerland, the Netherlands and Belgium. Germany has the fifth largest high-speed network in world, with 1,136 km of operative HSR lines and 285 under construction. Just behind Germany, Italy operates HSR trains on 981 km long lines whose speeds are between 250 and 300 km/h. Finally, HSR services are currently established in several more European countries, such as United Kingdom, The Netherland, Belgium, Turkey, Finland, Austria and Russia.

3.4. MSR experiences

In the absence of commercial viability to proceed with expansive HSR investments, many countries decided to reconstruct conventional railways for MSR service upgrading them for top speeds of the order of 160 km/h, optionally up to 200km/h. The strategy of developing MSR services is guided by the motto "not as fast as possible but as fast as necessary". MSR development strategies don't see higher operating speeds as an end in itself, but a means to provide additional benefits for both, passenger and freight services but under lower expenditures. These additional benefits refer to the reduced transit times and increased train frequencies. Although many these countries currently operate trains at speeds of the order of 160 km/h in passenger service, following paragraph consider a few experiences of providing MSR with top speeds of up to 200 km/h.
Analyzing the Swiss rail network, we noticed that short distances between cities and the often difficult terrain have limited the need for establishing HSR services. Instead of building HSR lines, Switzerland focused on infrastructure upgrades providing attractive passenger services with acceptable frequencies and transit time reductions at speeds of up to 200 km/h. Difficult terrain influenced that Sweden also chose to introduce MSR services on the mainline lines. In order to increase passenger train speeds, Sweden railways offered top speeds of 200km/h. Offering speeds of 200km/h, the Swedish railways increased average operating speeds by up to 30% with only minimal upgrades to track infrastructure. As a result, MSR increased rail's market share on the Stockholm-Gothenburg corridor from 42% to 57%, competing with airlines on journeys up to 400km.

4. HSR and MSR Research Challenges

The challenges of implementing higher train speeds, either through HSR or MSR concepts, are the most interesting and controversial topics in transport policy and research today. The development and planning of high performance railways is now a worldwide topic (Campos and de Rus, 2009). In the beginning, the research was mostly concentrated in Europe, especially in France, Germany and other highly developed European countries. Nowadays, China is a leader of building and research of high speed railways. Most of the papers in recent literature could be categorized in three groups: research on operational problems and high speed management; research on tactical and interconnectivity problems; and research on strategical and fundamental research on high speed rail.
In operational time frame authors are frequently working on timetables and planning of high speed trains. For example, in their research Yue et al. (2016) analyze on how to efficiently operate high speed trains in large-scale systems, as it is posing a new challenge to the railway industry. They propose a mathematical model for optimizing a high-quality train timetable that should take full advantage of the system's capacity to meet transportation demands. Cascetta and Coppola (2016) present an research on assessment to what extent the lack of modeling capabilities of frequency-based assignment models in the field of long-distance service (e.g. HSR or MSR services) modeling is acceptable. Espinosa-Aranda et al. (2015) propose a model that evaluates the attributes of railway services such as the timetable, fare, travel time and seat availability and computes the High-Speed railway demand for each planned train service. Chang et al. (2000) use the fuzzy mathematical programming approach to determine the best-compromise train service plan, including the train stop-schedule plan, service frequency, and fleet size.

For a longer time span and research on possible impact on other means of transport research have been made to impact of the new conditions on transport market. Adler et al. (2010) develops a methodology to assess infrastructure investments and their effects on transport equilibria taking into account competition between multiple privatized transport operator types. There are a number of research that analyze the competition and cooperation between high speed rail and air transport (Jiang et al. 2014, Albalate et al. 2015). Costa et al. (2016) propose a decision support systems for the optimization of the HSR alignment developed for addressing the requirements of large and complex real projects. The formulation includes costs, geometric constraints, connection requirements, and consideration of natural barriers such as protected land use and bodies of water, ubiquitous in real projects. Fu et al. (2015) describe an integrated hierarchical approach to determine line plans by defining the stations and trains according to two classes, and then analyze a range of scenarios that are developed to generate three line plans for a real-world example of the HSR network in China using a decision support system.
Transport planning and policy is closely related research on the experiences and issues are always essential for a future research (Vickerman 1997, Janic 2003). For a strategic planning authors have dealt with various problems arising from a high speed rail development: Ureña et al. (2009) analyse the high-speed rail challenge for big intermediate cities; Cheng et al. (2015) report on high-speed rail networks, economic integration and regional specialisation in China and Europe; Nash (2015) present a challenges on when to invest on high speed rail; and Vickerman (2015) analyse the impact on the intermediate areas between North-west Europe major metropolitan areas and the creation of potential cross-border inter-regional services.

5. HSR and MSR Development Plans in Central and Eastern Europe

The plans for extending the network of high speed rail towards eastern and southern Europe were made as a part of a long term development strategy for railways. Developing a Trans-European high-speed rail network is a stated goal of the European Union, and most cross-border railway lines receive EU funding. More are expected to be connected in the coming years as Europe invests heavily in tunnels, bridges and other infrastructure and development projects across the continent, many of which are under construction now. Until couple of years ago, the plans for extending the high speed rail in this region were related to Hungary and Romania. On the meeting in Bucharest in 2010 there was an initial idea concerning the EU Strategy for the Danube Region. The idea was that the Danube Strategy will include a high speed railway project on the route Vienna - Budapest - Bucharest - Constanta. Further steps regarding the project were also made following the China – Central and Eastern Europe Forum. The plan was that Romania and the Chinese partners could this work on a project of a high speed track that would link the Black Sea city of Constanta to Bucharest and then Budapest and Vienna. High-speed train network was officially included in the TEN-T map of Romania. Plan for the high-speed line that will cross Romania is to branch from Szeged, Hungary from line Budapest - Belgrade and will have a route Nădlac - Arad - Timişoara - Deva - Sibiu - Braşov - Bucharest - Constanţa. It will be a dedicated line, with new construction, and without any link to conventional lines already existing on this route. The works are scheduled to take place between 2017 and 2025.

Fig. 3.
Map of the Europe high speed rail lines
Source: uic.org

Another new initiative for HSR was the connection of Hungary and Serbia. One of the projects of China's Belt and Road Initiative (BRI), a 336 kilometer rail line from Serbian capital Belgrade to Hungarian capital Budapest Construction was originally set to start in 2015.The actual start of the project was introduced during the November 2017 16+1 summit, between China and Central and Eastern European (CEE) countries at Budapest. Designed to cut the travel time between the Serbian and Hungarian capitals down from eight to three hours, the line also dovetails into Chinese plans to turn the Greek port of Piraeus – where Chinese shipping giant Cosco Pacific holds a 35-year concession to upgrade and run two container cargo piers – into a regional hub for trade with Europe.

Fig. 4.
One Belt One Road Initiative for Belgrade – Budapest HSR line
Source: Yang et.al., 2017

In Serbia, the project is financing the reconstruction and modernization of the existing single-track railway and the construction of the second track for mixed passenger and freight traffic and speeds of up to 200 km/h on the Belgrade-Novi Sad-Subotica-state border (Kelebija) line. The total length of the Belgrade-Budapest railroad is 350.7 km (183.0 km in Serbia and 167.7 km in Hungary). The railway has three distinctive sections in the Republic of Serbia: (1) Belgrade Center - Stara Pazova (34,5 km), (2) Stara Pazova - Novi Sad (40,4 km), and (3) Novi Sad - Subotica - state border (108.1 km).

6. Conclusions

Higher train operating speeds brings railways as an innovative and expanding transport concept often regarded as the "transport mode of the future". The higher train operating speeds bring the highest level of advanced technologies and solutions within various technical aspects such as infrastructure, rolling stock and operations, as well as cross-sector issues. All these components contribute to the quantitative and qualitative global technical performance and commercial attractiveness. HSR and MSR systems depend on how all their components are designed and interact. The final system obtained (in terms of cost and performances) can be very different from one country to another depending on, among other things, commercial approach, operation criteria and cost management (see. International union of railways, 2015).
Analyzing different experiences around the globe, we find following main reasons for implementing HSR and MSR concepts: capacity congestions on railway corridors, congestions and traffic accidents in roads, delays and discomfort in air traffic, and coherent transport network development policy.
Implementation of HSR services in most countries involved huge investments and expenditures. Topology, including relief and several other spatial-planning constraints, as well as aforementioned technical features of HSR infrastructure implied that costs of building HSR networks considerably differed among countries. However, huge investments were not only influenced by widely different design characteristics, but they increased over time also.

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THE TRANSPORT ACCESSIBILITY OF TOURIST DESTINATIONS IN SERBIAN IRON GATES REGION – BETWEEN STRATEGY AND REALITY

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Abstract: The Iron Gates, the largest gorge of the Danube, is currently among the most prospective regions in Serbia. However, this is with a low-start position. Being a two-century borderland position between Serbia and Romania on the Danube, the region has been in a long-time isolation, which has caused deep socio-economic and demographic problems. This means that the Iron Gates region is not well-prepared for a new economic driver – tourism. Tourism blossom is generally related to easy accessibility by the Danube. Nevertheless, the loosening of national borders since 2000 has pushed the increase of tourists. Most of them visit the Iron Gates in organized tours by cruisers and tourist buses. This consequently focuses the visit of tourists to major attractions in the region and limits the possibility of the individual organization of their visit. Therefore, the tourism of the region flourishes only around the main attractions; the other ones, mostly smaller, cannot properly benefit from this emerging tourist interest. The aim of this research is the analysis of the tourist accessibility of the Iron Gates Region by those mass transport modes that freely open to prospective tourists who want to individually organize visit to region. They include just the regular lines of public buses. The research is organized in several steps. The first one is to collect and locate all tourist destinations that have been already enlisted in relevant spatial and strategic plans. Then, their spatial distribution is confronted with their transport accessibility by the mentioned mode. Finally, the obtained results from this comparison are given as recommendations to fulfil the gaps in the region connectivity regarding individual visits and tours. In that way, the final results can address the better organization of tourism development in the Iron Gates.

Keywords: transport accessibility, connectivity, tourist destination, Iron Gates, Serbia.

1. Introduction – The Planning of Tourism Destinations in Serbia

A tourist destination is among the most prominent terms in a hospitality sector today. Many sites with potentials in tourism are attempting to become well-known tourist destinations which will attract global travellers. However, the exact meaning of this term is still fluid and there is no wider acceptance about its definition (Saraniemi and Kylanen, 2011; Pike and Page, 2014). Laymen understand this term in the variety of ways, but most of them consider that it is a geographical area (settlement, region, country) which is seen as a site with one of more tourist attractions and which is reliant on tourism as an economic sector. In the other words, it is “a country, state, region, city, or town which is marketed or markets itself as a place for tourists to visit” (Beirman, 2003, p. 3).

It also seems that the term “tourist destination” is firmly attached to geo-political milieu. This stance is generally based on economic geography-oriented research (Davidson and Maitland, 1997). Pike (2016) underlines that this means that the areas attached to certain tourist destinations usually concur with outlined geo-political entities and that their promotion and marketing is usually financed by relevant governmental tier. The spatially largest types of tourist destinations are the whole countries. For example, Spain is among the most famous countries-tourist destinations, with almost 15% of gross domestic product (GDP) made in tourism in 2017; some smaller countries are even more linked with the basic definition of a tourist destination, such as Maldives, where tourism contributes to 77% in national GDP (Knoema, 2017).

The importance of governmental support in the establishment and functioning of a tourist destination is visible in the Republic of Serbia (RS). The national Law on Tourism in its glossary (GRS, 2009-15, Art. 3) defines the tourist destination as such “destination of tourist travel which enables to accept and accommodate tourists by its infrastructure”. In the same article, the strategic and planned development of the most important tourist destinations (‘preferred tourist destinations’) in the county is prescribed, including aims, programmes, competitiveness and marketing plans, etc. The list of preferred destinations is, inter alia, given it a national strategy of tourism development (Art. 7). The newest/second national strategy of tourism development was recently adopted (2016) by the Government of the RS. Its implementation horizon is the year of 2025. This 10-year strategic document recognises 18 major tourist destinations in the country, with their brief explanation and planned specific tourist products and activities. Aside of them, the strategy proposes the actions that are crucial for all of them and which will be financially supported by national budget (GRS, 2016).

The improvement of tourist infrastructure and superstructure, including the construction and modernisation of transport and communal infrastructure, is highly prioritised by the strategy (GRS, 2016). There is no doubt why this is important. First, the presence of tourist attraction, such as a thematic park, natural and cultural heritage or convention centre, is just a first step of the development of tourist destination; the more important one is to develop the tourist infrastructure which will support the attraction by easier accessibility, the better accommodation of prospective tourists or its promotion and appropriate information. Singh (2008) calls it a specific tourist environment. Second, tourism is a vigorous, progressive and always changing economic sector (Butler, 2006), which requires a more sophisticated infrastructure than in many other sectors. The authors of the strategy underpin that it thereby must be compatible to the (operative) Spatial Plan of the Republic of Serbia as well as to the other spatial plans. In accordance to this position, a

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particular respect is given to the planning objectives of those sectors that are significant for tourism development (GRS, 2016, p. 58).
The fundamentals of this research refer to this interlink between tourism, transport and territorial planning. Its aim is to analyse the tourist accessibility of the Iron Gates Gorge (Serbian: Đerdap) of the Danube River as one of the recently booming tourist destinations in Serbia. This region is not a monocentric tourist destination such as Belgrade or Zlatibor Mountain in Western Serbia; instead of that, it is abundant in many minor tourist destinations, mostly lined along the gorge. They will be identified by selected policy documents. The research is also narrowed to those transport modes that enables freely-organised individual tourist tours and visits. Hence, the research analyse the network and nods of the regular lines of include public buses that are freely available. Present-day situation is quite different. Local experts in tourism point that several destinations in the Iron Gates are becoming overwhelmed by organised mass-tourism by tourist buses and cruises, leaving a spacious attractive areas in the gorge without a proper tourist visit and the most of local community without tourism revenue, which should be a general aim of any plan or strategy. The obtained results from this comparison are given as recommendations to fulfil the gaps in the region connectivity regarding individual visits and tours. In that way, the final results can address the better organization of tourism development in the Iron Gates.

2. Methodology

This research is methodologically constructed as a "policy and practice" research, where the main elements from relevant policy documents are confined with the current on-site assessment of policy-related area. It is organised in three steps. The first one is to collect and locate all minor tourist destinations in the Iron Gates Gorge that have been already enlisted in relevant spatial and strategic plans. Then, their spatial distribution is confronted with their transport accessibility by the mentioned modes - public buses which connect the region internally and with the major cities in surrounding. Finally, the last step in dedicated to the main findings from this comparison and the recommendations derived from it.
Research material consists of (1) selected strategic documents and (2) on-site research, including the conversation with local experts in tourism, transport, territorial development and heritage, and (3) the research of official data available on internet. Three plans and strategies that entirely or mostly cover the proposed tourist destination of the Iron Gates Region are included in the research:

1) Master Plan of the Tourist Destination " Donje Podunavlje" (the Lower Danube Region),
2) Spatial Plan of the Special-Purpose Area of E-80 International Waterway – The Danube (Pan-European Corridor VIII), and
3) Plan of the Special-Purpose Area of "Đerdap/Iron Gates" National Park.

3. The Planning of Tourist Destinations in the Iron Gates Region

The Iron Gates or, in Serbian, Đerdap is the longest gorge on the Danube River. It is a 134-km long composite gorge, which size has caused the long-lasting isolation of the surrounding territories. Physically, the gorge divides the Middle and Lower Danube regions (ICPDR, 2002); politically, the Danube in the gorge is a long-lasting border between Serbia (southern side) and Romania (northern side). This isolation preserved specific natural heritage and amazing landscape in the gorge (Fig. 1 and 2), with many endemic species (NASP, 2009). Therefore, both sides of the gorge (Serbian and Romanian) are officially recognised as national parks.
The physical isolation and the position of borderland have had a strong negative impact on the socio-economic state of settlements and municipalities in the Iron Gates Gorge. All three municipalities in the gorge (Golubac, Majdanpek and Kladovo) have had demographic problems since the World War II. The severe socio-economic problems in all municipalities started with the collapse of socialist economy in 1991. Since this year, Kladovo Municipality lost 35%, Majdanpek 32%, and Golubac 33% of its population (inter-census period 1991-2011; SORS, 2014). Demographic situation is even more severe is in the rural parts of the municipalities. Some mountainous villages have lost more than 80% of their post-war population. Similarly, the economic state of all municipalities is very weak; all of them are bellow national average by economic performance and Golubac and Majdanpek are among 37 officially underdeveloped municipalities in the country (Bjelac et al., 2009).

Fig. 1a and 1b.
Magnificent landscape of the Iron Gates Gorge: the gorge entrance at Golubac Fortress (left) and Kazan, the narrowest part of the gorge (right)
(Author: B. Antonić)

Conversely, natural, political and socio-economic isolation of the Iron Gates region has preserved cultural heritage, as well as the numerous elements of traditional culture. Many of heritage sites, such as Golubac Fortress or Lepenski Vir archaeological site (Fig. 3 and 4), possess even an international significance. Putting cultural heritage together with preserved nature and magnificent landscape, it is obvious that the whole Iron Gates Region can become a prestigious tourist destination in Serbia. However, the gap between socio-economic difficulties and the abundance of heritage postponed tourist development, especially at international level.

Fig. 2a and 2b.
The main assets of cultural heritage in the Iron Gates: Golubac Fortress (left) and Lepenski Vir archaeological site (right)
(Author: B. Antonić)

The national strategy of tourism development 2016-2025 considers the Iron Gates Region as a key part of the tourist destination of (Serbian) Lower Danube Region (Table 1). Aside of the Iron Gates, the areas around Veliko Gradište (westernmost part) and Negotin (easternmost part) belong this designed destination, too. Interestingly, the only high-quality accommodation in this tourist destination mentioned in the Strategy is “Silver Lake Resort” (GRS, 2016, p. 12) on the same-name lake near Veliko Gradište town, i.e. outside the Iron Gates region.

Table 1
The tourist destination of (Serbian) Lower Danube Region

No.	Tourist destination	Spatial coverage	Key values (activities)	Development poles	Key products
9c	The Lower Danube Region	- Veliko Gradište - Golubac - Donji Milanovac - Kladovo - Negotin	- Cultural heritage - Natural resources - the Danube - Đerdap/iron Gates National park	- Veliko Gradište - Golubac - Donji Milanovac - Kladovo - Negotin	- nautical tourism - Eco-tourism - Ethno-tourism - Rural tourism - Cultural tours (cycling, gastronomy) - Special interests - Events (Danube Fair, “Sila” fiesta, Danube Ball, etc.)

Source: GRS, 2016

POLICY DOCUMENT 1: The Master Plan of the Tourist Destination "Donje Podunavlje" (the Lower Danube Region) was enacted in 2007 by the Ministry of Economy and regional Development of RS (with jurisdiction for tourism affairs). This document was developed in accordance with the previous strategy of tourist development of Serbia. It analyses the covered area of the master plan with administrative imperative, positioning all urban settlements in the gorge - Golubac, Donji Milanovac (in Majdanpek Municipality) and Kladovo - as main tourist destinations for their wider/administrative territories. Nevertheless, the master plan separately evaluates several more locations as key projects for the future investment: Golubac Fortress, Lepenski Vir archaeological site, Poreč Bay, and Tekija (fishermen) village. This evaluation was done to offer a complete tourist destination with the main attraction(s) and accompanying services and facilities (accommodation, entertainment, accessibility, information, etc.).

POLICY DOCUMENT 2: Spatial Plan of the Special-Purpose Area of E-80 International Waterway – The Danube (Pan-European Corridor VIII) was adopted in 2010, with the planning horizon of 2025. The vision of plan refers to the improved utilisation of the Danube River and its riverside, also containing its cultural and tourist potential (NASP, 2010). This plan also recognises the importance of tourism as an economical sector on the Danube, but it limits its interests to "nautical" types – cruising and yachting. The other types of transports and transport corridors, such as major roads or public bus lines, are not in the focus of the plan. In the part dedicated to tourism, the plan proposes several tourist destinations within the Iron Gates: Golubac Fortress, Lepenski Vir archaeological site, Đerdap hydro-plant. As it is visible, the textual part of the plan is mainly focused on the sites of natural and cultural heritage and it does not include the main (urban) settlements as tourist destinations, which are, however, better elaborated in the graphical parts of the plan. Interestingly, the plan mentions the importance of connection of the gorge with Serbian Carpathian Mountains in background, indirectly highlighting the position of nearby Majdanpek Town.

POLICY DOCUMENT 3: Plan of the Special-Purpose Area of "Đerdap/Iron Gates" National Park concurs with the area of the gorge with the surrounding mountainous system of Serbian Carpathians. This plan respects two previously explained policy documents in their main points. Therefore, the textual part of the plan also puts the sites of cultural and natural heritage first: Golubac Fortress, Lepenski Vir archaeological site, Trajan's table in Kazan (Inner) Gorge. Then, it also includes the main settlements as focal points to offer the variety of tourist offer: Golubac, Donji Milanovac, Majdanpek, and Kladovo. At the end, the plan also separately proposes the actions and projects for Poreč Bay and Tekija village.

The analysis of three selected policy documents results in nine prospective tourist destinations in given in the following table:

Table 2
Minor tourist destinations in the Iron Gates Region

No.	Minor tourist destination	Master Plan of Donje Podunavlje	Spatial plan of the Danube	Spatial plan of NP Đerdap	Total confirmations
1.	Golubac (with Vinci weekend cottage area)	Yes	Partly	Yes	2.5
2.	Golubac Fortress (with Ridan weekend cottage area)	Yes	Yes	Yes	3
3.	Lepenski Vir archaeological site	Yes	Yes	Yes	3
4.	Majdanpek (with Rajkova Cave)	No	Yes	Yes	2
5.	Donji Milanovac (with Kapetan Mišin breg/hill)	Yes	Partly	Yes	2.5
6.	Poreč Bay	Yes	No	Yes	2
7.	Kazan Inner Gorge with Viewpoints and landmarks (Tabula Traiana)	No	Yes	Yes	2
8.	Tekija	Yes	Partly	Yes	2.5
9.	Kladovo (with Đerdap hydro-plant and Karataš recreation zone)	Yes	Partly	Yes	2.5

It is also important to mention that all policy documents underline that importance of tourist destinations for the development of wider areas in their vicinity. They are mostly rural and/or natural, with limited accessibility due to mountainous character and with strong dependence to prospective tourism services and infrastructure in nearby destinations.

4. The Accessibility of Tourist Attractions

Focal transport modes in this research are those that are in the system of public use and which enable the easy and efficient accessibility of individual tourists/travellers. They must be available for individual tourist visits and tours of at least one of nine obtained (minor) tourist destinations. In the iron Gates, only one mode is currently present: public buses which connect the settlements in gorge with surrounding (mainly major cities), as well as internally.

Generally, the Lower Danube area is strongly dependent on Belgrade as a transport intermodal point (Kadar and Gede, 2018). This is also visible in all analysed policy documents. The main transport artery is so-called "Đerdap Magistrala" – the road of 1st class along the Danube – which connect Belgrade with Eastern Serbia. At local level, this road brings heavy transport (lorries) into the gorge and national park, which noticed as a problem in policy documents. For master plan, the second important road for the gorge is road Požarevac-Majdanpek-Negotin, which is still underused (MERD, 2007). In the case of two spatial plans, transport is developed as an independent thematic sector. However, there are even collisions in the related actions and projects and actual situation. For example, a new border crossing for ferry transport between Romania and Serbia in Golubac area is planned in the lower town marina. Nevertheless, the new border crossing and new transport node, which is currently close to opening, is located in the nearby suburban settlement of Usije, several kilometres upstream to the town and the lower marina.

Public bus lines are generally the only easily available public mode of transport. They generally follow the main roads and the frequency of all vehicles. The main observations from local experts can be scrutinised in the following statements:

1) The main transport corridors for public buses in Đerdap road in west-east direction, which connects major settlements in the gorge, as well as with Belgrade and Požarevac ('intercity lines');
2) Transversal bus lines, which connect the settlements in the gorge and settlements in Serbia Carpathian area, are scarce and restricted on the link Majdanpek-Donji Milanovac;
3) All three municipalities lack the real network of public bus lines at municipal level due to weak local finances. Consequently, many remote villages have not public bus lines at all. Public transport in them is organised through local taxies and minibuses on request. Therefore, this local "policy" makes them even more isolated and excluded from prospective tourists;
4) Tourist destinations which are not settlements at the same time (Golubac Fortress or Lepenski Vir archaeological site) which are located along Đerdap road are "unofficially" covered by the regular bus lines.

Linking afore mentioned observations from local experts on public bus transport with the position of nine tourist destinations and nearby towns and regions is presented in the following map (fig. 5):

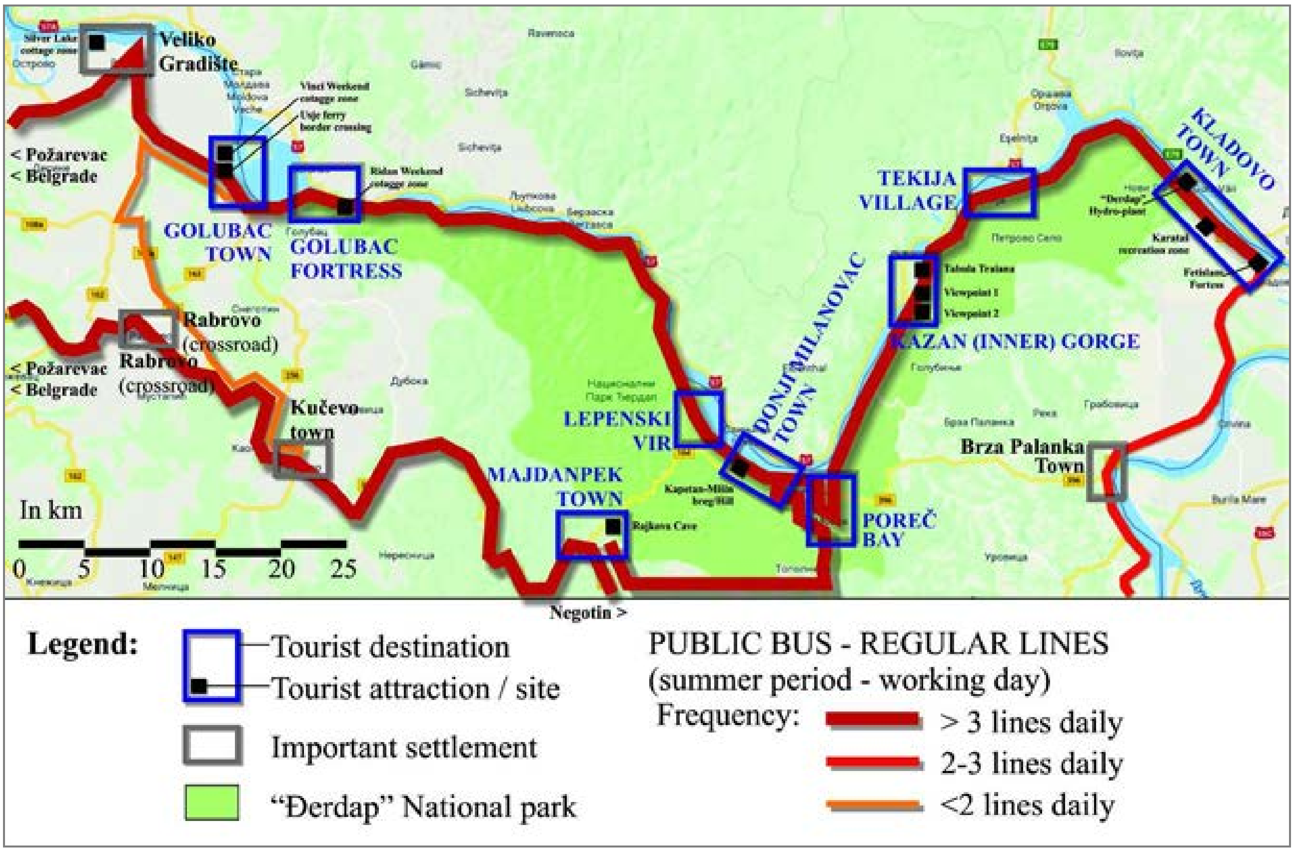

Fig. 3.
The accessibility of tourist destinations in the Iron Gates region by the regular lines of public buses (Author: B. Antonić; Substrate map: Google Maps)

5. Conclusions

The indirect aim of this research is to understand if and how prospective travellers and tourist visitors can organise their tour through the Iron Gates Region as rising tourist destination in Serbia on their own, by using regular public transport.

This aim was analysed by the comparison between the location of the policy-designed tourist destinations in the region and the network of regular bus lines as the only mass-transport mode convenient for individual visits and tours in the region. The results given by the Figure 5 indicate that the linear character of the gorge profoundly influence the patterns of transport. In background, there is certainly the significance of the network of major settlements, which is also mostly developed in linear manner due to natural conditions (morphology, altitude, etc.).

The broad meaning of a tourist destination was customised to local context though the analysis of three crucial policy documents that considers the whole space of the Iron Gates. In short, these documents mainly make a distinction between two types of planned tourist destinations; (1) urban settlements that are important as local service centres and (2) the sites of cultural and natural heritage, where this element is crucial for their prospective development into tourist destinations.

The current lines of public buses generally follow already present demand. Then, it seems that they are still more reliant on local people than tourist visitors. The real evidence is the equal frequency of two main bus lines; along the gorge (the main tourist route) and along the line Kučevo-Majdanpek-Negotin (mostly non-tourist route).

Acknowledging that both the location of the main tourist destinations and the system of bus lines are linear, huge mountainous areas in background are barely used for tourism purposes. This is in a deep contradiction with preserved rural culture and natural beauty located in these areas, which are consequently left for the future.

The major bus lines show the monocentric spatial development of Eastern Serbia, which is strongly western-oriented, towards Belgrade as a national capital via Požarevac as regional centre. The ends of these lines are usually in Kladovo and Negotin as border towns in the easternmost parts of Serbia.

Considering previous findings, several recommendations are underlined:

1) In the future development, special attention should be given to enable transitive/trans-border lines, to better connect Eastern Serbia with neighbouring regions in Romania and Bulgaria. This will be a strong development stimulus for already established local tourist destinations.
2) Transversal bus lines (between the Danube riverside and mountainous hinterland) are particularly necessary for the strengthening of already established tourist destinations in the gorge, such as Golubac or Donji Milanovac towns. In that way, they will add the component of rural, ethno- and eco-tourism, that exist in the rural hinterland, in to their tourist offer and which is proposed by the national strategy for tourism development;
3) The region lacks the real network of local, short-line public transport modes, for which minibuses and/or vans are suitable. They are equally important for remote village (rural tourism, local tradition) and for physically isolated tourist sites, such as several viewpoints on the gorge. The financial limitations of three municipalities in the gorge imply that upper levels (national, in particular) should be involved in their financing. For these purposes, special plan for transport network and nodes should be created. This plan must consider tourist needs in the future, prioritising their long-term viability.

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UNDERUTILISATION OF PEDESTRIAN SIDEWALKS IN URBAN RESIDENTIAL AREAS IN SOUTH AFRICA

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Abstract: Walking in South Africa is a mode of transport that approximately 60% of the population rely on. 21% of the population walks all the way to their place of work. Walking forms an integral part of our daily lives, yet being a pedestrian in South Africa has proven to be dangerous. A third of all fatalities on South African roads are pedestrian fatalities. This poses a need for governmental policies and projects to develop safer non-motorized transport. It has been observed that residential areas, however, seem to be last on the list when it comes to implementation. It is increasingly observed that pedestrians use the roadway for walking in residential areas. Sidewalks form an integral part to facilitate pedestrian access which in turn supports an effective and successful transportation network. This study examined the most important attributes that contribute to the walkability of residential areas to evolve urban planning design solutions for old and new pedestrian infrastructure in residential areas of South Africa. For this purpose, a case study was performed by using Bloemfontein city of South Africa. The study employed a Conjoint Analysis technique, which is a multivariate technique used to understand an individual's preference to identify the levels of importance with regards to sidewalk attributes. Findings suggest that the walkable width of a sidewalk, the number of obstacles in a walkway, the type of material used in a walking surface, and the changes in elevation are the major variables, which to a varied extent influence the number of pedestrians utilizing the sidewalk instead of the vehicle roadway. An optimal level of sidewalk widths and number of obstacles in a sidewalk, along with a comfortable sidewalk surface design and sidewalk elevations, will increase the use of sidewalks and migrate pedestrians from using the roadway towards using the sidewalks.

Keywords: pedestrian infrastructure, non-motorized transport, pedestrian safety, sidewalk utilization.

1. Introduction

The importance of pedestrian-friendly environments has been on the increase lately in the fields of urban planning, transportation planning, and medicine, be it for reasons of health, safety, sustainability or economic growth (Ewing and Cervero, 2000) (Gilderbloom, Riggs and Meares, 2015). For example, the reduction of emissions if a person decides to walk instead of using motorized transport or walking to improve health. The pedestrian environment, however, plays a much larger role and has a significant influence on a micro as well as a macro scale. The pedestrian environment has a big impact on the accessibility and mobility of residents, and in turn, the overall quality and efficiency of a transport network. For example, accessibility is one of the major determinants of the success of public parks and open spaces (Das and Honiball, 2016). Furthermore, a walkable environment produces advantages such as the increase in property values, decreased air pollution, and improved social integration to name but a few (Uysal *et al.*, 2016). Looking at South Africa, which has its own unique challenges, the benefits of a walkable environment can be much more as compared to developed countries.
Since the establishment of the new constitution in 1994, South Africa has been undergoing many transformations with regard to land use, urbanization, and the continuing migration to cities. Migration to cities is the main driver behind the physical growth of cities and the demand for services and infrastructure (Todes *et al.*, 2010). Consequently, there has been a significant increase in pedestrians in and around cities that warrant the need for pedestrian infrastructure. At the heart of a safe effective walkable environment are sidewalks. The importance of sidewalks is not only obvious but also evident throughout walkability research (Saelens and Handy, 2010). Sidewalks provide safety, better street connectivity, and less resistance in terms of walking. Along the same vein, these benefits influence travel time, route selection and ultimately the choice to walk (Tribby *et al.*, 2016).
According to literature, the majority of South Africans rely on walking as a mode of transport. This is evident and can not only be observed in central business districts, but also in and around local urban residential areas. More specifically, it has been observed that pedestrians in local residential areas jaywalk or travel directly on the carriageway. While this behavior is very dangerous, it is quite common. In some instances, pedestrians even obstruct the normal flow of traffic. This poses a hindrance to motorists and as Brysiewicz (Brysiewicz, 2001) points out, it's also a major concern in terms of pedestrian road traffic collisions. Looking carefully, even though the sidewalks are sufficient in width, it is littered with inappropriate urban furniture, poor maintenance, and low-quality materials. Typical examples are built up gardens, uneven driveways, vegetation, unmaintained surface water inlets, etc.
This investigation focuses primarily on the assessment of the built environment that influences pedestrians' choice to avoid sidewalks at a neighborhood level of cities in South Africa. For this purpose, the city of Bloemfontein has been chosen as the study area.

2. Methodology

2.1. Conjoint Analysis Technique

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The investigation comprises of a Conjoint Analysis, a multivariate technique initially developed for marketing research to understand an individual's preference (Green and Srinivasan, 1978). Conjoint Analysis is based on the idea that an individual will trade-off between attributes that make up a specific product before making a final decision. For this study, it was assumed that pedestrians' behavior with regard to sidewalks can be presented in terms of sidewalk's attributes. The recent research by Wicramasinghe and Dissanayake (Wicramasinghe and Dissanayake, 2017) where they applied the Conjoint Analysis technique as an unbiased method to evaluate the attributes influencing pedestrians to evade sidewalks, was used as a basis for this study. The same methodology was followed as outlined by Wicramasinghe et al. (2017) but applied to residential areas instead of central business districts. This evaluation (1) validates the research done by Wicramasinghe et al. (2017), (2) evaluates the method in a different setting, and (3) possibly contribute to research with regard to pedestrian perception and walkability development in South Africa.

2.2. Generating Primary Influential and Independent Sidewalk Attributes

The selection of appropriate attributes used for evaluation emulated from a comprehensive literature study which identified attributes researched internationally as well as locally. Furthermore, the sidewalk attributes identified from physical surveys in Universitas were also taken into consideration.

From reviewing various tools and methods to measure sidewalk elements, the common attributes are the presence of sidewalks, sidewalk width, obstructions, type of surface, and slope (including vertical separation). Similarly, Wicramasinghe et al. (2017) indicate that the width of sidewalks, availability of obstacles, opposing pedestrian flow rate, and availability of safety rails mainly influence the avoidance of sidewalks. However, while developing the first pedestrian environment assessment tool in South Africa, Albers et al. (Albers and Olwoch, 2010) identified essential factors such as pavement material, obstructions, condition, slope, and driveway cuts. To more accurately evaluate actual conditions, as Wicramasinghe et al. (2017) recommend, the sidewalk attributes within the study area were also identified.

After obtaining 319 respondents from a questionnaire issued to pedestrians located in and around the study area, and coinciding it with all available literature, walkable width, number of obstacles within the walkway, the type of surface, and changes in walking elevation were identified as the primary attributes of pedestrians not utilizing sidewalks. Each of these independent attributes were assigned three different levels of influence as shown in Table 1.

Table 1

Primary Sidewalk Attributes and their Different Assigned Levels of Influence

Sidewalk Attribute	Different Levels		
	Level 1	Level 2	Level 3
Walkable Width	> 2m	1-2m	< 1m
Number of Obstacles in Walkway	0	1-5	< 5
Type of Surface	Paved	Gravel	Vegetation
Changes in Elevation of Walkway	0	1 to 3 Changes	> 3 Changes

Typical prominent sidewalk features found within the study area are:

- Changes in elevation due to driveway cuts
- Built up gardens over a portion or full width of the sidewalk
- Various surface material such as paving blocks, short vegetation(grass), fine to coarse gravel.
- A range of obstruction namely trees, signboards, street lighting posts, refusal bins, garden décor, and electrical junction boxes.

The average sidewalk width from 35 measurements was found to be 3.7m wide. Even though the sidewalks within the study area are sufficient in width, the sidewalks are mostly littered with inappropriate urban furniture. Consequently, this results in various widths available for walking, from no space up to full width.

2.3. Creating Conjoint Profiles

To evaluate the selected attributes, hypothetical profiles were compiled with various combinations of the attributes. However, the generation of all possible combinations of these attributes would result in 81 (3x3x3x3=81) profiles. Since Conjoint Analysis uses a ranking response technique, this would be tedious for respondents to the extent that it could compromise the data. To resolve this issue, the use of the statistical method, the orthogonal fractural design was employed. The orthogonal fractional design is a method used to reduce product configurations, while all attributes are arranged to be presented equally and on an uncorrelated basis. The orthogonal fractional design was performed by using SPSS software (version 23). The 81 hypothetical profiles were then reduced to 9 profiles as shown in Table 2.

Table 1
Nine hypothetical profiles generated using orthogonal fractional design.

Card	Walkable Width	Number of Obstacles	Walking Surface	Changes in Elevation
1	<1m	1 - 5 Obstacles	Vegetation	No Change
2	<1m	> 5 Obstacles	Paved	1 to 3 Changes
3	1m-2m	No Obstacles	Vegetation	1 to 3 Changes
4	1m-2m	> 5 Obstacles	Gravel	No Change
5	1m-2m	1 - 5 Obstacles	Paved	>3 Changes
6	>2m	> 5 Obstacles	Vegetation	>3 Changes
7	>2m	No Obstacles	Paved	No Change
8	<1m	No Obstacles	Gravel	>3 Changes
9	>2m	1 - 5 Obstacles	Gravel	1 to 3 Changes

Each hypothetical profile was then constructed into a three-dimensional model by using Google Sketchup Make 2017. Reasonable care was taken to ensure uniformity of each profile to minimize any influence other than the attributes being evaluated. The constructed profiles were then employed in Section 2 of the pedestrian questionnaire for respondents to rank from 1 (most preferred) to 9 (least preferred).

2.4. Compilation, Analysis, and Synthesis of Results

The total number of usable responses to this section of the questionnaire was 284. These responses were compiled and analyzed by means of the SPSS Conjoint Analysis. When executing the Conjoint Analysis, a model to describe the expected relationship between attributes and ranking scores is required. For this analysis a discrete relationship between factors and ranking scores is assumed. A discrete model indicates that the attribute levels are categorical and that no assumption is made about the relationship between the attributes and the ranks.
The Conjoint Analysis produces the relative importance of each attribute. The importance values indicate the importance of an attribute in comparison the other attributes. To derive the importance of an attribute, the amount of difference that each attribute makes in the total utility of a product is considered. That difference is the range in the attributes utility values. Figure 1 illustrates the procedure to calculate the percentage importance from the relative ranges. Importance depends on the particular attribute levels chosen for the evaluation. For example, the larger the range, the more important the attribute would be. The importance measures are ratio-scaled, relative, and study-specific measures. Thus, an attribute with an importance of 60% is twice as important as an attribute with an importance of 30%

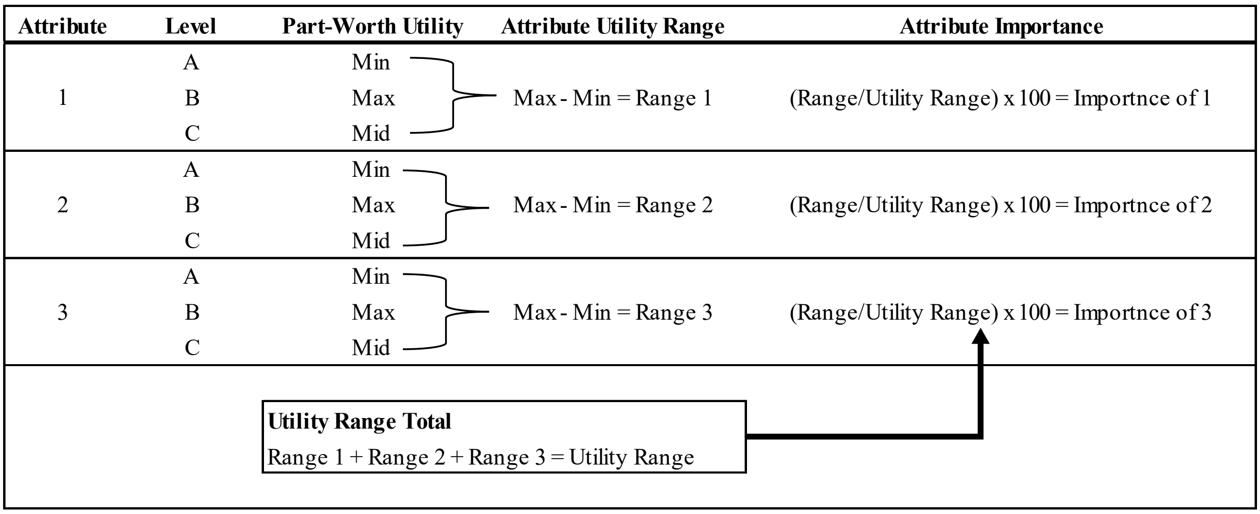

Fig. 1.
Determination of Attribute Importance
Source: (Green and Srinivasan, 1978)

The results of the evaluated attributes are shown in Table 3. As anticipated, Walkable Width (49.4%) and Number of Obstacles (36.6%) were found to have a high relative importance. Interestingly, the results of the Surface (9.6%) and Changes in Elevation (4.4%) attributes are very low in comparison.

Table 3
Conjoint Analysis Results: Importance Values

Importance Values

Walkable Width	49.4%
Number of Obstacles	36.6%
Type of Surface	9.6%
Elevation Changes	4.4%
Averaged Importance Score	

Regarding the use of a sidewalks, walkable width was found to be the most important attribute. The second most important attribute was found to be the number of obstacles. Number of obstacles, in this case, is closely related to walkable width due to large obstacles that often reduce the walkable width on a sidewalk. The more surprising result is the number of obstacles being four times as important as the surface material. Finally, the surface material was found to be twice as important as changes in elevation.
It is critical, however, to understand the importance of each attribute when evaluating the results of the part-worth utilities. Part-worth utilities allow for a deeper understanding of what specific features within an attribute drives a respondent's choice. Part-worth utilities are numerical values assigned to each attribute level in terms of how much each attribute and level influenced the respondents to make that choice. Attribute levels that are more preferred by customers are assigned higher scores and levels that are less preferred are assigned lower (in comparison) scores.
It is important to note that, these part worth's are relative. If an attribute level received a negative utility value is does not mean that the attribute level was unattractive. In fact, an attribute level with a negative value may have been accepted by all respondents. But, all else being equal, a more positive value is better. Part-worth's in the Conjoint Analysis technique are scaled to an arbitrary additive constant within each attribute and are interval data. Utilities are thus scaled to sum to zero within each attribute. The results for the relative and individual part-worth utilities are summarized in Table 4.

Table 4
Conjoint Analysis Results: Part-Worth Utilities

Part-Worth Utilities		
Attributes	**Attribute Levels**	**Utility Estimate**
Walkable width	>2m	1.329
	1-2m	-.007
	<1m	-1.322
Number of Obstacles	No Obstacles	1.194
	1 - 5 Obstacles	-.424
	> 5 Obstacles	-.770
Surface	Paved	-.180
	Gravel	.335
	Vegetation	-.155
Elevation Changes	No Change	.122
	1 to 3 Changes	-.113
	>3 Changes	-.009
(Constant)		5.000

What stands out in the table is the range of the walkable width. More than 2m was found to be the most desirable attribute and less than 2m was found to be least desirable attribute in relation to the other attributes. This also indicates the importance of the attribute (see Table 3). Another observation is that the walkable width attribute levels seem to have a logical and relative linear relationship.
The number of obstacles is the attribute with the second highest importance (see Table 3). The attribute levels indicate a logical increase in importance with more than five obstacles being the least important, followed by one to five obstacles, and then of highest importance, no obstacles. In relation to the other attributes and their attribute levels, no obstacles were found to be the second most important attribute level.
At first, the results of the surface material seem to be counter intuitive, with gravel material receiving a higher preference score than paved material. Similarly, vegetation material also has a slightly higher value than paved material. The main reason for this is the nature of the conjoint generated profiles. The conjoint profiles are generated to equally represent all attribute levels in an uncorrelated manner. Thus, resulting in attribute level combinations that forces the respondent to choose the most preferred attributes while sacrificing other attributes of less importance. For example, conjoint profile card nine with gravel surfacing and a width of more than 2m could be chosen over profile card two with a paved surface and a walkable width of less than 1m. In relation to the walkable width and number of obstacles, the importance of surface material was found to be very low and therefore seemingly disregarded.

Similar to the surface material, changes in elevation even more so, were identified as the least important attribute. Looking carefully, more than three changes in elevation received a higher importance score than one to three changes in elevation. This is also due to the combination of attributes in the generated conjoint profiles as mentioned under surface material. The part-worth utilities for the changes in elevation is very low and would therefore make little difference in calculating Total Utility Values.

2.5 Study Area

The Universitas neighborhood has been identified as a suburb where the identified problem of pedestrians using the roadway for walking is quite prominent. From site observations and surveys it was found that in some instances pedestrian even obstruct the normal flow of motorized traffic. Although there are sidewalks present, these sidewalks are not pedestrian friendly. To further investigate the issue, other residential suburbs in Bloemfontein were evaluated and compared to Universitas. Trip generating destinations were identified and compared, namely schools, universities, shopping centers, churches, retirement villages, residential homes, public parks etc. Additionally, other factors affecting pedestrians were considered, namely population, size, type of accessibility, and a thoroughfare for pedestrians.

From evaluating the 35 neighborhoods in Bloemfontein, Universitas was found to be ideal for this investigation. Universitas is very diverse in terms of trip generating destinations, it is the largest neighborhood in the city, and consists of a large number of pedestrians avoiding sidewalks. Universitas also seemingly sufficiently represents other neighborhoods in Bloemfontein.

Universitas has an area of 9.66 square kilometers and is located on the south-western side of Bloemfontein, the suburb holds major sub-arterial roads connecting adjacent neighborhoods to each other and to the business district. Consequently, Universitas acts a thoroughfare for motorists and pedestrians. Residents mostly stay in stand-alone houses, apartments, and townhouses. The University of the Free State with 37 000 enrolled students is also located in this suburb, and the growing number of students has been a major contributor to the increase in residents over the past few years. Many houses have been converted to student housing to accommodate this increase. Along with students, the overall income level of Universitas is medium to high. Schools within and directly adjacent to the suburb are Universitas Primary school, Greys College Secondary school, Eunice Secondary school, and Dr. Bohmer Secondary school. Other present trip generating destinations making Universitas pedestrian-rich is two retirement villages, five churches, two shopping centers, twelve public parks, and two hospitals.

2.6. Calculating Total Utility Value at Selected Locations of the Study Area

The part-worth utility index derived in the previous section was used to calculate the Total Utility Value of the selected sidewalks locations by making use of equation (1). The Conjoint Analysis theory states that the product (in this case, sidewalk) that receives a higher Total Utility Value than the other products will be considered more valuable (Green and Srinivasan, 1978).

$$\text{Total Utility Value } U(Xij) = \text{Constant} + \sum_{i=1}^{m} \sum_{j=1}^{k_i} u_{ij} X_{ij} \quad (1)$$

U(Xij)	=	Total utility of an alternative
m	=	Number of attributes
ki	=	Number of levels in ith attribute
uij	=	Utility associated with jth level of the ith attribute
Xij	=	Dummy variable that takes on 1 if the jth level of the ith attribute is present or 0 other

After matching appropriate attribute levels at each location, the Total Utility Value of all eleven locations were calculated (see Table 6). Table 5 shows an example of how the Total Utility Value is calculated at location 8

Table 5

Example of calculating Total Utility Value at a location

Attribute	Applicable Attribute Level	Part-Worth Utility	Sum	Conjoint Constant	Total Utility Value
Walkable Width	> 2m	1.33	2.33	+ 5	= 7.33
Number. of Obstacles	None	1.19			
Surface Material	Paved	-0.18			
Elevation Changes	None	-0.01			

Table 6

Attribute levels and Total Utility Value of each selected location

Location	Walkable Width (m)	Number of Obstacles	Surface Material	Elevation Changes	Constant	Total Utility

										Value
1	1-2	-0.01	> 5	-0.77	Veg.	-0.15	1 to 3	-0.11	5	3.96
2	1-2	-0.01	1 – 5	-0.42	Veg.	-0.15	None	-0.01	5	4.40
3	>2	1.33	> 5	-0.77	Gravel	0.33	1 to 3	-0.11	5	5.78
4	>2	1.33	1 – 5	-0.42	Paved	-0.18	1 to 3	-0.11	5	5.61
5	>2	1.33	> 5	-0.77	Veg.	-0.15	1 to 3	-0.11	5	5.29
6	1-2	-0.01	> 5	-0.77	Gravel	0.33	1 to 3	-0.11	5	4.44
7	<1	-1.32	1 - 5	-0.42	30% Gravel 70% Veg.	-0.01	None	-0.01	5	3.24
8	>2	1.33	None	1.19	Paved	-0.18	None	-0.01	5	7.33
9	<1	-1.32	1 – 5	-0.42	Gravel	0.33	None	-0.01	5	3.58
10	>2	1.33	1 – 5	-0.42	40% Paved 60% Gravel	0.13	None	-0.01	5	6.02
11	<1	-1.32	1 – 5	-0.42	Veg.	-0.15	1 to 3	-0.11	5	2.99

2.7. Pedestrians' Preference Score Calculation

Pedestrian preference was collected with the third section of the questionnaire. Each respondent had to indicate how likely they would make use of the selected location by selecting a value from 1 (least likely) to 5 (most likely). While summarizing the answers from 287 respondents, using equation (2) the pedestrian preference score was calculated for each location.

Pedestrian Preference Score = $= \frac{1}{n}\sum_{i=1}^{n}(\mathbf{WTC})_{ij}$ (2)

$(WTC)ij$ = Willingness to use at the j^{th} sidewalk by i^{th} respondent
N = Number of respondents

Table 7 shows the calculated pedestrians' preference score for each location. The column PPS Rank, ranks the pedestrians' preference score in ascending order from the most preferred sidewalk to the least preferred. The pedestrians' preference score is compared and evaluated against the calculated Total Utility Values of each location and shown in Figure 2.

Table 7
Pedestrians' preference score for each location

Location	Street Name	PPS	PPS Rank
1	Stofberg Street 1	2.53	9
2	Stofberg Street 2	2.87	5
3	Graniet Street	3.80	4
4	Paul Kruger Avenue	4.01	2
5	Tommy Border Street	2.70	8
6	De Bruyn Street	2.73	7
7	Walter Sisulu	1.92	11
8	Christoffel Du Plessis Street	4.22	1
9	Scholtz Street	2.81	6
10	Weitz Street	3.93	3
11	Magneet Street	2.15	10

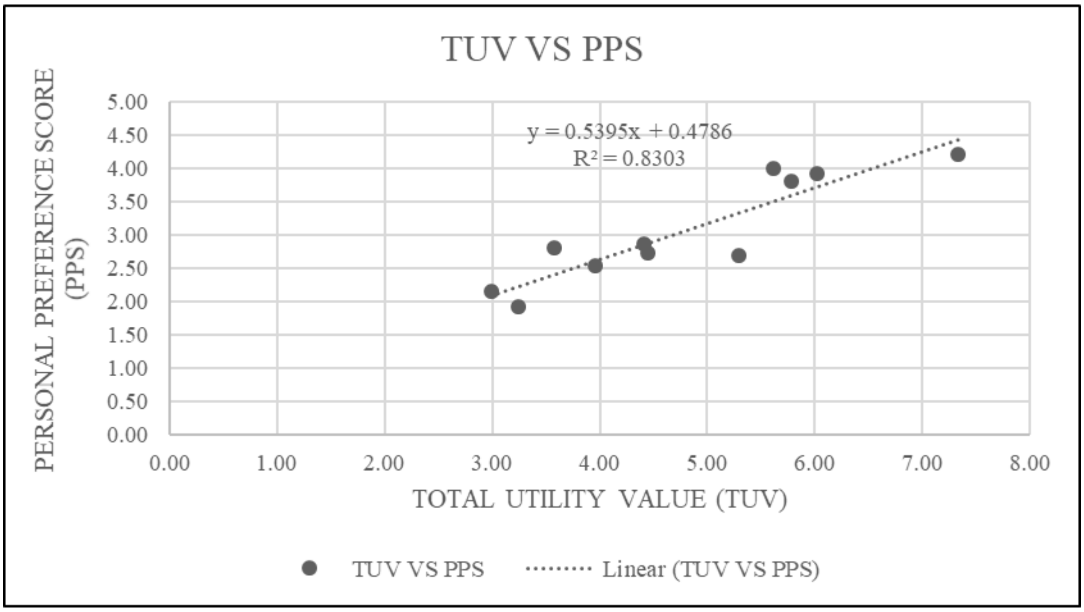

Fig. 8.
Regression between Total Utility Value and Pedestrians' Preference Score for each of the 11 locations

Finally, a correlation and regression analysis were done to evaluate the relationship, if any, exists between the Total Utility Value and Pedestrians' Preference Score for each sidewalk location. The calculated Total Utility Value and Pedestrians' Preference score were plotted on scatterplot graph for each location in Table 8.
There was a significant positive correlation found between the Total Utility Value and Pedestrians' Preference Score. The Pearson Correlation (r) of the two data sets show a strong positive linear pattern with a strength of 0.91. The positive linear pattern indicates that when the Total Utility Value increase or decrease, that the Pedestrians' Preference Score will do the same.
Thereafter, a regression analysis revealed that the data fits the linear model well with The Total Utility Value explaining 83% (R-squared) of the variability of the Pedestrians' Preference Score. Therefore, similar to the findings of Wicramasinghe and Dissanayake (Wicramasinghe and Dissanayake, 2017) the linear model indicates that the Total Utility Value can be used to predict how likely a pedestrian would use a specific sidewalk.

3. Conclusion

The results of the Conjoint Analysis provide important insight into the use of sidewalks and the avoidance thereof. In summary, the results show that a walkable area with no obstacles is the most preferred scenario. Moreover, a walkable width of more than 2m was found to be the most desirable attribute. The most striking result to emerge from the data is the importance of surface material and changes in elevation. In relation to walkable width and number of obstacles, the surface material and changes in elevation was found to be less important.
We can also conclude that obstructions in the sidewalks are the biggest detergent for pedestrians, which is understandable given that some obstructions are physically impossible to maneuver through. Once Pedestrians circumnavigate obstacles on the sidewalks by stepping into the roadways, they tend to remain in the roadway instead of returning to the sidewalk, which is why they prefer 0 obstacles on the sidewalks in which they would like to travel.
Home owners are the biggest contributors to creating sidewalk obstacles, and collaborative efforts will need to take place between city planners and home owners to create sidewalks in residential areas that are obstacle free.

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A GIS-BASED MULTI CRITERIA APPROACH FOR THE DESIGN OF A CYCLING NETWORK IN THE CITY OF CATANIA

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Abstract: Cycling mobility is a widespread mode of travel around Europe, in particular in countries with a high level of well-being. Italy takes realistic distances from these standards: the cities of the peninsula do not support the comparison with European models; in particular, the city of Catania, although in possession of some cycling tracks and promiscuous routes, still does not have a cycling network, since existing paths are not connected to each other. Even if literature on cycling and its planning is spreading, there is still poor research on decision making processes to prioritize and choose locations for investing in cycling infrastructure. The purpose of this study is to provide a multi criteria approach for the design of a cycling network, based on the use of Geographic Information System, in the context of a middle size city. The main objectives are the introduction of a methodology that allows to design a cycling network through the support of a GIS software; the characterization, through this methodology, of a road network based on a set of evaluation criteria that will determine the degree of cycling compatibility of each road segment; the assessment of the adequacy of the road paths for the realization of a cycling track. The GIS-based vector-model includes readily-available data sources in an easily interpretable graphical format suitable for decision-makers and the public and it aims at supporting bicycle facility prioritization and location.

Keywords: cycling mobility, sustainable transport, spatial planning.

1. Introduction

The sustainable mobility concept is nowadays an integral part of the urban transport policy of cities. It is considered a useful tool to counteract car dependency of our cities, as a clear consequence of a model of society based on the waste of economic, social and environmental resources. It is in this context that cycling mobility is becoming a sustainable way to move spreading all over the world.
Netherlands and Denmark in Europe are the most advanced countries in terms of cycling mobility and well-being as well. Italy takes realistic distances from these standards: about 3.5 million people in Italy cycling for traveling in the city (10%), to go to work (20%) and for leisure and/or to exercise (70%).
Cycling daily as a valid alternative to car mobility, requires dedicated infrastructures and routes with specific characteristics. It is of fundamental importance to guarantee safe cycling paths in urban areas (Rhodes, 2014) allowing easy access to the main daily destinations: schools, workplaces, parks, shopping and health centers.
Planning and designing of cycling infrastructure is confronted with two seemingly conflicting needs (Julien, 2000). The first expresses a holistic approach in which the entire road network must be fitted to cyclists (and pedestrian) through the sharing of urban space between pedestrians / cyclists and motorized vehicles, thanks to the adoption of traffic moderation systems. The second considers the infrastructures for cycling mobility as an additional network dedicated and separate from the existing road network. Cycling and motorized traffic are considered incompatible; the risks deriving from the speed gap between motorized modes is solved by segregating the cycling flows on separate and protected routes.
In cities where cycling mobility takes its first steps and motorized traffic is rather aggressive, the presence and quality of the infrastructures for cycling mobility are a fundamental element. Having clear these premises, the design of a cycling network has to be deployed as an interconnected set of safe routes, direct and continuous, serving a given urban area. It should be stressed that we are talking about itineraries (or routes) and not of tracks or lanes, in the sense that the quality of a network of itineraries must transcend that of the individual segments and be independent of the type of infrastructure, for example a separate track. The essential quality of the network is the ability to move along uninterrupted routes that respond as closely as possible to the requirements described below (LDCS, 2014):

- be safe, to reduce the risk, even if only perceived, especially at the intersections
- connect relevant points of origin and destination, to prevent the bicycle being used (only) for recreational and sporting activities
- be as direct as possible to reduce travel time and make the bicycle more convenient than other modes
- be continuous, logical, without unnecessary obstacles, deviations and interruptions, conceived in a holistic way precisely as part of a network
- be equipped with an adequate ride comfort, with flat, regular floor surfaces, and in a good state of maintenance
- be consistent, that is, legible, intuitive and inclusive
- contributing to the attractiveness and quality of the public space passed through
- be flexible, suitable for all types of bicycles and adequate to sustain a growth in the number of users over time

GIS software platforms can play a valuable role to embed most of the above requirements in a unique development environment to assist a multi-criteria design approach of a cycling network. Several studies use the GIS geo-referencing

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software for cycling planning. For example, a study carried out on the city of Athens, a cycling network is planned according to three successive steps: the identification of the main attractors, the development of a cycling network and the evaluation of cycling paths through evaluation criteria (Mikalis et al., 2012). The evaluation criteria focus on the different aspects of cycling mobility: physical effort of the cyclists during the journey, density of junction, intensity and speed of traffic, legibility of the routes, spatial coverage of the network, proximity to the main points of interest, etc. Through the software it is possible to associate the values of the different criteria to the different arcs. In this way, it is possible to create an easy-to-read map that allows anyone to understand which paths are suitable for a cycling network. A study by Rhodes (2014), after identifying the Origin-Destination pairs using the census areas, select the lines of desire according to the criterion of choosing the shortest path and then going to the calculation of the maximum and average slope; after acquiring this information, the planner finally assigns weights to the various factors to identify the best routes for the construction of a cycling network. Another aspect that should not be underestimated is that of the attractiveness of places: a cyclist, during his ride, must be able to cross pleasant and not crumbling places. A study conducted in the Czech Republic (Bìl et al., 2012) has developed a Unified GIS Database of Cycle Infrastructure (UDCI) with the aim of creating a unified system of cycling routes, increasing the safety of cycling routes and promoting cycling mobility inserting all the attractiveness present in the database. In all of these studies, analyzes are carried out taking into account various evaluation criteria which, in addition to have a design nature, have also a qualitative in nature.
The city of Catania, located in the south of Italy, currently has seven quite bumpy cycling paths, for a total of 14,200 m: it is not a real cycling network in strict sense. Furthermore, most of these routes are mixed traffic. The purpose of this study is to provide a GIS based multi-criteria approach for designing a cycling network, that even if applied to a particular case study, could be potentially scaled to any other urban context.

2. Current Cycling Paths in Catania

Catania is a city of about 300.000 inhabitants, located in the eastern part of Sicily (Southern Italy); it has an area of about 183 km2 and a population density of 1.754,54 inhabitants / km2. It is part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania. The main city contains most of the working activities, mixed with residential areas. Currently there are seven cycling routes in Catania (Fig. 1); two of them stretch across the Ionian coast (2 and 7), the others are located in the center of the city. These paths are extremely disjointed, and most of them share the bus lanes (1, 3, 4, 5).

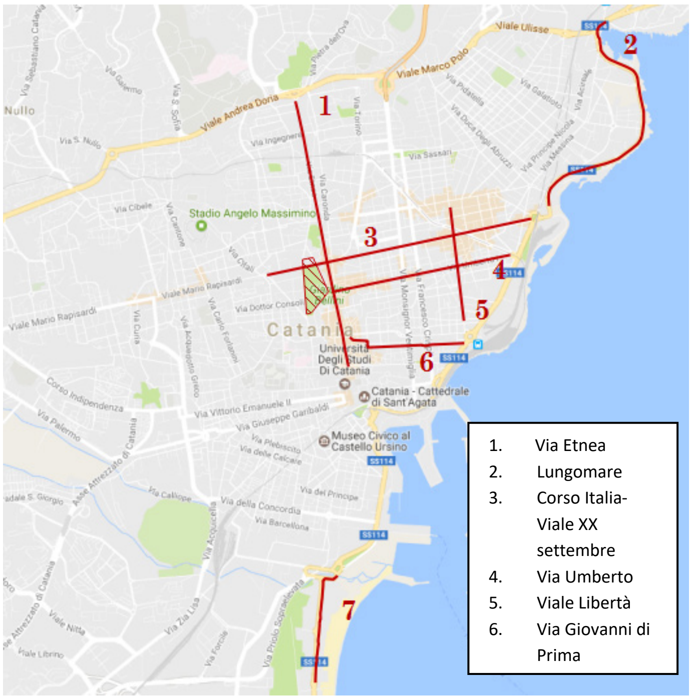

Fig. 1.
Current cycling paths in Catania
Source: Own elaboration

3. Methodology

The application of the methodology involves the calculation of a Global Compatibility Index, which, based on different spatial criteria, allows the selection of the road arcs most suitable to be included in a cycling path. The approach aims at evaluating the compatibility of the arcs for the construction of safe, low-hanging routes with low speed and low intensity car traffic. Moreover, the routes must be able to guarantee easy access to the main destinations: schools, workplaces, parks, places of attraction, etc.; aspects related to the attractiveness of the places crossed by the cyclist will also be evaluated. Based on similar studies carried out in other international cities (Malakis et al., 2012; Malakis and Athanasopoulos, 2014; Rhodes, 2014), in this design procedure, the calculation of the Global Compatibility Index is based on the following criteria: intensity of vehicular traffic; speed of vehicular traffic; state of the buildings; points of interest; number of employees. The values for all of these criteria are attributed to road arcs of Catania within the QGIS software, which is an Open-Source GIS for managing, visualizing, modifying, and analyzing geographic data. The data provided represent streets network, points of interest and geo-referenced census areas in the WGS 84 reference system (Fig. 2):

- The census areas are those published by the Italian Statistic Institute ISTAT;
- The road network is taken from the General Urban Traffic Plan (PGTU) data of the Municipality of Catania;
- The points of interest were exported through the Openstreetmap website service;

In the following sections thematic maps of the evaluated criteria are presented. Some of the criteria used have been derived from similar studies in the cities of Athens and Seattle (Malakis & Athanasopoulos, 2012; Malakis & Athanasopoulos, 2014; Rhodes J, 2014), others have been elaborated starting from considerations about what a cyclist might require from the path.

Fig. 2.
Study area and network model used for analysis
Source: Own elaboration

Our analysis focuses exclusively on the territory of the municipality of Catania, without taking into account connections with neighboring municipalities. Also for this reason, the presented model must be read as an example of design, and not as a definitive project.
Hereby follow the calculation and spatial representation on a map of each criterion included in the calculation of the Global Compatibility Index, as means to evaluate the adequacy of each road segment to be part of a cycling path. The values relating to each criterion have been normalized using a simple linear function, to obtain values between 0 and 1:

$$V'_{ij} = \frac{V_{ij}-V_{min}}{V_{max}-V_{min}} \tag{1}$$

Where: V_{ij}'= normalized value for crtierion i in path j; V_{ij}= for crtierion i in path j; V_{min}= minimum value for crtierion i V$_{max}$= maximum value for the i crtierion i.

3.1. Evaluation of Indices

The first two indices evaluated are *traffic intensity* and *traffic speed*. The first index is equal to the number of vehicles per hour; the second one is measured as average vehicle speed (Fig. 3).

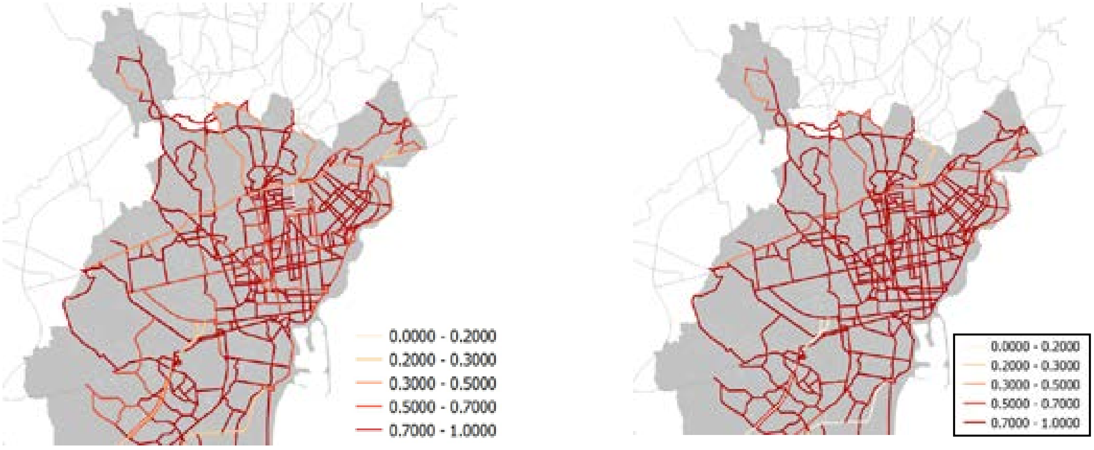

Fig. 3.
Traffic Intensity (a) and Traffic Speed (b) indices
Source: Own elaboration

The *State of the Buildings* (SoB) index evaluates the quality of the urban architectural environment of the route. ISTAT informs about the number of buildings in good, well, mediocre and bad conditions in each census area. It is therefore possible, given the areas crossed by cycling routes, to make a weighted average of the values:

$$SoB = \frac{4NO_i + 3NB_i + 2NM_i + NP_i}{NE_i} \tag{2}$$

Where: NO_i= Number of buildings in perfect conditions; NB_i= Number of buildings in good conditions; NM_i= Number of buildings in mediocre conditions; NP_i= Number of buildings in bad conditions; NE_i= Total Number of buildings
The data provided by ISTAT, related to census tracts, is showed in , where green corresponds to the best condition, the red to the worst. Then, the QGIS Intersect tools, which allows to exclude the area that is not overlapping, was used to transfer the data to the arches (Fig. 4).

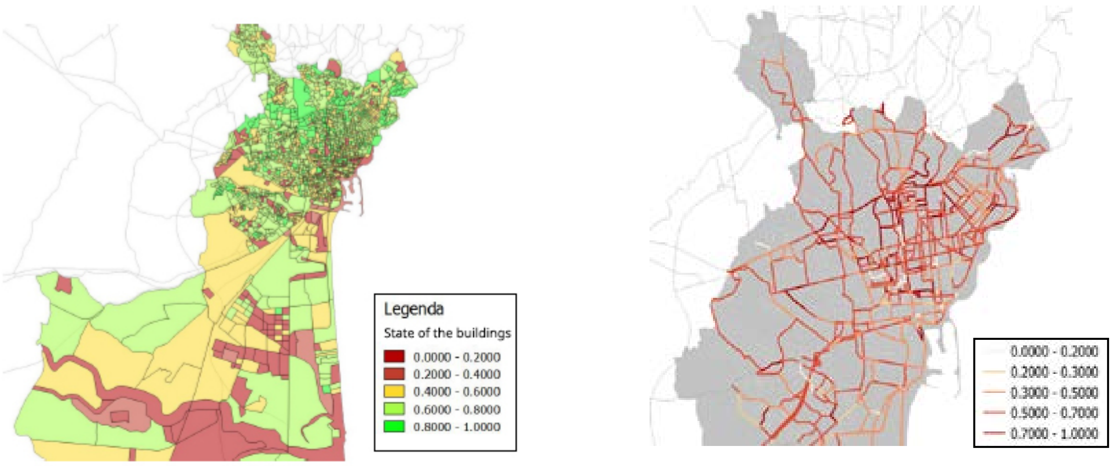

Fig. 4.
State of The Buildings for census tract (a) and map intersection with road network (b)
Source: Own elaboration

The *Points of Interest* (PoI) criterion describes the number of points of interest that fall within a radius of 200 meters from the axis of the road. Points of interest considered belong to various categories: entertainment venues (bars, restaurants, cinemas, theaters), education (university and schools), places and public offices (car parks, post offices, police, places of worship, social centers). To evaluate the index for points of interest, all the points for the municipality of Catania were selected and all of them within 200 meters from each road arc were counted through the QGIS analysis tool. Then the calculated value was attributed to each arc by the QGIS intersect tool (Fig. 5).

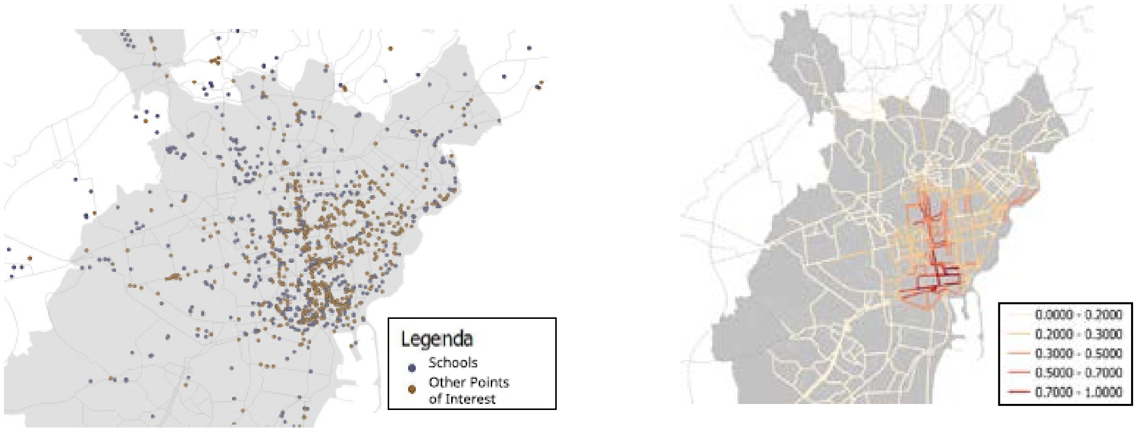

Fig. 5.
Points of Interest (a) and map intersect with road network (b)
Source: Own elaboration

For what concerns the *number of employees* criterion, data provided by the ISTAT has been processed. This information, as in the case of the *state of the buildings*, refers to census areas. An intersect procedure was performed to transfer the spatial information to the arc (Fig. 6).

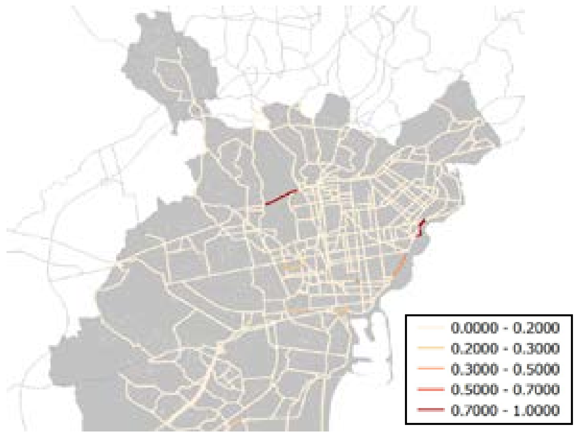

Fig. 6.
Map intersect with road network of number of employees' index
Source: Own elaboration

3.2. Evaluation of Compatible Arcs

After the analysis of each criterion a Global Compatibility Index (GCI) for each arc *i* has been calculated as the sum of the contribution brought by each normalized criterion variable:

$$GCI_i = V_i + S_i + SoB_i + PoI_i + E_i \tag{3}$$

Where: V_i= Traffic Volume criterion for arc *i*; S_i= Traffic Speed criterion for arc *i*; SoB_i= State of Building criterion for arc *i*; PoI_i= Points of Interest criterion for arc *i*; E_i= Number of employees' criterion for arc *i*.
Based on the results of the Global Compatibility Index, arcs have been classified into three levels of cycling compatibility and reported in Table 1. Thematic maps of arcs' compatibility are presented in Fig. 7.

Table 1
Classification of arcs according to compatibility

GLOBAL INDEX OF COMPATIBILITY OF α	COMPATIBILITY
0,7≤α<1,6	Poor compatibility
1,6≤α<2,5	Medium compatibility
2,5≤α<3,4	High compatibility

Source: Own elaboration

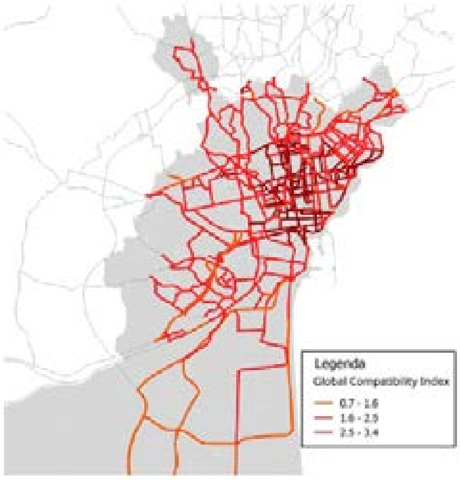

Fig. 7.
Map of the Global Compatibility Index
Source: Own elaboration

Fig. 8.
Map of arcs with low compatibility (a), medium compatibility (b), high compatibility (c)
Source: Own elaboration

As we can see form the maps in Fig. 8, the cycling compatibility of the arcs decreases as we move from the center of the city to the suburbs. The chart in Fig. 9 shows the seven classes of compatibility and the total arc's length in kilometers in each class.

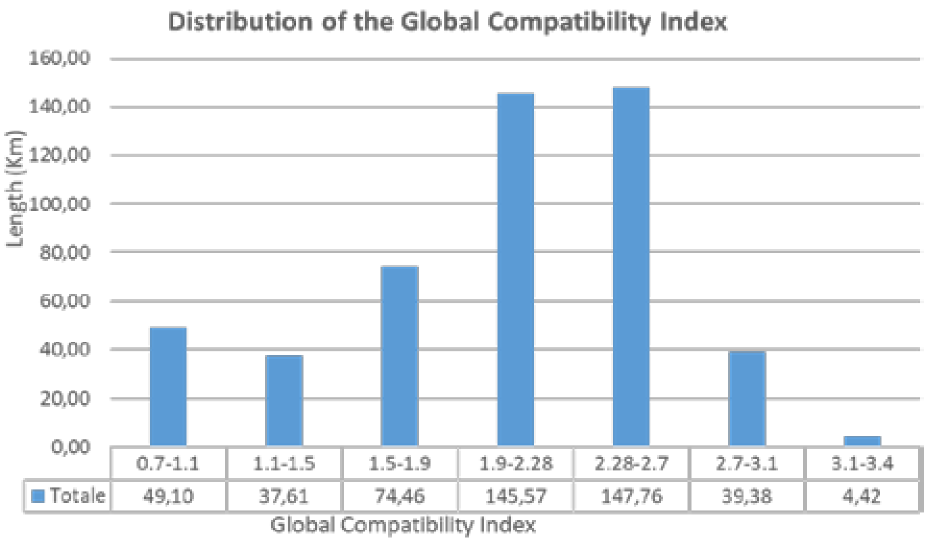

Fig. 9.
Distribution of the Global Compatibility Index
Source: Own elaboration

4.7. Slope Verification

The slope of a given cycling path segment is a key parameter of the planning of a cycling network. For this reason, the verification of the compatibility of the cycling routes with respect to the slope is performed separately from the calculation of the Global Compatibility Index. It is easy to understand that for long distances it is preferable to have little slopes; for short distances, however, higher slopes can be tolerated, while respecting the minimum standard provided by the technical norms. The ASSHTO guidelines (AASHTO, 1999) suggest the allowable slopes for short distances, according to Table 2.

Table 2
Maximum values of the slope for a cycling ramp

Slope	Maximum length of the ramp (m)
5%-6%	240
7%	120
8%	90
9%	60
10%	30
>10%	15

Source: AASHTO, 1999

In the present case study, more restrictive values were used, according to the following rules:
- For ramps of <100 m length, gradients< 5% are allowed;
- For ramps of <200 m length, gradients <3.5% are allowed;
- For ramps of length> 200 m, gradients <2% are allowed.

Based on this analysis, a thematic map of the arc slopes of has been elaborated. Then a verification of gradients on arcs in relation to the three different levels of compatibility have been performed and a thematic map have been realized (Fig. 10).

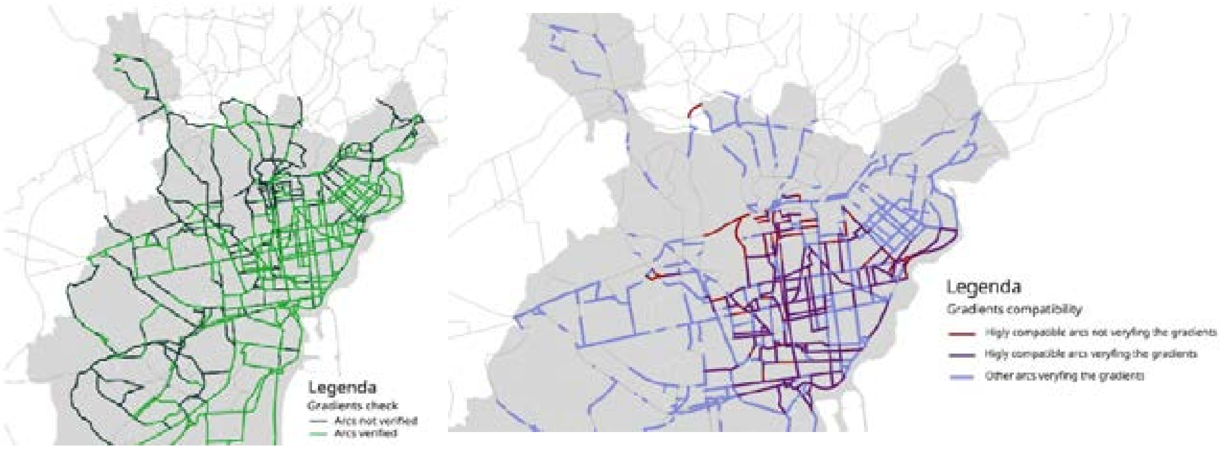

Fig. 10.
Arcs slope check verification and arcs verifying slopes check according to their compatibility
Source: Own elaboration

5. Result and Conclusions

The methodology outlined in this study, based on the Global Compatibility Index analysis and the verification of slopes and road widths, has led to the proposal of a new cycling network to be included into the transport system of the city Catania (Fig. 11).
The methodology used in this study allowed the combination of several attributes into a single compatibility index through a GIS-based bike planning analysis. Results show how GIS can be used to aid the planning of additions to an existing cycling network. The methodology described can be improved in order to increase accuracy by including all fixed-route transit stations, stops, and terminals. In addition, a bike demand analysis taking into account demographic information of residents and workers could be also included in future researches.

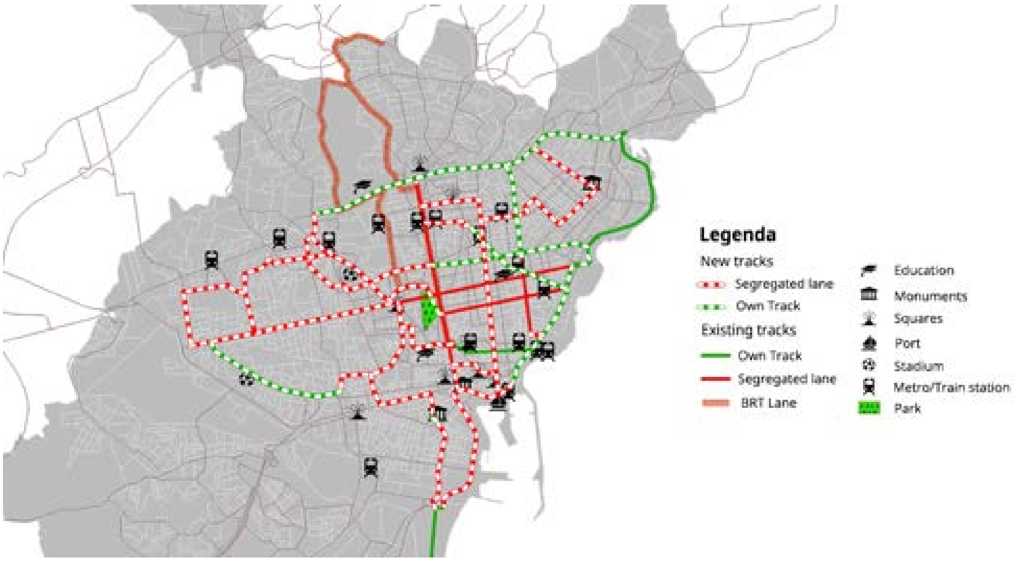

Fig. 11.
Proposal of new tracks according to GIS analysis results
Source: Own elaboration

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IMPROVEMENT OF THE METHODOLOGY FOR CALCULATING POLLUTION CAUSED BY ROAD VEHICLES

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Abstract: Most road streams pollute with harmful combustion engine exhaust and noise. We can reduce pollution in cities by applying tax or preferential policies, increasing the demand for renewable resources and introducing road safety measures. In order to reduce these emissions, effective methods for calculating and evaluating pollution caused by road vehicles are needed. A city-specific pollution estimation methodology allows to select optimal measures for transport policy development, therefore it is necessary to improve the existing calculation methodology. The article reviews the calculation methods, introduces the adjustments and presents SWOT analysis.

Keywords: road transport, vehicles, city, pollution, methodology.

1. Introduction

Several models used for analyzing environmental pollution may be applied attributing polluting cars to individual pollutants (Adacher & Tiriolo, 2018), (Akgunduz & Kazerooni, 2018). Microscopic pollution models (Yu & (David) Fan, 2017), (Heeroo, Gukhool, & Hoorpah, 2016), such as LASAT (Hirtl & Baumann-Stanzer, 2007) and MISKAM (Cai, Zhong, Wang, Chen, & Zeng, 2017), can be applied using direct data. These models reflect environmental pollution quite accurately, but are not suitable for large data amounts. Both of these models are suitable for analyzing small urban areas where transport emissions are static (Cai et al., 2017). Also was presented adapted the CALPUFF urban pollution model for multi-purpose simulation environment (Holnicki, Kałuszko, & Trapp, 2016). The CALPUFF model is used as a source of input data for MATSIM model (Novosel et al., 2015).

Semi-parametric models of local pollution simulation, such as CPBM (Canyon plume box model) (Solazzo, Vardoulakis, & Cai, 2007) and OSPM (Operational street pollution model) (Rzeszutek, Bogacki, Bździuch, & Szulecka, 2018), are usually used for modelling pollution of the street territory. These models allow reducing the time spent on the analysis of environmental pollution, and there are almost no uncertainties interfering with achieving accurate results. The accuracy and accessibility of input data is directly proportional to the objectives of the study and the pursued results, and they determine the selection of the model.

Some scientists propose environmental protection offers an innovative solution in modelling car pollution and presents an optimized model (Lazić, Urošević, Mijić, Vuković, & Ilić, 2016). This solution consists of combining the MATSIM multi-purpose simulation environment method and the macroscopic method intended for the analysis of environmental pollution in the street (Novosel et al., 2015). This allows expanding the boundaries of the territory of the study area and significantly increasing the traffic flow. Such an integrated model makes it much easier to track environmental pollution in the city, to formulate environmental policies, forecast costs and investments in transport infrastructure.

Such factors as safe road traffic, has almost no impact on drivers regulating their speed (Oviedo-Trespalacios, Haque, King, & Washington, 2017). Drivers are mostly intimidated by the likelihood of traffic accidents and fines for speeding. The researchers say that a new idea may be used to increase the effectiveness of the above measures. Such arguments as environmental protection are believed to also motivate responsible drivers to refrain from speeding. The scientific article overviews some of the driving factors causing environmental pollution (Oviedo-Trespalacios et al., 2017). First of all, this is the connection between the way people think about environmental issues and the use of cars. For example, one out of three trips is shorter than 3 km in cities. During such a trip, excess fuel consumption may be broken down as follows: + 80 % in the first kilometre; + 50 % the in second kilometre and so on.

Additional fuel consumption increases CO_2 and NO_x emissions or, to be more exact, higher speed increases pollutant emissions into the environment. Having increased driver awareness and forced them to reduce their speed, reducing environmental pollution and fuel consumption is possible (He, Zhang, Wang, Hao, & Ding, 2018). Although the idea is a good target, environmental pollution problems are very unlikely to cause Lithuanian drivers to reduce speed.

Road transport emissions are highly dependent on engine operation conditions. Different driving situations result in different engine operation conditions and the resulting emissions. In light of the above, conditions of driving in the city, suburbia and on the highway are distinguished in terms of speed changes. Distinguishing different driving conditions is consistent with the EMEP / CORINAIR methodology (Maes et al., 2009), (Monforti & Pederzoli, 2005). Different performance data and different emission factors are attributed to each driving condition. Also, cold start emissions are calculated under conditions of driving in the city, because the vast majority of vehicles is assumed to start their trip in cities. Thus the total emission is:

$$E_{sum} = E_{urban} + E_{suburbia} + E_{highway}; \quad (1)$$

where: $E_{\_urban}$ – pollution of vehicles driving under urban conditions;

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$E_{\_suburbia}$ – pollution of vehicles driving under suburban conditions;
$E_{\_highway}$ – pollution of vehicles driving on highways.

Several methodologies have been created to calculate road transport pollution (Saharidis & Konstantzos, 2018), which are based on similar principles, however different pollution results are possible due to different input data. One of the methodologies for analyzing traffic pollution in the city is the methodology based on average annual traffic intensity. The following are the main stages of the methodology:

- Determining average traffic intensity in separate road sections (cars per day);
- Determining average speed of traffic in individual road sections;
- Determining average values of road transport emissions (g/km);
- Calculating emissions and their level in individual sections of the road.

The following is a simplified pollution calculation model having applied the said stages:

$$\left(\frac{RI \cdot VMPEI \cdot EVV}{100}\right) \cdot 365\ ; \tag{2}$$

where: RI – the length of the road section;
VMPEI – average annual daily traffic intensity;
EVV – average speed pollution on the road section.

The application of new methods to reduce environmental pollution from road transport vehicles has already started. The methods applied include:

- Engines of new types, such as gasoline direct injection (GDI), controlled auto–ignition (CAI) or homogeneous charge compression ignition (HCCI);
- Use of new types of fuels (CNG, hydrogen, fuel with additives);
- Use of alternative power, such as hybrids, rechargeable hybrids, fuel cell vehicles or electric vehicles..

2. Methods for Calculating Pollution Caused by Road Vehicles

There is a number of methods that allow calculating vehicle pollution, but some of the most popular ones include:
One-tier method. Conditions of application of the method. The method is used when fuel consumption and specific emission factors of a vehicle are known. Having these data alone, applying a one-tier method is most efficient (Pereira et al., 2017). The following is the algorithm of the first tier method:

$$E_i = \sum j\left(\sum m\left(FC_{j,m} \cdot EF_{i,j,m}\right)\right)\ ; \tag{3}$$

where: $E_{\_i}$- emission of i pollutant [g];
$FC_{\_(j,m)}$ – fuel consumption by vehicle category j and the fuel used m [kg];
$EF_{\_(i,j,m)}$ – specific exhaust emission factor depending on the vehicle category j and fuels used m [g/km].

Vehicle categories: passenger cars; small cars; heavy road transport; motorcycles and mopeds.
One-tier specific exhaust emission factors are calculated using COPERT III software package, which is based on a three-tier model calculation methodology (Ekström, Sjödin, & Andreasson, 2004).
Two-tier method. Conditions of application of the two-tier method (Zhu et al., 2017). This method is used when fuel consumption data and pollution values determined by pollution standards of road vehicles are known. The following is the two-tier method algorithm:

$$E_i = \sum k\left(N_{j,k} \cdot M_{j,k} \cdot EF_{i,j,k}\right); \tag{4}$$

where: $M_{\_(j,k)}$ – average annual distance depending on the vehicle category and applied pollution limitation technologies;
$EF_{\_(i,j,k)}$– specific technologic pollution factor;
$N_{\_(j,k)}$ – number of vehicles corresponding to the technology and the category. (quote, necessary reference to a source of literature).

Three-tier method. A three-tier method is used when technical data (emissions factors) and active data (distance travelled by the vehicles) are known. This method is used to analyze different types of pollution caused by road vehicles. This method is much more accurate and complete than the aforementioned ones. One of the examples of the use of a three-tier method is temporary aggregate pollution:

$$E_{sum} = E_{hot} + E_{cold}; \tag{5}$$

where: E_{hot} – emissions in case of stable engine operation (warm engine);
E_{cold} – emissions in case of cold engine, immediately after starting a vehicle.

Pollution of this type strongly depends on the conditions of engine operations. Different driving technologies determine different engine operations and emissions. The following aforementioned three-dimensional pollution is presented in the distribution of emissions according to the conditions of engine operation:
Key principles of the three-tier method (Saharidis & Konstantzos, 2018). Key input data: fuel consumption; number of vehicles by category; the distance travelled by categories; climate conditions.
When calculating emissions in application of this method, the only driving conditions are speed by category or the road section. Emission factors may be distinguished by category, driving conditions and so on. (quote, necessary reference to a source of literature).

3. Drafting the Model for Calculating Pollution

The pollution calculation model is drafted as a diagram of the process flow (see Figure 1). This diagram has 2 optimization steps.

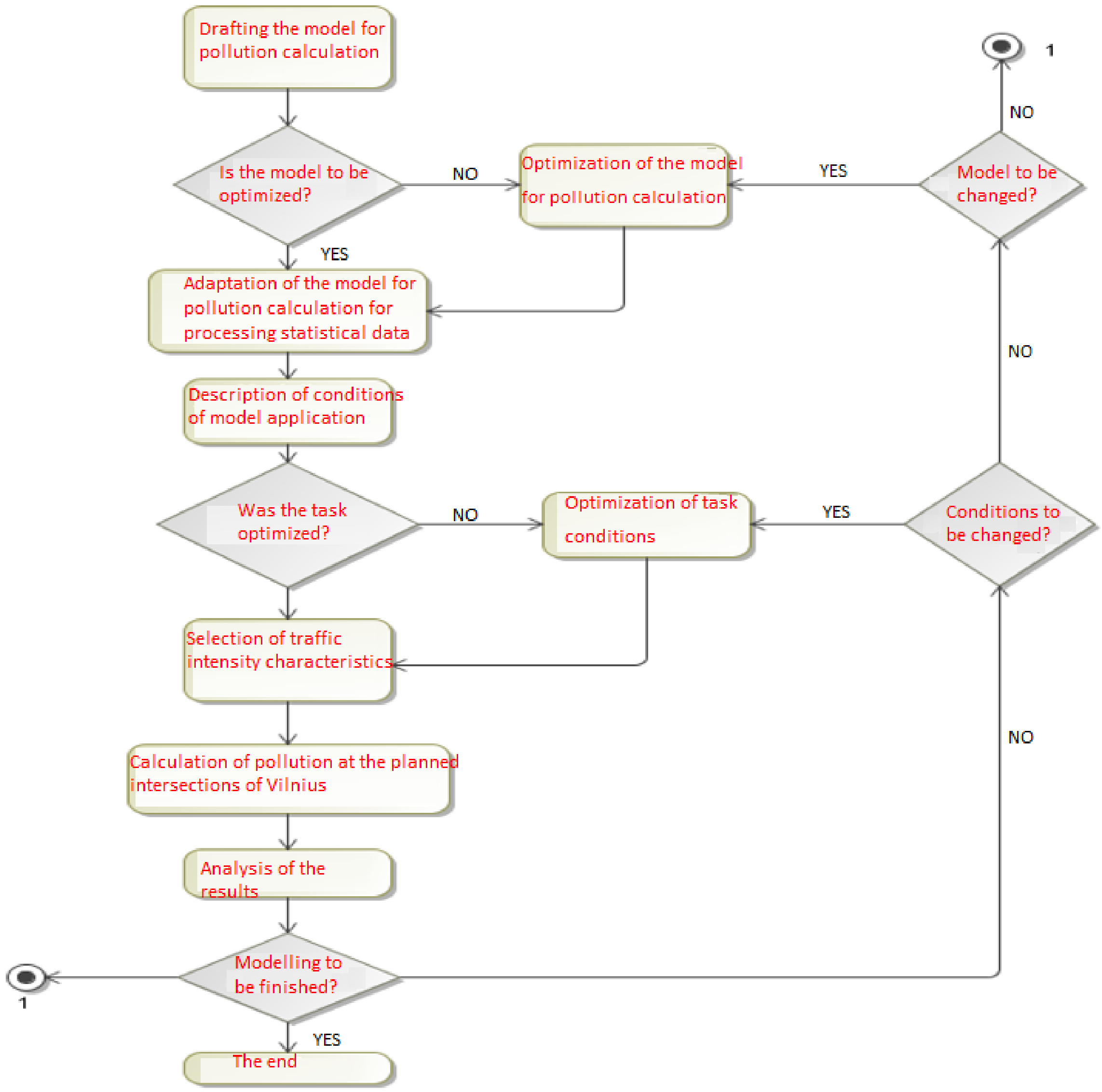

Fig. 1.
Process flow diagram
Source: compiled by the authors

Two of the largest intersections of the city, namely, the intersection of Kalvarijų–Kareivių Streets and Ukmergės–Geležinio Vilko Streets, were chosen for examining pollution in the city of Vilnius. Traffic intensity in these intersections is the highest in the entire city, thus air pollution is also likely to be the highest. Traffic intensity indicators in the said territories are necessary to calculate pollution. Traffic controllers K213 and K255 installed in the intersections generate these data. These controllers transmit traffic data to operators of the Vilnius Traffic Management Centre. These systematized data in particular will be used in further research stages. Figure 2 illustrates the scheme of Ukmergės–Geležinio Vilko Streets and Figure 3 presents the scheme of Kalvarijų-Kareivių Streets.

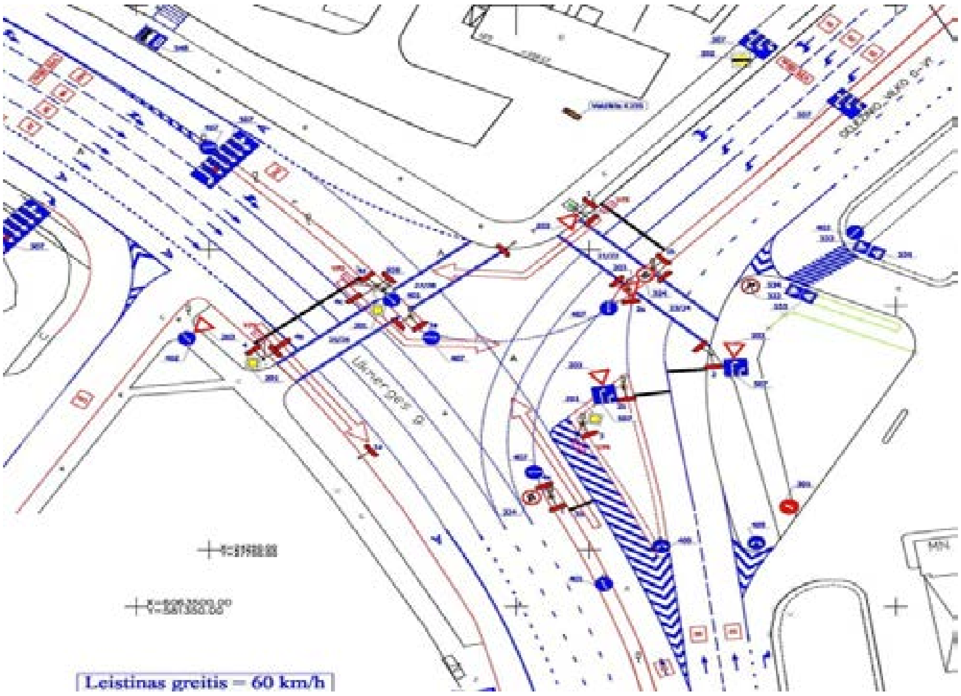

Fig. 2.
Intersection of Ukmergės–Geležinio Vilko Streets
Source: compiled by the authors

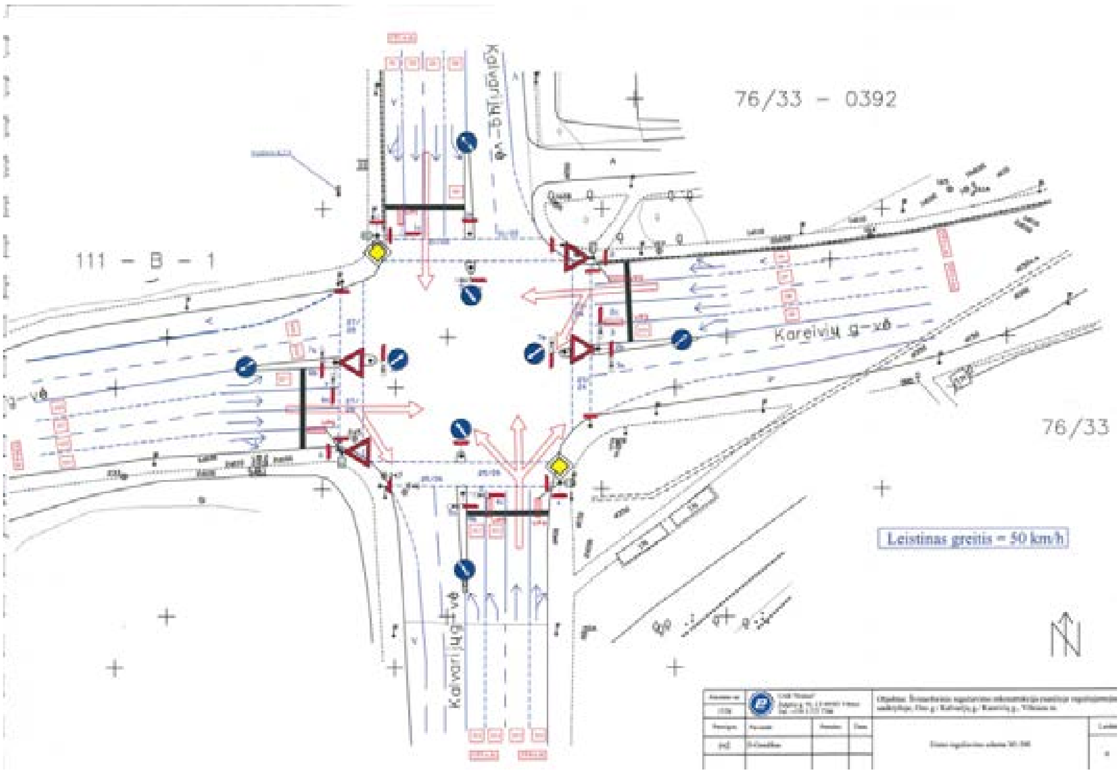

Fig. 3.
Intersection of Kareivių–Kalvarijų Streets
Source: compiled by the authors

Pollution calculation and assessment of the improved methodology will be carried out in 2 aspects. First of all, the dependence of pollution in the aforementioned streets on the traffic flow at the intersections will be analysed having amended the methodology, i.e. introduced a new category of vehicles. Real traffic intensity data and data of

composition of vehicle flow only will be used for this aspect of the research. Using only real data and seeking to assess the impact of traffic intensity on pollution, pollution in the said intersections will be calculated in 2 periods - when the intensity is the highest and when it is the lowest.
The second aspect of the research will be carried out by theoretically changing the composition of the traffic flow at the intersections, i.e. by increasing the share of hybrid cars up to 20% of the overall traffic flow at the intersection. This aspect of the research can still be called optimistic model of traffic flow composition. The application of optimistic forecasting allows calculating the dependence of pollution at the said intersections on the number of hybrid vehicles in the overall traffic composition. The results obtained would also allow conducting economic and applicability assessment of the methodology.

4. SWOT Analysis of Improved Methodology for Calculating and Assessing Pollution caused by Road Vehicles

This methodology has been approved and is often used to analyse urban pollution, but the situation in the world and in Lithuania has been changing. Increasingly more vehicles that are less polluting or absolutely do not pollute the environment have been driving in city streets. Assessment of such vehicles is one of the steps for improvement of the methodology.

Table 1
SWOT analysis of improved methodology

Strengths	**Weaknesses**
1. This methodology allows formulating a respective state policy in the field of vehicle hybridization and ecology, because it allows justifying the ecological effect and forecasting it with the change (increase) of the number of these vehicles in the country. 2. So far, there was not a single approved methodology for calculating pollution caused by traffic flow in Lithuania. The introduction of this methodology would allow for a realistic assessment of the value of pollution in monetary terms, through pollution taxes. 3. The demonstrative value of this methodology is its easy adaptability in other cities of Lithuania, which would allow assessing the negative impact of transport on the population of the country nation-wide (exhaust gases of vehicles are known to contain not only carcinogenic, but also mutagenic and other hazardous compounds, which determine the health of the population).	1. Despite its expected effect, the implementation of this methodology requires initial funds for the installation thereof, thus assurance of financing is a very important aspect in light of the difficult economic situation of the country. 2. Lack of political will is also an important aspect of threat, thus strengths and the expected benefit of the methodology must continuously be emphasized. Another method to eliminate this threat is lobbyism, but it is poorly developed under Lithuanian conditions.
Opportunities	**Threats**
1. Adapted for the conditions of the city of Vilnius, the pollution calculation methodology allows ensuring the validity of results and forecasting with changing structure of traffic flow. 2. The costs of development of the model are optimal, if we were to assess costs of development of similar programmes and their adaptability to a specific region. 3. The assessment of ecological indicators is a very important objective of the EU's long-term perspective if talking about ensuring and increasing the mobility of vehicles (EU White Paper). This methodology allows fully assessing pollution levels from mobile sources of pollution (traffic flow) and justifying the selection of individual measures to improve the mobility situation (e.g., setting up "A" road lanes).	1. The proposed methodology largely depends on the adequacy of target data. Ensuring accurate calculation of traffic flow is necessary. Sensors calculating traffic flow must function without any disorders. 2. Assessing the exact composition of the traffic flow is difficult, because different vehicles generate different pollution. 3. The number of hybrid and electric vehicles is hard to predict and is mostly dependent on political decisions, economic situation of the country and its residents; ecological education is also very poor in the country.

Source: compiled by the authors

5. Conclusions

1. Air quality in urban environments is highly dependent not only on the total emissions, but also on the environmental coefficient of the street. It becomes *const.* having reached the value of the environmental coefficient of the street of 0.8, which shows that in order to improve air quality in the city, engineering road solutions must also be considered.

2. The scale of traffic flow emissions largely depends on the type of vehicle and its operation modes. A diesel-fuelled vehicle, the operation mode of which is acceleration, is the "most dangerous" from this perspective. A particulate matter filter is the best pollution reduction measure for this type of vehicles.
3. According to statistical data, the highest concentration of vehicles is in the five major cities of Lithuania, and it is dominated by passenger cars; thus the methodology being improved has the prospect of becoming the justification instrument for the assessment of pollution trends in the city.
4. In terms of the applicability of pollution calculation methods, the three-tier method is the most accurate method without a doubt, but it requires a lot of specific data; the one-tier method is also sufficiently accurate, and can be adapted for the local assessment of the pollution situation.
5. The most efficient method of pollution reduction from economic perspective is environmental taxes, but the use of complex measures, combining these taxes, mobility promotion means and educational programmes, is necessary.
6. The compiled research algorithm allows completely resolving the set study tasks and the goal for the preparation of a pollution calculation model, the description of the model application conditions, applicability of the pollution calculation model for the processing of statistical data, in application of the optimization of problem conditions, calculation of pollution at the planned intersections and results analysis methods.

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SPATIAL ACCESSIBILITY ANALYSIS FOR ROAD TRANSPORTATION

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Abstract: The dynamic interaction among transport, land use and environment should be determined that is highly on demand due to sustainability goals. The indicators for the interaction between land use and transportation is defined as accessibility, spatial distribution of events/activities and spatio-temporal transportation volume/distribution. However, the previously designed and used models investigate these separately. Hence, interaction could not be quantitatively assessed. The spatial information technologies together with modeling techniques could serve as glue and integrate them that could serve as an integrated digital platform for sustainability analyses. Within this study, remote sensing images and other spatial information sources (maps in various scales, land-use data, vehicle counting's, demographical information, population, meteorological information and air quality information etc.) are used for determining the interaction between transport, land-cover/land-use and environmental impacts beginning from 1970's to 2014. Accessibility and connectivity are the selected methods to explore the interaction. In order to conduct a detailed study, a pilot area was selected at the European side of Istanbul, involving Bakırköy, Bahçelievler, Bağcılar, Güngören, Esenler, Küçükçekmece, Avcılar, Büyükçekmece districts, where these districts are the cross-road of many national and international highways and the airport and the rate of urbanization is very high. The interaction of transport, land-use and environmental impacts are changing within time and this mainly depends upon spatial information. The study captures the temporal and spatial change in accessibility, where the accessibility values for total distance in both modes, cumulative-opportunity in both modes, potential and daily accessibility indices increased by 80.49% and 99.07% respectively for the period of 2007-2014.

Keywords: Land cover/use, accessibility, urban, spatio-temporal.

1. Introduction

Highways carry a great majority of cities' load. Transportation authorities works on addressing the issues resulting from transportation such as road capacity, number of people travelling, vehicle capacity and the derivatives. Management of the entire domain requires studies that assess the performance of public transportation and its function on its ability to serve all citizens. However, it is a complex task, since planning, decision making tools and available methods are not integrated.

Mobility of goods and people from one location to another depends on how the transport infrastructure is built in different levels starting from urban scale to trans-national scale. From this point of view, accessibility is the main 'product' of a transport system. It determines the locational advantage of an area relative to all areas -including itself- (TRACC, 2015). There exists a land use-transport feedback cycle, as illustrated in Figure 1 (Wegener and Fürst, 1999). According to Rodrigue (2013), accessibility is the measure of the aptitude of a location to be reached by, or to reach different locations. Accessibility has a key role not only in reaching to opportunities and services but also in terms of regional development. Thus, highly accessible regions have an advantage on isolated regions to compete in local, in nationwide or in trans-national aspect. This significant role of transport infrastructure, that are networks and transport services, for spatial development simply shows that the regions with better access to the markets and raw materials are going to be more competitive and successful than the regions with low accessibility.

In order to assess the accessibility trends in metropolitan areas; several databases, methodologies or tools were developed, where all these studies benefited from the spatial information sciences. However, the work is still far from concluded. Studies requiring spatial information could benefit from the recent developments in spatial information technologies for example new satellites, tools, and open spatial databases, where several of them will be introduced and implemented in this study.

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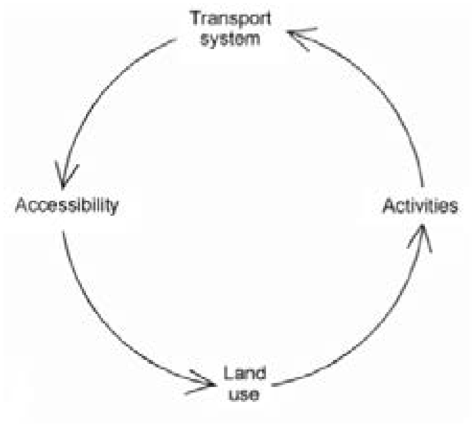


Fig. 1.
The land use-transport feedback cycle
Source: Wegener and Fürst, 1999

The aim of this study is to determine the dynamics of transport accessibility in the Istanbul Metropolitan area. Accessibility changes and trends analyzed between 1987 and 2014. Within the scope of this study mainly, urban areas road transport network is analyzed. This is one of the initial studies conducted for the region and the frame-work, methodology, results would be beneficiary for all metropolitan areas.

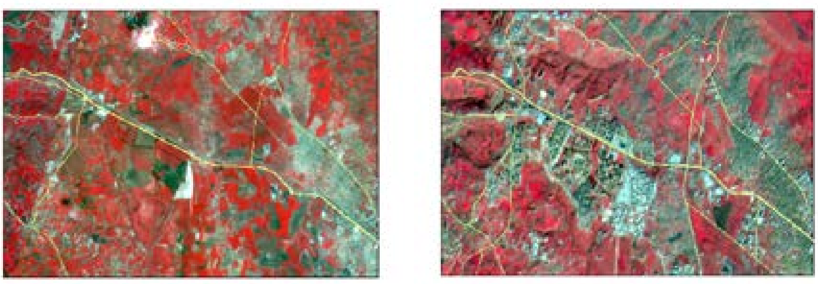
2. Data and Methodology

Satellite images that are used for analyzing accessibility were retrieved from various sensors as illustrated in Table 1. The spatial resolution of the image for 1975 is low due to the technology utilized within that period. In Table 1, the number of Ground Control Point (GCP) for rectification is provided, where the RMSE achieved is also presented. In this study, the satellite images were classified and geometrically enhanced in quality for better accuracy results. Pixel based classification was adopted for classifying these images in various resolutions ranging between 1.5-60m spatial resolution band. Pixel based classifications yield similar results when satellite images are 10m resolution and below (Alganci, 2013).

Table 1
Acquisition and geometric correction properties of the satellite images used in the study

Satellite	Date	Spatial Resolution (m)	Ground Control Point (GCP)	RMSE (m)
Landsat 2	1975	60	12	8.0
Spot 1	1987	20	50	4.0
Spot 2	1997	20	55	4.0
Spot 4	2007	20	50	6.0
Spot 6	2014	1.5	50	0.5

ITU. Road network data were taken as up-to-date data from OpenStreet Map service. It was corrected manually to extract the road networks of 1987, 1997, 2007 and 2014. Historical network was not available, hence OpenStreet Map was over laid with the rectified images of 1987-1997 and 2007. Figure 2 shows a section of the study area for four periods that is necessary to perform temporal analysis.



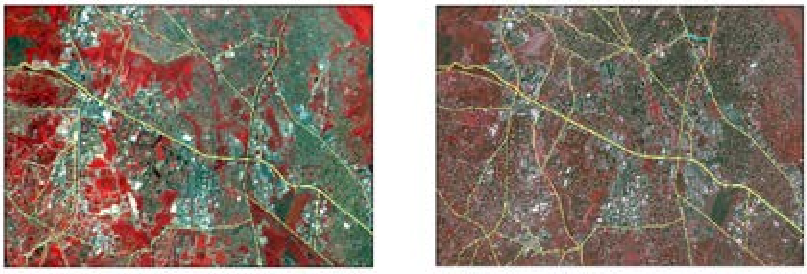


Fig. 2.
Section from the Study Area for the years 1987, 1997, 2007 and 2014

This pilot area was conserved for testing the accessibility indicators, which assisted on making healthy inferences about the entire study area regarding the accessibility indicators. The potential accessibility and the daily accessibility indicators used in this study are given by equations 1 and 2:
Potential accessibility is computed by inserting the number of the opportunities reached from origins to destinations, their cost and level of attraction of the places being visited (Hansen, 1959).

$$A_p = \sum_j \frac{w_j}{c_{ij}} \tag{1}$$

Daily accessibility only calculates areas of a selected region and other areas belonging to the neighborhood of corresponding region (Lutter, 1992). Maximum one-way travel time is calculated as 4-6 hours and events that exceed the maximum limit are assumed to be not accessible (Demirel *et al.,* 2015).

$$A_d = \sum_j \frac{\delta_{ij} w_j}{(c_{ij})^\beta} \tag{2}$$

In this equation, β is a parameter referring to distance impedance. $\delta_{ij}$is a variable of daily accessibility and this value equals 1 provided that $c_{ij} \leq c_{max}$, otherwise it equals 0. C_{max} is a daily accessibility threshold that limits the neighborhood area.

3. Results and Conclusion

Findings about the pilot area reveal that Metrobus line, which was completed in 2007 and launched the same year contributed to expansion of urban areas in the region. The area resulted in 17-fold increase in urban areas and 7-fold increase in industrial and commercial units and 0,5 fold decrease in forests proving that increase in accessibility led to land use change dramatically as it is experienced by the numbers above. Potential and daily accessibility were calculated for three periods, that is, the period between 1987 and 1997, the period between 1997 and 2007, and the period between 2007 and 2014. Potential indicator and daily indicator in all periods yield similar results. For the first period (1987-1997) origins and destinations tended to form a cluster rather than dispersion along the whole area. Accessibility rate increased progressively in the period between 2007 and 2014, where the clustering structure is not any more followed and land cover/change is along the Metrobus line. Five types of accessibility indicators, namely total distance, average distance, cumulative opportunity, daily accessibility and potential accessibility, were examined to make an assessment for which indicator fits the study area conveniently involving two travel modes such as foot and car. According to the results, for total distance, in year 2014 both foot and car has increased sharply when compared with the year 1987. Foot has increased 80%, where car is 100%. Cumulative opportunity reveals similar trend where the ratio is 80% for foot and 95% for car when year 10987 and 2014 is compared. The average distance indicator was not successful and the increase could not be detected. Daily and potential accessibility were found to yield similar results with total distance and cumulative opportunity. Daily accessibility increased 104.19%, where potential accessibility increased 99.07%.
For the selected study area, it could be concluded that the accessibility values within the selected time period has increased. This illustrates that the Metrobus line in operation since 2007 and other transportation investments increased the performance of the transportation network. Such spatial analyses should be performed continuously for longer periods in order to exactly understand the pattern of interaction and simulate scenarios for sustainable urban transportation policies.

Acknowledgements

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SIMULATION FOR LAND USE AND TRANSPORTATION INTERACTION: A SPATIAL APPROACH

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Abstract: A city is a complex system of dynamic interactive components, where transportation and land use are the two most determinative subsystems of this complexity. In order to enlighten this complexity, the interaction pattern could be determined and simulations for future policy decision could be successfully implemented. Hence, this study aims to aid decision makers to explore interaction between land use and transport within a spatio-temporal domain. In order to achieve the objectives, the methodology to be followed is to introduce measurable indicators for the local interaction pattern and utilize this for modelling the future interactions. The framework developed depends on patio-temporal analysis, hence the designed model is a geographic information system. For modelling the near future simulation neural network modelling techniques were applied. In order to test the developed concepts, a pilot area was selected at the European side of Istanbul, where transportation investments and the rate of urbanization is very high. According to the achieved results, urban areas within the study area are predicted to increase by 23% in 2023, where industrial and commercial units are predicted to increase by 24% for the same year. Hence, the framework developed aids policy makers for sustainable urban transport that integrates urban and transport planning.

Keywords: Land cover/use, logic regression, neural network, agent-based modelling.

1. Introduction

To achieve the ambitious goal of sustainable cities, transportation is a key component. By definition, the sustainable transportation should ensure that the transport systems meet society's economic, social and environmental needs while minimizing their undesirable impacts on the economy, society and the environment (Dobranskyte-Niskota *et al.,* 2009). Among several indicators to assess the degree of achievement, land use and transportation interaction is playing a vital role. The rapid change in land use is highly correlated with transport investments and decisions, where performance of transportation relevant decisions could be assessed via ease of accessibility and spatial distribution of activities. Hence, the main goal of transport policies is to improve the ability of individuals to access any type of economic and social activities, while minimizing the undesirable impacts. The four components of accessibility are land-use, transport system, temporal dimension and individuals. The spatial distribution of destinations, the pattern of land-use, and connectivity of the transport network influence the performance of the transport system. Such a challenge could be successful, if transport and urban planning is integrated and future scenarios for decision makers are simulated. However, such integrated systems are rare. Hence, the aim of this study is to develop a Geographic Information Based framework to assist decision makers for this challenge.

In this study, within a selected study area in Istanbul, the existence of correlation between transportation investment and accessibility values and the pattern are assessed. The generated reliable spatio-temporal land cover/use database is utilized as the base-map for this analysis. The period selected is 1975, 1987, 1997, 2007 and 2014, where the monitoring of land cover/use could be performed as needed. Remote Sensing techniques are highly mature for this purpose and serving for better decision making about the land management. (Civco *et al.,* 2002). Hence, the idea of analysing land cover/use change temporally and spatially in one model with a computer-assisted production is not new, where the accuracy problem is solved in 2002 due to high-tech satellites (Civco *et al.,* 2002). Cellular automata are a popular method in spotting the pattern of change and it is seen in researches studying land cover/land use change (Cetin and Demirel, 2010). Detecting land cover/use pattern of an area with multiple methods including artificial neural networks, expert systems, artificial intelligence are some of the methods that were tried in the past years, in order to overcome the uncertainty of external effects. After determining the pattern, simulation model for 2023 is generated via artificial neural network methodology.

2. Data and Methodology

2.1. Data Used

In order to generate a simulation land cover/land use within a time period is necessary. However, historical land use maps were not readily available or the resolution of such maps are low that can be utilized for these analyses. Therefore, satellite images of the years 1975, 1987, 1997, 2007 and 2014 were retrieved and images were processed. Land cover/use maps were generated by classifying satellite images using remote sensing techniques where the European

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Union standard “Coordination of information on the environment” (CORINE) land cover/use legend was utilized for classification. (EEA, 2018) Utilized classes are urban areas, industrial & commercial units, barren lands, forests and water structures. These land cover/use maps were chosen for predicting the land cover/use map of 2023.

2.2. Study Area

The selected study area is situated in the European side of Istanbul, Turkey. Istanbul Metropolitan Area, which consists of the Historical Peninsula, Central Business District, significant settlement areas together with natural and semi-natural areas, is the most dynamic region of the county in terms of mobility. Istanbul is located on two continents (Europe and Asia divided by the Bosporus), surrounded by the Black Sea at north and the Sea of Marmara at south, in the north-west of Turkey. Istanbul became one of the most important metropolises not only of Turkey but also of the world via its unique geographical location, via its well-established historical relationships with nations and countries that are centrally connected to Istanbul, via its cultural and historical heritage, via its dynamic demographic structure and its economic potential.

As a consequence of its unique location and of its cultural heritage the city has been an attraction centre since centuries. With its 13.854.740 million inhabitants, Istanbul is the most crowded city of Turkey according to the Turkish Statistical Institute. Istanbul connects Europe and Asia by the shortest path of roads and railways on one hand, and it connects Black Sea region countries to the Mediterranean Sea via maritime, on the other. 4th Pan European Corridor which is one of the ten main transport corridors developed by the European Union ends in Istanbul. Economic activities of the city mainly concentrated on services sector which has 73.1% and industry which has 26.7%. Agricultural activities account for only 0.2% of Istanbul’s economic output. Therefore, the city is considered as the most powerful logistics hubs of Turkey. Istanbul has outstanding features in terms of industry, agriculture, trade, culture, health, tourism and transportation. Consequently, the city plays a vital role in the country's economy. The study area is a recently developed part of Istanbul as it is marked with a red rectangle, in Figure 1. The major transportation axes such as Trans European North-South Motorway (TEM) and European Motorway (E5) are passing through the region. The Bus Rapid Transit (BRT) line, also known as, Metrobus line, is located on the European Motorway (E5) which was built in 2007. The study area includes 19 districts surrounding these roads.

Fig. 1.
Study Area

2.3. Methodology

The land cover/use classes are obtained via using Landsat 2(1975), Spot 1 (1987), Spot2 (1997), Spot 4 (2007) and Spot 6 (2014), where images spatial resolution varies. For the year 1975, the spatial resolution is 60 meters. For years 1987-1997-2007, the spatial resolution is 20 meters and for the year 2014, the spatial resolution is 1.5 meters. The satellite images were processed in order to obtain the land cover classes according to the CORINE standard. Supervised classification has been performed employing minimum distance classification and the accuracy assessments were done.

After land cover/use maps are produced within a time period of 40 years, Artificial Neural Networks (ANN) prediction method is performed to simulate land cover/use of the study area in 2023. The ANN method imitates humans’ nervous system and the characteristics of how brain works. It simply comprises of inputs, a processing element and outputs (McCulloch and Pitts, 1943). Multi layer perceptron and back propagation algorithm used for learning are sub-models in artificial neural networks and they are known for their convenience in classification and prediction (Rumelhart and Mcclelland, 1986). Multi layer perceptron is one of the methods, which is used for predicting a phenomenon that has a complex relationship with multiple factors depending on one another. It is capable of deriving sensible results from these multiple factors, which are hard to make sense of them together. In this project, its overall capacity to handle complex relationships is a reason behind opting for this method. MLP benefits from back propagation algorithm, which operates in reducing the error factor when constructing a land use/cover prediction model. Back propagation performs in an on-going cycle to minimize the error and continues to operate until reaching the desired output. In Figure 2, inputs (land cover/use variables), are weighted, sent to hidden layer’s function, processed and generated as one output (land cover/use prediction model).

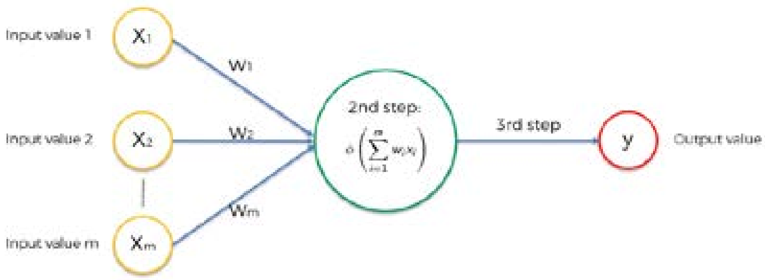

Fig. 2.
Architecture of Artificial Neural Networks

3. Results and Conclusion

Within the study area, urban areas and industrial and commercial units expanded near the existing urban areas between 2007 and 2014, as illustrated in Figure 3 and Figure 4. Within figures, as stated in the legend, urban areas are represented as red, industrial and commercial areas purple, barren lands yellow, forests green and water structures blue. According to the figures, industrial and commercial units expanded towards the north, penetrating into the residential areas. Forests are surrounded by small amount of barren lands in 2014 and urban areas with a small change replace them. Industrial areas and urban areas grow wider around the forests. Barren lands in the coastal areas are converted to urban areas. Land cover/use change towards the north is observed in general.

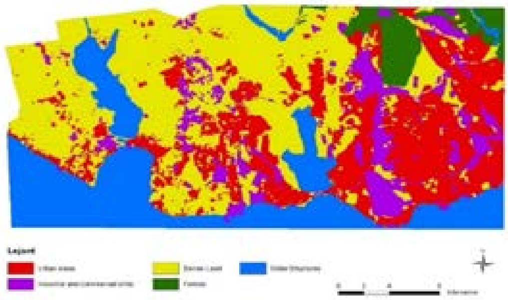

Fig. 3.
Land Cover/Use Map 2007

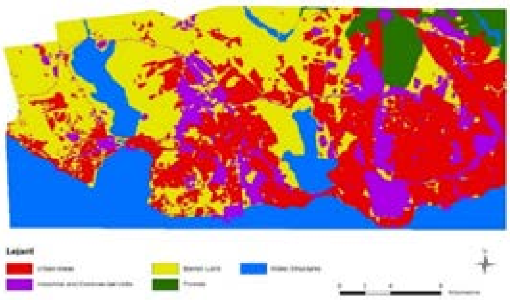

Fig. 4.
Land Cover/Use Map 2014

Quantitative results of change in land cover/use between 2007 and 2014 is given in Table 1. Urban areas in the study area increased by 47.15 km^2 with the percentage of 24. Industrial and Commercial Units increased by 20.82 km^2 by 26%. Barren lands lost 56.92 km^2 as a result of an increase in urban areas and industrial and commercial units. Forests experienced a slight change by losing only 2.24 km^2, indicating there has not been a big amount of change compared to barren lands. Water structures lost 9.51 km^2 between the same years. When the land use maps of 2007 and 2014 were compared as a whole, total area was seen to change with a decrease of 0.7 km^2 apart from the undergoing losses of classes individually.

Table 1
Land Use Change Prediction Values by Area

Class Names	Area (km^2)	
	2007	2014

Urban Areas	190.50	237.65
Industrial and Commercial Units	78.47	99.29
Barren lands	290.82	233.9
Forests	35.2	32.96
Water Structures	175.08	165.57
Total Area	770.07	769.37

In order to simulate land cover/use model of 2023, driving factors that contributed to the land cover/use change were fed into the input layer of the architecture of ANN. Distance is a key concept, which assists on associating the parameters such as roads or urban areas with the potential causes of change concerning the studied place. 7 factors were considered as driving factors. Distance to roads, distance to urban areas, distance to forests, distance to industrial areas, distance to hospitals, population and digital elevation model are the factors that are crucial for understanding the dynamics of the study area. They have an impact on potential change in the chosen area for this study. Places near to the roads are more likely to develop and urbanize. Residents are more likely to prefer houses near to the hospitals. Their choices are likely to shape according to the location in which their workplaces are situated as well. City centres contain a multiple number of opportunities and people are able to travel freely with flexible transportation hours with more than one vehicle option. Thus, distance to urban areas is significant. Population is able to trigger change when the city is open to domestic migration. Topographic structure affects the reachability of a place, number of residences, investments. Therefore, Digital Elevation Model is considered as a driving variable. Forest is included as a factor because of the fact that increase in population spreads to the natural areas. Land use maps of 2007 and 2014 were utilized for depicting the change and gains and losses regarding the classes. MLP Neural Network was utilized in order to benefit from back propagation algorithm in the process of modelling 2023. Minimum cells transitioned from 2007 to 2014 and minimum cells that persisted from 2007 to 2014 were calculated. Sample size per class is 1927 and this unit was transformed into even number by decreasing the sample size by 1. This application was adopted because of the fact that odd numbers cannot be used for training and testing in the network. This stems from sample size being divided by for 50% training and 50% testing. Learning rate and hidden layer nodes are two important parameters for creating the optimal network model. Start learning rate is 0.01, end learning rate is 0.001, momentum factor is 0.5, sigmoid constant a is 1.0 and hidden layer nodes are 7. MLP was terminated; by the time the iteration number reached 10,000. Neurons in input layer are provided to the network as driving factors mentioned above. 7 input neurons were inserted in total. Output was obtained as one prediction model, that is, land cover/use map 2023.

In 2023, it is predicted that coastal regions become more crowded that barren lands in the corresponding areas will see a considerable amount of decrease. Urban areas in northern parts of the study area will increase substantially. Industrial areas will surround the forests from the east, necessitating environmental conservatory plans in the future. Industrial and commercial areas and urban areas will replace barren lands according to the prediction model of 2023 modelled. The land cover/use simulation of the 2023 is illustrated in Figure 5. Accuracy was found 74.09 % with kappa statistics. Urban areas were predicted to increase by 23% in 2023. Industrial and commercial units were predicted to increase by 24% in 2023. Barren lands were predicted to decrease by 33.6% as it was seen in 2014, indicating that barren lands are beginning to replace with the other land use types with near a decade of intervals, progressively. Forests were predicted to decrease by 0.75%, which can be considered as a merely small portion. Water structures were predicted to decrease by 0.17%. Quantitative results for the year 2023 are illustrated in Table 2, where values of 2007 and 2014 is also provided for comparison.

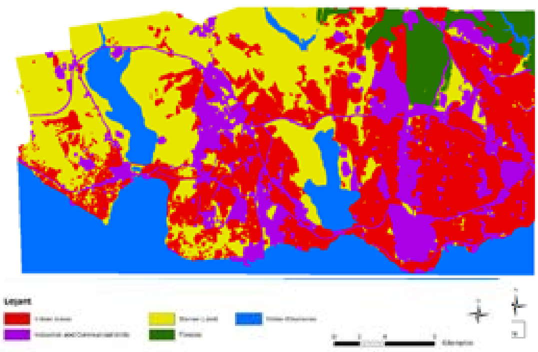

Fig. 5.
Land Use Simulation 2023

Table 2
Land Use Change Prediction Values by Area

Class Names	**Area (km^2)**		
	2007	**2014**	**2023**
Urban Areas	190.50	237.65	292.54

Industrial and Commercial Units	78.47	99.29	123.77
Barren lands	290.82	233.9	155.21
Forests	35.2	32.96	32.71
Water Structures	175.08	165.57	165.28
Total Area	770.07	769.37	769.51

In order to assess the suitability of spatial factors and model validity, an ANN simulation for the years 1997 and 2007 were performed and the year 2014 land cover/use map is simulated. The kappa value of the 2014 was found as 83%. The next step is to perform four-step model in order to assign new roads or develop new strategies such as increasing the performance and quality of existing ones, according to the 2023 simulation. This should be presented to the decision makers excluding the complexity of the method via user friendly interfaces. After these steps, sustainable transport strategies and scenarios could be performed and such tools could aid to explore the "the best" possible solution for cities.

Acknowledgements

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