University of Zagreb

Faculty of Transport and Traffic Sciences

Professional Meeting and Workshop on Program for stimulation of research and innovation at the Faculty of Transport and Traffic Sciences PROM-PRO

Programming period 2015 – 2017

Proceedings of the technical reports

Zagreb, 2017

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FOREWORD

Science and research in all areas is oriented towards research groups and networks. Education, research and innovation are characterised by a strong flow of knowledge, introduction of research results and innovation practice into education, strong partnerships and intellectual property management. New ideas and knowledge, new processes, products and services, and new entrepreneurship are the ingredients of investigative creativity. In the service of a research-oriented university, the Faculty of Transport and Traffic Sciences intends to take special care of its students as potential researchers. This is especially important for postgraduate students who should have the opportunity to do research as a part of a project. However, research should be equally introduced at the graduate level where learning should be oriented towards research (as a function of the paradigm shift from learning after research to learning through research).

Faculty of Transport and Traffic Sciences established in 2014 a strategic framework in order to improve the quality of research activities and increase productivity in the field of traffic and transportation engineering. The purpose of the strategic framework is to create all necessary conditions for the development of the knowledge triangle at the Faculty, according to the following goals: establish a system for active participation in collection, processing, interpretation and publication of statistical and other indicators of research, development and innovation; encourage and evaluate the work of researchers and the establishment of research groups; encourage cooperation in research, development and innovation; develop e-infrastructure in order to facilitate research and education activity; plan research investments, and active participation in smart specialisation processes.

Critical segment of the framework is the Program for stimulation of research and innovation at the Faculty of Transport and Traffic Sciences. The goal of the Program is to encourage the development and innovative character of scientific activities at the Faculty. The program's emphasis on the outcomes of scientific research (impact of scientific activities on certain segments of society and the economy), and the outputs in the form of research results.

After only two years of active implementation of the Program, it is our pleasure that we can present general results from Faculty’s research groups in forms of technical reports in this proceedings.

Faculty will continue to encourage the development and innovative character of scientific activities, with emphasis on the outcomes it terms of impact of scientific activities on specific segments of transport and traffic.

Assoc. Prof. Doris Novak
Chairman of Committee on Science and Projects
Faculty of Transport and Traffic Sciences

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DRIVERS VISUAL DETECTION EVALUATION AND IMPACT ON ROAD SAFETY

ABSTRACT

Given that over 90% of the information that driver receives in traffic have visual character, it is cruical that driver can receive this information timely, in order to react in an adequate and safe way. Traffic signalization represents the basic means of communication between road authorities and road users which is why for the overall traffic safety quality transmission and understanding of the message that it carries is essential. The reserches conducted under this project were planned in two parts. In the first part, the process of driver's perception of traffic signs was analyzed using sophisticated eye tracking system (Tobii Pro Glasses), in simulated and real-life traffic conditions. Based on the above, factors influencing the identification and timely understanding of the signs, and thus the entire road safety, have been identified. The survey also found that drivers twice as many focus on signs whose messages they do not understand clearly in comparison to the signs that are understandable to them. Also, there is a significant difference between the total duration of the fixations of driver's eyes when looking at these signs. The results lead to the conclusion the examinees much more focus on signs they do not understand because they are trying to understand their meaning. In addition, research has shown that familiarity of certain routes significantly affects the perception of traffic signs and that identification and perception of traffic signs change according to the frequency of driving on a particular route, or in accordance with the familiarity with a route. The results showed that the driver driving at an unknown road section will perceive a greater number of traffic signs in order to gather more information which they need to continue their journey safely. The second part of the research is related to the examination of the visibility and durability of various materials for road markings. The results show that waterborne paints, although so far often underestimated, are high-quality and environmentally friendly alternative to solventborne paints.

KEY WORDS:

traffic signs; road markings; eye tracking; perception; driver's behavior

1. INTRODUCTION

Traffic accidents are a significant social problem considering that on the roads of the European Union in 2015, nearly 26 112 people died and is estimated that there was over 135 000 injured [1]. In the Republic of Croatia, in 2015 in traffic accidents died 348 people, which is an increase of almost 12% compared to 2014, with a relatively smaller number of injured people (a decrease of 3% compared to 2014) [2].

Precisely for this reason traffic safety is an important determinant of each country and a key focus of the European Commission, which in 2010 adopted a fourth European Road Safety Action Programme. The main task of the program is to reduce the number of fatalities on the roads of the EU in the period from 2010 to 2020 focusing on several major goals including the improvement of traffic infrastructure which important element is traffic signalization. Since the traffic signalization is the basic mean of communication between road authorities and road users, proper setup and maintenance of traffic signs and road markings will greatly affect the overall road safety.

The main elements of the system of traffic signalization are traffic signs and road markings. Traffic signs are the basic elements of communication between the relevant road authorities and road users. With the use of colours, shapes and symbols they give important information with which they manage, regulate, inform and warn road users to ensure their safe movement throughout the transport network [3]. Road markings are one of the most important components of traffic control plan because of their position in the central area of driver attention. They represent a set of lines, signs and symbols which combined form the surface transportation infrastructure [4]. Their function is to warn drivers about conditions on the road and its construction characteristics and to help drivers in determining lateral or transverse position of their and other vehicles.

To achive that signs and markings perform their function, they must be visible, clear and understandable in all traffic and weather conditions.

The quality of information transfered to all road users through traffic signs will depend on several factors such as visibility ie. traffic sign retroreflection, position of the sign in relation to the direction of vehicle movement, sign dimensions, symbol simplicity or used text etc.. On the other hand, as most of the road markings are formed as lines and symbols, transmission quality of information will depend largely on the markings visibility.

The task of this project was to get a clear insight into how drivers perceive traffic signs and road markings in simulated and real-life traffic conditions, using the sophisticated eye tracking system, such as Tobii Pro glasses. By analyzing the driver's perception, it is possible to identify factors that influence the identification and timely understanding of the signs and get a glimpse of critical traffic signs, in terms of clarity of visual perception. Also, with implementation of various materials for road markings at test fields and periodic testing of their visibility, new insights were obtained related to the durability of those materials.

2. RESEARCH GOAL AND MOTIVATION

As the perception of traffic signalization is a complex process, in previous scientific researches different methods of data collection were applied, which are mainly related to researching the subjective evaluation of traffic signalization.

The mission of this research is aimed at researching and defining the connection between the impact of human factor (driver and his visual detection) and of traffic signalization on general road safety. The project is divided into two parts. In the first part, the perception of traffic signs using the eye tracking system was investigated.

Previous scientific studies have proven that the signs, which are well adjusted and designed, are clearer and more uniformed and taken more seriously by the traffic participants, compared to the signs with clashing symbols [5, 6, 7].

Although the scientific activity related to understanding of traffic signalization is aboundeth and up to now many studies related to the identification, reading and perception of traffic signs have been conducted, existing knowledge and results need to be rexamined using modern technology. That is why, for the implementation of this project, a sophisticated eye tracking system was used by whom an insight into the number and duration of driver's eyes fixations of traffic signs was obtained.

Also, the motivation for carrying out this research is the fact that greater uniformity of traffic signs is necessary at the international level and that there is a need for greater implementation of ergonomic principles when designing new signs or redesigning existing [8].

The second part of the project is related to the research of quality of the different materials for road markings. Constant progress of chemical industry led to the creation of new versions of certain road markings materials. The aim of this part of the project was to investigate the durability of those materials and to analyze how the marking visibility changes over time.

The project is a continuation of many years of professional and scientific projects of the Department of Traffic Signalization, Faculty of Traffic Sciences, University of Zagreb, and as such represents the expansion of research activities of the Department. Also, purpose of this type of research is to establish the Department's Testing Laboratory as the leading scientific research laboratory in Croatia and region in the field of traffic signalization and road safety which is in corespondance with the Strategic development plan of the Faculty (strategic measure 3.5.). The project involves two doctoral students of the Faculty of Transport and Traffic Sciences, who, with the work on the project, gained experience and skills needed for finishing their doctoral dissertations (strategic measures 3.3.).

The main goal of the project is to gain new skills and knowledge that could be applied in practice. For this reason, during this project, the Department of Traffic Signalization has established an active scientific and technical cooperation with international and domestic economic entities (such as Swarco, 3M, Hrvatske ceste d.o.o., Pismorad d.o.o. etc.) enabling evaluation and application of acquired knowledge in the transport system. In addition, this cooperation has enabled the organization of the professional practice for students and researchers in accordance with the strategic measures 4.2. and 3.4., thereby improving the competitiveness and quality of scientific research and teaching process in accordance with the strategic measures 5.2..

3. RESEARCH ACTIVITIES

Research activities, as already mentioned, are divided into two parts. In the first part perception of traffic signs using the eye tracking system was researched, while in the second part the visibility and durability of various materials for road marking was studied.

3.1 Research of traffic signs perception

Generally, it can be said that the perception is complex unconscious process of active collecting, organizing and interpreting received sensory information and already existing information that allows an individual to know and identify the meaning of objects, phenomena and events in the area. It is based on information received from the environment, but also on existing knowledge, experience, expectations, emotions and other. Given that about 90% of all information that the driver receives while driving has visual character, it is clear that visual perception is crucial for safe traffic.

Since traffic signs are basic elements of communication between road authorities and drivers, researching how the drivers perceive signs is necessary to improve the system of traffic signalization, and thus the overall traffic safety.

Research related to the perception of road signs was conducted in the laboratory at the Department of Traffic Signalization, Faculty of Transport and Traffic Sciences, and in real conditions on the road. Laboratory studies were led by Dario Babic, mag. ing. traff. under the guidance of Prof. Ph. D. Anđelko Ščukanec and Asst. Prof. Ph. D. Darko Babić. The research was based on an analysis of recognition and understanding of the warning and mandatory signs using the eye tracking system Tobii Pro.

Before the study started, test procedure was clarified to participants, but they the aim of the research was not revealed in order not to influence the respondents, and thus the research results. Also, before conducting the tests, it was required to calibrate the system for each subject to ensure the accuracy of the collected data. During the test, subjects were asked to look at the displayed road signs and after 10 seconds to say their meaning (Fig. 1.).

Figure 1 – Conducting the research

The collected data were then processed and analyzed for each subject in a specialized software tool Tobii Anaylzer (Fig. 2.).

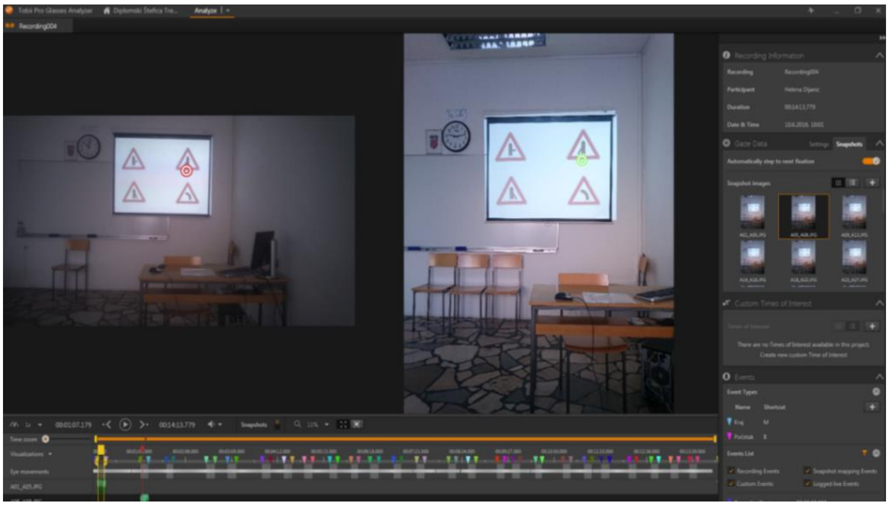

Figure 2 – Data processing

The study showed that drivers twice as many focus on signs whose messages do not understand clearly in comparison to the signs that are understandable to them. Also, there is a significant difference between the total duration of driver eyes fixation at these signs. The results lead to the conclusion that the subjects much more focus on the signs they don't understand because they are trying to understand their meanings.

Part of the research that has been carried out in the field was led by Mario Fiolić, mag. ing. traff. also under the guidance of Prof. Ph. D. Anđelko Ščukanec and Asst. Prof. Ph. D. Darko Babić. The vehicle used for this purpose was Department's Mercedes Citan. Field research was conducted on a section of State Road DC30 in Zagreb County on the section from Velika Gorica to Ogulinec. The aim of this study was to gain insight into how the driver's perception of traffic signs is changing with the familiarity of the route on which they drive. Each participant was driving the same road section ten times during the day in normal weather conditions, five times in one direction and five times in the opposite direction, at intervals of several days. Each ride was recorded using the eye tracking Tobii Pro glasses (Fig. 3.). Analysis of the data gained insight into the perceived number of signs for each subject.

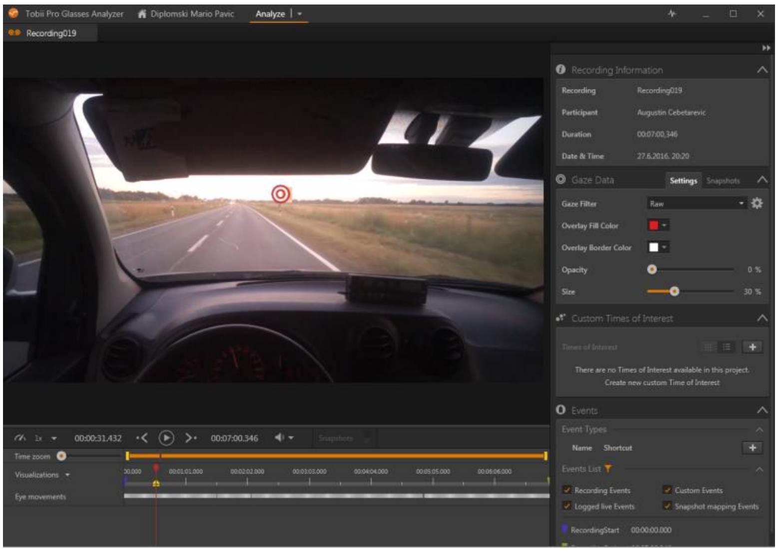

Figure 3 – Data processing in the program tool Tobii Analyzer

In conducting the research and data processing, students of the Faculty of Transport and Traffic Sciences, University of Zagreb actively participated.

The results of the first phase of the research will be published in two conferences in 2017: *International Conference "Environmental Engineering"* (Vilnius, Lithuania) and *International Conference on Traffic Development, Logistics & Sustainable Transport* (Opatija, Croatia).

3.2 Research of visibility/durability of road markings

Two test fields were set up at three locations near Zagreb in cooperation with partner company M. Swarovski - SWARCO GmbH. On those test fields the effect of different combinations of road marking materials and glass beads on the visibility and durability of road markings has been explored. Markings on these test fields were periodically tested by employees of the Department of Traffic Signalization Mario Fiolić, mag. ing. traff. and Dario Babic, mag. ing. traff., with the assistance of students from the Faculty, according to the plan agreed with the partner company.

For research purposes, various combinations of paints, paint thicknesses and glass beads were applied on edge and middle lines. The selected road near Zagreb, has AADT of 8469 vehicles; hence, the systems were subjected to traffic of 5.3 million vehicles in reserched period.

Measurements of retroreflection were done with a dynamic retroreflectometer ZDR 6020 mounted on a side of a vehicle, as shown in Figure 4. Data collection was done during normal driving, at speed up to 80 km/h permitted on the test site [9].

Figure 4 – Vehicle with side-mounted retroreflectometer

The results achieved with selected road marking systems are provided in Table 1.

Table 1 – Road testing results: Retroreflectivity [9]

System, location	Paint (applied wet film build) + glass beads type and size range [μm][(a)]	Retroreflectivity [mcd/m²/lx][(b)]			
		Initial	10 months	21 months	Loss
1, edge line	Solventborne toluene-containing (400 μm) + SWARCOLUX50 200-800	425 (50)	317 (25)	233 (30)	-45%
2, edge line	Solventborne aromatic-free (400 μm) + SWARCOLUX50 200-800	385 (51)	234 (44)	183 (32)	-40%
3, edge line	W13 (400 μm) + SOLIDPLUS30 300-1000	516 (81)	527 (60)	329 (57)	-36%
4, centre line, passing[(c)]	W13 (400 μm) + SOLIDPLUS100 212-850	623 (84)	679 (57)	476 (156)	-24%
5, centre line, passing	W13 (400 μm) + SWARCOLUX50 212-1400	265 (35)	180 (12)	233 (8)	-12%
6, edge line	W15 (400 μm) + SWARCOLUX50 212-1400	343 (87)	365 (54)	261 (62)	-24%
7, edge line	W15 (400 μm) + SOLIDPLUS30 300-1000	455 (52)	370 (37)	291 (24)	-36%
8, centre line, no passing[(d)]	W15 (400 μm) + SOLIDPLUS100 212-850	697 (46)	543 (36)	396 (25)	-43%
9, edge line	W15 (600 μm) + SWARCOLUX50 212-1400	338 (53)	290 (52)	231 (40)	-32%
10, centre line, passing	W15 (600 μm) + SWARCOLUX50 212-1400	358 (21)	297 (28)	215 (36)	-52%
11, centre line, no passing	W15 (600 μm) + MEGALUX-BEADS® 600-2000	422 (22)	276 (42)	204 (47)	-58%
12, centre line, no passing[(d)]	W15 accelerated (600 μm) + MEGALUX-BEADS® 600-2000	455 (22)	280 (54)	192 (33)	-52%

In summary, road marking systems consisting of waterborne paints reflectorised with high quality glass beads were shown to be a viable alternative to the currently used solventborne paints. The best performance was measured with SOLIDPLUS glass beads, which due to their exceptional finish and roundness provided systems that after two years had retroreflectivity exceeding 400 mcd/m²/lx. Since the retroreflectivity loss over two seasons was less than 50%, it might be possible that such systems are capable of providing three or even four-season durability. The use of other glass beads provided excellent results as well – in none of the cases retroreflectivity drop below 150 mcd/m²/lx was recorded.

4. BUDGET SPENDING

The most important item of the budget is related to the purchase of the eye tracking system Tobii Pro which was the basis for conducting this researches. Most of the other budget items such as the purchase of equipment (computers, portable drives, cameras, etc.), equipment of the Laboratory of the Department of Traffic Signalization, costs associated with conducting research (device calibration, students fees, tolls, fuel, etc.) were financed from the funds of the Department. The budget item, which in 2016 was not realized, is the purchase of the driving simulator and equipment related to it.

The main budget items are shown in Table 2.

Table 2 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget (kn)	Achieved	Cost
1.	*Purchase of a eye tracking system - Tobii Pro glasses*	*190.000,00*	*YES*	*190.000,00* ***The overall amount allocated for PROM-PRO - the first cycle is spent in the this item - the rest is funded by the Department of Traffic Signalization***
2.	*Purchase of a driving simulator*	*50.000,00*	*NO*	
3.	*Personal computer - workstation*	*8.000,00*	*NO*	
4.	*Laptop*	*6.000,00*	*YES*	*6.000,00* ***Paid from the funds of the Department of Traffic Signalization***
5.	*Driving simulator accomodation costs (electrical installation, driver's seat, necessary construction work)*	*7.000,00*	*NO*	
6.	*Small IT equipment (portable drives, memory, card, camera ...)*	*1.500,00*	*YES*	*1.500,00* ***Paid from the funds of the Department of Traffic Signalization***
7.	*Supply and installation of equipment for the testing laboratory of the Department of Traffic Signalization (models of traffic signs, of road markings, car models, etc.)*	*5.000,00*	*YES*	*2.000,00* ***Paid from the funds of the Department of Traffic Signalization***
8.	*Electrical installations and equipment needed to launch and manage models in the Laboratory*	*12.000,00*	*YES*	*12.000,00* ***Paid from the funds of the Department of Traffic Signalization***
9.	*Other construction at the Laboratory of the Department (toilets, partition wall, ceiling, installation ...)*	*18.000,00*	*YES*	*15.000,00* ***Paid from the funds of the Department of Traffic Signalization***
10.	*Course of data processing on a computer (statistics)*	*5.000,00*	*YES*	*5.000,00* ***Paid from the funds of the Department of Traffic Signalization***
11.	*The costs of field tests (vehicle, fuel, tolls ...)*	*10.000,00*	*YES*	*3.000,00* ***Paid from the funds of the Department***
12.	*A visit to the SWARCO's laboratory, Amstetten, Austria (two visits predicted)*	*12.000,00*	*YES*	*15.000,00* ***Paid from the funds of the Department of Traffic Signalization***
13.	*Conference costs (four conferences planned - registration fee, accommodation, travel expenses for one author per conference)*	*15.000,00*	*YES*	*15.000,00* ***The overall amount allocated for PROM-PRO - the second cycle paid in full for the International Conference "Environmental Engineering" (Vilnius, Lithuania), the costs of travel and stay Darko Babic, Dario Babic***
14.	*The cost of calibration of measuring instruments*	*2.000,00*	*YES*	*2.000,00* ***Paid from the funds of the Department of Traffic Signalization***
15.	*Fee for working students (for the students' work in the field, work on data collection and processing)*	*20.000,00*	*YES*	*8.000,00* ***Paid from the funds of the Department of Traffic Signalization***

5. RESULTS

Through two years of the project a significant progress is achieved in the form of equipping the Laboratory of the Departments of Traffic Signalization and the establishment of research groups. Also, the research helped in the formation of a coherent and competitive research group which represent one of the objectives of the project.

5.1 Involvement of students

In the project, actively were involved two PhD students of the Faculty of Traffic Science (Mario Fiolić and Dario Babić) who, with the work on the project, gained basic knowledge related to the methodology for devising, planning and implementation of research. Also, skills and knowledge obtained through the project were used for improvement of the quality of scientific papers and parts of Dario Babić's doctoral dissertation under the theme: Road Markings Service Life Prediction Model. In addition to doctoral students in research were actively engaged students from Faculty who have thus gained new skills and work experience. Two students (Štefica Tremski and Mario Pavić) have done their master theses as a part of the research conducted through the project. Those theses were:

1. Analysis of The Traffic Signs Perception Using the Method of Montoring the Driver's Eyes (Štefica Tremski)
2. Analysis of Traffic Signs Perception Using Eye Tracking Method (Mario Pavić)

5.2. Cooperation with industry and academia

In cooperation with partner company M. Swarovski - SWARCO GmbH., two test fields were set up in three locations near Zagreb. At these test fields the impact of different combinations of materials for road markings and glass beads on retroreflection and durability of road markings was explored. Markings on these test fields were periodically examined by the employees of the Department of Traffic Signalization according to the plan agreed with the partner company. Within the framework of cooperation with the company SWARCO, the Department's employees visited companies Futurit and Heoscont that are within the SWARCO Group. The Faculty and Department of Traffic Signalization were presented there, and the presentation of road markings retroreflection testing methodology was performed on the test fields of the company SWARCO GmbH in Austria.

In addition to the company SWARCO, cooperation has been established with domestic companies such as Hrvatske ceste d.o.o. (Croatian Roads Ltd.) and Pismorad Ltd. which enabled evaluation and ultimate application of acquired knowledge in the traffic system.

5.3. Project applications

Table 1 – Overview of submitted project proposals.

Nr.	Funding scheme	Project name	Budget	Status
1.	Support for scientific and artistic research in 2015 by the Ministry of Science, Education and Sports	Analysis of the impact of traffic signalization on the drivers' visual detection	11.473,49 kn	**Granted** The overall allocated amount was used for the purchase of Tobii Pro glasses
2.	Horizon 2020	Enhanced Retroreflectivity of Horizontal Road Markings to Improve Night Time Traffic Safety		**Rejected**
3.	The project proposal in the field of road safety on the Croatian territory for 2017	Visibility of pedestrian in traffic using the eye tracking system	255.000,00 kn	**Delivered, in the evaluation process**

In the first two years of the research activities of working group three projects were applicated:

1. **The application on "The support of scientific and artistic research in 2015" University of Zagreb - short-term support for research in 2015:**

The mission of the research team and the implementation of research is aimed at researching and defining the connection between the impact of human factors and its surroundings while driving on a general road safety. Primarily this applies to traffic signalization and equipment, weather conditions and the state of the driver. The main objective of the research is to obtain new, and review existing knowledge and insights into the area of traffic safety, in terms of the impact of driver's visual perception.

Expected contributions:

- strengthening the scientific and research activities of the Faculty and the establishment of the Testing Laboratory of the Department of Traffic Signalization in the Republic of Croatia and region
- the acquisition of new and expansion of existing knowledge in the field of traffic safety and traffic signalization
- increasing the competitiveness of researchers
- publication of research results in journals and at international conferences and organized workshops
- connecting and strengthening cooperation with other research groups of the University
- inclusion of doctoral students and students from the Faculty in the research in order to increase their competitiveness
- connect with industry with the aim of evaluation and application of acquired knowledge in the transport system

2. **Project application in the context of Horizon 2020 as a partner institution:**

The coordinator is Politechnika Krakowska, Poljska

Project title: ERINTS – Enhanced Retroreflectivity of Horizontal Road Markings to Improve Night Time Traffic Safety

The project is related to the research of road markings visibility and is encompassed by an international team made up of: Politechnika Krakowska, Kraków University of Technology (project coordinator), Generalna Dyrekcja Dróg Krajowych and Autostrad (General Directorate for State Roads and Motorways, GDDKiA), Faculty of Transport and Traffic Sciences, University of Zagreb, Chemosignal d.o.o., SmartView, Svarovski GmbH and Naami-V OÜ, Estonia.

The goal of the project is related to the study of the impact of road markings with enhanced retroreflection on drivers' attention and thus safety. Additional benefit of markings with enhanced retroreflectivity would be their better visibility by senior citizens, who are becoming increasingly large part of European society.

Expected contributions:

- Correlation between enhanced retroreflectivity of road markings and safety.
- Discovery of the optimum patterns of transverse markings of various shapes and various retroreflectivity that would furnish maximum speed reduction.
- Field correlation between enhanced retroreflectivity and speed and accuracy (number of lane departures) of driving.
- Improvement of road safety for night time driving.
- Improvement of quality of life for elderly and persons of less-than-perfect vision by delivering markings that could be seen better. Hence, increased mobility of these vulnerable society members would be increased.

- The expected outcome would permit road authorities to select appropriate markings to increase safety in various accident-prone zones and thus comply with the European Union target of decreasing road fatalities to 15750 in 2020.
- The selection of road marking materials shall be done based on their durability and sustainability. The enhanced markings in danger zones shall also positively influence the environment by limiting traffic jams caused by collisions and making the drivers to drive more smoothly, thus lowering the use of fuel.

3. Project application in the field of road safety on the Croatian territory for 2017

The goal of the research is to determine how the driver's detection, the number of fixations and the duration of eye fixation on pedestrians varies depending on the visibility of pedestrians. The study will analyze how the use of reflective vests and bright clothing affects the perception of pedestrians in traffic.

Expected results of the study are focused on identifying the factors that influence the perception of pedestrians in traffic and analysis of various types of reflective vests and bright clothes on the visibility of pedestrians. By using a sophisticated method of eye tracking, a clear insight into the number and duration of fixation of the driver's eyes on pedestrians will be determined. Based on that analysis the impact of reflective vests and bright clothes on visibility and conspicuity of pedestrians will be determined and solutions related to the elimination of potentially dangerous traffic situations for pedestrians will be proposed.

5.4 Obtained additional projects and funds

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	Academic mobility (University of Zagreb)	Mobility of doctoral students	Conference fee for the conference: *International Conferences on Traffic and Transport Engineering 2016* (Belgrade, Srbia)	2.150,00 kn
2.	Academic mobility (University of Zagreb)	Mobility of doctoral students	Conference fee for the conference: *International Conference “Environmental Engineering”* 2017 (Vilnius, Lithuania)	2.150,00 kn

The results of two years of research of visibility/durability of road markings were presented at the International Conferences on Traffic and Transportation Engineering in 2016 in Belgrade, Serbia. Also, the results of the first phase of research related to the perception of traffic signs will be published in 2017 on two conferences: International Conference "Environmental Engineering" (Vilnius, Lithuania) and the International Conference on Traffic Development, Logistics & Sustainable Transport (Opatija, Croatia).

5.5. Published papers

- Burghart, E. T., Babić, D., Babić, D. Application of Waterborne Road Marking Paint in Croatia: Two Years of Road Exposure. *Proceedings of the Third International Conference on Traffic and Transport Engineering*, Belgrade, Serbia, September, 2016. p. 1092-1096.

Waterborne road marking paints with various glass beads were applied two years ago at a test field in Croatia, on a road with Annually Average Daily Traffic (AADT) of 8469 vehicles. Retroreflectivity (R_L) was measured periodically using a dynamic test method and the results showed that performance of the evaluated systems depended mostly on the utilised glass beads, with high-performance glass beads of exceptional roundness and surface quality clearly furnishing the highest R_L after the two seasons. With other evaluated glass beads, all systems were also clearly passing after two years. Overall, waterborne paints were found to be an excellent choice, somewhat outperforming simultaneously applied solventborne paints. Their lesser environmental impact is an additional benefit that should be considered.

- Tremski, Š. Analysis of The Traffic Signs Perception Using the Method of Montoring the Driver's Eyes. *Master thesis*. Faculty of Transport and Traffic Sciences, Zagreb, 2016.

The purpose of this research is to analyse the concept of driver’s visual perception of traffic signs using eye tracking method. The main goal was to analyse how well the drivers differ danger, notification and mandatory traffic signs.

- Pavić, M. Analysis of Traffic Signs Perception Using Eye Tracking Method. *Master thesis*. Faculty of Transport and Traffic Sciences, Zagreb, 2016.

In this paper the driver's perception of the traffic sign is analysed using such a system. The goal of this paper is to determine how the perception of traffic signs changes according to the frequency of driving on a specific route or in accordance with the familiarity of the route. The results show that the driver’s perception of the traffic signs will decline as he gets familiar with the route and road conditions. Also, older drivers with more driving experience perceived fewer signs and elements from the environment because they are often lead by their own experience and knowledge so they do not need the same amount of information as compared to the younger drivers.

- Mitrović, A., Ščukanec, A., Babić, D. Impact of Winter Maintanance on Retroreflection of Road Markings. *Proceedings of the International Scientific Conference – ZIRP: Perspectives on Croatian 3PL Industry in Acquiring International Cargo Flows*. Zagreb, 2016.; p. 119-127 (poster, international review, published, scientific)

The retroreflective properties of the road markings represent their most important characteristic and it is closely related to their durability or service life that is affected by several factors. One of the factors is winter maintenance activities, or removing snow form roads. The mentioned factor is subject of the analysis carried out in this paper. The analysis was made based on the results of retroreflection measurements of painted road markings before and after winter on state roads in Republic of Croatia. The research results show that in similar traffic conditions, retroreflection of the painted road markings was significantly degraded on the roads with winter service activities in relation to the roads without winter service activities. The average absolute difference of the retroreflection degradation of painted road markings on the roads with and without winter service is 17.40% for the center lines and 21.01% for the edge lines.

- Banović, B., Fiolić, M., Babić, D. Value Assessment of Traffic Signs Retroreflection in Their Life Cycle. *Proceedings of the International Scientific Conference – ZIRP: Perspectives on Croatian 3PL Industry in Acquiring International Cargo Flows*. Zagreb, 2016.; p. 1-9 (international review, published, scientific)

The retroreflective materials for traffic signs began to be applied from 1939 when the experts in the 3M company produced first reflective traffic sign that is set at the intersection of State Road in Minnesota in the United States. The last 30 years the numerous studies were implemented and the different reflective materials (High Intensity Grade, Diamond Grade) have been developed and used for making traffic signs with the aim of increasing the visibility, especially at night and harsh conditions, and thus the overall traffic safety on the roads. This paper presents the analysis of the retroreflection value of traffic signs for a certain period of time and their impact on traffic safety.

- Babić, D., Burghardt, T., Babić, D. Application and Characteristics of Waterborne Road Marking Paint. *International Journal for Traffic and Transport Engineering.* 2015.; 5(2):150-169. (journal article, scientific).

The focus of this paper is on road marking paints with a special emphasis on contemporary waterborne materials. Analysis of characteristics of waterborne road marking paints and preliminary results from their trial application in Croatia are presented herein. Based on the presented comparison with solventborne materials, after results from test application become available, intelligent decisions regarding future use of waterborne road marking paints in Croatia and other countries that have not embraced this technology shall be possible.

- Fiolić, M., Ščukanec, M., Sokol, H. Function of Decision Support System in Traffic Signs Maintenance. Proceedings of the International Scientific Conference – ZIRP: Cooperation Model of the Scientific and Educational Institutions and the Economy. Zagreb, 2015.; p. 77-85. (international review, published, scientific)

This paper proposed a Decision Support System in case of replacement old and inadequate road signs with new. Proposed Decision Support System in the traffic signs maintaining function based on specific parameters (after testing signs at a certain section) will develop a plan for maintenance and replacement of traffic signs which do not meet the minimum legal requirements of retro-reflection, those who are not technically correct or will give warning for those signs who are on the verge of meeting all these requirements.

- Babić, D., Stažnik, A., Petr, P. Durability of Cold Plastic Material for Road Markings on the Part of the State Road D31 in Zagreb County. *Proceedings of the International Scientific Conference – ZIRP: Cooperation Model of the Scientific and Educational Institutions and The Economy.* Zagreb, 2015.; p. 1-8. (international review, published, scientific)

Road markings represent entity related to the pavement curtain composed of interconnected materials whose task is to ensure durability in poor weather conditions, durability, high value of skid resistance and more. This paper will present the analysis of plastic material durability (cold plastic) for road markings. Durability analysis implies a four-year retro-reflection value monitoring of performed road markings on the part of the state road D31 including their surface condition.

- Babić, D., Ščukanec, A., Krleža, J. The Possibilities for Improving Safety on Croatian State Roads D3 and D29 with the Analysis of the Traffic Signs Quality. Proceedings of *International Scientific Conference – ZIRP: Cooperation Model of the Scientific and Educational Institutions and The Economy.* Zagreb, 2015.; p. 9-18. (poster, international review, published, scientific).

Traffic accidents represent a significant social problem on the roads throughout the European Union and for this reason traffic safety is one of the key focuses of the European Commission which passed the fourth European Road Safety Action Programme in 2010, whose main task is to reduce the number of fatalities on the EU roads in the period from 2010 to 2020. One of the preventive actions of this program is aimed at improving road infrastructure, and thus at improving traffic signs as a vital part of traffic signalization. This paper represents the analysis of the quality of traffic signs and traffic accidents on Croatian state roads D3 and D29. The main objective is to get an insight look in to the quality of traffic signs and the number of traffic accidents on these two state roads.

6. CONCLUSION AND FUTURE WORK

Through two years of the project significant progress has been achieved in the form of equipping the Testing laboratorie of the Department of Traffic Signalization and the establishment of the research group. Also, research has resulted in new knowledge and insights into the drivers' perception of traffic signs and resulted in two graduate theses and several scientific articles. In the research activities, actively were involved doctoral and master students, which enable the creation of a coherent and competitive research group which was one of the main objectives of the project. Due to the time required for traning of the researchers for efficient use of sophisticated test equipment and longevity of data collecting and processing, a significant scientific contribution is expected in the next year, in the form of specific papers.

Firm cooperation with domestic and international business entities has been established, such as Swarovski - SWARCO GmbH., 3M, Hrvatske ceste d.o.o. and Pismorad d.o.o., with which the evaluation and application of acquired knowledge in the transport system has been enabled.

Also, the formation of a research working group has resulted in the three project applications of which one was accepted, one rejected and one is under evaluation.

Future scientific and research activities of the working group will be focused on the expansion of so far conducted researches. Planned studies involving Tobii glasses will be focused on the impact of vehicles, weather conditions, psychological and physical condition of drivers (periodical and permanent condition) and background effect on the visibility of objects. In the collaboration with the Department of Psychology of Center for Croatian Studies, research will be conducted to study the impact of those elements in simulated and actual conditions. As mentioned plan involves a multidisciplinary approach and the inclusion of a large number of participants, it is being predicted that the implementation of research and analysis and processing of collected data will greatly contribute to strengthening the research potential of the Working group an all employees individually. Students will be actively encouraged to participate through their work at the Department as well as through the development of master theses and thesis that will compete for the Rector's Award.

Since the Working Group plans to conduct laboratory testing, it is planned to further equip the Testing laboratory with the driving simulator. This will enable the implementation of further research of the driver's perception of traffic signs and the general behavior of traffic participants in simulated conditions.

Also, further application on the international and domestic scientific and research procjets is planned, as well as strengthening of the international cooperation with the economic and scientific entities.

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RESEARCH OF MEASURES TO IMPROVE SAFETY AT LEVEL CROSSINGS – 2nd PHASE

ABSTRACT

The research plan included a number of activities that have been used to encourage work on scientific research, with the aim of establishing an interdisciplinary research group that will be continuous and long-term deal with research in the field of safety at level crossings and prevention measures and to disseminate research results in the context of the publication of research results in scientific and professional journals and participation at conferences and networking with other research groups.

KEY WORDS:

Level crossing; safety; measures

1. INTRODUCTION

From the safety point of view, level crossings (LCs) are critical points in the safe conduct of rail and road traffic. Due to the different characteristics of rail and road vehicles (size, speed, stopping distance, manoeuvring capabilities etc.) level crossings are often places with frequent accidents which and in most cases, result in human fatalities and big material damages, even though, all of them are secured with appropriate level of technical protection. Accident statistics have shown that the main cause for all accidents (more than 95%) is human factor of road users (drivers, cyclist and pedestrians) who didn't follow and obey traffic safety regulation at level crossings.

On average, fatalities at level crossing accidents in EU counties represent almost 30% of all fatalities in railway traffic, but only about 1% of fatalities in road traffic. Due to this fact, accidents at level crossings don't represent a significant issue for road sector authorities, but they are mayor obstacles for both traffic efficiency as well as rail safety. When it comes to Republic of Croatia, accident statistics are even worse, with an average of 44% fatalities in railway traffic happened on level crossings. What is even more concerning is the fact that almost half of those fatalities happened on actively protected level crossings (flashing lights and sound and/or half-barriers). This suggests that in Croatia, as in many other countries, risky road user behaviour is a prime contributor to LC accidents. Currently there are total of 1.520 level crossings in Croatia on 2.605 km of railway lines. Every level crossing in Republic of Croatia is protected with a legal minimum passive protection. Out of all level crossings, 62,76% are protected with passive protection systems and remaining 37,24% with active protection system.

Research plan consists of several activities of which main goal is encouraging work on scientific research, with a purpose of creating an interdisciplinary research group that will long-term and continuously conduct research in safety at level crossings and accident prevention measures. Research results will be published in scientific and expert journals as well presented at international and domestic scientific conferences.

2. RESEARCH GOAL AND MOTIVATION

Approximately 45% of Croatian LCs lie within urban environments where safety is a particular problem. This is especially true in Zagreb area with highest traffic volumes both in railway as well in road traffic. Also, Zagreb area has the highest number of pedestrian fatalities on level crossings when comparing to the rest of Croatia.

One challenge to investigating LC safety in Croatia is the highly-fragmented way in which data about LC incidents are gathered and collected. The national railway (HŽ Infrastruktura), Ministry of the Interior (MUP), Agency for Accident Investigation in Air, Sea and Rail Traffic (AIN), and Ministry of Maritime Affairs, Transport and Infrastructure (MPPI) separately collect, monitor and analyse LC incident data using different methods. As a result, the databases sometimes do not overlap and when they do, they can deviate substantially from one another.

The present study is aimed to examine the behaviour of pedestrians and cyclists at urban LCs in the Croatian capital, Zagreb. Analysed behaviour will then be used to propose and implement best safety measures for preventing or completely diminish level crossings accidents.

3. RESEARCH ACTIVITIES

Firs part of research activities was screening all LCs in Zagreb to identify ones where road users (motor vehicle drivers, cyclists and pedestrians frequently show risky behaviour. After selecting a high-traffic LC with known safety issues as a case study, we combined survey and video recording approaches to examine whether risky crossing behaviour can be influenced by the presence of video cameras or officials who are empowered to issue fines (uniformed police officer) or not (HŽ railway gate keeper).

To identify an appropriate LC in Zagreb that would serve as a case study of urban LCs at high risk of accidents, we screened 41 LCs in the capital in terms of geometric elements, road traffic density, rail traffic, safety systems and numbers of accidents. Over the last decade, 53 accidents were reported at 17 of the 41 LCs, resulting in 23 deaths. All LCs were also examined based on video camera images. In the end, we selected an LC connecting Austrian Republic Street and Jagić Street to the north with Magazine Street to the south. This LC (localy called R.Austrije) features a macadam-paved surface crossing the double track international main corridor M101 (Dobova – Savski Marof – Zagreb Gl. Kolodvor). This LC forms part of the western rail field lying immediately ahead of the Zagreb Main Railway Station for trains approaching from the east.

The study was based on continuous observation of pedestrian and cyclist behaviour at the LC with the goal of determining the frequency of risky behaviour and identifying potential causes. In addition, the study aimed to examine whether risky behaviour was affected by the presence of video cameras, HŽ personnel and a uniformed police officer empowered to issue fines. We conducted field observations and video-recorded user behaviour at the LC during five days, Monday to Friday. Video footage was collected using two cameras, filming from the opposite directions of each other. Field observations was carried under various conditions (Table 1) to assess and compare pedestrian and cyclist behaviour.

Table 1 – Summary of observation conditions at the LC.

Day	Camera		Researcher		Police officer visible	Survey	Posters	HŽ gate keeper visible
	Hidden	Visible	Hidden	Visible				
Monday	✓		✓					✓
Tuesday	✓		✓					✓
Wednesday		✓		✓				✓
Thursday		✓		✓	✓	✓	✓	✓
Friday	✓		✓				✓	✓

On the fourth day, together with the presence of police officer and educational posters, a short survey was conducted by project members of approaching pedestrians and cyclists at the LC. Project members asked patrons fill out a brief, 8-question paper survey concerning their demographic characteristics (age, gender, residence), frequency of LC crossing, reasons for LC crossing, knowledge of crossing rules and awareness of a fine for illegal behavior.

4. BUDGET SPENDING

This section describing summary of how the budget for the project was planned and spent during the two project years.

As the significant funds generated from other projects, some planned activities were financed from these other sources. Table 2 shows summary of budget and realized activities.

Table 2 – Planned and realized activities with budget overview

Nr.	Planned activity	Planned 2-year budget [kn]	Achieved [kn]
1	Field research of LCs	32,000.00	2,082.00
2	Survey	3,000.00	705.00
3	Equipment	6,000.00	7,376.13
4	Dissemination	46,000.00	21,915.23
	∑	90,000.00	32,078.36

5. RESULTS

Project results achieved during the two project years are describe into five subsections related to involvement of students (including PhD students), cooperation with industry and academia (domestic and foreign), submitted project applications, obtained additional project and funds, and list of published papers.

5.1 Involvement of students

During the project students were actively involved in data collection in the filed by observing and monitoring targeted level crossings in Zagreb area. Some of the research that came throughout this project was used in doctoral dissertation “Level Crossings Risk Assesment Model” by Martin Starčević. Data collected during this research project was also used for 2 graduate thesis of students Tomislav Gotić and Filip Pižeta.

List of PhD and Master thesis:

- Starčević, Martin: LEVEL CROSSINGS RISK ASSESMENT MODEL, doctoral thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 2015
- Gotić, Tomislav: EVALUATION OF SOLUTIONS FOR LEVEL CROSSINGS RECONSTRUCTION AT THE ZAPADNI KOLODOVOR AREA IN ZAGREB BY APPLYING ANALYTIC HIERARCHY PROCESS, master thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 2016
- Pižeta, Filip: PROJECT VARIANTS EVALUATION OF LEVEL CROSSING TRNAVA BY APPLYING ANALYTIC HIERARCHY PROCESS, master thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 2016.

In addition, LC students research group were formed. Three students from LC student research group prepared student research work which was awarded the Dean's Award:

- Gotić, Tomislav; Habuzin, Igor; Pižeta, Filip: MULTI-CRITERIA ANALYSIS OF ENVIRONMENTALLY SUSTAINABLE AND SOCIALLY BENEFICIAL TRAFFIC DESIGN SOLUTIONS TO IMPROVE SAFETY AND MOBILITY FOR THE AREA OF ZAGREB ZAPADNI KOLODVOR, University of Zagreb, Faculty of Transport and Traffic Sciences, 2016

5.2 Cooperation with industry and academia

During the project period cooperation with domestic and foreign industry, companies, institutions, and academia was established. List of institution:

- The national railway - HŽ Infrastruktura
- Ministry of the Interior (MUP)
- Agency for Accident Investigation in Air, Sea and Rail Traffic (AIN)
- Ministry of Maritime Affairs, Transport and Infrastructure (MPPI)
- ILCAD association (International Level Crossing Awareness Day)
- Several Universities

5.3 Project applications

Based on preliminary research through the support of PROM-PRO, the research group apply for a funding of a total of eight projects. Description of submitted project application including funding scheme, project name, budget and status are shown in Table 3.

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Project name	*Budget*	*Status*
1	National Road Traffic Safety Programme of the Republic of Croatia 2011 - 2020	IMPLEMENTATION OF MEASURES TO INCREASE SAFETY OF THE MOST VULNERABE ROAD USERS AT LEVEL CROSSINGS (2017)	500,000.00 kn	under review
2	National Road Traffic Safety Programme of the Republic of Croatia 2011 - 2020	IMPLEMENTATION OF MEASURES TO INCREASE SAFETY OF THE MOST VULNERABE ROAD USERS AT LEVEL CROSSINGS (2016)	500,000.00 kn	approved
3	Agency for Accident Investigation In Air, Sea and Rail Traffic (AIN)	ANALYSIS OF THE CURRENT STATE OF THE RAILWAY CROSSING FACTORY KNAUF (235 + 141) IN KOSOVO	12,500.00 kn	approved
4	Agency for Accident Investigation In Air, Sea and Rail Traffic (AIN)	ANALYSIS OF THE CURRENT STATE OF THE RAILWAY CROSSING KUPINEC	12,500.00 kn	approved
5	University of Zagreb	THE EFFECTS OF THE IMPLEMENTATION OF MODELS OF RISK ASSESSMENT AT LEVEL CROSSINGS	6,152.45 kn	approved

Nr.	Funding scheme	Project name	*Budget*	*Status*
6	HORIZON 2020, Work Programme Part: Smart, green and integrated transport, RIA, MG-3.4-2016	LOCATOR - NOVEL LEVEL CROSSINGS SAFETY ASSESSMENT METHODOLOGY	3,200,000.00 eur	rejected
7	H2020-S2RJU-OC-2015-01-2 SHIF2RAIL-RIA	OPTIMISER - OPTIMAL PLATFORM FOR TRAIN INTEGRATED MOBILITY AND INTEROPERABLE SAFETY ENVIRONMENT IN RAILWAYS	1,475,850.00 eur	rejected
8	COST	PREVENTRAIL - BUILDING CAPACITY AND SKILLS TO PREVENT SUICIDE AND TRESPASS ON EUROPEAN RAILWAYS		rejected

5.4 Obtained additional projects and funds

During the 2 year of project, four project proposals are accepted and funds received. Overview of submitted and accepted project proposals for funding is shown in Table 4.

Table 4 – Overview of submitted and accepted project proposals for funding

Nr.	Funding scheme	Name of project or grant	*Budget*
1	National Road Traffic Safety Programme of the Republic of Croatia 2011 - 2020	IMPLEMENTATION OF MEASURES TO INCREASE SAFETY OF THE MOST VULNERABE ROAD USERS AT LEVEL CROSSINGS (2016)	500,000.00 kn
2	Agency for Accident Investigation In Air, Sea and Rail Traffic (AIN)	ANALYSIS OF THE CURRENT STATE OF THE RAILWAY CROSSING FACTORY KNAUF (235 + 141) IN KOSOVO	12,500.00 kn
3	Agency for Accident Investigation In Air, Sea and Rail Traffic (AIN)	ANALYSIS OF THE CURRENT STATE OF THE RAILWAY CROSSING KUPINEC	12,500.00 kn
4	University of Zagreb	THE EFFECTS OF THE IMPLEMENTATION OF MODELS OF RISK ASSESSMENT AT LEVEL CROSSINGS	6,152.45 kn

5.5. Published papers

Members of the project team published papers in journals and presented on conferences: List of published papers [1-5]:

- Barić, Danijela; Starčević, Martin; Pilko, Hrvoje: ANALIZA PONAŠANJA SUDIONIKA U PROMETU NA ŽELJEZNIČKO-CESTOVNIM PRIJELAZIMA. // Željeznice 21: stručni časopis inženjera i tehničara Hrvatskih željeznica. 15 (2016), 3; 7-17
- Starčević, Martin; Barić, Danijela; Pilko, Hrvoje: SURVEY BASED IMPACT OF INFLUENCING PARAMETERS ON LEVEL CROSSINGS SAFETY. // Promet - Traffic & Transportation. 28 (2016), 6; 639-649
- Barić, Danijela; Pilko, Hrvoje; Starčević, Martin: VIDEO- AND SURVEY-BASED ANALYSIS OF PEDESTRIAN AND CYCLIST BEHAVIOR AT AN URBAN LEVEL CROSSING // Transportation Research Procedia. 2016. C4-4C1-1-C4-4C1-11
- Barić, Danijela; Starčević, Martin; Pilko, Hrvoje: EVALUATION OF PEDESTRIAN BEHAVIOR AT LEVEL CROSSINGS IN URBAN AREAS // GLXS2016. 2016
- Starčević, Martin; Barić, Danijela; Pilko, Hrvoje: SAFETY AT LEVEL CROSSINGS: COMPARATIVE ANALYSIS // Road and Rail Infrastructure IV / Stjepan Lakušić (ur.). Zagreb: Department of Transportation; Faculty of Civil Engineering; University of Zagreb, 2016. 861-868

6. CONCLUSION AND FUTURE WORK

There is no one single measure for increasing safety at level crossings. Since the main cause of all level crossings accidents is human behavior of road users (motor vehicle drivers, cyclist and pedestrians), every implemented measure for increasing safety at level crossings should designed so they can maximally possible remove unacceptable human decisions while driving or walking over level crossings. The only effective solution could be building overpasses or underpasses, but high cost of such projects brings a need for more cost-effective solutions. Unfortunately, technical solutions are only effective if the road users completely obey traffic rules regarding level crossings. According to this fact and accident history on level crossings, it is equally important to systematically implement educational campaign for all level crossing users, for all age groups, as a part of a national strategy for increasing safety at level crossings. [1-6].

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[4] Barić, Danijela; Starčević, Martin; Pilko, Hrvoje: EVALUATION OF PEDESTRIAN BEHAVIOR AT LEVEL CROSSINGS IN URBAN AREAS // GLXS2016. 2016

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DEVELOPMENT OF RESEARCH CAPACITIES IN THE FIELD OF APPLIED AERODYNAMICS

ABSTRACT

The Faculty of Transport and Traffic Sciences (FPZ) established the Aerodynamic Laboratory with a low speed wind tunnel. The beginnings of the Laboratory establishment activities date back to 1997 as a joint cooperation and investment of FPZ and Faculty of Mechanical Engineering and Naval Architecture (FAMENA). The first location of Laboratory was in the FPZ hangar at the Lučko airport. The tunnel is used for educational purposes in laboratories of several courses at aeronautical study of FPZ and Aeronautical Engineering study at FAMENA.

The AT-1 wind tunnel located in the Aerodynamic Laboratory is the only wind tunnel in Croatia. The goal of this project was better utilization of laboratory research purposes and raising the competitiveness of research groups in the field of applied aerodynamics. The main objective of the research activity is focused on the development of measurement systems in the wind tunnel, improving existing and acquiring new measurement and other equipment.

The PROM-PRO research program contributed to the development of wind tunnel measurement systems and raising the competitiveness of research groups in the field of applied aerodynamics.

KEY WORDS:

Wind tunnel; experimental research; applied aerodynamics; aerodynamic coefficients.

1. INTRODUCTION

The Faculty of Transport and Traffic Sciences in Zagreb has had the small subsonic wind tunnel AT-1 settled in the Aerodynamic Laboratory at Borongaj University Campus since 2014.

The research and laboratory work on the wind tunnel started in 1997 jointly by the Faculty of Mechanical Engineering and Naval Architecture (FAMENA) and the Faculty of Traffic and Transport Sciences, University of Zagreb. The past research of the aerodynamic characteristics is associated with the research project "Experimental investigation of aerodynamic characteristics", project code 120046, which is supported by the Ministry of Science and Technology managed by FAMENA from 1997 to 2002. The aim of the project was to establish, equip and organize the scientific work of the Laboratory of experimental aerodynamics.

Wind tunnel at the Aerodynamic Laboratory was established in 2000 at FPZ Lučko hangar through cooperation and joint investment of the FAMENA and FPZ. The tunnel is intensively used for instructional purposes for students of both faculties until 2010, when is due to a problem with a lack of space disassembled.

In early 2014, the wind tunnel was reassembled and launched within the Laboratory of Aerodynamics at the Faculty of Traffic Sciences, Borongaj Campus, building 210.

This report is organized as follows: Section 2 describes the research goal and motivation for the project. In Section 3 the project research activities are described. Following, Section 4 gives an overview of the budget spending including a short description of the purchased equipment. Section 5 shows the project results with emphasis on applications for new projects, obtained projects and grants, and published papers. The report ends with a conclusion and future work section.

2. RESEARCH GOAL AND MOTIVATION

One of the ways to obtain experimental aerodynamic data is to use scaled aircraft models in subsonic wind tunnel at low speed. Figure 1 shows scheme of closed subsonic wind tunnel.

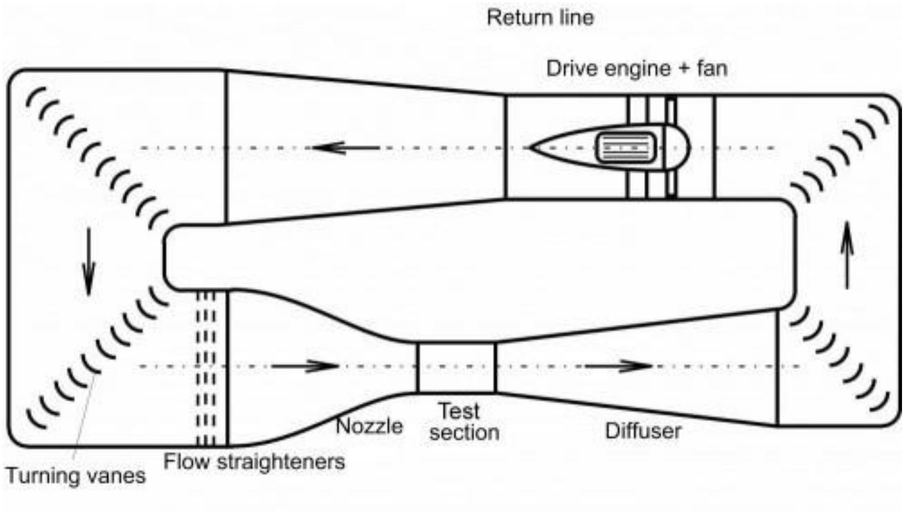

Figure 1 – Scheme of closed subsonic wind tunnel

After the re-establishment of the Laboratory of Aerodynamics in the beginning of 2014, the continuation of experimental research in the Laboratory of Aerodynamics is based on the development of measurement systems for determining the aerodynamic characteristics of aircraft in the wind tunnel. To achieve this goal, long-term investment in the competence of researchers and purchase of equipment is necessary.

A prerequisite for the setting and development of experimental research in the wind tunnel was previously good knowledge of the characteristics of the tunnel. For this purpose a research plan was made, which included:

- calibration of the wind tunnel
- pressure distribution on the airfoil in a wind tunnel,
- data acquisition system mounting,
- scanning a possibilities of aerodynamic coefficients determination,
- selection system for setting the aircraft model in the wind tunnel,
- measurements of aerodynamically generated noise in airfoils,
- scanning a possibilities of improving the quality of the flow by closing the working sections and installation additional air flow straighteners

The research plan should be realized through the following activities:

- establishment a research team
- raising the competence of researchers through education
- involvement of students through undergraduate and graduate theses

Results of some of these activities are realized in the period of the past two years, it was made a study about measurement capabilities in the wind tunnel and a few student theses.

One part of the planned activities is achieved within the first cycle of the PROM-PRO research program (FPZ, february 2015 - february 2016), second part within the University of Zagreb research support (june – december 2015.) and third part within the second cycle of the PROM-PRO research program (FPZ, february 2016 - february 2017).

Results of the research will be prepared for publication in the form of scientific papers and publish in journal and conference during 2017.

3. RESEARCH ACTIVITIES

The two-year research activities can be divided in three parts. The first part of research is related to data acquisition systems mounting. Second part of research is theoretical and related with possibilities of aerodynamic coefficients determination. The third part of research about measuring the aerodynamic noise in boundary layer is still in progress.

3.1 Data Acquisition System Mounting

In determining and analysing the aerodynamic characteristics of the aircraft, the best results are obtained by combining analytical, numerical and experimental methods.

The AT-1 wind tunnel has small opened test section with elliptical cross section (Width = 352 mm, Height = 310 mm and Length = 450 mm), Figure 2.

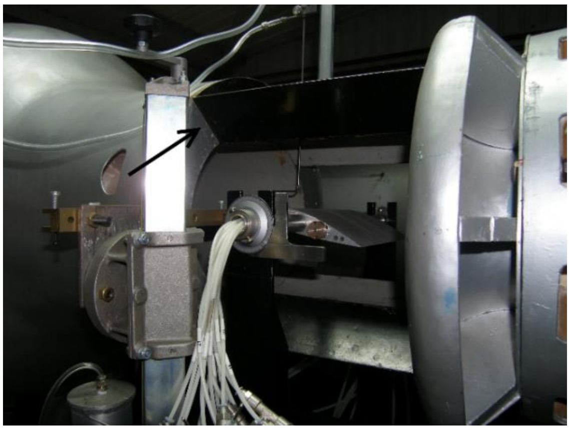

Figure 2 – Airfoil in the test section of AT-1 wind tunnel

The airflow is produced by a single-stage fan powered by a 4 kW, variable-speed synchronous motor with a variable-frequency speed controller up to 50 Hz. The maximum air velocity is up to 50 m/s.

The system for acquisition of pressure Intelligent Pressure Scanner 9016 (Figure 3) in wind tunnel AT-1 is used for measuring of pressure distribution over NACA 2421 airfoil.

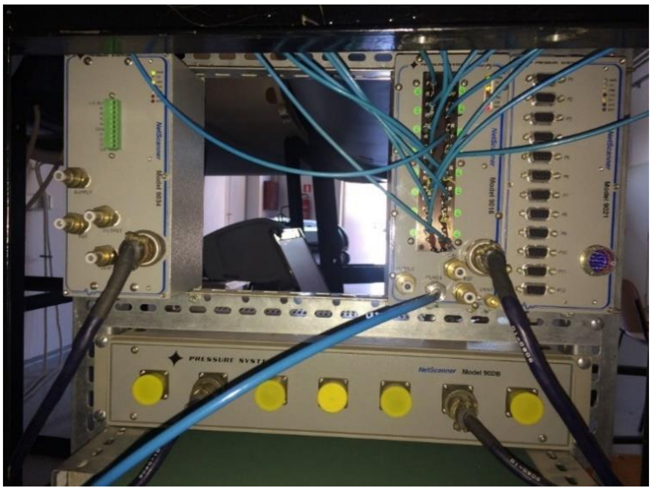

Figure 3 – Intelligent Pressure Scanner System

This is an old system that had burned processor and needed to be repaired and reinstalled. The undergraduate student Domagoj Mežnarić in his thesis described the principles of measuring pressure with pressure scanner and also performed the pressure measuring over airfoil mounted in test section. The pressure from sensor is transformed into digital shape so it could be shown on the screen, within the LabView software. His thesis describes necessary settings needed for the system to work properly. The performance and correctness of measured pressure distribution for installed system is compared with pressure measured using piezometric harp.

3.2 Measuring Aerodynamic Coefficients in Wind Tunnel

For the purpose of improved education and some basic research, our goal is upgrading the wind tunnel facility with force measuring balances. Specifically, the idea is to measure the aerodynamic coefficients of airplanes using inner strain gage balance. To hold the model inside the test section, the model body will be truncated.

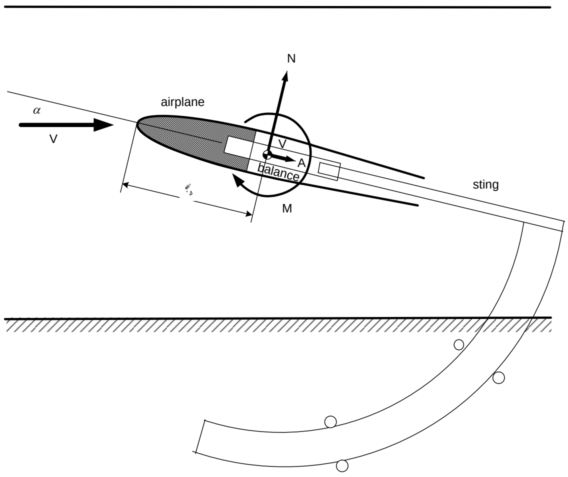

Figure 4 – The aircraft model in the wind tunnel

Through the rear part of the truncated body, we will install the model-balance-sting connection as shown on Figure 4. The measuring set up shown on Figure 4 is considered as classical organization scheme for using inner strain gage balance in high speed tests. The interfering flow effect due to the presence of the rear sting on the model is called sting interference, which will influence the final measurement results. Measuring forces at different angle of attack α is also possible by adjusting the model around the point V which is considered fixed in space. The attachment of the sting with the balance must be provided without touching the model airframe.

The problem with this wind tunnel tests is that we must use scaled models but with the intention of finding the characteristics of full-scale aircraft in flight. There is a great leap between a small-scale wind tunnel model and a full-scale aircraft in flight. Differences in model fidelity, aeroelastic effects, flow conditions and suspension interferences may cause the scale model test not to be the representative of the full-scale aircraft. These differences between free flight and tunnel conditions has to be identified to evaluate the correction of the measured aerodynamic coefficients.

There are experimental, empirical and CFD methods used as correction technique data depending on the flow conditions (Reynolds and Mach number effects), geometry and types of measurements [1], [2], [3], [4]. Many of these methods are used in conjunction with CFD technology for more accurate results [5]. Alternatively, there are highly expensive cryogenic wind tunnels such as European Transonic Windtunnel (ETW) that has ability to match the respective high Reynolds number, as a key feature which cannot be done in conventional wind tunnels at ambient temperature.

Among listed possible sources of differences between free flight testing and wind tunnel testing, the purpose of our research is estimation of preliminary measurement errors due to scale effects differences and model-sting interaction for chosen organization of measurements.

The dependency of the aerodynamic properties from the Reynolds number is a typical example of so-called Reynolds number scaling effects, which play an important role when results from subscale wind-tunnel tests have to be extrapolated to flight conditions [6]. The Reynolds number is the ratio of inertial to viscous forces, and is the primary aerodynamic scaling parameter used to relate sub-scale wind tunnel models to full-scale aircraft in flight.

Also, one of the crucial points of measurements in wind tunnels is the attachment of the aircraft model within the tunnel. The aerodynamic coefficients measuring methods depends on the available working space dimensions. If this space is very small the model must be also very small. The problem is how to organize the measurement considering problem of holding the model on the balance and then attaching the balance to the sting big enough to accommodate the wires from the balance to the acquisition computer.

3.3 Measurements of Aerodynamically Generated Noise in Airfoils

With the aim of extend wind tunnel laboratory activities in concurrence with the complementary research objectives of Laboratory for Aircraft Emissions, the aerodynamically generated noise investigations are scheduled to be underway in 2017. The strategy is to design measurement layout which will initially function as student laboratory exercise and diploma essay workstation, whereas in future, being progressively upgraded, will serve in more complex scientific research.

The core of the future measurement set is the sensor array consists of several solid state (piezoceramic) accelerometers distributed along the airfoil in a particular manner, which can be optionally altered, in order to assess the correlation between noise data and airfoil geometry. Since the possibility of altering few other variables, like the angle of attack (AoA) of the airfoil, airstream speed etc., is the inherent feature of the wind tunnel, the corresponding changes in noise characteristics will be possible to document as well. The output of the accelerometers will be monitored by PC via condition (charge) amplifier(s) and saved for further post-processing.

4. BUDGET SPENDING

This section is describing how the budget for the project was planned and spent during the two project years, see Table 1.

Table 1 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	Preparation of the study "Analysis and development plan of small wind tunnel" by prof. S. Janković	16.500,00 HRK	A study, "The possibilities for measuring aerodynamic coefficients in a small wind tunnel AT-1" is prepared by Slobodan Janković, July 2015 and presented to the members of the research team.	12.000,00 HRK
2.	The five-day training seminar at the Von Karman Institute in Belgium.	13.225,99 HRK	Not performed due to lack of funds	0,00 HRK
3.	Small equipment for the purpose of digitization pressure measurements in the wind tunnel	2.000,00 HRK	Realized from the other fund (University support)	0,00 HRK
4.	Consulting services for project documentation preparation and translation	10.000,00 HRK	Not performed	0,00 HRK
5.	Participation in an international conference abroad	7.030,00 HRK	Participation of Karolina Krajček Nikolić (without paper) at the conference INAIR 2015 in Amsterdam	3.000,00 HRK
6.	Training in the wind tunnel at the Von Karman Institute in Belgium (Karolina Krajček Nikolic) (Transferred from the first cycle)	14.000,00 HRK	Not performed	0,00 HRK
7.	Education of research team and consultations - contract for the professor. Jankovic (Transferred from the first cycle, has not been paid due to lack of funds)	4.500,00 HRK	Not performed	0,00 HRK
8.	Participation in the International Conference / paper with students	4.000,00 HRK	Will be performed in May 2017.(conference MIPRO or ZIRP, publication fee and other costs will be pay in February 2017.) Paper Title: "Data Acquisition System for Wind Tunnel Pressure Measuring" Authors: Mežnarić, D. (student); Krajček Nikolić, K; Franjković, D.	4.000,00 HRK
9.	Publication fee in the open access journal	12.000,00 HRK	Not performed (the paper will be submitted for publication in Journal PROMET- Traffic&Transportation)	0,00 HRK
10.	Small equipment for measuring, teaching or theses experiment preparation	5.000,00 HRK	Realized for buying Scherrer RC Long Range System, 3D printer filaments, nozzles, and other supplies for student thesis experiments	6.000,00 HRK
11.	Laboratory equipment for structure-borne noise and boundary layer noise measurements in airfoil models	0.000,00 HRK	Will be accomplished in February 2017 by purchasing following equipment: condition amplifier, solid state (piezo) accelerometers, wire harness, power supply	5.000,00 HRK
12.	Dissemination and visibility of the Laboratory of Aerodynamics (Printing info brochures and posters, web sites and translation into English, the organization day open doors for students, teachers and other interested	3.000,00 HRK	Not performed	0,00 HRK

The first year budget was planned for 48.755,00 HRK, but the approved budget was 15.000,00 HRK. The first year budget was spent for research team education and consultations given by professor Slobodan Janković and author honorarium for professor Slobodan Janković who wrote a study "The possibilities for measuring aerodynamic coefficients in a small wind tunnel AT-1". Also, some part of budget is spent for participation at international conference INAIR 2015 in Amsterdam for team member Karolina Krajček Nikolić.

The second year budget was planned for 42.500,00 HRK, but the approved budget was 15.000,00 HRK, too. The part of this budget was spent for laboratory equipment and 3D printer supplies such as filament, nozzle, and supplies needed for student thesis experiments. Also, some part of budget will be spent for participation at international conference for student paper with the theme of his undergraduate thesis.

5. RESULTS

This section is describing the results achieved during the two project years. The results section is divided into five subsections related to involvement of students (including PhD students), cooperation with industry and academia (domestic and foreign), submitted project applications, obtained additional project and funds, and finishes with a list of published papers.

5.1 Involvement of students

During this two-year project, students at undergraduate and graduate level, were involved in the project by setting up different experiments in the field of applied aerodynamics. Some of their work had resulted with thesis. The thesis written are at undergraduate level:

- Domagoj Mežnarić (2015): "Data Acquisition System for Wind Tunnel Pressure Measuring"

The main topic of this thesis are devices for measuring the pressure in wind tunnels and the purpose and division of the same. The system for acquisition of pressure Intelligent Pressure Scanner 9016, which is produced by the company Pressure Systems is described in detail. The system for acquisition of pressure in wind tunnel AT-1 is used for measuring of pressure distribution over NACA 2421 airfoil, and it is contained of sensors, measuring equipment and computers with corresponding programs. The pressure from sensor is transformed into digital shape so it could be shown on the screen, with the help of computer program. For the purpose of the final work, mentioned system for the acquisition of pressure is connected to the airfoil in the test section of the tunnel. The way of measuring pressure and transferring data from the measure point to the computer and the essential settings needed for the system to work properly are also described. Another part of the work is the comparison of correctness and accuracy of the installed system with the existing system by measuring of pressure distribution with piezometric harp.

- Matej Petrović (2016): "Airspeed Measuring in Subsonic Wind Tunnel AT-1"

In this undergraduate thesis principles and usual ways of measuring air velocity in wind tunnels are described with special reference to subsonic wind tunnels. The air velocity in subsonic wind tunnel AT-1 is measured using different frequencies of engine. Air humidity is taken into consideration as well.

- Luka Hendelja (2016): "The Measurement of Physical Quantities in Experimental Aerodynamics"

This undergraduate thesis describes methods for determining various physical size in aerodynamics. Parts of the wind tunnel and its design are described. With the wind tunnels are still listed methods of measuring temperature, pressure, flow velocity and the aerodynamic forces and moments. This paper describes the methods that are used primarily in aerodynamics. The paper detailed external and internal aerodynamic scales, their differences and applications as well as the advantages and disadvantages of internal wind tunnel of external wind tunnels. For work were taken and measured some quantities on the wind tunnel AT-1.

- David Ribić (2016): “Design of a Small Fixed Wing Unmanned Aerial Vehicle”

This undergraduate thesis is a description on how to make an Unmanned Aircraft Vehicle. The goal of this project is to design and mathematically verify a model plane performance. This allows for students to familiarize with basics of building an aircraft and resolving structural and aerodynamic problems. Composite materials are used for the structure; this type of material is most complex due to its manufacturing process. In building a plane, the process begins with an idea wich is mathematically tested. After that follows the free flying model test which is used for cancelling all problem for the build of the final product. The aircraft is controlled via remote control. The power plant is an electric ducted fan motor with possible afterburning butane gas to increase thrust. The performance of this aircraft are relatively good with a maximum speed of 25 m/s since it's a small aircraft with a small and weak power plant. After getting the mathematical performance they are compared with real performance given in the flight of the aircraft.

- Nikola Renčelj (planned to be done in 2017): “Conceptual Design and Performance Evaluation of UAV with Canard Configuration”, graduate thesis, in which the selected canard configuration and development of the aerodynamic drag will be analysed and experimentally verified.
- David Fujs (planned to be done in 2017.) “Measurements and Analysis of Aerodynamically Generated Noise in Airfoil Models”, graduate thesis, in which the structure-borne noise and boundary layer noise in airfoil model, generated by wind tunnel airstream, will be investigated. For that purpose, equipment set will be assembled and configured to meet specific measurement demands.

5.2 Cooperation with industry and academia

The Aerodynamic Laboratory at University Campus Borongaj is used for educational purposes of students at the Faculty of Traffic and Transport Sciences, and students at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb.

During this two-year research program, there was cooperation with colleges at the Faculty of Mechanical Engineering and Naval Architecture, Milan Vrdoljak, PhD, who is Head of Aeronautical Department at the Faculty of Mechanical Engineering and Naval Architecture, and Slobodan Janković, PhD, retired professor.

On 29 January 2016 students of elementary school "Ljubo Babic" in Jastrebarsko and high school students of school Jastrebarsko who are preparing for a competition in physics visited the wind tunnel. We demonstrated them the flow over airfoil and aeronautical engineering in general.

5.3 Project applications

During this two-year project, there is no rejected project applications. Approved project is listed in table 3 in the next subsection.

5.4 Obtained additional projects and funds

During the first cycle of research, the team submitted the project proposal at the University of Zagreb (June 2015) entitled "Development of measurement systems in the low speed wind tunnel", the number of TP037, for which they received funding in the amount of 22.079,63 HRK. These funds were available until 31.12.2015 and are fully spent for the purposes of research.

The team member Karolina Krajček Nikolić applied twice for the short visit grant schema funded by University of Zagreb, but without success.

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	University of Zagreb	Development of measurement systems in the low speed wind tunnel	The grant holder is Anita Domitrović. Aim of the project is to equip the Laboratory for Aerodynamics with basic measuring systems.	22.079,63 HRK

5.5 Published papers

Professor Slobodan Janković in 2015 wrote the study: "The possibilities for measuring aerodynamic coefficients in a small wind tunnel AT-1". The results of two-year research are prepared for submitting to PROMET- Traffic&Transportation Journal. The authors of this paper entitled "Preliminary Analysis of Measurements of Aerodynamic Coefficients in the Very Small Subsonic Wind Tunnel" are professor Slobodan Janković, Karolina Krajček Nikolić and Anita Domitrović. The purpose of this paper is to present one approach to estimate the corrections due to sting interference and due to the difference in Reynolds number between the real airplane in cruise regime and its model 1:100 in the wind tunnel. The results for correction of axial and normal force coefficients are given. The results of this analysis indicate that the Reynolds number effects and the problem of the installation of the interior balance are very high.

The results of research within undergraduate thesis of Domagoj Mežnarić will be published as a student paper at the conference MIPRO or ZIRP in May 2017. Title of the paper is: "Data Acquisition System for Wind Tunnel Pressure Measuring" and authors are Domagoj Mežnarić, (student) Karolina Krajček Nikolić and Davor Franjković. The purpose of this paper is to present system for acquisition of pressure in wind tunnel AT-1 which is used for measuring of pressure distribution over NACA 2421 airfoil. There are also described the way of measuring pressure and transferring data from the measure point to the computer and the essential settings needed for the system to work properly.

6. CONCLUSION AND FUTURE WORK

The goal of the project was to set a starting point for the research in the field of applied aerodynamics. That included building up the competence of researchers through education, equipping and installation of acquisition systems of measured data in the tunnel, calibration of the tunnel for the purpose of determination of the air flow in the tunnel and the identification of scientific research possibilities for low wind speed tunnel AT-1. The research results are planned to be published in A category journal. The results from this research gave us the new direction for experimental wind tunnel using. The future research will be aimed toward building our own force measuring balance since the commercial ones are very expensive and will not solve the problem of small test section.

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POSSIBILITIES OF APPLYING INFORMATION AND COMMUNICATION TECHNOLOGIES AND SERVICES IN THE FUNCTION OF CARPOOLING SYSTEMS

ABSTRACT

The topic of the conducted project is categorized under the developmental research and based on the results of scientific research whose final product is in the function of improved connectivity of share ride users/carpool users through the application of information and communication technologies and services. The development and overall application of numerous advanced technologies (and services) affects significantly the improvement and availability of information with the aim of connecting the users of the carpooling system by passenger cars. Dynamic carpooling supported by Information-Communication (ICTS) and Location-Navigation Technologies and Services (LNTS) represents the upgrade of the traditional and casual carpooling and the modern method of connecting the users. The project consists of two main phases. The first phase is an analysis of information and communication technologies and services that are operable in carpooling, and the second phase is the identification of relevant factors of technology application for the purposes of connecting car pool users and the entire development of dynamic carpooling.

In order to realize a better connection of users, the project analyses the characteristics of key software applications that can improve carpooling functioning. The survey method was used to determine the needs of carpooling users within the traffic environment. The goal of the conducted research is to identify the relevant factors of applying technologies in order to connect the carpooling users. The contribution of the project is reflected in the determination of relevant factors of applicable technologies for the needs of carpooling development as an alternative and sustainable transportation mode.

KEY WORDS:

Dynamic carpooling; Information-Communication Technologies and Services (ICTS); Location-Navigation Technologies and Services (LNTS); traffic environment.

1. INTRODUCTION

Carpooling/ridesharing is one of the strategies for the mobility management, e.g. a transport demand management, and it consists of various models such as car/van-pooling, carsharing, dial-a-ride, card car, etc. The intensity of the traffic system development in general, as well as the intensity of the development of shared ride models require increased application of information and communication technologies and services. In order to achieve the efficiency in performing passenger car joint rides, it is important to deliver real-time information and a corresponding access to the information about vehicles and rides, and to establish communication and mutual connection. It is undeniable that carpooling development depends on the future evolution of information and communication technologies; therefore, three segments are especially important: interoperability and integration of the databases; development of advanced systems for connection of users, and openness of users towards carpooling mobile applications.

This report is organized as follows. Section 2 describes the research goal and motivation of the project, and Section 3 provides descriptive analysis of the project research activities. Next, Section 4 gives an overview of the budget spending, including a short description of the purchased equipment. Section 5 shows the project results with emphasis on applications for new projects, obtained projects and published papers. The report ends with a conclusion and a section on the future work.

2. RESEARCH GOAL AND MOTIVATION

The research goal of conducted project is to identify relevant factors of technological application for connecting carpooling users and clarification of the entire dynamic carpooling, e.g. to define evaluation parameters for the valuation of acceptability and usability of different information and communication technologies and services supported on the basis of multi-criteria analysis (analytic hierarchy/network process). The purpose of the project is to improve the connection of shared ride users with personal vehicles through the application of information and communication technologies and services.

A motivation for the application and research of this particular topic is a desire to determine additional possibilities of appliance of information-communication technologies and services for share ride users with personal vehicles.

Within this project various technical aspects are being examined (tested) for the application, such as specified communication tools (mobile devices, tablet devices, and similar), compatible specialized web portals/program tools/mobile applications and location based services (GNSS based LBS), and the role of social networks in the users connection, all for the purpose of providing reliable, precise and real-time information to the users, which is necessary for more efficient realization of car sharing and ride sharing. A review of the users' needs set on communication equipment, services and content is provided through the conducted survey.

Relevant literature from research domain refers to scientific articles that provide the analysis of dynamic carpooling/ridesharing issues and the application of information-communication technologies in the past, present and future [1], [2], [3]. The world trends of implementing various models of joint rides by passenger cars (e.g. carpooling, carsharing, ridesharing, etc.) are oriented to the need of using innovative systems and solutions from the domain of Intelligent Transportation Systems (ITS), Innovative Transport Systems (INTS), Information and Communication Technologies and Services (ICTS) and Location and Navigation Technologies and Services (LNTS) in order to increase the use of alternative and sustainable modes of travelling [4], [5]. For carpooling to function adequately, the passengers should have the possibility of accessing timely information about the vehicles and rides, realizing communication and interconnections. The application of information and communication technologies has positive effects in connecting the users in such a manner that they realize joint mobility [6], [7], [8]. Until recently, carpooling systems had limited usage because of the lack of efficient data processing and information-communication support. However, recent development of information, communication and location-navigation services have contributed towards the upgrade and acceptance of the carsharing system. In the last 10 years, a substantial number of various types and categories of papers have been analysing the application of information and communication technologies in the function of carpooling. In the previous studies [9], [10] and [11], the analysis was made on the application of information and communication technologies in the function of carpooling.

The analysis of the current available studies has shown a lack of studies that identify and define the relevant factors of applying technologies that affect the performance of joint rides by passenger cars – carpooling.

The conducted project supplements (builds on) the international European project CIVITAS PLUS (ELAN, 2008 – 2012, program FP7[1]), measure 4.4 Mobility management for large institutions (Grad Zagreb) related to the subject of carpooling. Several research members were active researchers in the CIVITAS PLUS project. The leader of the project was previously active in applications (Horizon 2020) and realizations of several subject-oriented projects and studies. All members of the project team (research group) are tightly connected to the subject of this project through their previous work activities and research. The stated project included two associate professors (senior assistants), associate researchers (Petar Feletar, PhD and Marko Slavulj, PhD), a doctor of science and a licensed lecturer (Adam Stančić, PhD), a PhD student (Ivan Forenbacher, PhD), an assistant professor (Ivan Grgurević, PhD), an associate professor (Dragan Peraković, PhD) and business associate from the sector of industry (Tomislav Milinović, mag. ing. traff).

The subject of the project has been conformed in accordance with the strategic documents of the Faculty of Transport and Traffic Sciences, precisely, the document: The Programme Background for the Strategic Programme of Scientific Research of the Faculty of Transport and Traffic Sciences of the University of Zagreb for the period from 2012 to 2017 (Faculty of Transport and Traffic Sciences, Zagreb, 2012) regarding item D. According to the presentation of the scientific subjects, declared by the Faculty as strategic, in the segment related to the Department of Information and Communication traffic, it is a connecting point with Subject 1: Modelling of information and communication services for the offer of services based on traffic system data.

Further in the text the conducted activities are given through the project phases.

3. RESEARCH ACTIVITIES

The project consists of two main phases:

- The analysis of information and communication technologies and services in the function of carpooling (the first phase); and

[1] *The Seventh Framework Programme of the European Community for Research, Technological Development and Demonstration activities*).

- The identification of relevant factors of the application of technology for the purpose of connecting the carpool users and the provision of an overview of the entire development of dynamic carpooling (the second phase).

Phases of the project are elaborated within Table 1.

Table 1 – Detailed activities of conducted project in phases

Ord. No.	**Detailed activities of conducted project in phases**	
	The first phase (2015/2016)	**The second phase (2016/2017)**
1	Review of the existing research on the application of technologies in passenger car joint rides	Survey on the use and the ability of the use of information-communication technologies and services in the function of joint rides by passenger cars
2	The analysis of features and requirements of *dynamic carpooling*	The analysis of web portals and mobile applications in the function of passenger car joint rides
3	Defining the value chain of delivery for information-communication services within the system of *dynamic carpooling*	The research on the users' requirements set on communication equipment, services and content
4	The characteristics of program applications in the function of dynamic *carpooling*	The integration of the users' database (number of vehicles and rides), source-destination (S-D) matrix, traffic indicators, etc.
5	The analysis of the interoperability of communication systems' architectures of the segment of communication	An overview of the advanced systems and models for the connection of (joint ride) users with the passenger cars
6	-	The identification of relevant evaluation parameters for the assessment of acceptability and usability of different information-communication technologies and services for passenger car joint rides based on the multi-criteria analysis (analytical hierarchy/network process)
7	Preparation of proposal and the application on the Tenders for funding scientific and developmental projects	
8	Project dissemination (publication of papers)	
9	Continuous monitoring of project work (project activities) *Project evaluation*	

The overview of the present research on the subject of application of technologies in passenger car joint rides is given in published articles of the research group members [11] and [12]. Paper [13] gives an overview of studying the application of technologies in joint rides by passenger cars and proposes a value chain of providing the information and communication services in the system of joint rides by passenger cars (dynamic carpooling). The basic requirements of dynamic carpooling include the following elements of the value chain of information and communication technologies and services in the carpooling system, previously studied in [13]:

- User equipment (smartphones and other mobile terminal devices);
- Applications (carpooling applications, GPS functionality);
- Services (ride matching algorithms);
- Network (constant network connectivity); and
- Contents (traveller information, pre-trip information and data repository).

Also, paper [11] analyses the application of information and communication technologies and services for the purpose of carpooling system development. Using a survey method, the current situation, trends and the possibilities of applying information and communication technologies and services have been defined in case of the users of carpooling option in the city of Zagreb.

The paper [12] analyses the possible application of the concept of Internet of Things (IoT) in the traffic environment based on the example of the carpooling/ridesharing system with the use of private vehicles – the carsharing model. The research has been conducted by surveying and interviewing traffic system participants (i.e. users) who frequently use modern communication devices, technologies, and services. Quantitative research comprises the following knowledge obtained from the collected responses of targeted groups of users:

- Selection of relevant data from the survey;
- Segmentation of data and mapping of respondents according to classification of workplaces, gender, age, passenger car ownership, parking, etc.;
- The weights of survey data and implementation of statistical tests; and
- Reports of quantitative results of research.

The contribution of the paper [14] is reflected in determining the relevant factors of applying technologies for the needs of carpooling development as an alternative and sustainable transportation mode.

Systematic approach enables recognition of the key factors of applying technologies for dynamic carpooling needs. The proposed research methodology in the second phase, which consists of five main operation elements is presented in Figure 1. Systematic research of relevant factors is presented by a flowchart using UML (Unified Modeling Language) notation which shows all the activities of studying the relevant factors of applying the technologies for the needs of dynamic carpooling.

Figure 1 shows the activities of systematic research of relevant factors of applying the technologies for the dynamic carpooling requirements.

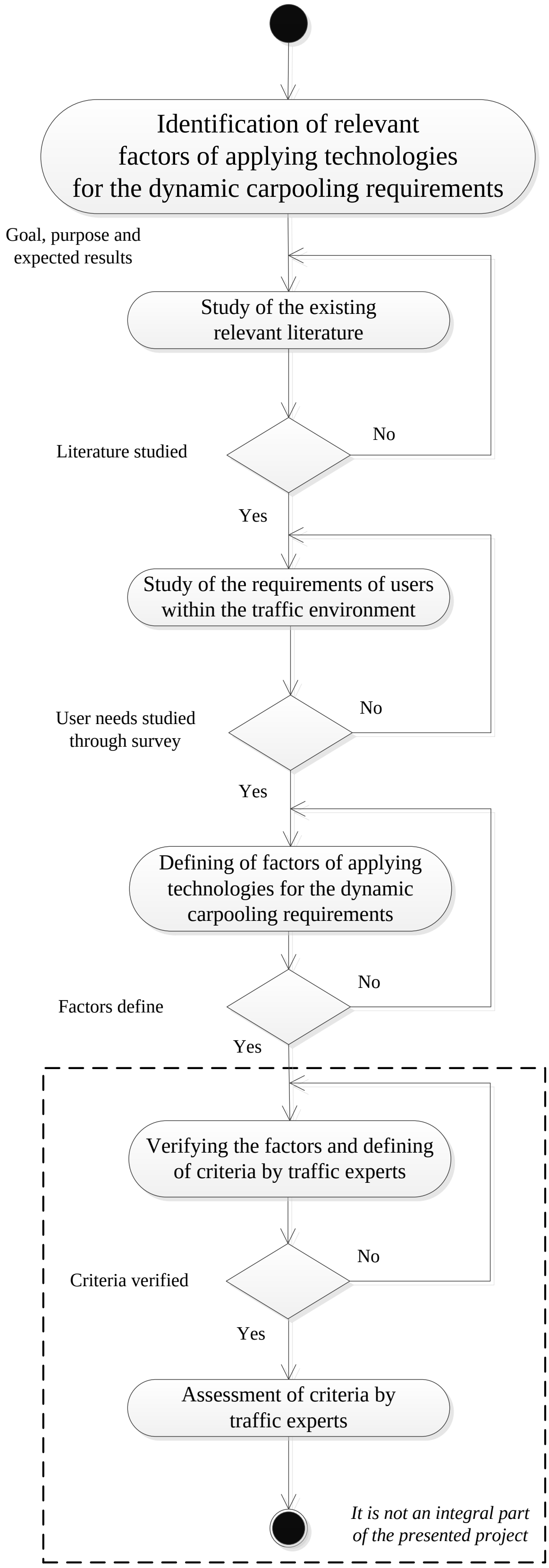

Figure 1 – Research methodology of relevant factors of applying the technologies for dynamic carpooling requirements [according to 13].

The continuation of research should include the definition of criteria for the selection of technology for the needs of dynamic carpooling, review of criteria based on qualitative research (traffic experts) and evaluation of criteria by traffic experts. For the evaluation of criteria, the use of multi-criteria analysis is proposed. The properties of the multi-criteria analysis, such as: larger number of criteria, differences or conflicts among criteria, incomparable units of measuring criteria, selection of the best alternative (e.g. solutions, systems, implementation methods), or ranking the alternatives, can find adequate implementation in defining the factors of applying the technologies for dynamic carpooling needs.

A detailed budget spending is given in the chapter below.

4. BUDGET SPENDING

By the approved and secured funds in the amount of 13.7% of the requested value (first phase of the project) the ground is prepared for further developmental research on the subject. For the realization of the second phase of the project 52.6% of financial resources is approved and secured.

Table 2 – Planned and realized activities with budget overview

Ord. No.	Planned activity	Planned budget [HRK]	Achieved	Cost [HRK]
1.	The overview of the existing research on the subject of application of technologies in passenger car joint rides	10,000.00	Achieved (proven by publications in science book, journals and conferences)	From other sources
2.	Characteristics of program applications in the function of dynamic carpooling	25,000.00		
3.	Project dissemination (publication of papers/articles u 2015 and 2016)	50,000.00	Publication of papers in science book, journals and conferences. Expenses of travel to conference. Costs of poster production.	12,030.00
4.	Characteristics of program application in the function of dynamic carpooling	24,000.00	Completed (mobile phone and tablet)	6,081.52
5.	Identification of relevant evaluation parameters for the assessment of acceptability and usability of different information-communication technologies and services for the purposes of joint rides by passenger cars based on multi-criteria analysis	6,000.00	In the procurement process, software D-Sight CDM.	4,667.85

Procured terminal devices (mobile phone and tablet) were used for the needs of research, such as collecting data, and are available in the Equipment catalogue of the Laboratory for modelling and optimizing information-communication networks and services, and will be further used (after the end of the project) for research and educational needs of the Department of Information and Communication technology.

Section 5 shows the project results with emphasis on the applications for new projects, obtained projects and published papers.

5. RESULTS

This chapter provides a description of results achieved within the project duration, and provides a comparison of the pre-application state and the state during two-year research.

The project is separated in two phases and the results are shown through the following subchapters:

- Involvement of students (including undergraduate and graduate students);
- Cooperation with industry and academia;
- Project applications;
- Obtained additional projects and funds; and
- A list of published papers.

5.1 Involvement of students

Students were included in the research activities of collecting, inputting and processing of data and by forming their undergraduate (2) and graduation thesis (4):

- Draganić, Siniša: Analysis of Short Range Technologies in the Function of IoT Networking Environment, Graduation thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 28.09.2016, p. 93. (Under the Supervision of Ivan Grgurević, PhD);
- Britvec, Slivija: ShareWay - New information and Communication Carpooling Service, Graduation thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 30.09.2015, p. 94. (Under the Supervision of Prof. Dragan Peraković, PhD);
- Grgurić, Gordana: Application of the Internet of Things Concept in Carsharing System, Graduation thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 24.09.2015, p. 94. (Under the Supervision of Ivan Grgurević, PhD);
- Vujnović, Goran: "Networking as a Service" as a Cloud Computing Model, Undergraduate thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 15.09.2015, p. 49. (Under the Supervision of Ivan Grgurević, PhD);
- Hunček, Matej: Application of Cloud Computing as a Platform for the Development of Carpooling, Graduation thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 24.09.2014, p. 55. (Under the Supervision of Ivan Grgurević, PhD); and
- Panijan, Damir: Analysis of Wireless Ad Hoc Networks as Support to Carpooling, Undergraduate thesis, University of Zagreb, Faculty of Transport and Traffic Sciences, 15.09.2014, p. 52. (Under the Supervision of Ivan Grgurević, PhD).

Paper [11], written with student Matej Hunček, was assessed as one of the best presented papers at the International Virtual Research Conference in Technical Disciplines RCITD 2014 (Žilina, Slovakia) and recommended for publication in the Sci-pub journals; suggested journal: “News in Engineering”.

5.2 Cooperation with industry and academia

Cooperation in the project development has been achieved and concretized precisely through members of the research team, listed in horizontal and vertical model:

- Stančić, Adam, PhD, Karlovac University of Applied Sciences, Ivana Meštrovića 10, 47000 Karlovac
  - Processing and data mining.
- Dugina, Marin, MSc (during the first phase), Ivan Seljanec High School, Transportation Department, Trg Svetog Florijana 14b, 48260 Križevci
  - Collecting of data from targeted user group.
- Milinović, Tomislav, mag. ing. traff., Hendal Market Research, Jurja Žerjavića 13, 10000 Zagreb

- Collecting of data from targeted user group.

- Vuger, Matija, mag. ing. traff. (during the first stage), The City of Zagreb. Office for Strategic Planning and Development of the City, Ulica Republike Austrije 18, 10000 Zagreb
  - Cooperation of great significance in the area of application for various EU programs.

Also, members of the research group are currently processing a preparation of the project proposal within the Horizon 2020 (H2020) programme in cooperation with the international consortium.

A cooperation between Departments is established in the home institution and includes:

- Slavulj, Marko, PhD, Department of Urban Transport; and
- Feletar, Petar, PhD, Department of Transport Planning / Chair of Transport Infrastructure.

5.3 Project applications

The research on the project idea includes a wide spectrum of information-communication system modelling for the offer of services based on traffic system data (e.g. the services related to the systems of passenger car joint rides). The project applications are harmonized with the stated area, i.e. conformed in accordance with the document: The Programme Background for the Strategic Programme of Scientific Research of the Faculty of Transport and Traffic Sciences of the University of Zagreb for the period from 2012 to 2017. List of denied project proposals and projects currently under review (i.e. in evaluation) is given in Table 3.

Table 3 – Overview of submitted project proposals

No.	Funding scheme	Project title	Budget [HRK]	Status
	The first phase (2015/2016)			
1.	National road safety programme of the Republic of Croatia 2011-2020	The influence of the use of mobile devices on drivers' behaviour	548,500.00	Denied after second circle of evaluation
	The second phase (2016/2017)			
2.	National road safety programme of the Republic of Croatia 2011-2020	The influence of the use of mobile devices on drivers' behaviour	548,500.00	In evaluation process

Two (2) project proposals have been prepared and sent during the first year (first phase) of the project, and one has been approved for funds from another institution resources. The stated fields/areas of research regarding the project idea (case study: *carpooling/carsharing*) are described as the segment of the research in the following project proposals:

- **Research Context Using Smart Mobile Devices and Related Information and Communication Services** (project within the Program of support of the University of Zagreb, No. TP102, the applicant: the Department for information and communication traffic, leading researcher Assoc. Prof. Dragan Peraković, approved from May, 2015.) – **Project status:** approved (1 July 2015 - 31 December 2016); and

- **The Influence of the Use of Mobile Devices on Drivers' Behavior** (National road safety programme of the Republic of Croatia 2011-2020: Improvement in road user behaviour MUP RH, the applicant: the Department for Information and Communication Traffic, leading researcher Assoc. Prof. Dragan Peraković, applied in November, 2015) – **Project status:** denied after second evaluation circle.

Two (2) project proposals have been prepared during the second year (second phases) of the project:

- **The Influence of the Use of Mobile Devices on Drivers' Behavior** (National road safety programme of the Republic of Croatia 2011-2020: Improvement in road user behaviour MUP RH, the applicant Department for Information and Communication Traffic, leading researcher Assoc. Prof. Dragan Peraković, applied in November, 2015.) – **Project status:** in evaluation process; and
- Project proposals within Horizon 2020 (H2020) programme, Call H2020 – MG – 2016-2017 – **Project status:** Forming of the application.

Approved projects and other grant proposals are to be listed in Table 4 in the next subsection.

5.4 Obtained additional projects and funds

Description of accepted project proposals and other funding is presented below, in Table 4.

Table 4 – Overview of the obtained projects and funds

No.	Funding scheme	Project title	Short description	Budget [HRK]
	The first phase (2015/2016) and the second phase (2016/2017)			
1.	Support program of the University of Zagreb	Research Context Using Smart Mobile Devices and Related Information and Communication Services	The key objective of this research is to analyse possible scenarios of smartphone usage and the usage of related ICT services depending on the different smartphone user groups. The expected scientific contribution is the establishment of the new model for identification of user's behaviour and prediction of user's future behaviour. This model will contribute to the development of human potentials and to better equipment of devices according to the specific user needs.	23,106.00
2.				23,106.00
3.	Academic mobility in 2015 (first round) - clause b, Tender of the University of Zagreb	Academic mobility 2015	Travel expenses for visits to potential partners for the application of the Project (NCP FP BIH, Mostar)	4,351.00

The list of published papers formed on the basis of the research results is provided as follows.

5.5 Published papers

The list of scientific papers published by the members of the research group (co-authors) is given below:

- Grgurević, I., Peraković, D., Forenbacher, I., Milinović, T.: Application of the Internet of Things Concept in Carsharing System, 26th DAAAM International Symposium 2015, DAAAM International Scientific Book 2015, Chapter 34, Katalinic, Branko (ed.), Vienna, Austria: DAAAM International Publishing & DAAAM International Vienna, 2015., 21.–24.10.2015., p. 401-414, (ISBN: 978-3-902734-05-1, ISSN: 1726-9687).
- Grgurević, I., Stančić, A., Slavulj, M.: Identifying Relevant Factors of Applying Technologies in Dynamic Carpooling, Tehnički glasnik - Technical Journal, Vol. 9, No. 4; 2015., p. 337-344 (ISSN: 1846-6168), original scientific paper.

- Grgurević, I., Kavran, Z., Pušeljić, A.: Simulation Analysis of Characteristics and Application of Software-Defined Networks, 3rd International Virtual Research Conference in Technical Disciplines, RCITD 2015, Proceedings in Research Conference in Technical Disciplines, Žilina: EDIS - Publishing Institution of the University of Žilina, 2015., p. 98-103, (ISBN: 978-80-554-0948-1, ISSN: 1339-5076).
- Slavulj, M., Kanižaj, K., Đurđević, S.: The Evolution of Urban Transport – Uber, Road and Rail Infrastructure IV, Lakušić, Stjepan (ed.), University of Zagreb, Faculty of Civil Engineering, 2016, p. 359-364.
- Vyroubal, V., Stančić, A., Grgurević I.: Mobile Devices as Authentic and Trustworthy Sources in Multi-agent Systems, IEEE MIPRO 2016 Proceedings, Opatija, Croatia, 2016., p. 736-741, (ISSN 1847-3938); and
- Grgurević, I., Dugina, M., Feletar, P.: Research of the Potential for Carpooling in the Cities of Koprivnica and Križevci, Scientific Multidisciplinary Research Journal "Podravina", Vol. XV, No. 30; 2016, (ISSN 1333-5286), original scientific paper, *in printing*.

A short description of the published papers is given in Chapter 2.

6. CONCLUSION AND FUTURE WORK

The project results can be implemented in the procedure of introducing and operationalization of carpooling as partial measures of mobility management in the cities, and in designing and production of various types of carpooling applications. The obtained research results also allow expansion of the possibilities of connecting the users of joint trips by applying the advanced information and communication technologies and the contemporary user terminal devices.

Future plans for the continuation of the research include defining of criteria (and sub-criteria) for the selection of technology for dynamic carpooling requirements, verification of the criteria on the basis of qualitative research (traffic experts) and an assessment of criteria by traffic experts. For the needs of criteria assessment, the use of multi-criteria analysis is expected.

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NAVIGATION OF ELECTRIC VEHICLES WITH THE CRITERIA OF MINIMAL ENERGY CONSUMPTION

ABSTRACT

Electric road vehicles are more and more being included in today's traffic imposing new ways how road vehicles should be used and how the transport network should be managed. To ensure optimal usage of electric vehicles, new routing algorithms are needed that take into account the road elevation in order to minimize the energy consumption. Additionally, the charging process has to be optimized so that the electric grid is not overloaded and the electric vehicle can be used as a short-term energy source in times of increased electric energy consumption. In the same time, the charging costs have to be kept on a minimum. Additionally, traffic control should be also adapted to maximize the transport network throughput and minimize the energy consumption. Goal of this project is to build a small scale electric vehicle using the Pioneer 3AT mobile robot, to start the development of a simulation model for the built small scale electric vehicle and of new routing algorithms suitable for electric vehicles in urban environments, create a simulation framework for urban road networks and to start the development of new traffic control algorithms appropriate for traffic flows containing electric vehicles.

KEY WORDS:

Electric vehicle; route optimization; traffic control; variable speed limit

1. INTRODUCTION

Development of electric vehicles resulted with their increasing inclusion into road traffic. Republic of Croatia is following this trend and charging stations for electric vehicles are being build in cities (Labin, Biograd, Koprivnica, Zagreb) and shopping malls (IKEA), retailers are looking into possibilities of using electric vehicles connected with renewable energy sources for freight delivery, Croatian companies are investing into development of electric vehicles (Doking, Rimac Automobili), the state started to subsidy electric vehicles and citizens have started to purchase electric vehicles. New electric vehicles are opening new research topics connected to optimal distribution of chargers for electric vehicles, production of electrical energy, development of new algorithms for route optimization, etc.

Researchers of the Faculty of transport and traffic sciences, collaborators on this project/report, have joined and started to research in this area to solve some of the mentioned problems. They are also networking with associated research groups and companies. This project represents a continuation of already finished projects and augmentation of research on existing projects on which the researchers of this report are active. Relevant projects are: short-term supports from the University of Zagreb: "Optimal navigation of small electric vehicles in indoor environments", and "Vehicle fleet route optimization using multi-agent optimization algorithms and real time traffic data", and research projects "Computer Vision Innovations for Safe Traffic (VISTA)", "System for route optimization in a dynamic transport environment (SORDITO)", and "Intelligent Cooperative Sensing for improved traffic Efficiency (ICSI)". In scope of the mentioned projects, a basic version of the mobile robot Pioneer 3AT, and laser sensor for measuring distances in outdoor environments was purchased. Additionally, research on route optimization algorithms that use speed profiles has been started, algorithms for vehicle detection and tracking in road traffic video footage have been developed, and cooperation with other research institutions (Faculty of electrical engineering and computing, and Faculty of mechanical engineering and naval architecture) and the company Mireo d.d. has been established.

This report is organized as follows. Section 2 describes the research goal and motivation of the project. In Section 3, the project research activities are described. Following Section 4 gives an overview of the budget spending including a short description of the purchased equipment. Section 5 shows the project results with emphasis on applications for new projects, obtained projects and grants, and published papers. Report ends with a conclusion and future work section.

2. RESEARCH GOAL AND MOTIVATION

Electric and hybrid vehicles are the next step in development of vehicles. For greater usage of electric or hybrid vehicles, it is essential that they have similar usability as vehicles with an internal combustion engine, but lower total cost. Firstly, it is important to develop a generalised charging/discharging model of electric vehicle. Digital map with a traffic layer should be extended with data that would help to predict energy usage when a given road segment is used. Estimation of electric energy usage for every route between certain locations could then be determined and used as input value for algorithms to route fleet of vehicles. Minimization of total energy consumption for the whole vehicle fleet is essential for green logistics. This idea is closely related to the research area that associates on this project are researching for more than ten years.

Importance of this research has become even more significant in the recent years. Tendency in growth of using electric vehicles in every day traffic can be observed in the European Union. In the Republic of Croatia, electrical vehicles are increasing its presence on the market also and for that reason, charging stations are being built in the last couple of years in every larger city. Logistic companies also make enquiries of current possibilities to replace their existing fleet of vehicles with internal combustion engines with more energy efficient and green equivalents (e.g. HRZZ project led by prof. Joško Deur that researched energy efficient routing for the retail company Konzum). In addition, it is important to notice that two Croatian companies (Doking and Rimac automobili) are currently developing electric vehicles.
Envisaged goals of this project are to:

- Establish a research team on the Faculty of transport and traffic sciences for navigation of electric vehicles;
- Create a plan to upgrade the mobile robot Pioneer 3AT to become a research platform for small electrical vehicles;

- Develop a methodology to enhance digital maps with information regarding road altitude and slope;
- Introduce new lecture materials for courses held by the project associates connected with the needs of the industry sector;
- Enhance already developed algorithms for the vehicle routing problem by adding constraints regarding energy consumption.

3. RESEARCH ACTIVITIES

This project was applied with the aim to do research related with navigation of electric vehicles. Planned research activities were related to making a small electric vehicle platform and developing route optimization algorithms with the criteria of minimal energy consumption. However, by attending the Workshop on Smart Urban Mobility in Edinburgh in the end of 2015 researchers got informed about the possibility to achieve energy efficient crossroads based on cooperation between electric vehicles and traffic control [5]. Therefore, a new research activity was added to examine traffic control approaches in urban environments. In continuation more details about research activities in all three parts are given.

3.1 Small electric vehicle setup

Transport Optimization Group is equipped with a four-wheel drive robotic platform P3AT. The mobile robot Pioneer 3AT comes complete with battery, emergency stop switch, sonars, bumper switches, wheel encoders and a microcontroller with ARCOS firmware, as well as a Pioneer SDK (included advanced mobile robotics software development package). The originally purchased Pioneer 3AT is additionally enhanced with an embedded computer and a solid-state hard drive for both, indoor and outdoor mapping and localization. Specially designed construction is added on the top of the robot for additional devices such as the Kinect camera, ZED stereo camera, GPS tracking device, additional batteries, laser range finder, etc. Additional sensors open the way for on-board vision and localization. The additional sensors are used for research involving mapping, navigation, monitoring, vision, manipulation, etc. Current form of the upgraded mobile robot Pioneer 3AT is shown in Fig. 1.

Figure 1 – Upgraded mobile robot Pioneer 3AT

3.2 Energy efficient route optimization

Traditional vehicle routing problem (VRP) heuristic methods are minimizing total distance or time vehicles travelled as the main objective function, while energy consumption minimization is the objective function of energy efficient VRP heuristics. Senior researcher assoc. prof. Tonči Carić mentored two students who modified the standard Dijkstra algorithm for calculation of energy optimal routes. They proposed a method of simulating the terrain with different percentage of gradient adding charts for simulation. Artificial traffic network was represented by a directed asymmetric graph with following attributes for all edges: length, slope and energy needed to traverse an edge. Figure 2 shows created graph on which the modified Dijkstra algorithm was tested.

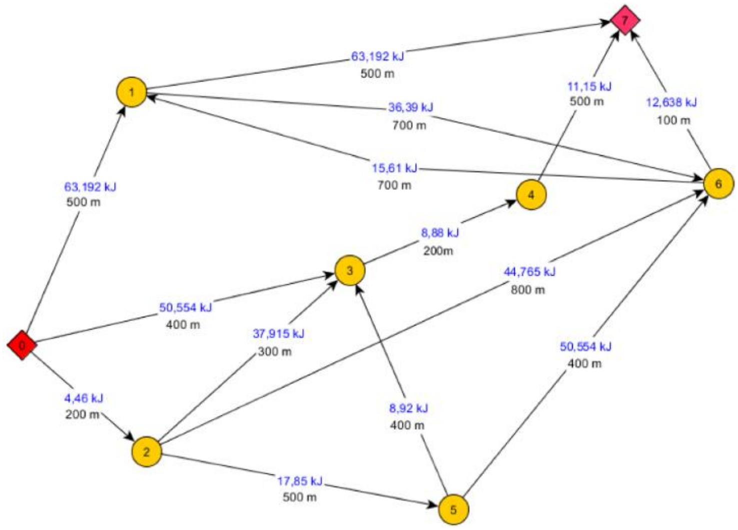

Figure 2 – Asymmetric graph used for testing

Modified Dijkstra algorithm was used to find the most energy efficient path through graph. Minimal state of charge (SOC) of the electric vehicle's battery for selected route is also estimated. Algorithm was implemented in the C# programming language. Results were tested using the mobile robot described in the previous subsection. With certain modifications, this idea can be applied to navigation systems for real electric vehicles in order to find the most energy efficient route from current location to given destination. If SOC is a known value to the navigation system, described route optimizer can estimate if current SOC is sufficient for the trip, and if it is, what will be its state after arrival to destination. These kind of systems have significant importance when routes are planned for autonomous electric vehicles also.

3.3 Traffic control approaches

This research activity was led by assist. prof. Edouard Ivanjko. Aim of traffic control is to enhance the level of service of a traffic network. With the implementation of intelligent transport systems services traffic control has become even more important because a control loop can be closed between the vehicle and the traffic control system. So pre-emptive actions on crossroads for emergency or priority (public transportation, taxis) vehicles can be taken to minimize their travel time on their assigned route. Such pre-emptive actions can be applied for heavy polluting vehicles and electric vehicles also. Electric vehicles would be in this case favoured in order to increase their share in the overall vehicle population. On urban motorways traffic control can detect build-up of congestion and by appropriate control actions slow down or stop incoming vehicles preventing the occurrence of congestion. Additionally, traffic control increases the network throughput enabling the users of electric vehicles a larger autonomy and faster access to a charging station in case of congested traffic.

In order to combine traffic control and vehicle navigation cooperation has to be established between these two systems. That means the traffic control centre and the vehicle have to exchange information. To simulate such systems the microscopic traffic simulator VISSIM was chosen. Its advantage is that it can be connected with the program package Matlab/Simulink and vehicle emissions simulator EnViVeR. This can be done by using the simulation framework given in Fig. 3 developed during this project. VISSIM is applied to simulate the road traffic, Matlab executes the traffic control law during simulation in a closed loop and EnViVeR computes the vehicle emissions when the simulation is finished.

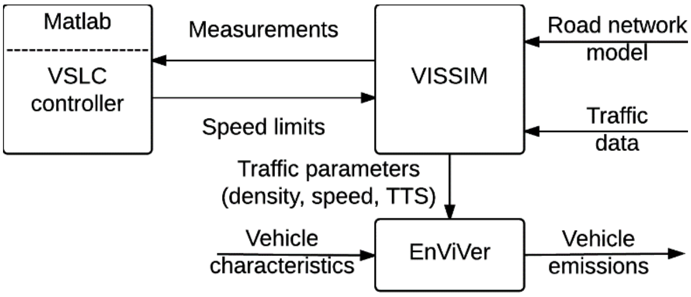

Figure 3 – Block scheme of the developed simulation framework [4]

As the first phase, a simple traffic control case of an urban motorway with variable speed limit control (VSLC) has been chosen. Cooperation between the vehicle and traffic control centre in this case include information exchange about the current speed limit value and current vehicle speed. Such information interchange can be used to ensure that vehicles comply with the current speed limit or to adapt the current speed limit value to reduce the speed variability on the urban motorway. Research activities done so far resulted with an urban motorway model with two on-ramps, one off-ramp and four sections (first three with VSLC) as given in Fig. 4. Two reactive VSLC approaches (mainline virtual metering (MVM)) and simple proportional speed controller (SPSC)) were simulated and both showed an improvement regarding mainstream travel time (TT) and the total time spent (TTS) by the vehicles in the simulated urban motorway section as shown in table 1 [4]. Additionally, vehicle emission are reduced as shown in table 2. These results are obtained when all vehicles comply with the imposed speed limit and the situation that not all vehicles are complying with the imposed speed limit has to be yet examined as well as the cooperation between the vehicles traffic control centre.

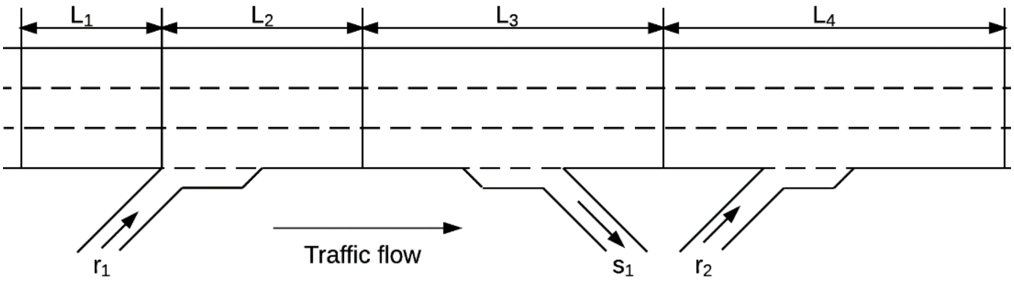

Figure 4 – Urban motorway section used for simulation [4]

Table 1 – Obtained traffic measures of effectiveness [4]

Measure of effectiveness	No VSLC	MVM	SPSC
Maximal TT [s]	228	205	216
Average TT [s]	160	151	156
TTS [veh·h]	716	675	701

4. BUDGET SPENDING

In the two application forms (first and second year) for this project a cumulative amount of 94,000.00 HRK was defined/asked for. Only a cumulative amount of 30,000.00 HRK was approved (15,000.00 HRK for the first and the second year respectively). Additionally, one project associate that was involved in creation of the proposal for this project left the Faculty of transport and traffic sciences and another project associate was on a longer leave. From these reasons, originally, planned activities could be only done on a smaller scale and some expensive research equipment could not be obtained. Most of the work was done by the senior researchers assist. prof. Edouard Ivanjko and assoc. prof. Tonči Carić, and the students that the senior researchers managed to attract.

Table 2 – Obtained vehicle emissions [4]

Emission type	No VSLC	MVM		SPSC	
		Obtained	Reduction [%]	Obtained	Reduction [%]
CO_2	$15.42 \cdot 10^6\ g$	$14.98 \cdot 10^6\ g$	2.85	$15.21 \cdot 10^6\ g$	1.36
	$6.167 \cdot 10^6 g/h$	$5.994 \cdot 10^6\ g/h$	2.81	$6.084 \cdot 10^6 g/h$	1.35
	$223.5\ g/km$	$217.2\ g/km$	2.82	$220.5\ g/km$	1.34
NO_x	$42.53 \cdot 10^3\ g$	$41.16 \cdot 10^3\ g$	3.22	$41.78 \cdot 10^3\ g$	1.76
	$17.01 \cdot 10^3\ g$	$16.46 \cdot 10^3 g/h$	3.23	$16.71 \cdot 10^3 g/h$	1.76
	$0{,}6164\ g/km$	$0{,}5966\ g/h$	3.21	$0.6056\ g/km$	1.75
$PM10$	$3080\ g$	$3040\ g$	1.30	$3068\ g$	0.39
	$1232\ g/h$	$1216\ g/h$	1.30	$1227\ g/h$	0.41
	$0{,}04465\ g/km$	$0{,}04407\ g/km$	1.30	$0.04447\ g/km$	0.40

In table 3 overview of the budget spending is given. Most important budget spending is related to items 2 and 4 in table 3. In scope of these two items new research equipment to build a small electrical vehicle and to start making experimental setups to teach students programming of the Arduino prototyping platform was obtained. Purchased equipment includes: (i) embedded computer for the Pioneer 3AT mobile robot; (ii) traffic data for the Republic of Slovenia; and (iii) parts for experimental setups with the Arduino platform.

Table 3 – Planned and realized activities with budget overview

Nr.	Planned activity	Planned budget	Realized	Cost
1.	New project applications (workshop, application counsellor, attending networking events, application meetings, attendance to conferences)	10,000.00 HRK	Two HORIZON2020 applications, one HRZZ application, two applications for short term support from the University of Zagreb, one Scientific centre of excellence application, four new COST action applications, one BICRO application, 9 papers published	4,098.85 HRK
2.	Establishing a local research group related to electric vehicles	10,000.00 HRK	Laboratory equipment purchased for a small scale electric vehicle platform based on the mobile robot Pioneer 3AT	6,886.39 HRK
3.	Connecting with national researchers and companies related to electric vehicles	5,000.00 HRK	Collaboration agreement signed with the company Promel projekt Ltd., connection established with companies Alfatech Group, VIP and LED elektronika Ltd., joint project proposals started with the group of prof. Joško Deur from the Faculty of mechanical engineering and naval architecture University of Zagreb and prof. Daniela Nechoska Koltovska from Faculty of Technical Sciences St Kliment Ohridski University, Bitola, Macedonia	0.00 HRK
4.	Making a proposition for a new course related to autonomous and electric vehicles	5,000.00 HRK	Laboratory equipment purchased for workshops about programming the Arduino prototyping platform	3,691.14 HRK

Other budget spending is related to new project applications and networking with other researchers and industry. Attendance to conferences was financed in order to present latest research results to the international community and use the conference for networking. For connecting with national researchers and companies no amount was spend since all interested researchers and companies were in Zagreb. Meetings were held in own premises were no lease fee and no travel costs had to be paid. Currently there are some funds left and it is planned to spend them to the end of the duration of the project on items 2 and 4 listed in table 3.

5. RESULTS

Results obtained in this project can be divided into five subsections: involvement of students, cooperation with industry and academia, submitted project applications, obtained additional projects and funds, and published papers. In continuation, each subsection is explained into more details.

5.1 Involvement of students

During the project duration, the researchers succeeded to gather two student teams to work on topics related with the research activities. First team, lead by assoc. prof. Tonči Carić, consists of students Leo Tišljarić and Dominik Cvetek, and they were working on the project ”Dynamic measuring the energy consumption of electric vehicle with Arduino prototyping platform” for which they received the rector price. They proposed a method of collecting data on the energy consumption of electric vehicles. Electronic circuit for measuring necessary parameters was made using the Arduino prototyping platform. Mobile robot Pioneer 3AT was used as an experimental setup of a small electric vehicle. Data of energy consumption of the robot with regard to the configuration of the terrain was collected. That research carries out the simulation of the gradient of terrain adding a simulation cart with added weight. They have proposed a modification Dijkstra's algorithm for the calculation of an energy optimal path.

Second student team tackled the problems related to road traffic control. Students Krešimir Kušić and Nino Korent managed to implement the simulation framework given in Fig. 1 and test the VSLC approach MVM. Their efforts were awarded with the rector's price for their work entitled "Analysis of the Impact of Variable Speed Limit Control on Traffic Throughput and Environmental Pollution" made under supervision of assist. prof. Edouard Ivanjko and young researcher Martin Gregurić. Currently they are both working on their master theses with topics related to control of urban motorway traffic. Students Borna Kapusta and Mladen Miletić joined recently into the team and started they work on traffic control tackling the problem of pre-emptive traffic light control for emergency vehicles. Additional help to solve traffic problems on urban motorways can be expected from the foreign student Gabriel Melo from São Carlos School of Engineering, University of São Paulo, Brazil who will perform an internship from the 15 January 2017 until 15 July 2017 under the supervision of assist. prof. Edouard Ivanjko. Goal of this internship is to make a calibrated model of a chosen segment of an urban motorway in California, USA using the PEMS traffic data database, implement a fuzzy logic based VSLC, and evaluate the implemented VSLC with emphasis on traffic and vehicle emission criteria.

5.2 Cooperation with industry and academia

During the project duration, several meetings with companies and academic institutions were held with the goal to establish cooperation in research, education and joint project proposals. Regarding cooperation with industry, meetings with LED elektronika Ltd., Promel projekt Ltd., AlfaTec Group Ltd. and VIP were held. Results of these meetings can be summarized with the following: (i) informal agreement about cooperation in research and education; (ii) bachelor and master thesis topics interesting to particular companies will be defined to attract perspective students; (iii) student visits to mentioned companies during class will be made in order to introduce the companies to perspective students; and (iv) information about possible interesting grant calls will be shared. In cooperation with the company LED elektronika Ltd. the first bachelor thesis was made with the title "Possibilities for Complementation of Measured Traffic Parameters Data Based on Historic Values", author Pavao Petrač and supervisor assist. prof. Edouard Ivanjko. With the company Promel projekt Ltd. a cooperation agreement was signed and a student visit to this company in scope of the course Artificial intelligence was organized under supervision of assist. prof. Edouard Ivanjko.

Regarding academia, cooperation with the Faculty of electrical engineering and computing, Faculty of mechanical engineering and naval architecture (both part of the University of Zagreb), Energy Institute Hrvoje Požar and Faculty of Technical Sciences St Kliment Ohridski University, Bitola, Macedonia was extended. Results achieved can be summarized as following: (i) joint project proposal with the Faculty of mechanical engineering and naval architecture for the Croatian science foundation has been submitted; (ii) project proposal with Energy Institute Hrvoje Požar as one of the partners of an international consortia has been submitted; and (iii) funds for researcher visit between the Faculty of transport and traffic sciences University of Zagreb and Faculty of Technical Sciences St. Kliment Ohridski University, Bitola, Macedonia have been granted (grants for one researcher from each institution). Two student visits to the Institute Ruđer Bošković and the Faculty of Kinesiology were also organized in scope of regular class of the course Systems of virtual reality in traffic under supervision of assist. prof. Edouard Ivanjko.

5.3 Project applications

In table 4 all submitted project proposals that got rejected or are currently in review are listed. The first two project proposals are result of participation in EU COST actions. In this case the actions TU1102 Towards Autonomic Road Transport Support Systems and TU1305 Social networks and travel behaviour. In these two proposals, researchers from this project were included to bring knowledge related to road traffic control, modelling and simulation of urban traffic networks, and route optimization. Networking done during mentioned two COST actions resulted also with proposals for new COST actions and entrance in consortia for applications to the program Interreg Central Europe.

5.4 Obtained additional projects and funds

In table 5 accepted project proposals and other grants received during the duration of this project are listed. Most successful project granted is the "Scientific centre of excellence for data science and cooperative systems" were researchers from this project are participating in the Research unit data science, Research area Multidisciplinary Data Intensive Applications, subarea Real-time intelligent transport analytics. Participation in this scientific centre of excellence opens access to new grant calls in the next five years for financing PhD students, research equipment, summer schools and scientific conferences. Other important grants are the two COST actions enabling networking with international researchers in the area of data science, and priority to attend to short-term scientific missions and summer schools organized in scope of these two COST actions.

5.5 Published papers

Research results related to vehicle routing are published in papers [6] to [9]. Research published in paper [10] describes a method to obtain optimal locations of charging stations based on a large set of GPS tracks of commercial vehicles.

Table 4 – Overview of submitted project proposals

Nr.	Funding scheme	Project name	Budget	Status
1.	HORIZON2020	Eliminating air QUality problems using an Autonomic Layer In the Smart city Environment EQUALISE	6,580,578.75 EUR	Rejected
2.	HORIZON2020	COLlective TRAnsport/TRAvel INtelligence COLTRAIN	3,440,000.00 EUR	Rejected
3.	HRZZ	Optimization of Routes for Electric Delivery Vehicles OpRED	702,000.00 HRK	Rejected
4.	PoC BICRO	Advanced traffic counter based on multispectral video	260,000.00 HRK	Rejected
5.	COST	OC-2016-1-20366 "Cooperative intelligent systems for transport "	Yearly defined	Rejected
6.	COST	OC-2016-2-21618 “Intelligent Mobility Pan European Skills Network“	Yearly defined	In review
7.	Interreg CENTRAL EUROPE	Transport and Energy Initiatives for a Low-carbon Europe (TEILE): electric vehicles and the smart grid	1,399,400.00 EUR	In review
8.	Financing scientific centres of excellence in Croatia	Scientific centre of excellence for data science and cooperative systems	5,000,000.00 EUR	In review

Research results related to control of road traffic are published in papers [1] to [4]. Three of them (papers [1], [3] and [4]) are student papers describing the results students obtained during their work on their bachelor and master thesis. In [1] a framework in VISSIM for simulation of cooperative ramp metering is described. Possibilities of applying urban traffic control approaches based on artificial intelligence are discussed in [2]. Short review of control approaches for variable speed limit control on urban motorways in [3] served as a starting point for a simulation based comparison of two chosen variable speed limit controllers given in [4].

6. CONCLUSION AND FUTURE WORK

Aim of this project was to start the research related to the navigation of electric vehicles and to tackle the problem of finding energy optimal routes. During the project, a new research activity was added in order to include traffic control into improvement of energy consumption.

Regarding the build-up of a small electric vehicle setup, achieved results include an upgraded mobile robot Pioneer 3AT ready to make outdoor experiments. First outdoor experiments were performed successful in order to make an energy consumption model of the small electric vehicle setup. Future work on this research activity will include preparation of the Campus Borongaj area (WLAN coverage, road map, points of interest) to perform longer outdoor experiments.

To improve the existing vehicle routing optimization algorithm in order to include energy consumption, the standard Dijkstra algorithm was modified to be able to calculate energy optimal routes. For this, the classical graph based road network presentation was augmented so that all edges contain additional attributes to describe length, slope and energy needed to traverse a particular edge.

Current results related to the research activity of traffic control include a framework for simulation of road traffic including vehicle emissions and the associated control law, urban motorway simulation model with two on-ramps and one off-ramp, and two basic VSLC algorithms. With this, there exist basic prerequisites for development, simulation and analysis of more advanced traffic control laws. Future work on this research activity will include modelling of a larger urban motorway segment and part of a city with signalized intersections using real world data, development of traffic control laws based on learning, and its simulation and analysis regarding traffic and environmental parameters.

Table 5 – Overview of obtained project proposals

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	EU JCR	Road-transport & Emissions Modelling (REM) workshop	Networking event and workshop regarding modelling and simulation od road vehicles emissions. Held in Skopje, Macedonia and Edouard Ivanjko participated.	700.00 EUR
2.	Scientific centres of excellence	Scientific centre of excellence for data science and cooperative systems	Research and collaboration project related to establishing a scientific centre of excellence in data science and advanced cooperative systems. Project associates are members of the research unit related to data science.	Yearly 550,000.00 HRK
3.	ERASMUSplus	Teaching visit to the Department for traffic and transport Faculty of Technical Sciences St Kliment Ohridski University, Bitola, Macedonia	Grant holder is Edouard Ivanjko. Aim of the visit is to teach the foreign students to new developments in application of artificial intelligence in road traffic control and how to simulate such systems using VISSM, EnViVeR and Matlab. Additionally, existing research cooperation will be extended.	1,000.00 EUR
4.	COST	IC1406 High-Performance Modelling and Simulation for Big Data Applications (cHiPSet)	Researchers Tonči Carić and Edouard Ivanjko are management committee members for Croatia. They are also members of the traffic group of the application workpackage.	Yearly defined for networking meetings
5.	Program contracts of the University of Zagreb	Supporting students to attend scientific conferences	Student registration fee for the conference ZIRP2016	200.00 EUR
6.	COST	COST Action TU1305 Social networks and travel behaviour.	Researcher Tonči Carić works as the management committee member for Croatia.	Yearly defined for networking meetings
7.	IPA CBC Adriatic Programme	Adriatic IPA project Traveller Information System for the Adriatic Region (TISAR)	The aim of the project was implementation of an ICT platform where public transport and journey planning data will be merged and made available in the languages of the IPA Countries.	1,514,012.43 EUR
8.	University of Zagreb	Route optimization for small electric vehicles with the criteria of minimal consumption	The aim of the project is to develop method of collecting data of the energy consumption of electric vehicles and construct electronic circuit for measuring necessary parameters of electric vehicle.	3,121.67 EUR

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DEVELOPMENT OF AIR TRAFFIC MANAGEMENT RESEARCH CENTRE

ABSTRACT

The main aim of this project was to gather scientists and young researchers around air traffic control management topic with a goal of improving and increasing air traffic efficiency. During this two-year project main activities were conducted regarding development and application of the ATC simulators, analysis of air traffic controller training, research on impact of trajectory based operations on the complexity of air traffic and development of a language technology system as a support for air traffic control communication. The main results of this research are presented through five published papers and two additional project applications. Additional results are enhanced scientific capacity of young researchers, established research teams, upgraded technical characteristics of the simulators and functions of the Laboratory for the control of air navigation, developed basic software for the 3D tower simulator, improved cooperation with aviation industry in Croatia and established partnership with other European universities and institutions through the application of the KAAT project.

KEY WORDS:

Research centre; air traffic management; air traffic control; simulator

1. INTRODUCTION

This report contains the main characteristics of the internal two-year project *Development of Air Traffic Management (ATM) Research Centre*. Air traffic management is a wide set of functions (air traffic services, air traffic flow and capacity management, airspace management) that ensures safe, orderly and expeditious flow of traffic with a maximum utilization of air traffic control (ATC) capacity and optimal dynamic utilization for different airspace users [1]. Air traffic in Europe and Croatia is characterised by a constant growth in air traffic demand [2]. Under certain conditions increased air traffic demand can generate negative impacts on flight efficiency (appearance of delays, usage of longer routes, higher fuel consumption, higher financial expenses and increased negative impact on the environment) and on air traffic safety (increased air traffic controller workload, increased air traffic complexity and loss of situational awareness).

To prevent or reduce negative impacts of increased traffic demand, it is necessary to explore and provide new technical and technological solutions within the air traffic management system. These solutions should ensure optimal use of airspace in order to increase flight efficiency, improve air traffic safety, and enhance sustainability of air traffic management system. Development of ATM in Europe, as well as in Croatia, is based on the Single European Sky (SES) requirements of performance scheme for air navigation services [3] and high-level goals from the Single European Sky ATM Research (SESAR) ATM Master plans [4, 5].

Until 2015, the research in the field of ATM in Croatia has solely been the result of the individual efforts of the scientists from the Faculty of Traffic and Transport Sciences, Department of Aeronautics regarding air traffic control training [6], airspace capacity and sectorization improvement [7, 8, 9], air traffic flow analysis [10], implementation of the new navigation concepts [11, 12] in Croatian airspace and its impact on the complexity of air traffic [13].

The main characteristics of this project are presented in the following sections. The research goal and motivation of the project are described in Section 2, while Section 3 describes main research activities along with the individual contribution of every team member. Section 4 gives an overview of the planned and spent budget. In Section 5 project results are presented with an emphasis on the new project applications, finished projects, obtained additional grants and published papers. The report ends with a conclusion and recommendations for the future work.

2. RESEARCH GOAL AND MOTIVATION

There are two main goals of this project. The first goal is establishment of the ATM research centre and increase in research capacities, i.e. gathering scientists and young researchers interested in ATM.

The second goal is a specific research in ATM field – the impact of air space modification and its influence on air traffic efficiency and environment, implementation of new navigation systems and their impact on air traffic complexity and air traffic controller workload, research related to the development and use of ATC simulators in air traffic controller training, and finally application of language technologies as a support in ATC communication.

In 2012, a Laboratory for the control of air navigation was founded at the Department of Aeronautics as the first prerequisite to improve and strengthen scientific research in the field ATM. In order to increase research potential and to continue with ongoing scientific work, it was important to develop a research centre that would gather scientists and young researchers, who would investigate, explore and enhance the ATM system. Furthermore, this research centre should also be a meeting point of aviation industry and science.

The research centre follows the latest achievements in the field of air traffic management which are the result of SESAR. Moreover, it follows the latest achievements in the development of European air traffic management, and all relevant European regulations on the efficiency of air traffic management system and its elements.

3. RESEARCH ACTIVITIES

The research activities done by the project team members are presented in this section. The activities are divided into four main scopes *(Project management, ATC training, ATC Simulators, Communication and language)* with an emphasis on contributions of all individual team members. These scopes are defined in accordance with the project research goals.

3.1 Project management

Project manager is the lead member and coordinator of the project, responsible for the project implementation, time scale and budget spending. The project manager during this two-year project was Assist. Prof. Biljana Juričić. She proposed the project aims and organised and managed the project activities and tasks. Her main task was to gather and establish the network between the team members and to insure technical and technological tools that would be used during the project. She mentored PhD student and foreign exchange student involved in the project. She actively participated in the main research activities that are visible through the dissemination of project results. During this project she participated in the preparation of the project application documentation that was used as a basis for applying of two new projects. At the end she prepared the project final report.

3.2 ATC training

During the project, new European regulation on air traffic controllers training EU REG 2015/340 was analysed in detail and compared to previous EU regulation REG 805/2011. Project manager Biljana Juričić did the majority of these activities. She mentored PhD student Bruno Antulov-Fantulin who also participated in this part of the research. Regulation 2015/340 brought several novelties in air controller (ATCO) training that should be implemented into training organisations before the provision of ATCO training. They created the list of major differences in the training requirements of air traffic controllers related to ATC training organization, and air traffic controller licence (Table 1).

Table 1 – Major differences in EU REG 2015/340 comparing to EU REG 805/2011

Nr.	Major differences:
1.	ATCO Licence – age limitation (21) is abolished
2.	English language proficiency – Level 6 is 9 years valid
3.	STD – Synthetic Training Device (simulator and part–task trainer)
4.	Instructors: theoretical and practical (OJTI and STDI)
5.	STDI – licence endorsement
6.	Practical training – incorporated into the Basic Training course
7.	Assessment – assessment of practical exercises incorporated into the Basic Training
8.	Assessor – licence endorsement
9.	Continued validity - there are no expiration dates of certificate
10.	Management system of TO
11.	Contracted activities
12.	Different Personnel requirements

<u>Finances spent in this scope of activities: 250,00 kn.</u>

The results were implemented in HUSK ATCO basic training plans and programmes and used in the provision of air traffic controller training.

3.3 ATC Simulators

ATC simulators played a vital role in this project when three different simulators were used during the research. Two of the simulators enabled the use of the *real-time simulations* while the third one is still in the development phase. The activities done within the scope of ATC simulators improved the technical equipment and enhanced the functions of the Laboratory for the control of air navigation:

- **BEST Radar Simulator** used for ATC training and scientific research – its main aim was to enable real-time human-in-the-loop simulations primarily used for ATC training. Biljana Juričić and Bruno Antulov-Fantulin fully implemented the novelties of the above mentioned EU REG 2015/340 into the practical part of ATC training and prepared the new ATCO training plans and programs (for ATCO basic training courses and synthetic training device instructor training course) and adjusted simulation exercises used during ATCO training. The new graphics cards and cables were acquired to enable implementation of the new wide screens (Figure 1.) that improved the ATCO working environment during training.

Figure 1 – BEST Radar Simulator implemented wide screens

- **New Research Simulator** used for scientific research – this software was built earlier and was using hardware of the BEST Radar Simulator. Its main aim was to enable real-time human-in-the-loop simulations after implementation of new navigational concepts and to examine their influence of on ATC and ATM. This simulator imitated a real ATC environment (Figure 2.). Tomislav Radišić, PhD, worked on the development and function of this simulator. He prepared the scientific paper of the concept of the development, methods, technology and process of validation in building an ATC simulator for real-time human-in-the-loop simulations.

  The other activities regarding the new research simulator was its usage for simulations of trajectory based operations (TBO) and for measuring the impact of TBO on air traffic complexity. T. Radišić and B. Juričić worked on analysis and testing of complexity scores. Results showed that TBO significantly reduced complexity in specific traffic situations. Results of these activities were used in preparing a scientific paper.

  In the third activity PhD student Bruno Antulov-Fantulin used subjective complexity data and other recorded human-machine interactions from the previous human-in-the-loop simulations. In cooperation with T. Radišić who advised him on data processing and statistical analysis, B. Antulov-Fantulin made the research and analysed the data. The results of the research showed that human-machine interactions can be used, with some limitations, to detect increases in air traffic complexity and situations where the controller's workload capacity is used. They prepared the scientific paper of these results.

At the end of this scope of activities an evaluation of the air traffic controllers working environment was done. This analysis was mostly carried out by PhD student Bruno Antulov-Fantulin. He made a review of previous research on the significance of ergonomic approach in designing working environment of an air traffic controllers and prepared a scientific paper. The main focus of the research was the influence of ergonomic chairs on air traffic controller working environment and performance.

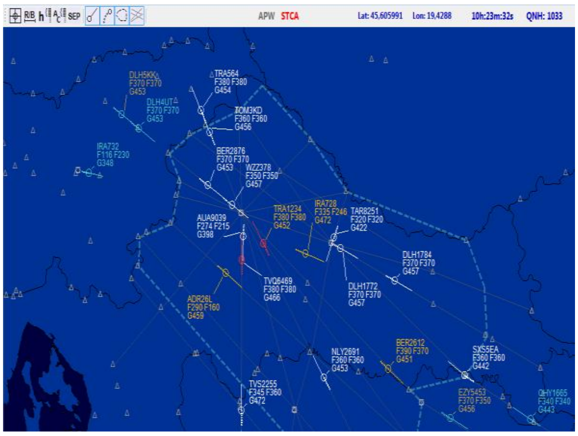

Figure 2 – Main Radar Display of the New Research Simulator

- **3D Tower Simulator** – hardware development of this simulator started during previous project but software development continued during this project. The project enabled modification of existing and development of new simulator components of aircraft model and flight management system used for aircraft trajectory generator. The main value of this project is the development of aircraft trajectory generator for aircraft movement when on ground, when aircraft is on final approach to land and when aircraft is in the first phase of climb on departure. Another project outcome is the development of air traffic controller interface with 3D tower view that enables future air traffic controllers to provide air traffic control in the training environment similar to the real one (Figure 3.).

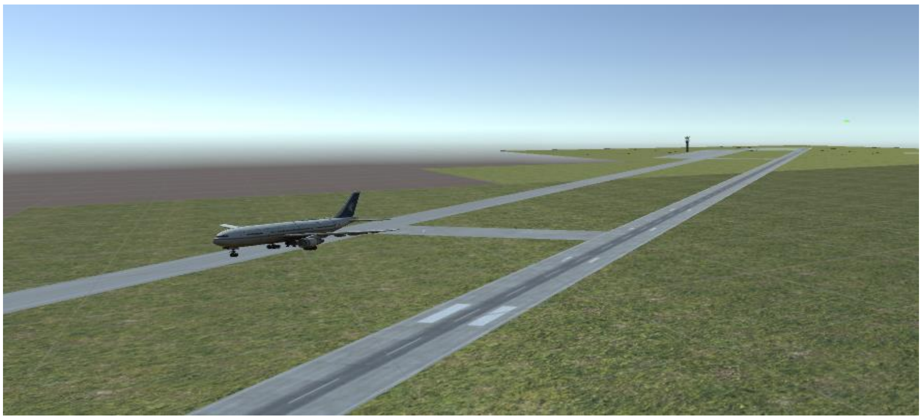

Figure 3 – View from the TWR – aircraft in the initial climb after take-off

Unity software was used as the most suitable for visualisation of the 3D tower view. It was necessary to undergo *On-line* education and training in Unity software to start working. At the end a simple pseudo-pilot interface was developed that enabled interaction between air traffic controller and pseudo-pilot in the simulated environment.

<u>Total finances spent within this scope of activities: 10.565,28 kn.</u>

3.4 Communication and language

This part of the research was done by Mira Pavlinović, PhD and it included research on language and communication in air traffic control. The activities that were carried out include: development of a language technology system as a support for air traffic control communication, comparison of current language models and proposed language technology system, compilation of spoken corpus of radiotelephony phraseology, language analysis of compiled spoken corpus and prescribed radiotelephony phraseology, development of a system for control of radiotelephony communication using MATLAB software package, dissemination of results and publication of a paper.

Table 2 – The steps of research on language and communication in air traffic control

Phase	Activity
1.	Research on prescribed radiotelephony phraseology
2.	Compilation and analysis of spoken corpus of radiotelephony phraseology
3.	Development of a system for control of radiotelephony communication using MATLAB software package
4.	Modelling of a proposed language technology system as a support for air traffic control communication
5.	Comparison of current language models and proposed language technology system

<u>Total finances spent within this scope of activities: 1.984,00 kn.</u>

4. BUDGET SPENDING

The following tables contain financial scope of the project. They describe šlanned and achieved activities as well as the project planned budget and costs spent during the two year period (Table 3 and Table 4). The activities that were not achieved could be planned in future research.

Table 3 – Planned and realized activities with budget overview for the Phase I (2015)

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	Education or training	9.000,00	not achieved	0,00
2.	Participation on ZIRP conference – Conference fee for 4 persons – 2 published papers	1.000,00	partially performed, 1 published paper (*The New ATCO Training Requirements*)	250,00
3.	Participation on INAIR 2015 conference in Amsterdam – Conference fee for 2 persons – publication of 1 paper	15.000,00	performed, 2 published papers (D*evelopment and Validation of an ATC Research Simulator and Using Human-Machine Interaction Frequency as a Proxy Measure of Subjective Air Traffic Complexity*)	9.473,53
4.	Services of aviation industry experts in development of research, calculations and simulations	5.000,00	not achieved	0,00
5.	Preparation of project application	10.000,00	applied and funded University research grant *Enhancement of Air Traffic Control Simulation Centre* (TP053)	0,00
6.	Preparation and translation of scientific papers	6.000,00	not achieved	0,00
7.	Fee for publication of a scientific paper in a journal (A or B category)	8.000,00	not achieved	0,00
8.	Unplanned performed activities: Participation on international workshop: *Workshop on Education and Training Needs for Aviation Engineers and Researchers in Europe, September 23, 2015, Brussels expenses of transport and accommodation for one person*			5.308,42
		Total: 54.000,00	Received funds: 15.000,00	Total: 15.031,95

Table 4 – Planned and realized activities with budget overview for the Phase II (2016)

Nr.	**Planned activity**	**Planned budget**	**Achieved**	**Cost**
1.	Education or training	9.000,00	Not performed	0,00
2.	Participation on ZIRP conference – Conference fee for 1 person – 2 published papers	400,00	Participation on *Ergonomics* 2016 conference instead of ZIRP 2016 conference	1.494,49
3.	Participation on INAIR 2016 conference – Conference fee for 2 person – publication of a paper (location is still unknown)	15.000,00	Performed, without paper publication and expenses	0,00
4.	Fee for publication of 2 scientific papers in a journal (A or B category)	16.000,00	Not yet performed *	0,00
5.	Preparation and translation of scientific papers	6.000,00	performed for 1 published paper	1.984,00
6.	Data preparation, analysis, calculations and simulations	5.000,00	Simulator preparation – acquisition of new graphics cards and cables for new simulator wide screens	752,00
7.	Data preparation, analysis, calculations and simulations	5.000,00	*On-line* education and training in *Unity software*	339,75
		Total: 51.400,00	Received funds: 15.000,00	Total: 4.570,24*

***As it can be seen from the Table 2, only 4.570,24kn is spent during second year of the project. There is still 10.429,76 kn on the project account. These funds are planned for publishing scientific paper *Reduction of air traffic complexity using trajectory-based operations and validation of novel complexity indicators* in the journal IEEE Transactions on Intelligent Transportation Systems which is explained later in part 5.4.**

5. RESULTS

The results achieved during this project are presented in this section. Firstly, the students involved in the project are stated, then cooperation with the other universities and industry. Project results were disseminated through published scientific papers at the international conferences or scientific journal.

5.1 Involvement of students

The activities in which Bruno Antulov-Fantulin, a PhD student, participated are named and described in the Section 3. He used the experience he gained during this project to prepare the final qualifying exam before defending his PhD thesis.

An exchange student Mathilde Marc from Frech Air Force Academy also participated in the project. During her three month studies at the Department of Aeronautics, she took part in Phase II of the project. Using *Unity* software, she developed one part of the code for the 3D Tower Simulator which was in the development phase at the Department. Her mentor was Biljana Juričić. Tomislav Radišić was providing help and guidance on *Unity* software and the development of new code. She successfully defended her master thesis at French Air Force Academy.

5.2 Cooperation with industry and academia

During the course of this project, a closer cooperation with aviation industry in Croatia was developed through involvement in KAAT project application. Important stakeholders from aviation industry in Croatia – Croatia Control ltd., Croatia Airlines, Croatian Civil Aviation

Agency and Aeronautical Technical Centre J.S.C. – gave their Letters of Support to KAAT project application.

Also some new connections with international universities and aviation institutions were established: University Politechnica of Bucharest, Instituto Superior Tecnico, University of Portugal, Transport and Telecommunication Institute - Transporta un SakaruInstitūts (TSI), University Of Strasbourg, Inova+, Quasar Human Capital, Deep Blue, University of Zilina, Menzies Aviation, AigleAzur, AvramIancu Airport, ÉcoleNationaleSupérieure des Mines D'albi-Carmaux, Romanian Aviation Academy.

A short description of KAAT project is given in Section 5.3.

5.3 Project applications and obtained additional funds

Team member activities during the project were also used for preparation of two new project applications that are presented in the Table 3.

Table 5 – Additional project applications

Nr.	Funds resource	Type of program	Time schedule	Name o the project	Obtained funds	Status
1.	University of Zagreb	Support funding	2015.	Enhancement of Air Traffic Control Simulation Centre	15.013,14 kn.	*Finished*
2.	EU	Erasmus+	3 year project	Knowledge Alliance in Air Transport - KAAT	In evaluation phase	In evaluation phase

1. *Enhancement of Air Traffic Control Simulation Centre*

The main aim of this support project was enhancement and upgrade of the existing ATC simulator (procurement of the hardware components used for development of 3D Tower simulator such as 3D visualisation tool). In Phase II of this on-going project these activities continued with software development using *Unity* platform.

2. *Knowledge Alliance in Air Transport - KAAT*

KAAT project has been applied by the consortium of 17 partners from education and business of 7 countries: Croatia, France, Italy, Latvia, Portugal, Romania, and Slovakia. It tends to develop innovative partnership between universities, training providers, airports, airlines, maintenance and handling companies, air traffic providers, regulatory bodies and international organizations. One of the partners is Faculty of Transport and Traffic Sciences of University of Zagreb.

The main aim of the project is the development of new, innovative and multidisciplinary approaches to teaching and learning in aviation industry in Europe. The consortium identified the need for better skilled work force for aviation business and operations in the future but also a modernization of initial higher education. KAAT also focuses on the development of methodology for Aviation Sectorial Qualification Framework as basis for recognition of prior learning or work experience.

Before the project was applied, a *Workshop on Education and Training Needs for Aviation Engineers and Researchers in Europe* was held on which the guidelines for KAAT project application were agreed (Table 1.).

5.4 Published papers

The following papers were published and presented at international conferences as a result of this project:

- Juričić, B., Antulov-Fantulin, B., Ivković, M.: *New ATCO Training Requirements*, ZIRP 2015, FPZ, ZAGREB, 2015.
- Radišić, T., Novak, D., Juričić, B.: *Development and Validation of an ATC Research Simulator*, INAIR 2015, Amsterdam, 2015.
- Antulov-Fantulin, B., Rummens, M., Radišić, T.: *Using Human-Machine Interaction Frequency as a Proxy Measure of Subjective Air Traffic Complexity*, INAIR 2015, Amsterdam, 2015.
- Antulov-Fantulin, B., Bucak, T., Juričić, B.: *The Significance of Ergonomic Approach in Designing Working Environment of an Air Traffic Controller*, 6th International Ergonomics Conference ERGONOMICS 2016 – Focus on Synergy, June 15 – June 18, 2016, Zadar, Croatia

The following was published in scientific journal as a result of this project:

- Pavlinović, M., Boras, D., Juričić, B.: Development and Implementation of a Language Technology System in Air Traffic Controller Student Training, International Journal of Education and Information Technologies. 10 (2016); 251-256.

Paper *Reduction of air traffic complexity using trajectory-based operations and validation of novel complexity indicators* (authors: T. Radišić, D. Novak, B. Juričić) is accepted by the reviewers of the scientific journal IEEE Transactions on Intelligent Transportation Systems and is being prepared for the final version of manuscript.

6. CONCLUSION AND FUTURE WORK

The development of air traffic management in Europe is an ongoing process that continues due to a constant increase in air traffic and due to different requirements of airspace users. Aviation industry, universities and authorities are actively taking part in this process. The goal of this process is to increase safety and efficiency of air traffic and to reduce negative effects such as environmental impact, delays and financial losses.

The established ATM research centre has contributed in specific issues in the field of ATM what can be seen from the results of this project. The emphasis was on the application and development of the ATC simulators and research of the impact of trajectory based operations on air traffic complexity. Research centre contributed in improvement of cooperation with the aviation industry in Croatia and in establishing partnership with the other European universities and institutions through the application of KAAT project

Overall outcomes of this project are improvement and upgrade of the technical equipment and functions of the Laboratory for the control of air navigation.

The research centre should continue its work and widen its activities and investigation in the following issues of ATM: development and validation of automated data processing systems (fast time simulations) and innovative air traffic controller tools, testing and enhancement of voice communication system, upgrade of aerodrome control simulator and development of approach control simulator, identification of elements for improving safety of air traffic, analysis of assessment methods during air traffic controller training, determining measures to increase air traffic efficiency and to reduce environmental impact, defining methods for separation of unmanned aerial vehicles and defining measures for monitoring of air traffic controller efficiency.

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DISTRIBUTED FLIGHT CONTROL SYSTEM SIMULATOR FOR AIRCRAFT AUTOSTABILIZATION

ABSTRACT

The current automatic aircraft control concept includes a central system of computers that controls the servo-actuators located near the flight control surfaces. The main point of this project is to decentralize the flight control system in a way to locate the microprocessors near the flight control surfaces that would enable reduction of mass and simplification of the control system and architecture. The work done so far is combination of theoretical and experimental research. The first results are published as conference papers indexed in IEEE Explore and Scopus database. The first paper was aimed to provide a survey of technologies developed and deployed for distributed flight control system, while the second one outlines design for Fully Distributed Flight Control System (FDFCS) and its control units, identifies the possible problems that a distributed flight control system implies and solves, and sets requirements for the planned FDFCS Hardware in the Loop Simulator.

KEY WORDS:

Distributed control system; aircraft control; Federated Architecture; Integrated Modular Architecture; fault tolerance

1. INTRODUCTION

Recent advancement in aviation requires more and more sophisticated control systems. New control systems are needed for both, air traffic control and aircraft flight control systems. One of the new approaches are distributed control systems which are the subject of our research project. The need for distributed control systems arises from the demands of today's modern aircraft, which contain many subsystems. All subsystems have to work in an optimal way to ensure that all security and economic constraints are fulfilled. To ensure that, new smart sensors and actuators are used. Such smart elements contain a local embedded computer (controller) with data processing and communication abilities comprising a distributed control system. In such a system significant amount of data processing is done in local embedded controllers and the master control unit has a global overview of the whole system.

This project is continuation of written project proposal for funding from the EU structural fund at the end of 2014 within the tender “Research scholarships for professional development of young researchers and postdoctoral fellows”. The research team started to collaborate during writing of the mentioned project proposal. This collaboration resulted in a scientific review article: “Technologies for Distributed Flight Control Systems: a Review”, presented at IEEE MIPRO conference in May 2015 [1].

This report is organized as follows. The research goal and motivation of the project is described in Section 2. Section 3 overviews the project research activities. An overview of the budget spent including a short description of the purchased equipment is given in Section 4. Section 5 shows the project results with emphasis on applications for new projects, obtained projects and grants, and published papers. Report ends with a conclusion and future work sections.

2. RESEARCH GOAL AND MOTIVATION

Flight control system (FCS) consists of flight control surfaces, cockpit controls and connecting linkages. Fly-by-wire (FBW) FCS replaces mechanical linkages with transducers, wires and actuators. A reliable communication network provides the backbone of every FBW system. Electrical components comprising the FBW system are integral part of the avionics architecture. FCS performs critical applications as flight stability augmentation, flight guidance and envelope protection.

There are three possible types of system architectures for a control system in general: (i) Centralized architecture; (ii) Distributed architecture; and (iii) Federated architecture. A centralized architecture uses a centralized hardware and a centralized software framework. One computer is used for several subsystems. As all control hardware is centralized, the environment can be controlled very well [2]. In addition, the maintenance of these systems is easy. All calculations are also centralized. The distributed architecture uses a distributed hardware and distributed software framework. All calculations are finding place in the applied smart sensors and the results are transmitted. A central control unit does not exist and all subsystems have to communicate with each other [2]. The federated architecture is a compromise between the centralized and distributed architecture. It uses a distributed hardware and centralized software. There are more subsystems than in the case of centralized hardware, but fewer than in the case of distributed hardware [2].

A centralized control approach for a FCS requires a large amount of electrical cables originating at the flight control computer and ending at actuators and control surfaces in one case, and originating in sensors and the flight computer in the other case. The issue of larger mass and complexity of centralized FCS, along with the susceptibility of servo control signals and sensory wiring to noise originating from surrounding electrical systems, are the main technical reasons for the development of distributed FCS.

The goal of our research is to develop concepts and control algorithms for a distributed FCS. The emphasis is on implementation of a simulator for distributed FCS and associated control hardware in the loop. The main idea is to decentralize the FCS by putting the control system units near the control surfaces. The benefits of such FCS are: less wiring for transferring the signals, faster response time and greater robustness.

3. RESEARCH ACTIVITIES

This section is describing the research activities done by the project team members during the project. The planned activities are divided among team members and include theoretical and experimental parts.

3.1 Review of current research in the field of distributed FCS

Continuously increasing requirements for aircraft and air transport safety along with operational demands for reliability, performance, efficiency and costs, are shifting the focus of recent development to distributed systems. The massive voting architecture proposed by Airbus [3] suggests to allocate the task of control laws and logic between flight control computers and control surface actuator nodes as shown in Figure 1. Flight control computers and actuator nodes are connected via an advanced data communication network developed by Airbus. Flight control computers execute the control laws and proprietary commands for control surface actuator nodes, which are then broadcast as messages over the communication bus. Actuator nodes are equipped with flight control remote modules, and perform massive voting upon receiving the messages from many flight control computers. The massive voting architecture resides upon digital communication technologies. New smart actuator technologies are explored for particular system application. Fault handling in the system proposed from Airbus is resolved within the actuator nodes. A high degree of fault detection as well as fault location is demonstrated, both due to the large number of nodes [4].

A distributed FCS architecture is presented also for accessing fault handling and redundancy managing on the military aircraft JAS39 Gripen [5]. The proposed system included 16 nodes. Various simulations showed that distributed sensor nodes meet fault detection coverage of 99% for both transient and permanent faults. The proposed system used triggered multi master broadcast bus with time division multiple access communication. As a result, the failure on any node cannot jeopardize communication by sending data outside the dedicated time slot, resulting in a fail silent system.

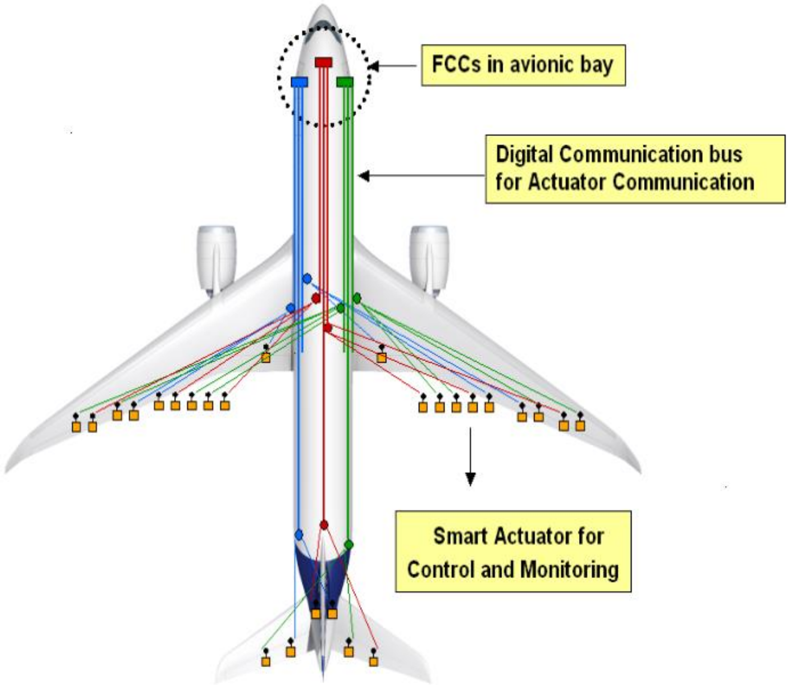

Figure 1 – Fully distributed FCS architecture [4]

Power line communications (PLC) have been proposed for distributed aircraft control systems in [6]. The PLC communications approach eliminates the need for a digital data bus wiring by modulating the data on power cables that are installed between the flight control computer and control surface actuators.

Although technology is promising and widely used in other applications, vehicular control systems are not usually installed with PLC systems. For aircraft's FCS, there are many requirements that make implementation of PLC difficult, such as using negative return wires on the power bus instead of chassis return as usual. The problem arises from selective frequency fading or multipath fading. Furthermore, as a general system design safety rule requires that primary and secondary flight surfaces must remain independent. More than one network must be used to reduce wiring and for tail surface reliability also. Communication speed requirements for various standards must be met, and to ensure reliability with a given number of remote units also. From many other aspects, PLC has to be further developed for aircraft use and its usability is yet to be explored.

Decentralisation is entering other aircraft subsystems, with the development of larger and more complex aircraft. Smart components are proposed for a decentralised fuel management system [7] and microcontrollers are embedded in the pumps, valves and sensors (Figure 2).

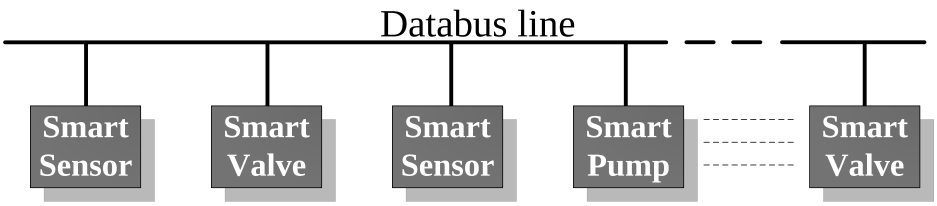

Figure 2 – Architecture of a distributed fuel control system

Proposed system components make their own decisions during various fuel operations, depending on the performed action. They share a time-triggered bus for communication. When a smart component reaches a decision, it transmits it over the bus. For safety, all system components retain a copy of the state vector that describes the system state. Laboratory and real scale testing have been performed proving that such a distribution is possible and that the new system can be adaptable to faults.

Distributed FCSs present a significant leap in the evolution of aircraft FCS architectures. Novel technological advances in areas of embedded computing and communication, machine learning, and multi agent systems control continue to push FCS design towards distributed systems. Although there are some demonstrations of distributed systems for aircraft, they are mostly analysed from the aspect of fault detectability and identification. However, distributed control systems should be further explored to find the final optimal way how the execution of the control law can be decentralised at the same time fulfilling all safety criteria. For example, some systems offer voting mechanisms for identical flight control computers and nodes, to achieve redundancy.

The authors conclude that other ways of decentralisation, possibly across hardware architecture boundaries between different control surfaces should be investigated, and that the possibility of decentralised decision-making needs to be further examined.

3.2 Proposed design of Central Units for FDFCS

A fully distributed flight control system is defined as one where all the FCS roles and functions are distributed to the network of embedded CUs located on, or near the control surface actuators. Control units have to be networked in a secure and reliable way for the Fully Distributed Flight Control System (FDFCS) design to operate safely. The choice of the connection standard is not proposed for the system; however, the controller area network (CAN) will be used as an example to demonstrate how safety and certification standards can be assured. Two separate CAN networks are assumed for redundancy. Terminating the two networks at different parts of the aircraft assures that no part of the system is left unconnected for the case when the communication lines break at one point as shown in Figure 3.

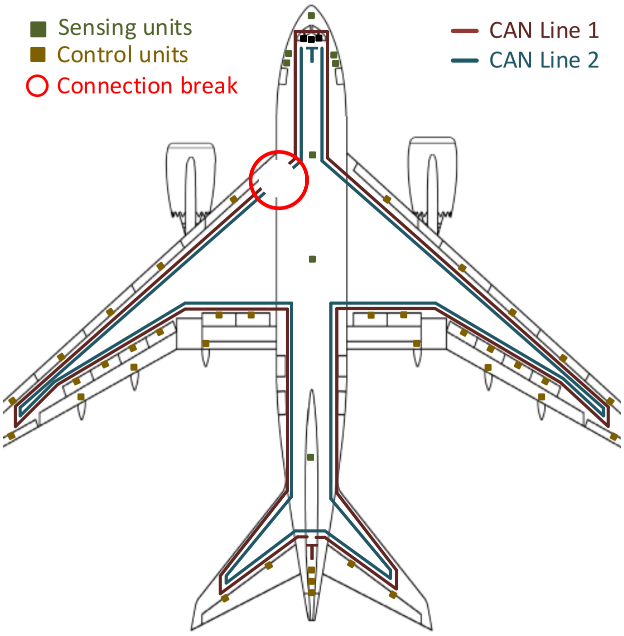

Figure 3 – FDFCS CAN network routing with separate termination points for case of connection break near left wing root

Additionally, provisions within the CUs have to be made to make actions in case of connection loss to ensure minimal intermission of the disconnected unit to the operation of the rest of the system and the controllability of the aircraft. This can be achieved by implementing automatic passivation of the affected control surface in a neutral position, on total connection loss.

The proposed design of the CUs consists of three embedded systems integrated into a single case called simply units. The term units will be used in this paper to avoid confusion with the term module used to describe software modules run on IMA. The primary embedded unit within the CU performs FCS functions and roles, and will be referenced from here as flight control unit (FCU). The secondary embedded system, referenced as external override unit (EOU), has the sole purpose of overriding the FCU outputs on a certain event, and allowing the remote control of the corresponding actuator.

The power regulation and communication level translators are doubled and not shared amongst the units, removing any chance for communication loss on both devices within the CU caused by translator or rectifier failure. The third embedded system is the actuator control unit (ACU) or the executive unit. The role of this unit is to manage actuator(s) connected in a way ordered by FCU and when overridden, the EOU. The unit uses power provided by both units, FCU and EOU as a redundancy to assure that when at least one unit is operating, the ACU has power available. Figure 4 shows the proposed design for the CU.

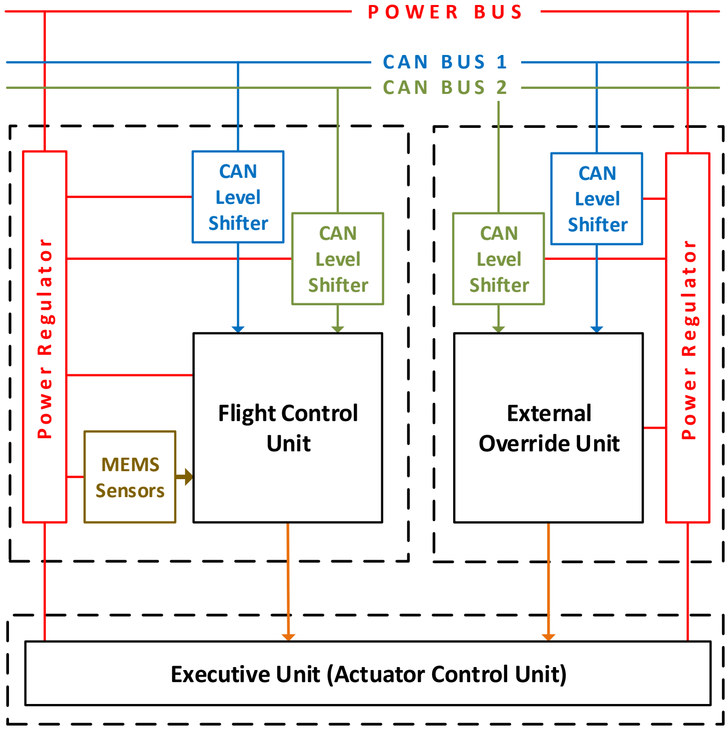

Figure 4 – Proposed CU design for FDFCS

Microelectromechanical systems (MEMS) based sensors are also an option but are not yet precise enough for aviation purposes [8] to serve as the only input of positioning data instead of the sophisticated and expensive inertial reference units (IRU). However, it can be expected that they will reach the required specifications in future [9]. Considering the low price of MEMS sensors, it is reasonable to propose the integration of MEMS sensors within each CU. Low cost, low precision MEMS sensors within every CU can be used to estimate positioning data for short periods of time. Higher precision IRU should be used to correct MEMS sensors positioning on regular intervals. This approach helps to reduce the traffic on network that would be caused by constant positioning data transfer from the IRU, GPS receivers and other sensory units to the CUs. In addition, the number of IRUs on board can be reduced once the precision of MEMS sensors rises to the required level. Theoretically, once the satisfactory precision can be maintained for the time the aircraft requires to complete the precision approach, the aircraft should be fully capable to continue the approach to the airport (runway) in case of IRU failure at the most critical moment, or at the beginning of the approach to the airport (runway).

Control system should not be solely time triggered or event triggered. It would be beneficial that sensory units as GPS receivers and IRUs broadcast data on the network on regular intervals. That would assure that all the units have the positioning data corrected at certain regular interval. CUs should communicate between each other on a specific event, only when communication is required to perform FCS functions. However, provisions in each node have to be made to protect the buses by limiting the data bandwidth consumption [5].

All units need to transmit two kinds of data. The first kind would be data request, and the second data send. Units should be able to request and send data from and to other units such as control surface position or positioning data. Such a request allows that the monitoring function of one unit can be assigned to any other unit on the system, facilitating fault detection. When a certain number of units on the system detect a malfunction in operation of the monitored unit, the EOU should be activated and take control of the control surface.

In the emergency event of loss of many systems necessary for the normal or the automated operation of FCS, degraded mode of operation should be available. The degraded control mode must allow direct control of minimal necessary units. Direct control should transfer pilot commands to the control surfaces without any interference. Under no circumstances like other systems failure or corruption, should the direct mode of operation be affected. These dependencies have to be designed in the system and validated.

The normal control mode should improve the stability of the aircraft and protect the flight envelope, independent of weather the aircraft is operated by a pilot or guided by the flight management system (FMS) and controlled by the autopilot. When normal control mode is active, CUs must cooperate to control the aircraft. For instance, the port and starboard ailerons and spoilers should differentially deflect in a way to prevent unwanted yaw. Communication is required for whichever motion the surfaces are coupled and produce total effect. To assure coordinated outputs, cooperation between units should be organized. Massive voting can be applied to achieve the desired result. However, for the system to be fully distributed there should be no central unit assigned to decide on the control surface positions. The network and its units should be self-sufficient to provide for all roles of FCS.

3.3 Hardware in the Loop Simulator

The proposed distributed FCS system rises many questions about the choice of the appropriate control concept, dependability, implementation of fault detection and dependencies between control units. Therefore, a dedicated HIL simulator will be built to answer these open questions and estimate the benefits and disadvantages of the proposed architecture. In order to make such a simulation certain requirements have to be fulfilled. The proposed HIL schema for FDFCS is shown in Figure 5. An accurate aircraft and flight model including atmosphere and aircraft engines have to be simulated in real-time using appropriate simulation software like Matlab/Simulink, and the communication network with the CUs has to be implemented as a real system is this case. In such a simulation framework the control hardware will receive accurate inputs and computed control outputs will be forwarded to corresponding actuators and act as a feedback to the simulated aircraft.

The embedded CUs will be designed so they will be able to run the FCS. CUs will be executing control laws necessary to control the simulated aircraft control surface actuators. Needed data from aircraft sensors like the air data unit, inertial reference unit, and GPS receiver will be simulated in Matlab/Simulink to ensure needed realistic sensor measurements. The dynamics of the actuators controlled by CUs, will also be emulated in Matlab/Simulink. Finally, the equal processing power centralised control FCS will be developed alongside, to serve as a reference for comparison of the centralised and fully distributed system. Another important requirement is detailed logging and analysis of data traffic in order to create procedures to enable certification tests of the proposed architecture.

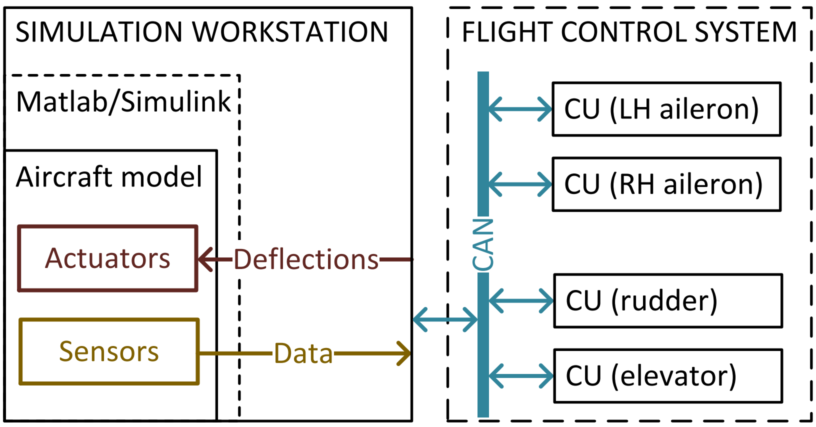

Figure 5 – Proposed HIL schema for FDFCS

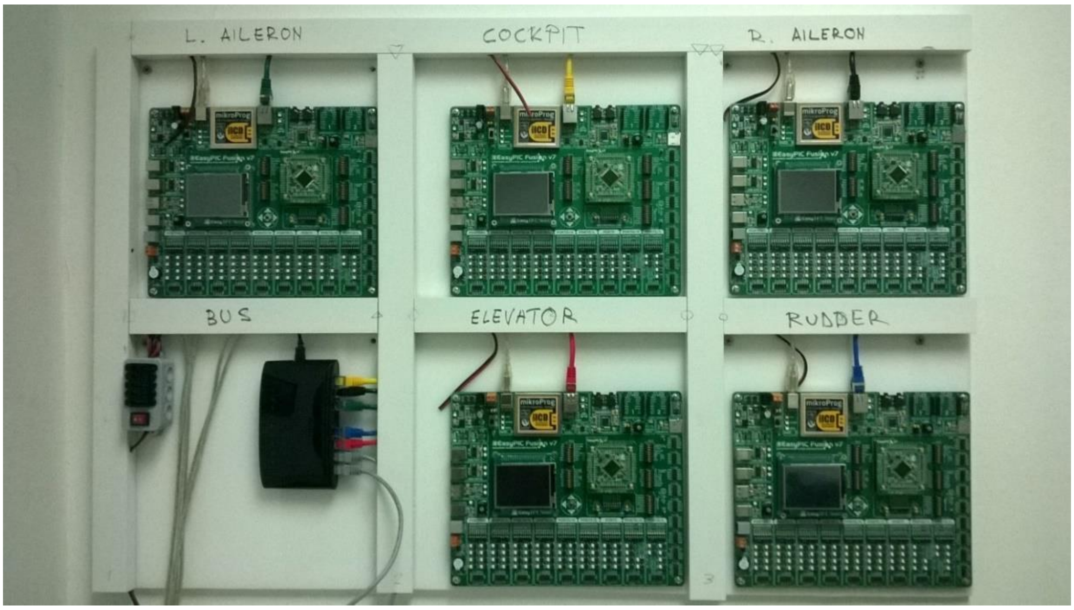

Figure 6 – CUs that will be used in the HIL simulator

4. BUDGET SPENDING

The approved budget for the project per year was 15,000.00 HRK, cumulatively 30,000.00 HRK. The first year budget was spent for equipment necessary for building a HIL simulator, conference paper presentation and an e-course for EU project management. The total spent amount was 15,140.00 HRK. The second year approved budget was also 15,000.00 HRK. Some of the funds for the second year of the project (2,442.16 HRK) have been spent for attending the MIPRO 2016 conference to pay the conference fee and travel expenses. The rest of the funds will be used for buying of a work-station and subscription on two leading journals in the field of aircraft flight control as listed in table 1.

Table 1 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	Essential equipment purchase	11,300.00 HRK	Bought 1 ATX power supply, S-FTP cable, 5 development boards EasyPic Fusion v7	11,129.50 HRK
2.	Research dissemination (1st year)	3,270.00 HRK	1 x registration fee for the conference MIPRO 2015	1,511.75 HRK
3.	Professional education	5,000.00 HRK	Completed E-course for EU funds project management	2,499.00 HRK
4.	Research and experimental work (1st year)	0.00 HRK	Written two scientific conference papers andmounted development boards	0.00 HRK
5.	Advisory services	10,000.00 HRK	No (insufficient funds)	0.00 HRK
6.	Research dissemination (2nd year)	11,700.00 HRK	1 x registration fee + travel expenses for the conference MIPRO 2016	2,442.16 HRK
7.	Purchase of additional equipment and servers to simulate the flight of aircraft in real time	4,000.00 HRK	1 x workstation	10,675.94 HRK
8.	Research and experimental work; writing project applications	0.00 HRK	Membership fee and subscriptions to the Journals Guidance, Control and Dynamics and Journal of Aircraft	1,881.90 HRK
9.	Short Term Mobility	9,500.00 HRK	No (insufficient funds)	0.00 HRK
10.	Attending Transport Research Arena Conference in Warsaw, April 2016.	6,500.00 HRK	No (insufficient funds)	0.00 HRK

5. RESULTS

This section is describing the results achieved during the two project years. The results are divided into five subsections related to involvement of students (including PhD students), cooperation with industry and academia (domestic and foreign), submitted project applications, obtained additional project and funds, and finished with a list of published papers. The list of published papers contains a very short paper description.

5.1 Involvement of students

The research member of our team Miroslav Šegvić is also a PhD candidate at Faculty of Transport and Traffic Sciences. His research field is flight control and dynamics. Through this project, Miroslav Šegvić profiled himself on the experimental flight control system research. He used the experience gathered on the research topics, that were facilitated by this project, to write the two scientific papers that were presented on the international conference MIPRO.

5.2 Cooperation with industry and academia

Regarding cooperation with industry and academia, our team made an initial contact with Prof. Ruxandra Botez from Laboratory in AeroServoElasticity, Active Control and Avionics, University of Quebec in Canada. Prof. Botez invited us for a visit to the aforementioned Laboratory. The leader of this research team, Karolina Krajček Nikolić applied twice for a short visit grant schema funded by University of Zagreb, but without success. Due to lack of funds, this activity was not realized. Industry cooperation is established with company Croatia Airlines (CA) since our research team member Miroslav Šegvić is working in CA as an engineer. This working place gives him first row insights into problems related to control of commercial aircrafts.

5.3 Project applications

In table 2 all submitted project proposals that got rejected or are currently in review are listed. The project proposals are result of participation of the research team member Edouard Ivanjko in the EU COST action TU1102 Towards Autonomic Road Transport Support Systems. To increase the probability of obtaining new funding the leader of this research team, Karolina Krajček Nikolić participated the workshops “Kako napisati uspješnu projektnu prijavu za individualnu stipendiju u okviru Marie Sklodowska - Curie akcija” during June 2015 and “Od neuspješnih projekata do dodjele bespovratnih sredstava” during November 2015. The first workshop was organized by the Agency for mobility and EU programs, and the second by WYG International.

Table 2 – Overview of submitted project proposals.

Nr.	Funding scheme	Project name	Budget	Status
1.	HORIZON2020	Eliminating air QUality problems using an Autonomic Layer in the Smart city Environment EQUALISE	6,580,578.75 EUR	Rejected
2.	HORIZON2020	COLlective TRAnsport/TRAvel INtelligence COLTRAIN	3,440,000.00 EUR	Rejected
3.	HRZZ	Optimization of Routes for Electric Delivery Vehicles OpRED	702,000.00 HRK	Rejected
4.	PoC BICRO	Advanced traffic counter based on multispectral video	260,000.00 HRK	Rejected
5.	COST	OC-2016-1-20366 "Cooperative intelligent systems for transport "	Yearly defined	Rejected
6.	COST	OC-2016-2-21618 “Intelligent Mobility Pan European Skills Network“	Yearly defined	In review
8.	Financing scientific centres of excellence in Croatia	Scientific centre of excellence for data science and cooperative systems	5,000,000.00 EUR	In review

5.4 Obtained additional projects and funds

Description of accepted project proposals and other funds received are given in Table 3. Obtained funds enabled networking with foreign researchers and access to future summer schools.

5.5 Published papers

The results of our research are published in papers two papers ([1] and [10]) indexed in IEEE Explore and Scopus database. Both papers are scientific conference papers for the MIPRO international symposium in 2015 and 2016. The first paper reviews the state of the art (SOTA) in distributed flight control technologies using publicly available, scientific and technical publications. The SOTA summary comprises a description of challenges in the design of flight control systems with a distributed structure, technologies currently used in flight control systems and also technologies not specifically related to distributed flight control but applicable for the design of future flight control strategies. Described system and technologies are represented with examples of real systems including swarms of small Unmanned Aerial Vehicles and distributed networks for Fault Detection and Isolation.

The second paper outlines design and requirements for planned FDFCS HIL simulator and its Control Units (CU). Main contribution is that aircraft stability and trajectory control logic is distributed to a network of independent CUs collocated on actuators collaborating to control the aircraft with respect to common goal. The paper also identifies the problems that a distributed FCS implies and solves.

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	EU JCR	Road-transport & Emissions Modelling (REM) workshop	Networking event and workshop regarding modelling and simulation od road vehicles emissions. Held in Skopje, Macedonia and Edouard Ivanjko participated.	700.00 EUR
2.	Scientific centres of excellence	Scientific centre of excellence for data science and cooperative systems	Research and collaboration project related to establishing a scientific centre of excellence in data science and advanced cooperative systems. Project associate Edouard Ivanjko is member of the research unit related to data science.	Yearly 550,000.00 HRK
3.	ERASMUSplus	Teaching visit to the Department for traffic and transport Faculty of Technical Sciences St Kliment Ohridski University, Bitola, Macedonia	Grant holder is Edouard Ivanjko. Aim of the visit is to teach the foreign students to new developments in application of artificial intelligence in road traffic control and how to simulate such systems using VISSM, EnViVeR and Matlab. Additionally, existing research cooperation will be extended.	1,000.00 EUR
4.	COST	IC1406 High-Performance Modelling and Simulation for Big Data Applications (cHiPSet)	Researcher Edouard Ivanjko is management committee member for Croatia. Hi is also member of the traffic group of the application workpackage.	Yearly defined for networking meetings
5.	University of Zagreb	Development of Measurement Systems in the Low Speed Wind Tunnel	The grant holder is Anita Domitrović. Karolina Krajček Nikolić is a research team member. Aim of the project is to equip the Aerodynamic Laboratory with basic measuring systems.	22,079.63 HRK
6.	University of Zagreb	Route optimization for small electric vehicles with the criteria of minimal consumption	The aim of the project is to develop a method of collecting data of the energy consumption of electric vehicles and construct electronic circuit for measuring necessary parameters of electric vehicle.	3,121.67 EUR

6. CONCLUSION AND FUTURE WORK

The primary goal of the project was to set a starting point for the research of experimental flight control systems. That included the research of the state of the art and academic focus on the research area. After that, a proposal for an experimental flight control system followed. Research equipment for HIL simulation was pre-set. All the goals from this project were completed and make a solid base for planned future work. The future work will include development of the software for the distributed flight control system. Build simulation setup will allow an analysis of the proposed distributed system and comparison with classic centralised control system. The exploration of the characteristics of the proposed control concept and practicality for the application in the aviation vehicles will be the topic of future scientific papers.

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TRANSEUROPEAN PUBLIC TRANSPORT REGIONAL INNOVATIVE STRATEGY – TETRIS

ABSTRACT

TETRIS project responses to the current challenges in terms of public transport planning and coordination. One of the problems is lack of the PT operational data at the local and regional level. It results in poor data exchange and coordination between PT organization parties in connections, scheduling and common ticketing strategy. This is a consequence of lack of the tool for the regional authorities that helps to control the quality of the transport service provided and to use available data from the nodes and TEN-T corridor. Another important issue is a disproportion of maturity level in the area of PT coordination and planning in the regions of the Central Europe corridor. Main objective of the project is a long term improvement of PT planning and coordination in order to increase the availability, capacity and quality of transport system in the region and better connection of the rural areas and peripheral regions with the main nodes and TEN-T network in Central Europe. Objective will be achieved by an innovative transnational methodology and regional strategies for PT planning and coordination elaborated in the project, experimental piloting of a new low-cost tool that improve regional and local management of public transport. Expected change will arise as a reduction of disparities of knowledge between regions in the Central Europe corridor, elaboration or update of the regional strategies to improve transport system and low cost IT tool that enables stakeholders to collect data and to manage the regional connections based on the standardized data exchange. Main beneficiaries are passengers of the rural areas and peripheral regions, local and regional authorities and PT service providers.

KEYWORDS:

TETRIS; public transport; planning; coordination; TEN-T network; PTV Visum

1. INTRODUCTION

Project *TETRIS* was applied on 1st Call for project proposals within EU Regional Development fund Interreg Central Europe, programme priority: 4. Cooperating on transport to better connect CENTRAL EUROPE, specific goal: 4.1 To improve planning and coordination of regional passenger transport system for better connections to national and European transport networks.

Project was developed with 11 partners from Croatia, Poland, Slovenia, Italy and Czech Republic. Project leader was Institute of Logistics and Warehousing from Poland.

Proposed project results were directly linked to the regional partners challenges: **Dubrovnik**: Partial availability of modern motorways and rail network, together with specific territorial challenges result in poor PT connections with other Croatian regions as well as within the Region itself. The PT services of different operators are currently not harmonized and there is a lack of holistic approach to planning and coordination on a regional level. **Slovenia**: Lack of regional PT (Public Transport) strategies, KPIs (Key Performance Indicators) and action plans including recommendations on different modes of supply. Main problems of the Region are divergent maturity levels of planning and organization of PT supply between particular areas of the country. Experience and knowledge acquisition from the other partners and new solutions, how to avoid redundancies in PT management, will be crucial. **Emilia Romagna**: Inefficiencies in the PT service, as a result to lack of coordination among PT providers. There are missing connections to/from several villages in peripheral areas, therefore commuters are forced to use private transport. In this case, on-demand or dial-a-ride services are desirable. There is often also an inappropriate time lag for taking the following mean of transport, for users performing trip chains to reach their destination. **Wielkopolska**: There is no IT tool for the regional authorities that helps to control the quality of the transport service provided and to use available data from the nodes and TEN-T corridor. Lack of the PT operational data at the local level leads to the poor PT coordination of connections, scheduling and common ticketing strategy at the regional level between transport organizers. **Bohemia**: Poor cooperation among various partners - Czech rail, Prague PT service provider and regional transportation system, regarding to traveller behaviour change, which is to be defined in SUMP.

2. RESEARCH GOAL AND MOTIVATION

TETRIS project approach and methodology were intended to pursue the defined objectives by performing the following main activities such as:

- creating regional strategies for planning and coordination of the passengers transport
- developing an international IT tool that enables stakeholders (regional authorities and transport organizers) to collect and analyze data
- performing regional pilots (Wielkopolska/Slovenia/Emilia Romagna/Dubrovnik/ Bohemia) in order to provide public transport traffic analyses (using simulation tool PTV Visum) to detect links and capacity gaps
- elaborating transnational common methodology for Public Transport planning and coordination stategy on the regional level.

The project proposal define all relevant stakeholders in the public transportation in the involved regions and provide an insight into the status of local transportation plans, methodology used for plan development and best practices. Based on this input and the experience from other regions a regional PT action plan will be tailor made in order to improve the quality and accessibility of public transport service in this heterogeneous regions.

TETRIS IT tool will be an innovative low-cost alternative version of a complex expensive ITS solutions, that enables regional authorities to collect data at the operational level and use it for planning and coordination purposes on regional territory. It will result in an increase of the availability and quality of public transport in rural and peripheral areas.

Process-oriented innovative approach of TETRIS project result from demonstration of novel transnational methodology within different regional contexts, experimental piloting of new TETRIS IT tools with a view to their future implementation and their policy integration as well as from capitalizing on previously acquired knowledge.

Main objective of TETRIS project is a long term improvement of public transport planning and coordination in order to increase the availability, capacity and quality of transport system in the region and better connection of the rural areas and peripheral regions with the main nodes and TEN-T network. Main objective will be achieved as a result of the actions undertaken within the project.

Reliable data collected in the TETRIS IT tool, created within the project, will be used in the long term to develop policy that enables an upgrade of the regional Transportation Plans, which results in improved mobility service in the public interest and strengthening the link to the national and European transport networks. It will be done through the implementation of the elaborated regional strategies for planning and coordination based on the transnational common methodology created within the project. More efficient development of connections between particular levels (local, regional, national) of the PT management will be performed.

Unified transnational methodology, sharing of experience and mutual learning will allow stakeholders to cooperate with authorities from the Central Europe corridor not involved in the TETRIS project to make passengers transport more sustainable and environmentally friendly contributing to climate change mitigation.

3. PLANNED RESEARCH ACTIVITIES

TETRIS IT tool will help to manage the regional connections based on the standardized data exchange (from the previous EDITS project output) between main nodes and peripheral areas in the region. *TETRIS* will allow transport providers to control quality of their service (in different modes of transport and territorial areas). Operational coordination will be performed thanks to the usage of available data from the nodes and TEN-T corridor for a dynamic reaction to the real changes of the passengers needs or demand (eg. schedules integration, additional runs). Operational data collected in the TETRIS tool can be also used for the strategic planning to create regional and local Transportation Plans.

Performing pilots in order to provide public transport traffic analyses (using simulation tool PTV Visum) to detect links and capacities gaps. Simulations will be based on the reliable data (described in WP2) collected in the TETRIS IT tool as well as available historical data. It will allow to model transport networks and travel demand, to analyse expected traffic flows, to plan public transport services and to develop advanced transport strategies and implementation of the plans elaborated in WP1.

Developed methodology will be unified, so it could be used in the different regions across the Europe, not only involved in the project. Trainings will be conducted in which the local/regional authorities will learn how to elaborate strategy for public transport planning and coordination using transnational common methodology and TETRIS IT tool. Knowledge gained within the project will be successively utilised in tackling regional policy development.

Work package description

WP1 Strategy for planning and coordination

Objective: To create a Regional Strategy for planning and coordination of the passenger transport (mainly for the regional authorities and transport organizers) – to detect lacking connections, to integrate schedules between main nodes and peripheral areas at the particular levels of transport organization, to create and implement the Transportation Plan and to help to achieve the common ticketing strategy at the regional level.

Activities:

- Regional authorities pooling and round table - to identify the Public Transport information needs, that allows to recognize the level of regional maturity of each partner region in terms of PT coordination.
- KPIs elaboration based on State-of-the-art (Key Performance Indicators such as: availability of scheduled information, availability of real time information, availability of ticketing info, number of mobile apps, number of open data sets publication...).
- Elaboration of the Regional strategies of the Public Transport planning and coordination based on the transnational common methodology (from WP 4) developed through international experience
- Elaboration of the Strategy implementation action plan including technical requirements on interoperable public transport information and ticketing systems as a base for near future interconnection of CE regions.

Outputs:

- State of the art based on pooling results including regional Transportation Plans, methodology used, benchmarking and best practices in each partner region
- Set of KPIs for a different regional levels of maturity,
- PT regional startegies
- Action plan.

WP2 Transnational IT Tool development

Objective: To develop an IT tool that enables stakeholders (regional authorities and transport organizers) to collect and analyze data such as passengers flow, timetables, real-time tracking – delays, public transport vehicle GPS data, available connections, ticketing.
TETRIS IT tool will help to manage the regional connections based on the standardized data exchange (from the previous EDITS project output) between main nodes and peripheral areas in the region. TETRIS IT tool will allow to control transport providers and quality of their service (in different modes of transport and territorial areas). Operational coordination will be performed thanks to the usage of available data from the nodes and TEN-T corridor for a dynamic reaction to the real changes of the passengers needs or demand (eg. schedules integration, additional runs). Operational data collected in the TETRIS IT tool can be also used for the strategic planning to create regional and local Transportation Plans.

To achieve the main objective following **activities** will be performed:

- Creation of the IT tool architecture based on the stakeholders real needs and State-of-the-art from WP1
- Development of the TETRIS IT tool that collects reliable data and enables Public Transport operational management by regional and local authorities and transport operators

Each activity will result in substantial **outputs**:

1. TETRIS IT tool architecture
2. TETRIS IT tool

WP3 Regional pilot actions

Objective: To perform 5 regional pilot actions (Wielkopolska/Slovenia/Emilia Romagna/ Dubrovnik/Bohemia) in order to provide public transport traffic analyses (using simulation tool PTV Visum) to detect links and capacity gaps. Simulations and forecast will be based on the reliable data (described in WP2) collected in the TETRIS IT tool and available historical data. It will allow to model transport networks and travel demand, to analyse expected traffic flows, to plan public transport services and to develop advanced transport strategies and implementation plans elaborated in WP1.

Activities:

- Configuration of the TETRIS IT tool and feeding in the needed regional static data (eg. geolocalization of public transport stops, time tables, lines) in order to conduct the pilots
- TETRIS IT tool real-time data collection (eg. GPS positioning – delays, passengers flow)
- Simulation in PTV Visum [calculation of traffic scenarios for near and distant future, showing detailed levels of demand (passenger flows between zones), time tables (headway, line, single units), costs, revenue (different types of tickets etc.), utilization of the fleet (different vehicle types, on one line, on the network, depot times etc.) and schematic networks] based on the input data from TETRIS IT tool and GIS, demographic data and area development plans, etc.

Outputs:

- Configured TETRIS IT tool
- Input database
- Model of the transport network and its connection and capacity gaps in the regional pilot area.

WP4 Common methodology

Objective: To elaborate transnational common methodology for development of Public Transport planning and coordination strategy on regional level based on the outputs from WP1 and WP3. Developed methodology will be unified, so it could be used in different regions across Europe, which will ensure the project transferability. Trainings and experience exchange will be provided to local/regional authorities who will learn how to develop a strategy for public transport planning and coordination using transnational common methodology and TETRIS IT tool. Knowledge and experience gained within the project will be successively utilised in tackling regional policy development even after the end of the project.

To achieve the main objective following **activities** will be performed:

- Elaboration of the transnational common methodology for development of Public Transport planning and coordination strategy on the regional level.
- Workshops and trainings for the local authorities in the involved regions
- Workshops and trainings for the local authorities from the other regions based on the case studies from the project pilots.

Each activity will result in substantial **outputs**:

- Guidelines for the development PT planning and coordination strategy on the regional level using common methodology.
- Training materials for the local authorities.

The main planned role of FTTS in TETRIS project was to take the leadership over the Work Package 4: Monitoring and evaluation of pilot application results and elaboration of guidelines. This task is assigned to FTTS due to its experience in conducting the impact and process evaluation in collaborative EU funded projects and transferring gained knowledge in a form of a guidelines. In the first phase of the project the FTTS will produce detailed evaluation plan capturing all relevant information about local, regional and transnational context of TETRIS implementation, as well as defining evaluation indicators for project objectives and developing data collection procedures for them. During the whole duration of the project FTTS will continuously work on the process evaluation tasks, investigating drivers and barriers of the project. This information will be essential for creation of guidelines and transfer of know-how in later stages of the project. Before and after the implementation of the pilot actions, FTTS will collect the data from the partners and conduct impact evaluation. Apart from Work Package 4, it was planned that FTTS participate in all other thematic Work Packages of the project by collecting and providing the data to other partners (Work Package 1), contributing to implementation of TETRIS platform (in Work Package 2) or implementing pilot actions on local level (in Work Package 3).

4. BUDGET SPENDING

Table 1 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	Travelling costs	11.000,00 HRK	Workshop - PTV Vissim VisVAP London - travelling costs	3.871,30 HRK
2.	Accommodation costs	5.000,00 HRK	London - Accomodation costs	1.400,00 HRK
3.	Costs of text editing	3.000,00 HRK	Worskhop PTV Vissim VisVAP - cotization	3.879,65 HRK
			User group Meeting PTV Zagreb - cotization	1.418,44 HRK
			Bank provisions	160,00 HRK

Achieved activities primarily aimed at raising the level of competence in the field of intelligent control of traffic flows at intersections, especially in the form of giving priority to certain groups of vehicles, coordination of signal plans at intersections etc. An upgrade of the existing knowledge of simulation modeling is achieved especially in terms of making algorithms for vehicle actuated intersection control.

At the time of approval of funding from the program PROM-PRO, partners have already been defined as well as main guidelines of the project application to the Interreg Central Europe call. All meetings between partners were conducted via "Skype" conference and there was no need for travel expenses in terms of the meetings of the working group. For this reason, the planned financial resources are redirected to the training program: Modelling Vehicle Actuated Signal Programs with VisVAP with PTV Vissim.

5. RESULTS

Since the project application has not been accepted, achieved levels of quality and productivity are reflected in:

- Active participation in the writing of application for project financed by the EU
- Finding appropriate partners for the project application
- Exchange of knowledge and experience with partners who have participated in several FP5, FP6 and FP7 projects, Horizon 2020, Interreg and other
- Coordination of work with 11 partners.

5.1 Cooperation with industry and academia

Transnational cooperation need results from the common challenges and issue of interest. Each project partner brings the peculiarity of its regional context to find common methodology for the public transport planning and coordination that will be used for elaboration of strategies at the regional area (more efficient and innovative solutions). Varied international skills and competences of the project partners will contribute to higher level and

quality of the project results. Mutual learning and experience exchange enable decrease of knowledge disparities at different levels of regional maturity of public transport organization. Transnational cooperation is an important step towards the equalization of quality and maturity level of Public Transport systems in the TEN-T Central Europe corridor regions.

In Table 2 are shown involved partners on project from Croatia, Slovenia, Italy, Poland and Czech Republic.

Table 2 – Partners in TETRIS project

Partner list

Number	*Partner name*	*Country*	*Abbreviation*	*Role*
1	Instytut Logistyki i Magazynowania	PL	ILIM	LP
2	Urząd Marszałkowski Województwa Wielkopolskiego	PL	UMWW	PP
3	Call Freedom Sp. z o.o.	PL	CF	PP
4	Regione Emilia Romagna	IT	RER	PP
5	Università di Pisa	IT	UNIPI	PP
6	Univerza v Mariboru	SI	UM	PP
7	LOGITEH projektiranje, svetovanje, založništvo in druge storitve d.o.o.	SI	LOGITEH	PP
8	Fakultet prometnih znanosti Sveučilišta u Zagrebu	HR	FTTS	PP
9	Regionalna razvojna agencija Dubrovačko-neretvansk e županije DUNEA d.o.o.	HR	DUNEA	PP
10	Centrum dopravního výzkumu, v.v.i.	CZ	CDV	PP
11	Regionální organizátor pražské integrované dopravy	CZ	ROPID	PP

Source: [1]

5.2 Project applications

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Project name	Budget	Status
1.	City of Zagreb	Microsimulation of Center of City of Zagreb with priority of PT vehicles on signalized intersection	455.000,00 HRK	Under review

5.3 Obtained additional projects and funds

Table 4 – Overview of submitted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	Horizon 2020 - Partner City of Zagreb	SocialCar	Development of macro and microsimulation on test sites after implementation of carpooling systems	200.000,00 HRK

6. CONCLUSION AND FUTURE WORK

The main TETRIS project result would be an increase of the availability, capacity and quality of transport system in the region and rural areas and peripheral regions as well as better connection to the main nodes and TEN-T network. It would be achieved through the implementation of regional strategies elaborated within the project, that enables more efficient planning and coordination of connections between particular levels of the Public Transport management (regional-local authorities).

The project would develop a TETRIS IT tool that enables stakeholders to collect data (passenger flows, timetables, operational data etc.) necessary to manage the regional connections. Low-cost TETRIS IT tool allows standardized data exchange (developed in EDITS project) between peripheral areas and main nodes and TEN-T corridors, where Public Transport is supported by the expensive ITS tools. Operational data collected in the TETRIS IT tool would be used for strategic planning to create regional and local Transportation Plans.

Another important effect would be a reduction of existing disparities of knowledge between regions in the Central Europe through the elaborated transnational common methodology for a Public Transport planning and coordination strategy. Developed methodology would be unified, thus it could be used in the different regions across Europe, which would ensure project transferability. International trainings conducted for the local and regional authorities would enable experience sharing between particular stakeholders.

In future work focus will be on implementation of gained knowledge on projects conserning micro and macrosimulations of traffic flows, especially public transport.

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SYSTEM OF AUTOMATIC IDENTIFICATION AND INFORMING OF MOBILE ENTITIES IN THE TRAFFIC ENVIRONMENT

ABSTRACT

Among today's methods of identification and collection of data about traffic entities, a large number of traffic and logistic systems uses one of the AIDC technologies (Automatic identification and data capture). Technologies such as RFID, RTLS, NFC, GPS and modern labeling technologies Barcode and QR Code, can easy implement in the function of mobile entities identification in traffic system. Basis on the stated, it is possible to offer new classes of value added services for all stakeholders (users) of traffic/logistic process and finally improve the existing QoS (Quality of service) for the end users as well as to optimize business in favor of network and logistic operators. The aim of stated research is to define a new value chain of delivery for service of mobile traffic entities identification and new services of informing for traffic system users.

KEY WORDS

Internet of Things; Sensors; Assistive technology; Web 2.0; value chain

1. INTRODUCTION

Automatic identification and data capture (AIDC) technologies indorsed by connection technologies, such as Bluetooth and Wi-Fi, are nowadays growing in their application within traffic environment. Identification (ID) technologies are quite useful in logistic systems (post offices and smart warehouses), as for identifying and informing users about their environment. Identification technologies can be divided into short range and long range [1]. ID solutions and services have purpose of providing accurate and real-time data and can be based on *Internet of things* (IoT) and *Cloud Computing* (CC) concept. By exploring possibilities of AIDC and connection technologies such as Bluetooth and Wi-Fi, it is possible to introduce new functions of identification and tracking/informing of traffic entity in real time environment. Basis on the above, it is possible to introduce additional functionalities of identification and tracking of traffic entity in real-time. Furthermore, new classes of services can be provided, appending an added value for all stakeholders of traffic/logistic process, an endorsement of quality of service (QoS) and the optimization of business for network and logistic operators as a final result.

The second chapter explains a purpose of the research and provides descriptive analysis of development of AIDC technologies in the field of identification and informing within the traffic environment. The process of research is described in the third chapter, providing an overview of individual technology and services. The list of equipment and its possibilities is provided in the fourth chapter, and the results and defined guidelines for the future research work in this field are given in the final chapter.

2. RESEARCH GOAL AND MOTIVATION

Through the research of AIDC technologies, which include RFID, RTLS, GPS, telemetry, NFC and 2D codes, it is possible to contribute to more efficient delivery/provision of information service. For that purpose, it is necessary to explore the relevant parameters (user's needs) that are to be satisfied in order to meet the wanted objectives. The main purpose of the research is to define new value chain of delivery of service of mobile traffic entity identification and to provide a new defined service of informing traffic system user. The research process of identifying mobile entities and informing user is divided into following areas of application:

- form of assistive technology;
- more efficient processing of logistic activities (container);
- tracking of shipment (postal traffic), and
- user's movement thought traffic network (pedestrian).

RFID technology with these specifications is used in identification of traffic and transport entities during which is important to define requirements that are necessary for determination of the RFID tags [2]. These research based papers provide the analysis of RFID sensor technology, readers and tags, as well as the resulting integration of risk management practice into transportation processes via mobile control system which increases intermodal container transportation mobility, safety and overall effectiveness. Today's development of applications based on NFC technology can be divided into several categories: Touch and Go, Touch and Confirm, Touch and Capture, Touch and Link, Touch and Connect, and Touch and Explore [1].

NFC technology can be used for informing the user about the environment, during which is important to precisely define the information written in *tag* [3]. System's architecture based on NFC technology is a current developmental challenge, mostly because of difference in the needs of users (people with disabilities) [4].

AIDC technologies are increasingly used in postal traffic, in particularly within the systems for tracking shipments [5]. In such systems, RFID technology has been increasingly used, especially within the concept of RTLS system where combined with Wi-Fi technology. Mentioned technologies can be used indoors, inside places like storages, and for identification and informing of mobile users indoors [6]. Due to its testing errors, GPS technology should be systematically explored [7] before developing suggested AIDC supported system architecture, which is one of the main objectives of the research. Within the research on functionalities of individual information and communication technologies, with an aim of providing accurate real-time information to the user, the analysis of functions and possibilities of Bluetooth Beacon BLE technology has been made in Ambient Assistive Living (AAL) concept. ALL concept implies appropriate technology of collecting, processing and distribution of information. This research includes a suggested architecture for informing traffic users about their current environment.

The relevance of presented topic is manifested in strategic documents of the Faculty indicating the aim and the contribution of topic: Modeling of information and communication systems for the offer of services based on traffic system's data. Suggested topic meets the expected scientific contribution through detailed description of expected results of the research.

3. RESEARCH ACTIVITIES

The research is conducted in two cycles and the detailed plan of research is presented in Figure 1. Figure 1 describes procedures of research and the given results that were consequently published on international scientific conferences and journals.

The first cycle includes the research of the process of identification of all relevant mobile traffic entities that should be automatically recognized. Within the research, the classification of the parameters has been made depending on the type of service that should be provided by designed system of automatic recognition. For that purpose, many available scientific and professional literature has been studied, as well as the means of existing technical solutions.

The following step of research includes the explored possibilities of the application of AIDC technology depending on the field of research. The included fields of research are:

- Assistive technologies;
- Logistics (container);
- Postal services and
- Movement and informing of user.

Security aspects of individual technologies were explored within the IoT and CC environment aiming the reliability of the information system.

In the second cycle, the research is conducted on the equipment necessary for designing the system for delivery of real-time informing service. For that purpose, the IoT technology analysis has been made as the analysis of Arduino elements and the RasberryPi component. Aiming to define user's requirements and in a collaboration with Up2Date association, 112 respondents were included into survey. Besides the analysis of users' needs, the analysis was made on the issue of accessibility of the users' equipment. All previously mentioned surveys and analysis have been conducted within the work of the Laboratory of Development and Research of Information and Communication Assistive Technology, which was partially equipped with the funds of this project idea.

Along with stated research work conducted at the Faculty of Transport and Traffic Sciences, the research work in the second cycle of the research was conducted at the Faculty of Operation and Economics of Transport and Communications, Department of Communications, AIDC Laboratory.

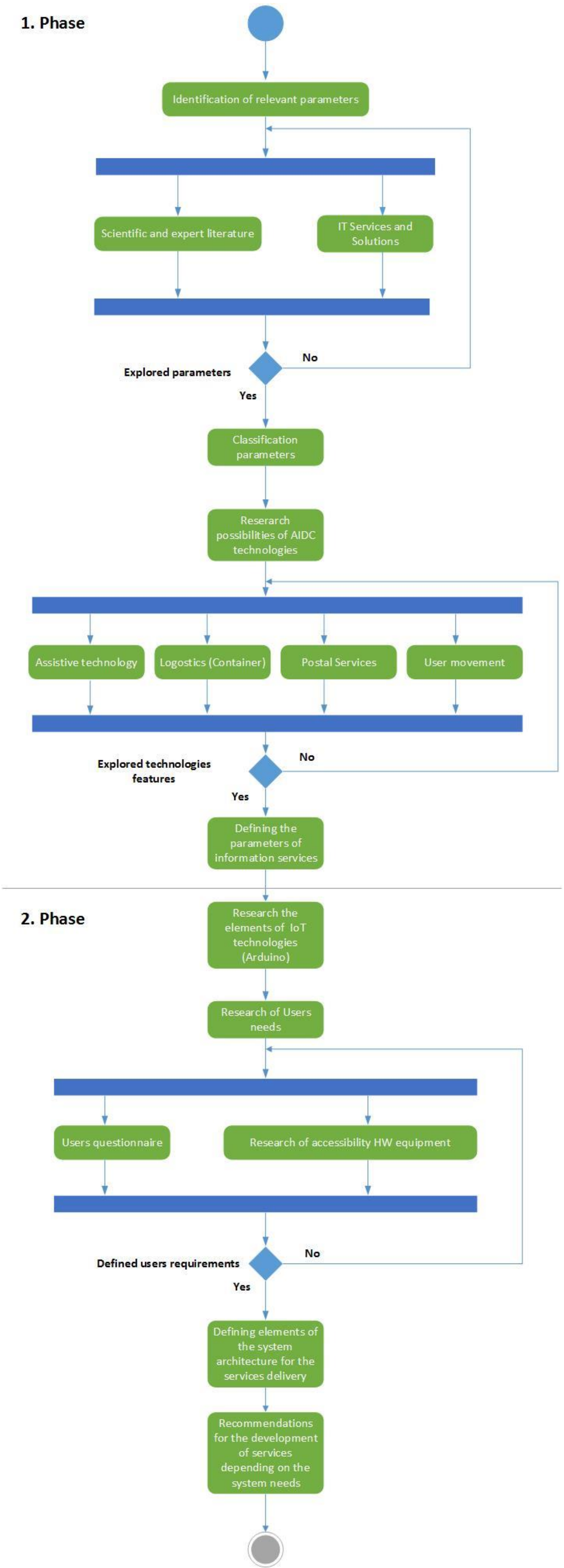

Figure 1 – Conducted research activities

4. BUDGET SPENDING

Granted resources in the amount of 5,4% of required value belong into the group of funds intended for developmental research, what is confirmed by the realization of the planned objectives through scientific research papers. The granted funds of first cycle are in amount of 15.000,00 kn, followed by second cycle where the same amount was granted.

Table 1 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget	Achieved	Cost (kn)
1.	Exploring the possibilities of AIDC and IoT technology	83.000,00	NFC and Bluetooth technology and Arduino equipment	4.836,01
2.	Publication papers	45.000,00	Conference: TST 2015, DON'T 2015, ICTIC 2015 and EAI 2016	20.835,95
3.	Presentation of project idea within H2020	60.000,00	FH Campus Wien, Faculty of Transportation Sciences	6.914,98
4.	Maintenance of research equipment	1.000,00	-	222,70
	TOTAL:	189.000,00		**32.809,64**

The given funds have been spent as described by Table 1. In order to provide an insight into diversity of expertise, important collaborations were made through project application within the frame of H2020, as well as the collaboration between laboratories for the research of AIDC technologies; the Faculty of Operation and Economics of Transport and Communications, Department of Communications and the Laboratory of Development and Research of Information and Communication Assistive Technologies. The collaboration with the FH Campus Wien (field of safety and assistive technologies) was also established for the purposes of this research.

5. RESULTS

The results of two cycle segmented research are manifested through published scientific research papers in international conferences and journals. Except for listed researchers, interested undergraduate and graduate students were included into the research by conducting research activities related to the availability and accessibility of information and communication solutions and services. Aside from the scientific papers that were made as the product of conducted research activities, the given results were individually utilized in forming students' graduate thesis.

5.1 Involvement of students

The students from undergraduate, graduate and PhD program were engaged in the activities of the research with the outcoming results in two cycles of funding:

Application of the idea for Rector's Award in the first cycle:

- Sente, R.E., Radošević, M., Zorić, P.: Proposed development of new web based services for targeted group of users – *Web 4 Health*, University of Zagreb, 2015. (Mentor: Assoc. prof. Dragan Peraković, candidates for the Award).

Publication of paper at international conferences:

- Peraković, D., Periša, M., Sedlar, V.: Research of IoT Concept in monitoring the activities of the Elderly Person, Zborník príspevkov a prednášok DoNT 2015, pp. 133-145 (ISBN: 978-80-554-1148-4).

- Peraković, D., Periša, M., Cvitić, I., Radošević, M., Sente, R.E., Zorić, P.: Web 2.0 services for informing elderly people: Web for Health, RCITD - Proceedings in Research Conference in Technical Disciplines, 2015. pp. 65-70 (ISBN: 978-80-554-1125-5).
- Peraković, D; Periša, M; Čavar, J.: Cloud based architecture of e-commerce systems for offering group buying services, Proceedings in Conference of Informatics and Management Sciences, The 4th International Virtual Conference, ICTIC 2015, Žilina, Slovakia, 2015. (ISBN: 978-80-554-1002-9).

The second cycle of project idea funding includes the provision of research equipment based on IoT platform (Arduino) for the purpose of defining usable IoT functions as well as the needs of users. The second cycle of funding has produced following results:

- Bijelica, N., Brletić, L., Bucak, B., Ignjatić, A., Mišić, V., Papac, A., Sente, R.E., Vuletić, M., Zorić, P.: Proposal of Information and Communication System for informing Users in Traffic Environment – SAforA, University of Zagreb, 2016. (Mentor: Assist. prof. Marko Periša, winners of the Rector's Award).

Publication of paper at international conference of European Alliance for Innovation (EAI). Members of Department for information and communication traffic, Assoc. prof. Dragan Peraković and Assist. prof. Marko Periša, are acknowledged as active members of EAI (European Alliance for Innovation), basis on the open lecturing on the topic of: Information and Communication System for informing Users in Traffic Environment – SaforA (Authors: Peraković, D., Periša, M., Bijelica, N., Brletić, L., Bucak, B., Ignjatić, A., Mišić, V., Papac, A., Sente, R.E., Vuletić, M., Zorić, P.).

Publication of paper at international conference:

- Periša, M., Sente, R.E., Brletić, L.: Proposal of Information Communication Technology Architecture for People with Disability, ScieConf 2016, University of Žilina, Žilina, Slovakia, 2016.

5.2 Cooperation with industry and academia

The second cycle of research work was also conducted in AIDC Laboratory at the Faculty of Operation and Economics of Transport and Communications, Department of Communications, during which following papers were published:

- Kolarovszki, P., Tengler, J., Kolarovszká, Z., Peraković, D.: Development of smart tool for efective logistics processes measurement, Carpathian Logistic Congress, Technical University of Kosice, 28-30.11.2016, Zakopane, Poland.
- Kolarovszki, P., Kolarovszká, Z., Peraković, D., Periša, M.: Laboratory Testing of Active and Passive UHF RFID Tags, Transport and Telecommunication Journal (1407-6179) 17 (2016), 2; p. 144-154.
- Kolarovszki, P., Tengler, J., Peraković, D., Periša, M.: Impact of sorting machine on life cycle of passive UHF RFID tags placed on letter mail, Komunikácie (1335-4205) 2 (2016); p. 143-147.
- Kolarovszki, P., Tengler, J., Peraković, D., Madlenak, R.: Identification and monitoring of the container at the postal operator, ZIRP 2016, Faculty of Transport and Traffic Sciences, 2016. 65-75 (ISBN: 978-953-243-081-3).

5.3 Project applications

Research fields of project idea (identification, recognition, automatic processing and management of collected information) are elaborated through work packages in following project applications within the H2020.

Table 2 – Overview of submitted project proposals.

Nr.	Funding scheme	Project name	Budget	Status
1.	H2020	Supporting Mobility of Disabled People in Central Europe Metropolitan Regions, DISMOB	200.000,00 EUR	Postponed for 2016-2017
2.	H2020	Integrated Planning and Processes for Secure Border Crossings-INFuSE	1.170.750,00 EUR	Application didn't achieve sufficient points
3.	H2020	Dual Education applicable for students throughout the Danube region	200.000,00 EUR	Application in processing

DISMOB project

Project description:

The project is aimed at supporting, improving and harmonizing mobility of disabled persons, i.e. people with affected hearing, sight, mobility, as well as the old people and parents with baby carriages in the cities of Central Europe.

Project main objective:

The main objective of the project is to allow safe, effective and independent door-2-door mobility of disabled persons in the cities of Central Europe.

Expected results:

- Methods and procedures for obtaining and maintain specific information beneficial for disabled people.
- Extension of transport databases about specific information beneficial for disabled people.
- Design and realization of web and mobile applications to find transport connection using information beneficial for disabled people.
- Design and implementation of human-machine interface (HMI) for mobile application suitable for disabled people (audio, video and touch signal analysis, i.e. gestures, voice etc.)
- Pilot operation of an open mobile barrier-free transport system (design and implementation of server solutions, operation of websites, mobile barrier-free application for finding transport connection, processing options of connecting another metropolis to the proposed system).
- Unified/universal barrier-free solution for ticket purchasing.
- Pilot barrier-free mobile transport application for universal ticket purchasing
- Optimization planning system.
- Mapping routes for walkers with respect to persons with mobility impairment.
- Extension of vehicle and station information systems by barrier-free interface and information beneficial for disabled people.

INFuSE project

Project description:

INFuSE aims at contributing to the research and analysis of the possible application of new methodologies and EU shared tools, in order to better improve prevent illegal crossing, support controls and envision the modalities for more efficient work of border control authorities, in order to ensure easier legitimate border crossing and at the same time better detect and prevent illicit activities. The main objectives of the INFuSE are:

- To research and analyse the existing borders controls systems and the security procedures carried out by different actors (border control authorities, competent ministries and other governmental bodies) in both EU and EU neighboring countries in order to support them and at the same time include human-rights aspects of the border control and security procedures.
- To study and test the development of tools for better planning of cost- and performance-efficient allocation of assets and human resources to border control tasks.
- To develop and test the best models for optimal combination of operators with new technologies.
- To develop and test the improved and optimal designs for information workflows for particular border control scenarios to avoid disproportionate burden on EU and EU neighboring countries border control authorities and economic operators/citizens.

Having in mind the different issues each bordering country (Schengen, non-Schengen, EU, non-EU) is facing, especially with the increase in number of migrants from the so called "third countries" attempting to enter the EU Schengen zone in the past years, INFuSE is addressing both the operational issues, technical issues and legal standards and their gaps and deficiencies in the border management in selected countries (as a pilot to be applied to broader European area).

Dual Danaube project

Project description:

The proposed project will offer both the theoretical and practical dimensions of the system as a need for the development of a dual education network. The student will be the beneficiary of a blended learning system, having both the theoretical and practical component altogether in a digitized content, which will bring him more close to the real situations within a company. The student will have the chance to evaluate and to be evaluated in the learning process, by practical situations created in order to stress the knowledge and skills acquired in school. Additionally, the student will be able to determine what the next step in his development should be.

Project main objective:

- To develop curricula adapted to the real needs on the market, for increasing flexibility of the students in the working process.
- To develop digital content according to the curricula settled, to increase the practical dimension in the teaching process.
- To establish a set of indicators for those who participate in the project as compared to the graduates in the past, to compare the applicability and efficiency of the dual education system.
- To compare the above-mentioned indicators to those in the other Danube countries with experience in the field.
- To evaluate the impact in the economy in different sectors of a dual education system in the Danube countries
- To involve companies in the learning process of the future employees

In order to reach the project's objectives, the implementation will be focused at the following levels:

- the development of a methodological framework to support the dual education system;
- the development and implementation of a curricula based on the mentioned methodology;
- the development and implementation of the ICT learning solution – digitized applications in accordance with the curricula;

- the identification of those companies interested in finding the employees suitable to their activity.

The project should:

- be guided by lessons learned and best practices from the most experienced Danube countries in the field;
- raise the interest of all Danube countries in as many fields of activities as possible for a quicker integration of the graduates in the working process.

5.4 Obtained additional projects and funds

The project idea was enrolled within the Support program of the University of Zagreb (2015).

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	Support program of the University of Zagreb	System of automatic identification and informing mobile entities in traffic system	Objectives are equal to the project idea within Prom-pro	20.006,10 Kn

5.5 Published papers

Stated papers published in journals include conducted research on the possibilities of AIDC technology (RFID) in laboratory environment on the example of identification of articles in post office or logistics (envelope, package or container). A recently reviewed paper: Beacon Technology for Real Time informing the Traffic Network Users about the Environment, provides an analysis of Beacon technology functions for the purpose of directing mobile user through traffic network (a Matlab simulation).

Papers admitted at the international conferences are classified in the field of application of AIDC technology with a purpose of identifying mobile entities and providing information about current environment to the end user. Also, the possibilities of IoT concept and Web 2.0 technology have been analyzed with an aim of providing relevant information to the user (accessibility to all groups of users).

Journals:

- Kolarovszki, P., Kolarovszká, Z., Peraković, D., Periša, M.: Laboratory Testing of Active and Passive UHF RFID Tags, Transport and Telecommunication Journal (1407-6179) 17 (2016), 2; p. 144-154.
- Kolarovszki, P., Tengler, J., Peraković, D., Periša, M.: Impact of sorting machine on life cycle of passive UHF RFID tags placed on letter mail, Komunikácie (1335-4205) 2 (2016); p. 143-147.
- Kolarovszki, P., Tengler, J., Peraković, D., Madlenak, R.: Identification and monitoring of the container at the postal operator, ZIRP 2016, Faculty of Transport and Traffic Sciences, 2016. 65-75 (ISBN: 978-953-243-081-3).
- Peraković, D., Periša, M., Bukljaš Skočibušić, M.: Possibilities of implementing Ambient Assisted Living concept in traffic environment, Archives of Transport System Telematics (1899-8208) 8 (2015), 1; 30-34.
- Periša, M., Peraković, D., Cvitić, I., Husnjak, S.: Beacon Technology for Real Time informing the Traffic Network Users about the Environment, Mobile Information Systems, special issue: Mobile Information Systems for Ambient Assisted Living (AAL), in the review progess, (Transport).

International scientific conferences:

- Peraković, D., Periša, M., Bijelica, N., Brletić, L., Bucak, B., Ignjatić, A., Mišić, V., Papac, A., Sente, R.E., Vuletić, M., Zorić, P.: Information and Communication System for informing Users in Traffic Environment – SaforA, EAI Endorsed Transactions Bratislava: EAI Euroepan Alliance for Innovation, 2016.
- Kolarovszki, P., Tengler, J., Kolarovszká, Z., Peraković, D.: Development of smart tool for efective logistics processes measurement, Carpathian Logistic Congress, Technical University of Kosice, 28-30.11.2016, Zakopane, Poland.
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- Peraković, D., Periša, M., Sedlar, V.: Research of IoT Concept in monitoring the activities of the Elderly Person, Zborník príspevkov a prednášok DoNT 2015, p. 133-145 (ISBN: 978-80-554-1148-4).
- Kavran, Z., Mostarac, K., Šarac, D.: Postal Network Organization Criteria of the Universal Service Provider, Postpoint 2015, Zbornik prispevkov, Perspectives and Innovation for the Postal, Express and Courier Services, Žilinka: Žilinska Univerzita v Žiline, 2015. p. 104-108 (ISBN: 978-80-554-1104-0)
- Peraković, D., Periša, M., Cvitić, I., Radošević, M., Sente, R.E., Zorić, P.: Web 2.0 services for informing elderly people: Web for Health, RCITD - Proceedings in Research Conference in Technical Disciplines, 2015. p. 65-70 (ISBN: 978-80-554-1125-5).
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6. CONCLUSION AND FUTURE WORK

Due to the evolving information and communication technologies, and the concept of IoT, everyday presence of the application of AIDC technology is in an expected progress. Current indicators predict 25 billion of devices based on IoT concept by 2020 (current number: 4.9 billion). Mentioned technology and the elements of IoT infrastructure are making a firm ground for design and development of new services in defined IoT system. The application of IoT is currently targeted research field, particularly with an aim of protecting and improving the quality of life for users within the traffic system (AAL concept, systems of real-time informing, monitoring of everyday activities and users' requirements, identification and tracking of packages).

Future research work within this field requires detailed analysis of information technologies (Bluetooth v5.0) and the appropriate user equipment. Furthermore, an additional research work is requisite in the field of logistics where information and communication services represent a foundation for formation of new services.

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ROBUST NAVIGATION SYSTEMS FOR UAVs

ABSTRACT

Small and micro UAVs currently mostly use GPS/INS integrated navigation systems to provide position information. These are most commonly supplemented with barometric altimeters, ultrasound or laser rangefinders, and optical flow detectors. Overall, these systems work well under nominal conditions, however, there are multiple single points of failure present. Loss of GPS signal, for example, whether due to radio interference, flying through urban canyons or equipment failure, will render most systems unusable. This project aims to determine weak points in currently used navigation systems for small and micro UAVs, find appropriate solutions and test them in flight. So far, most of the outputs of this project were related to increasing the research capacities of the involved researchers, development of an in-flight test bed, and testing already existing algorithms.

KEY WORDS:

UAV; in-flight testing; system redundancy; visual navigation

1. INTRODUCTION

Decrease in the production costs of unmanned aerial vehicles (UAVs), sensor and actuator equipment, and recent technological advances make them easily available for industrial and private usage. Drones are an emerging technology of unmanned aerial vehicles (UAVs) which combine two major branches of the technology – remotely piloted aviation systems (RPASs) and fully autonomous vehicles ([1], [2]). Academics and industry are investing essential resources into constructing UAVs and estimating their societal and economic impacts ([3], [4]). However, numerous aspects of this quickly maturing technology remain uncharted and the future of the urban UAV-traffic is not clear at all [5].

The current market share of civil government and commercial use is relatively small when compared to military, 56M€ or 0.94% of market share in 2014. However, the forecasts agree about the rapid growth of the civilian use of UAVs [6] and their economic impact and according to one report world civil UAV market is predicted to reach 9.85% ($1088 million) of the global UAV market by 2023 [7]. The UAVs are already intensively used in agriculture, aerial photography, surveying, law enforcement, advertising, and, more recently, in construction safety, package [8] and food delivery [9]. Industry leaders like Amazon, DHL and Google are already testing and using UAVs for various civil purposes, e.g. package deliveries [8]. The former Mayor of London Boris Johnson called for UAV package delivery solutions to help solve the city's congestion problem [10].

It is recognized by the research groups worldwide that all these applications rely on safe navigation in a very difficult environment, therefore several visual algorithms for simultaneous localization and mapping were developed ([11], [12], [13]).

2. RESEARCH GOAL AND MOTIVATION

Navigation of small and micro UAVs has many things in common with navigation of conventional aircraft, however, there are many challenges which are specific to the UAV operations. Conventional aircraft, here defined as those operating in general and commercial aviation environment, rely on a layered navigation infrastructure consisting of ground-based systems, satellite-based systems and on-board systems. These systems overlap in function and availability, thus providing redundancy over the whole range of operations. In addition to these navigation systems, all manned aircraft are also able to operate based on the visual navigation which is the main mode of navigation for some aircraft or a backup for others. UAVs have comparatively fewer systems available, whereas those that are available are not suitable to support all types of activities which are expected of UAVs (Table 1).

Table 1 – Comparison of Navigation Systems used in Conventional Aircraft vs. Micro UAVs

Navigation system	Conventional aircraft	Small and micro UAVs
Ground-based radio-navigation systems (NDB, VOR, DME, ILS)	Widely used. NDBs are being phased out.	Not used. Receivers have not been miniaturized, accuracy too low for the intended purposes.
Satellite-based systems (GPS, GLONASS, Galileo, ABAS)	Widely used. Considered the back-bone of the future air traffic management.	Widely used. In most cases this is the sole provider of navigation information.
On-board systems (INS)	Used in commercial aircraft, not as much in general aviation. Highly accurate systems are used to provide autonomous long-range navigation.	Widely used. Low-cost, low-accuracy systems are integrated with GPS to provide high-frequency attitude and position information. INS is not used for autonomous navigation.
Visual navigation	Always available, sometimes used. Commercial air transport relies on visual navigation mostly for take-off and landing or as a backup. General aviation pilots use mostly visual navigation for all phases of flight. Visual navigation is primary source of position information for all low-altitude operations (SAR, law-enforcement, industrial operations such as crop dusting, logging, power-line inspection etc.).	Currently used for experimental purposes. Commercial solutions do not exist yet.

As can be seen in Table 1, small and micro UAVs lack the redundancy of navigation systems which is available to conventional aircraft. Radio-navigation receivers could be miniaturized and deployed on UAVs, however, their accuracy is not good enough for the type of operations which are expected of UAVs. Among other environments, micro UAVs are expected to operate within urban areas, flying safely, accurately, and precisely in close proximity to buildings and people. Flying in GPS-denied environment, such as indoors, will further push the limits of UAV navigation. Interaction with ground objects is also one of the activities which will drive future application of UAVs.

Current situation can be summarized as follows:

- Small and micro UAVs use single source of navigation information (integrated GPS/INS).
- Flying in urban environments requires redundancy [14].
- Flying in GPS-denied environment requires other sources of navigation information.
- Interaction with ground-based objects requires high accuracy and precision.

- Research is already underway with purpose of enabling autonomous visual navigation for UAVs.

The aim of this project, therefore, is to determine alternative means of navigation which can support highly accurate small and micro UAV operations in a GPS-denied environment.

Development of novel methods will be in line with the *Measure 4. Supporting Research and Innovation* of the Faculty's *Strategic Research Programme 2015 – 2020.*

Project team members have previously researched air navigation systems, but only in the domain of conventional manned aircraft navigation ([15], [16]). This is their first foray into the research area of UAV navigation. To increase the probability of a successful achievement of the project aims, team members will take part in networking activities with the goal of establishing connections with other organizations and teams working in the field of UAV navigation. Also, the general objective of this project is to apply for funding from outside sources, such as Horizon 2020 or Croatian Science Foundation. Therefore, this project is in line with the Faculty's *Strategic Research Programme 2015 – 2020, Measure 7. Development of Mobility and International Cooperation*.

3. RESEARCH ACTIVITIES

Activities undertaken for this project can be grouped under following four themes, or work packages: increasing research capacity of team members, networking with other research teams, development of research test-bed, and development and testing of the navigation methods.

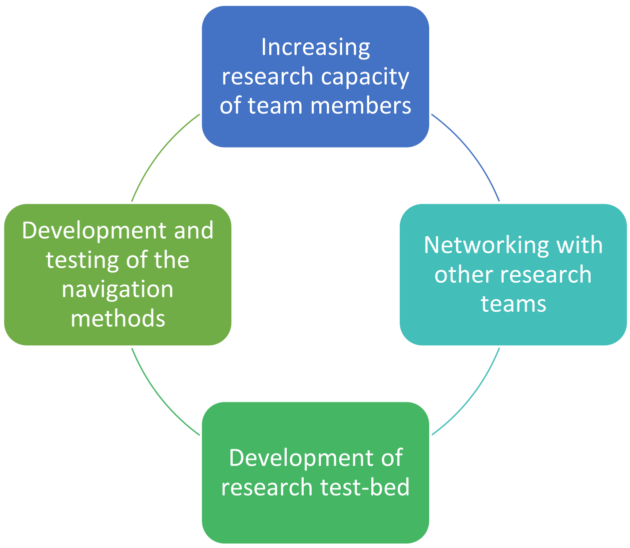

Figure 1 – Work-packages

3.1 Increasing research capacity of team members

Team members have experience in researching methods and techniques for navigation of conventional manned aircraft. It was necessary to improve their understanding of possible methods for autonomous air navigation of UAVs. That is why they took the certified on-line course called '*Autonomous Navigation for Flying Robots*' by *Technische Universität München*. The course contents included, among others, linear algebra refresher, 2D and 3D geometry, motor controllers, probabilistic state estimation, Bayes and Kalman filters, and visual odometry.

Besides networking with other research teams, attending the relevant conferences was also one of the ways research capacity of team members could be increased. Team members can listen to presentations of the new research papers and ask questions about topics of interest. This is why, in this project, two visits to international conferences were planned (*InAir* conference and *Transportation Research Arena* conference).

One of the research capacities, often overlooked, is the ability to apply for grants or funding from external organizations. For team members to know to which calls they can apply, how to write the proposal and to have necessary knowledge to manage the project, it was planned that the team members will attend several courses about EU funds and project management.

Another way to increase research capacity is to build the knowledge base relevant to the research aim. To achieve this, team members have gathered more than 50 papers from the most cited authors in the field. A review of these papers was built into a single document.

3.2 Networking with other research teams

Several activities were planned in order to enable networking with other research teams studying UAV navigation. One activity was to visit the Zurich University of Applied Sciences whose team studies usage of UAVs for search and rescue operations and environmental monitoring. This activity was realised in April of 2016. Before that, in June of 2015, a visit was made to the French Air Force Academy in Salon.

Other activities involved attending conferences where direct contact with UAV researchers and users was established. Team members attended the DroneFest conference in Zagreb in March of 2016. Also, they attended the InAir conference for two years in a row, in 2015 and 2016.

3.3 Development of a research test-bed

A flying research test-bed is required for testing navigation methods in real conditions (Figure 2). For this purpose, a low-cost multirotor in a hexacopter configuration was developed. It was built from commercial off-the-shelf components with following requirements:

- ability to lift 3 kilograms of payload,
- flight endurance of at least 20 minutes,
- motor redundancy (flying with one motor turned off),
- multiple anchor points for sensors.

Figure 2 – Research test-bed

Students were included in the design and building process of the UAV as a part of coursework for the *UAV Operations* course.

Since visual navigation algorithms require relatively more processing power than conventional navigation algorithms, in the second year of the project a more powerful small form factor computer was purchased (Odroid XU4). This computer enables real-time on-board processing of video data. Odroid XU4 has a calibrated camera connected to it which provides an oblique forward view of the terrain. Based on the results of the visual navigation algorithm, Odroid XU4 sends waypoint instructions to PixHawk autopilot which then guides the UAV towards the destination.

3.4 Development and testing of the navigation methods

In this part of the project currently used navigation algorithms were analysed for possible improvement and integration with visual navigation techniques. Most of the efforts were concentrated on monocular simultaneous localization and mapping (SLAM) algorithms. These algorithms enable mapping of the surrounding terrain by comparing coordinates of the features in the images acquired from different locations. This type of comparison relies on accurate automatic feature detection and matching. Therefore, feature matching algorithms were studied in detail.

Once a map is built, it becomes possible for the UAV to determine its position in relation to the ground features. However, it is not possible to determine the global coordinates of the UAV in this way. Because of this, current solutions to integration of position information gained through visual means with GPS/INS data was studied.

4. BUDGET SPENDING

The budget for the project was planned to support main work packages (Table 2). Following list connects work packages with budget lines.

Increasing research capacity of team members:

- Arduino programming course
- RaspberryPi course
- Project management courses and EU structure funds workshop
- Conferences

Networking with other research teams:

- Conferences
- Visits to other organizations

Development of a research test-bed:

- Equipment procurement (for assembly of the research test-bed)

Development and testing of the navigation methods:

- Equipment procurement (sensors and integration)

Not all activities were completed in the same manner as planned. For some activities, a more affordable alternatives became available after the project started. These include the project management course and RaspberryPi course.

Assembly of the research test-bed, an UAV which is to be used in testing navigation algorithms, experienced a major setback when the UAV crashed on one of the first flight.

Therefore, additional funds were reallocated towards procurement of parts necessary for repairing the UAV.

Some savings were accomplished by financing some of the activities through other means of financing. Most notably, visit to the Zurich University of Applied Sciences in Switzerland was accomplished through University of Zagreb Mobility Fund.

Table 2 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	Project management courses	5751,00 kn	Completed as part of Applicants Workshop organized by the Ministry of Science, Education and Sport	0,00 kn
2.	Attend a workshop on EU Structure Funds	3125,00 kn	Not yet attended.	0,00 kn
3.	Visits to other organizations (Exploring the opportunities for networking)	3000,00 kn	A visit to the French Air Force Academy was made (co-financed from other sources). Additionally, a visit was made to Zurich University of Applied Sciences, Switzerland (financed from other sources)	2535,00 kn
4.	Attending conferences (InAir conference and Transportation Research Arena conference)	13996,00 kn	InAir conference attended and a paper was presented at that conference. Transportation Research Arena was not attended because the paper was not ready in time.	6500,00 kn
5.	Arduino programming course	1645,00 kn	After further consideration, a more appropriate course was found (*Autonomous navigation for flying robots*)	375,00 kn
6.	RaspberryPi course	518,00 kn	A free on-line course was found	0,00 kn
7.	Equipment procurement (Pixhawk autopilot, DJI E600 tuned propulsion set, Frsky Taranis, S680 Carbon Fibre Folding Hexacopter Frame, Odroid XU4, accessories)	5405,00 kn	Equipment procured. Additional equipment was needed due to crash of the flying test-bed (another S680 frame, E600 tuned propulsion set, propellers). Also, additional sensors were acquired (oCam, GPS sensor, Firefly HD camera, gimbal)	14583,00 kn

5. RESULTS

Considering the relatively small-scale of the project, significant progress was made in some areas. Most of the progress was made in development of the research test-bed. It was assembled, tested, and flown. Additional, more powerful, computer was attached to it. This enables real-time video processing for visual navigation.

Significant involvement of students was achieved as well. Students were instrumental in assembly of the research test-bed and have shown great motivation for further work in the field of UAVs.

Several project proposals were written regarding UAVs and are currently being in different phases of evaluation. Most importantly, funding for these projects is from external sources (EU and NATO).

5.1 Involvement of students

From the beginning of the project Master students were heavily involved. First, through UAV related courses, and second, by working on the project itself. Students helped develop and assemble the research test-bed and apparatus for propulsion efficiency testing. Also, several students have organized a development team of their own as a direct consequence of this project and are currently developing a fixed-wing long-range UAV. Besides using some of the equipment purchased for this project, their project has received additional funding from the Faculty and a donation from Croatian Civil Aviation Agency.

Two students are currently in the process of writing their master thesis on the topic of UAVs and visual navigation:

- Development and Operation of UAV Propulsion System Efficiency Testbed
- Creating Terrain Elevation Model Based on Aerial Video Recording

5.2 Cooperation with industry and academia

Throughout the duration of this project, an emphasis was made on building relationships with other organizations. Following is the list of organizations with which some form of cooperation was established:

- Universiteit Hasselt – CityFly project coordinator. Cooperation was established during the writing of the project proposal. Also, 15 other partners are involved in this project.
- Croatian Mine Action Center for testing, development and training Ltd. – Bee4Exp project leader. This organisation is a part of Croatian Mine Action Centre. Cooperation was established during the writing of the project proposal. Through this project, contact was made with 3 other universities as well.
- Hellenic Institute of Transport – Cooperation was established on the CREATE project.
- French Air Force Academy – Cooperation was established on the topic of student exchange. Several French students visited the Faculty to write their master theses.
- Faculty of Mechanical Engineering and Naval Architecture – Cooperation was made for the writing of the project proposal for CREATE project. Also, dr. Radišić was a member of the PhD thesis evaluation committee for a PhD student working on UAVs.

5.3 Project applications

During the course of this project following project proposals, in cooperation with other Faculty employees, were made (Table 3):

- Bee4Exp – Bees for Detection of Explosives.

  The goal of this project is to develop a system for detection of explosives by monitoring flight patterns of specially trained bees. The Faculty is a partner in this project and its role is to conduct video capture from UAVs. The budget is to be spent mostly on procurement of UAVs and sensors.

- CityFly - Smart CITY's Traffic Control Infrastructure for Societies of FLYing Vehicles.

  The goal of this project is to develop the technology needed to integrate UAVs into urban areas. The Faculty is a partner in this project. Its role is to identify positioning infrastructure necessary for UAV self-awareness and develop semantic description of static and dynamic spatial elements and their relationships. The budget is to be spent mostly on research.

- KAAT – Knowledge Alliance in Air Transport

  The goal of this project is to develop smart and flexible educational pathways in aviation sector which satisfy both European Qualification Framework and civil aviation regulations. The Faculty is a partner in this project. Its role is to develop a list of aviation-related qualifications with the description of leaning outcomes and to cooperate on the improvement of the study programme.

- CREATE - Croatian Centre of Excellence in Advanced Transport and Mobility Research

  The goal of this project is to evaluate the need for establishing a Centre of Excellence in advanced transport and mobility research. The Faculty is a partner in this project and its role is to research the needs of the transport sector in Croatia. Most of the budget is to be spent on evaluating these needs.

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Project name	Budget	Status
1.	NATO – Science for Peace and Security Programme	Bee4Exp – Bees for Detection of Explosives	€374,262	In preparation
2.	Horizon 2020	CityFly – Smart CITY's Traffic Control Infrastructure for Societies of FLYing Vehicles	€3,738,581	Under evaluation
3.	Erasmus+ - Knowledge Alliances	KAAT – Knowledge Alliance in Air Transport	€997,555	Under evaluation
4.	Horizon 2020	CREATE – Croatian Centre of Excellence in Advanced Transport and Mobility Research	€396,718	Under evaluation
5.	European Social Fund	INATKO – Innovative Tools for Air Traffic Control	€46,841	Rejected

5.4 Obtained additional projects and funds

Two smaller grants were obtained so far (Table 4). One, a Short-term University of Zagreb Grant, was obtained in cooperation with other research groups at the Faculty. Another, by the University of Zagreb Mobility Fund, was used to visit the Zurich University of Applied Sciences. This visit was directly related to the work-package *Networking with other research teams*.

Table 4 – Overview of submitted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	Short-term University Grants	Improvement of the Air Traffic Control Simulation Centre	The grant was used to upgrade the air traffic control simulator which is used for research of air traffic capacity and training of student air traffic controllers. This project has ended.	€5,920
2.	University Mobility Fund	The Effect of Trajectory-based Operations on Air Traffic Complexity	The grant was used to visit the Zurich University of Applied Sciences whose team studies usage of UAVs for search and rescue operations and environmental monitoring. This grant was used in April 2016.	€710

5.5 Published papers

Currently, there was only one conference paper directly related to UAVs which was presented at the DroneFest conference in Zagreb:

- *UAVs: The Challenges of Education for the Technology of the Future.* The paper presented the challenges of project-based education in the context of UAV assembly and operation.

  So far, there are no journal papers which were directly related to UAVs.

6. CONCLUSION AND FUTURE WORK

The scope of this project was reduced due to reduction in funds for the first year of the project in comparison with planned expenses. Therefore, not all of the objectives could be achieved. Nevertheless, the project was a success in terms of laying foundation for future activities in field of UAV navigation. Mainly, research test-bed was built, tested and flown. This test-bed will be used to test navigation methods in the future. Also, three project proposals are currently under evaluation and one project proposal is being written. Future efforts will be concentrated on applying to new calls for proposals.

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IDENTIFICATION OF PARCEL LOGISTICS FLOWS IN THE CITY OF ZAGREB CITY LOGISTICS

ABSTRACT

Logistics flows in Zagreb varied as a consequence of the concentration of a large number of businesses in relatively small area, resulting in differentiation of logistics flows. The goal of the research is to analyze the distribution and reverse logistics flows in city of Zagreb by:

- *technical and technological and*
- *organizational aspect.*

The project analyzed trends in distribution and parcel returns and their share it total logistics goods flow within the area. Research about impact, needs and measures for development of the city logistics services in terms of most important participants in the city logistics in Zagreb (representatives of the city government, citizens and logistics operators) are made.

Proposed solution is unburdening of logistics flows and environmental acceptability in the city center, as a zone of special interest to the urban population and city government.

KEY WORDS:

City logistics; reverse logistics; goods flow; parcel shipments

1. INTRODUCTION

According to the study conducted by the UN, in 2010. almost 50% of the world's population lives in urban areas[1], while in Europe that share is 70%[2], assuming an increase in the trend at global level to 60% by 2030. Level of motorization in Zagreb is relatively high and amounts about 320 cars per 1,000 inhabitants. Of these, most of the vehicles are in private ownership.

As a result of such high concentration of vehicles and other factors, traffic flow in city area is very small, with an average vehicle speed of about 20 km/h. The emergence of heavy duty vehicles and delivery vehicles in periods of heavy traffic adding additional burden to traffic network and slows it down even more.

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[1] Taniguchi, E.: Concepts of city logistics for sustainable and liveable cities, Procedia - Social and Behavioral Sciences 151, 310 - 317, 2014.

[2] Bozzo, R., Conca, A., Marangon, F.: Decision support system for city logistics: literature review, and guidelines for an ex-ante model, Transportation Research Procedia 3, 518 - 527, 2014.

Increasing trend of ordering, especially orders by Internet, which according to research from 2014. in Europe use 45% of buyers[3], and the need for delivery to the final address, implies a transformation of goods flows from the views of:

- organizational changes in distributional chain,
- size of shipments,
- type of shipment,
- number of deliveries on route,
- delivery places,
- number of stops on route,
- errors in deliveries,
- the frequency of deliveries,
- time windows of deliveries,
- category and number of delivery vehicles.[4]

Optimization of city logistics based on analysis and modeling of specially created solutions, and IT support enables:

- reducing traffic congestion,
- traffic safety and
- energy saving.

Goal of the research is:

- analysis of distribution and revers flows of parcels in the city of Zagreb from:
    - technical and technological and
    - organizational aspect
- defining key shortcomings of current situation;
- creating parcels flow map in the city of Zagreb;

Research are conducted at:

- relevant logistics operators;
- representatives of city administration,
- citizens.

2. RESEARCH GOAL AND MOTIVATION

City logistics divide every city into zones for different functions which include all activities and events of citizens which have urban character: living, industry, trade, recreation, and other services. Each of that urban zones have specific logistics requirements. The city center zones are characterized by high concentration of mainly small objects that generate a large number of deliveries with small quantity of goods. On the other hand, city centers particularly in old cities, are characterized by inherited infrastructures with vast narrow streets. Distribution flows are mixing with other traffic flows which further complicates the situation. Structure and intensity of logistics flows, and the problem of their realization, are different from zone to zone. In central city zones with a large number of commercial objects supply chain flows appears but also reverse flows for unsold goods, packaging materials and waste materials.[5]

[3] Morganti, E, Seidel, S., Blanquart, C., Dablanc, L., Lenz, B.: The impact of e-commerce on final deliveries: alternative parcel delivery services in France and Germany, Transportation Research Procedia 4, 178 – 190, 2014

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The problem of transporting goods in cities perhaps is most easily can be seen through an analysis of the need to supply the city inhabitants. The annual quantity of shipments generated in 2014. in the Republic of Croatia (according to the Central Bureau of Statistics, statistical report of transport and communications from 2014) was slightly more than 13 million shipments. Mentioned data and data for previous years are provided in table 1.

Table 1 – Displayed statistical data on the amount of data sent parcels

Parcels (figures are expressed in thousands of pieces)					
Year	**Total**	**Domestic transport, received**	**International transport**		
			Total	**Received**	**Shipped**
2010.	7689	7426	263	43	220
2011.	8059	7778	281	49	232
2012.	8929	8651	278	50	228
2013.	10398	9778	620	112	508
2014.	13619	12360	1259	222	1037

Source: created authors according to http://www.dzs.hr/Hrv_Eng/publication/2015/SI-1541.pdf

Previous studies related to city logistics services, especially for distribution system and reverse logistics flows of parcels (Internet online shopping) in area of Zagreb and Croatia are insufficiently explored. There are few studies with city logistics topic and the most important are:

- CIVITAS – a project which aimed to define changes towards sustainable urban mobility in which city of Zagreb participates in publication CIVITAS PLUS, where the aim is to highlight key problems in the city distribution flows and creating an integrated transport policy. Measures for limiting distribution flows are defined and they are not successfully implemented.[6]
- TRAILBLAZER – project for preparation of the development and implementation of plans for urban areas deliveries in Zagreb city center and reducing negative impact of the distribution flows on the environment, primarily in terms of exhaust emissions and fuel consumption.

Distribution flows characteristics in the city of Zagreb is concentration of a large number of business entities in relatively small area resulting in:

- traffic congestion;
- decreased level of security;
- adversely affected distribution traffic on the environment.

Lack of research on city logistics in Zagreb, as well as distribution system and reverse logistics flows of parcels, primarily shipments within online shopping system, which occupy an increasingly important place in the city logistics represents the need to involve the scientific support for finding solutions that will allow mitigate the negative effects of city logistics of Zagreb. Research is primarily focused on identification of distribution system and reverse logistics flows of Internet shopping parcels in city center, as a zone of special interest to urban population and city government.

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3. RESEARCH ACTIVITIES

Research has divided into two phases. First phase, in duration of 12 months, the basic premise is cooperation development with relevant logistics operators which provide distribution and reverse logistics services of parcels in the city center of Zagreb, in order to collect all the necessary and relevant information for a comparative analysis of existing logistic flows (deliveries and returns) in city logistics system in the observed research area. The analysis was made with technological and organizational aspects.

Technical and technological aspects are analyzed according to:

- quantities of goods,
- weight of goods and,
- types of goods subjected to distribution and reverse logistic flows in the city of Zagreb.

Additional criteria are:

- types of delivery vehicles (technical and environmental criteria),
- category and number of the delivery vehicles used in distribution and reverse logistic flows of parcels in city center.

The organizational aspect is analyzed according to operational and environmental activities criteria required for performing the process of distribution and reverse logistics flows such as:

- total number of deliveries in city center,
- time required to execute all deliveries,
- number of stops and time share for stopping to the total time of distribution process,
- distance covered and,
- utilization of load space.

Goal of the first phase is to define current trends of distribution and revers logistics flows of parcel shipments within the area, and identification the most important areas of parcel shipments logistics flows. Analysis of logistic operators (national postal service operator, global and other courier operators) was used for this purpose, who carry out distribution and return of parcels in city center of Zagreb, since they, as passive participants in city logistics system, have the greatest impact on the defining of cargo flows in city logistics. In this way, cooperation between Department for transport logistics and commercial entities operating in city logistics was realized, which is one of the goals of Development Strategy of the Faculty of Traffic and Transport Sciences University of Zagreb for the period from 2012 to 2017 (measure 4.2.) and Program base of strategic program scientific researches document of Faculty of Traffic and Transport Sciences University of Zagreb for the period 2012th-2107th (chapter 5.2.).

As a supplement to the first phase the study on the impact, needs and measures for city logistics development was performed, from the aspect of most important participants in city logistics system in Zagreb, primarily representatives of city government, citizens and logistics operators. In particular, citizens are considered as the most vulnerable participants in city logistics system, and their views and suggestions for improvement have been found in order to reduce negative impact of city logistics and increase quality of life.

3.1 Analysis of Internet users in Croatia

Approximately 64% of population over the age of 15 use Internet. If the Republic of Croatia is compared with neighbor countries, Internet penetration is very similar to Bosnia and Herzegovina - 63%, Serbia – 65%, Macedonia – 67%. Although it is neighboring country, Slovenia is far ahead in the number of Internet users – where 80% of population over 15 years old use Internet, while the share in Slovakia is – 70%, in Hungary – 74%, while, for example, in Russia, population of Internet users is smaller – 58%, Internet use varies significantly according to age of population: among the youngest population (15-24 years old), only 3% of them do not use Internet, while in the age of 25-34 is 7% of such. With increasing age number of Internet users significantly decreases, and among the oldest (over 65 years) only 10% of population use Internet. In the last few years the growth of users in Croatia has been slowed down.[7]

Number of users is not growing with same intensity as before, but use of different features and benefits which Internet provide is rapidly increasing. One of possibility is purchasing a various range of products and services. In Croatia, at the end of 2010. only 6% of citizens was purchasing online. In just two years, this number increased almost four times, and the latest data show 23% of Croatian citizens at least once bought something over the Internet. Younger generations are buying more often than the average: 15-24 years old – 44%, 25-34 years – 39%, highly educated people – 38%. Over the Internet buys even 1/3 (36%) of total users. Although 36% of online users buys over Internet, their purchases are not so common: highest number of "buyers" (44%) buys several times a year, and once every few months – 24%. Furthermore, products that most Croatians buys online are clothes, footwear and electronic appliances, while the least is spent on personal services, health services and food as shown in figure 1.[8]

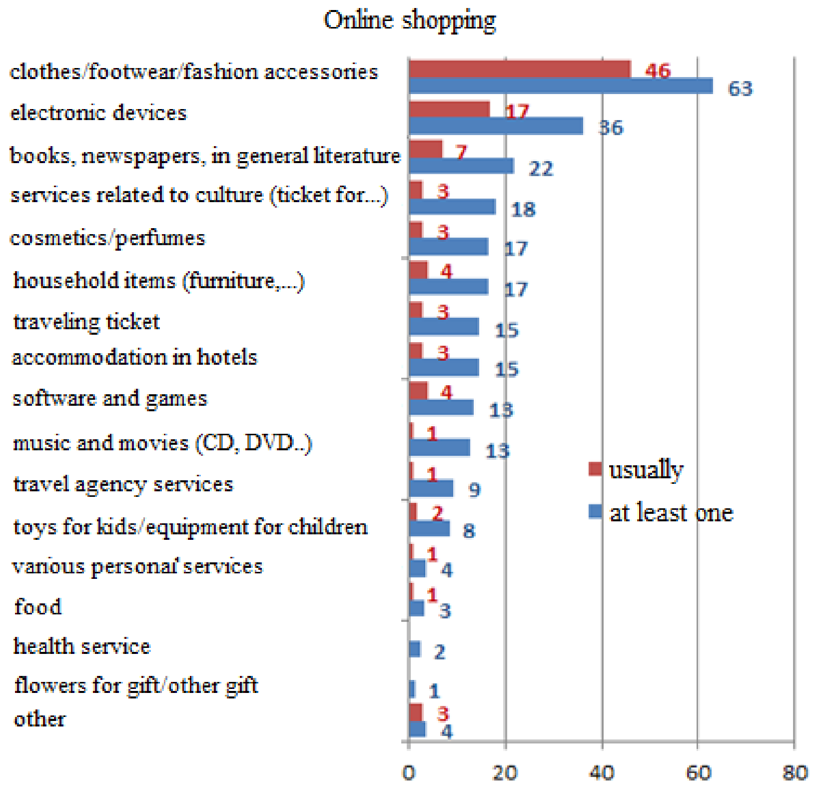

Figure 1 – Display of products customers in Croatia usually buy over Internet
Source: https://www.askgfk.hr/

[7] https://www.askgfk.hr/
[8] https://www.askgfk.hr/

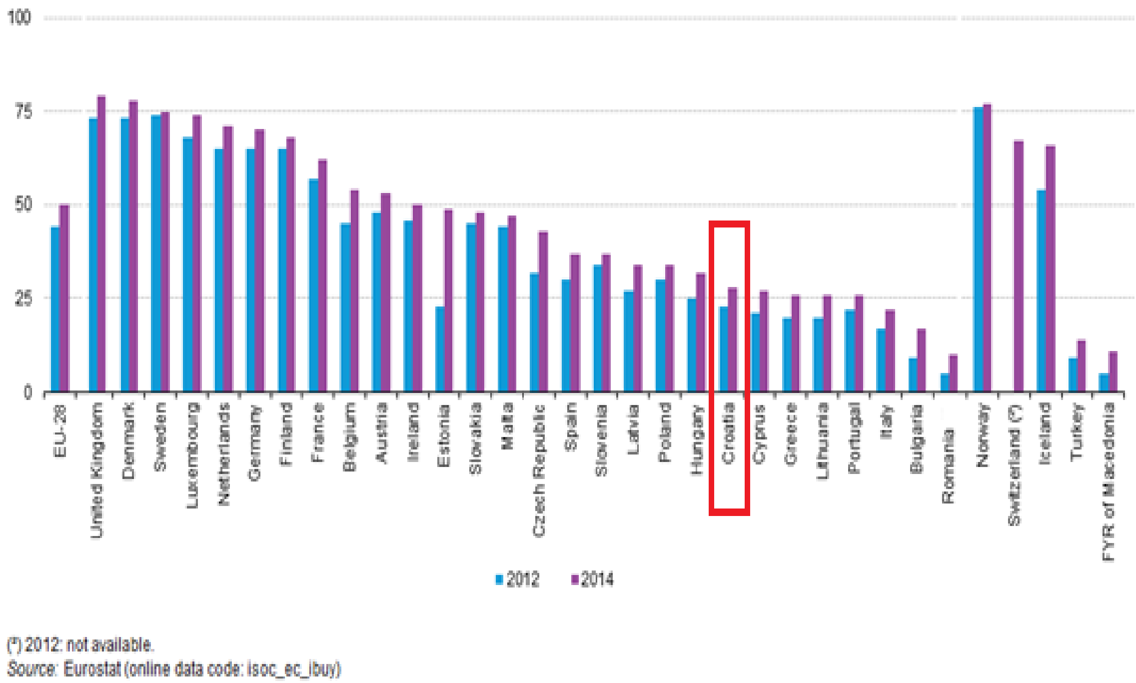

Figure 2 – Displayed statistical data on the percentage of the European countries population that ordered goods or services for personal use online
Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Information_society_ statistics_-_households_and_individuals/hr#Glavni_statisti.C4.8Dki_nalazi

3.2 Trends in distribution and returns of parcels by users

In order to determine trends in ordering items online, receiving and returning of same, a field study was carried out on 818 users of various age. After the field research was carried out it was concluded that the most common age of users which order items over Internet are between 15-19 years old, followed by 20-24, and between 25-29 years old. As part of the research trends of ordering items over Internet was analyzed, as well as the most common types of products ordered. For this purpose, an additional analysis was made according to age of users, but also by gender.

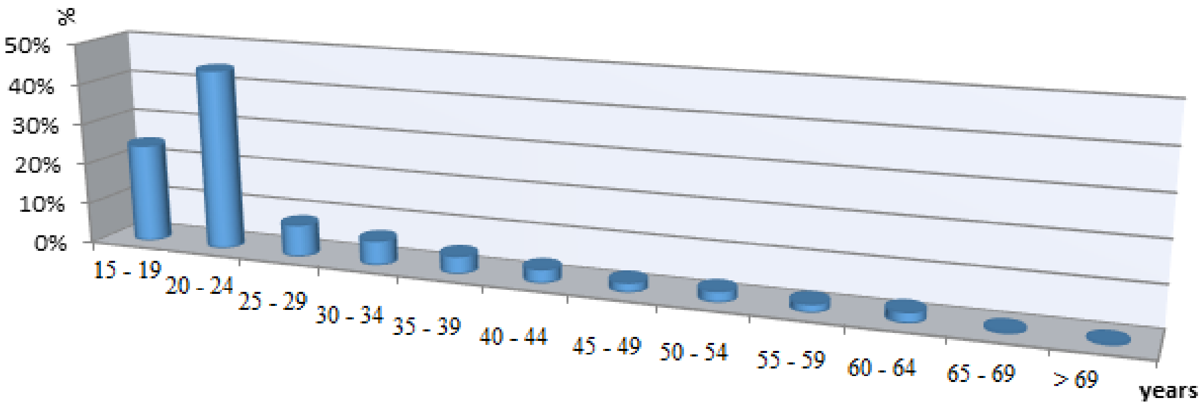

Figure 3 – Display of surveyed users by age groups

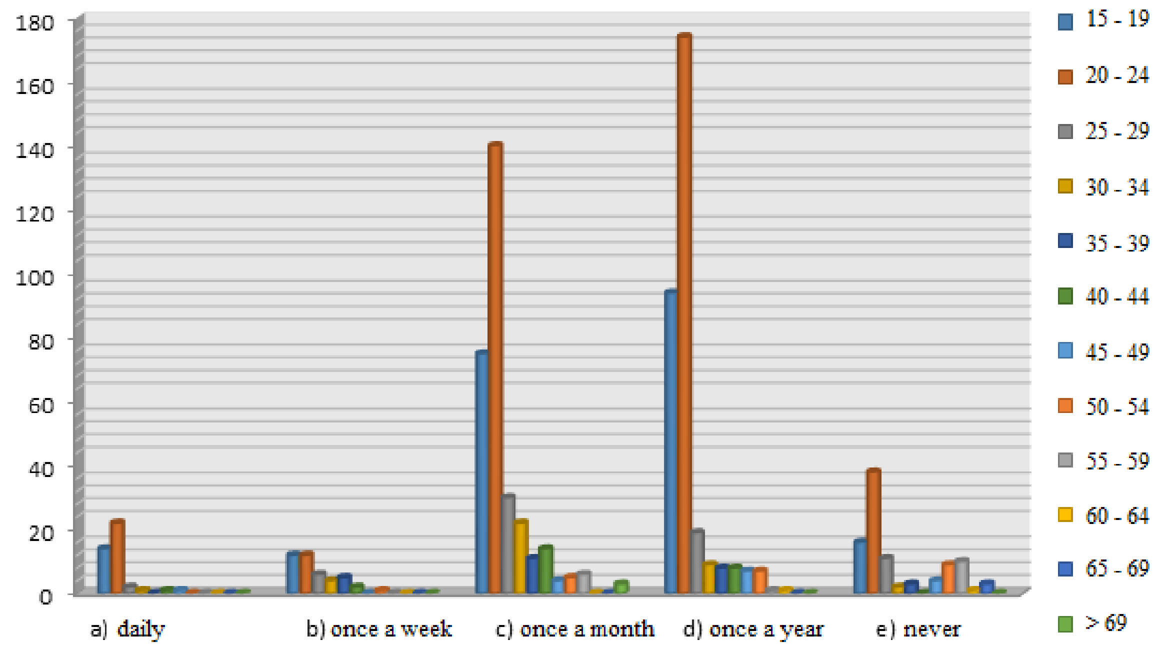

Figure 4 – Displayed frequency of internet shopping of users by age groups

According to the survey of 818 users, 5.3% or 43 of total Internet users use online shopping services on a daily basis, 5.16% or 42 subjects uses once a week, 37.94% or 310 once a month, 40.3% or 330 annually while 11.3% of them or 93 doesn't use Internet shopping services. Displayed results are visible in one-month and one-year usage. Specifically, 140 persons between 20 and 24 use Internet shopping services once a month, and 174 persons from 20 to 24 years old use same service once a year. This is certainly the result of a large number of respondents in this range, but it is evident that as subjects increases in age, intensity of Internet shopping decreases.

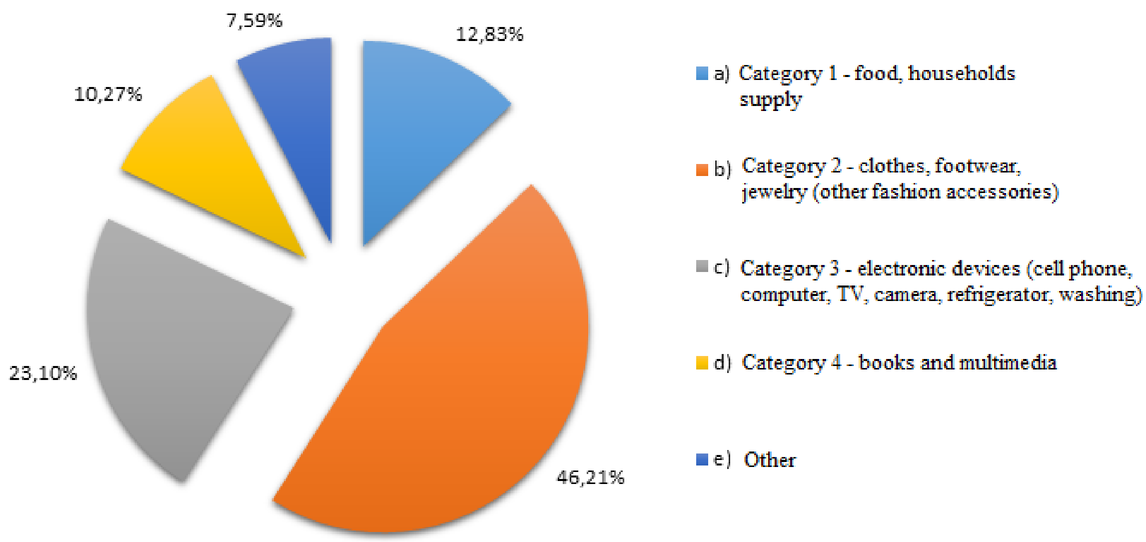

Figure 5 – Displayed products categories purchased in online shopping services according to surveyed persons

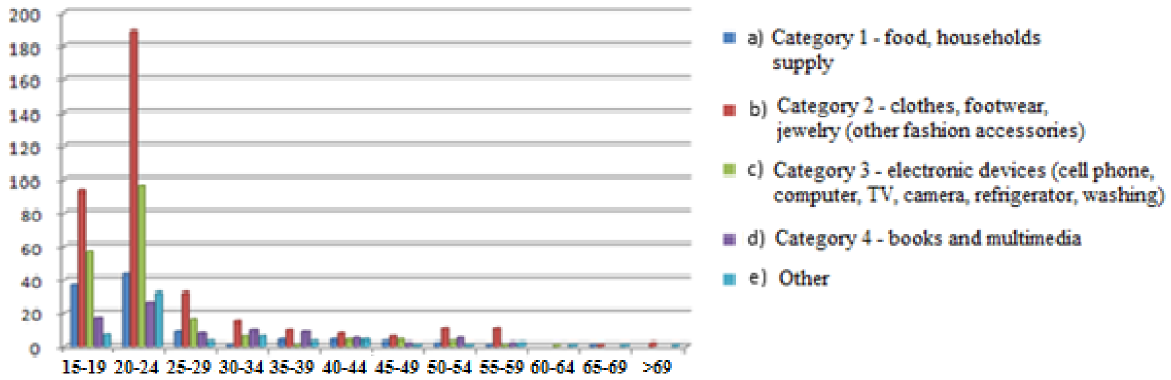

Figure 6 – Displayed products categories purchased in online shopping services according to surveyed persons by age groups

The first category, which includes food and household supplies (salt, sugar, vegetable oil, milk, fruits, vegetables, cleaning products, hygiene products, etc.) is chosen by 12.83% or 105 subjects, the second category which includes clothing, footwear and jewelry (shoes, pants, shirts, hats, jackets, earrings, necklaces, etc.) chosen by 46.21% or 377 subjects, the third category, which includes electronic products (cell phones, computers and parts, televisions, cameras, refrigerators, washing machines, etc.), 23.10% of them or 189 people, the fourth category which includes books and multimedia (physical books, books to read on the Internet, songs, movies, etc.) 10.27% or 85 of total subjects, while the category of others is chosen by 7.59% subjects or 62 of them. According to figure 21 it can be seen that in all age categories dominates second category of products (clothing, shoes and jewelry), and that ordering products from third category perform subjects younger than 29 years. Specifically, 169 subjects younger than 29 years buys electronic products, which is 89.41% of total subjects who buys electronic products online.

3.3 Impact of online shopping to traffic congestion?

Particular overview during customer research has been focused on their opinions about impact of ordering items over Internet on traffic flow in the city, or does costumers consider that ordering over Internet causes traffic congestion or not. Method of delivering goods to end users, so as services provided by distributors with the aim of tracking shipments was additionally researched.

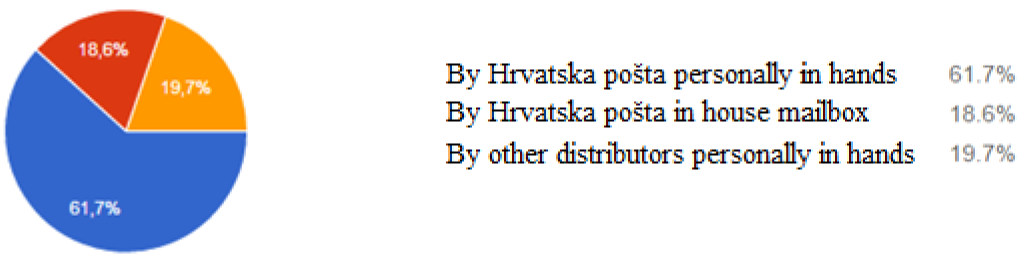

Figure 7 – Display of different distribution types of the products purchased online according to surveyed users

This research revealed that the majority of products ordered over Internet was delivered by Hrvatska pošta d.d. (more than 80% of total shipments – personally in hand, exact number - 505 or in the house mailbox, the exact number – 152), while other distributors delivered only 20% or, 151 customer answered that his package was delivered by other distributors. This ratio can be changed in favor of other distributors, primarily with high quality and increased level of service. First of all, it is proposed to shorten time of delivery by including customers in making decision of modes and time of delivery, more modern ways of parcel shipping, simpler processes and the like.

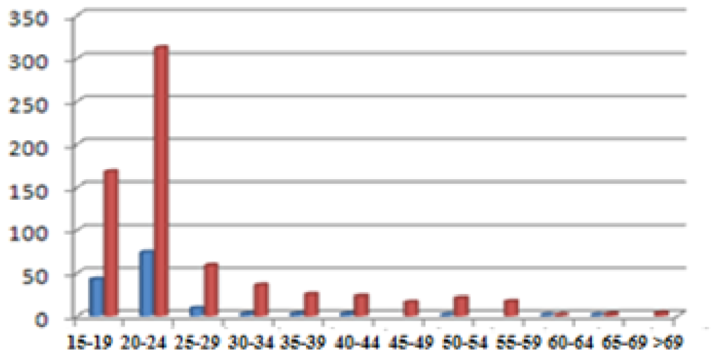

Figure 8 – Impact of product delivery purchased online to traffic congestion in the city of Zagreb according to surveyed users by age groups

It should be noted that 83.5% of customers, that is 683 subjects believe that delivery vehicles do not effect on traffic flow and congestion. According to the results, the delivery services, that is couriers are very good in their job in terms of driving quality and speed of delivery. Those users who are bothered by delivery vehicles in city center area state that delivery vehicles are often seen taking a lot of space and illegal parking in city center creating even more unnecessary traffic jams and congestion. On the other hand, young people are not well educated and familiar with problem of traffic congestion and air pollution by delivery vehicles, so it is necessary to educate young people about the problem.

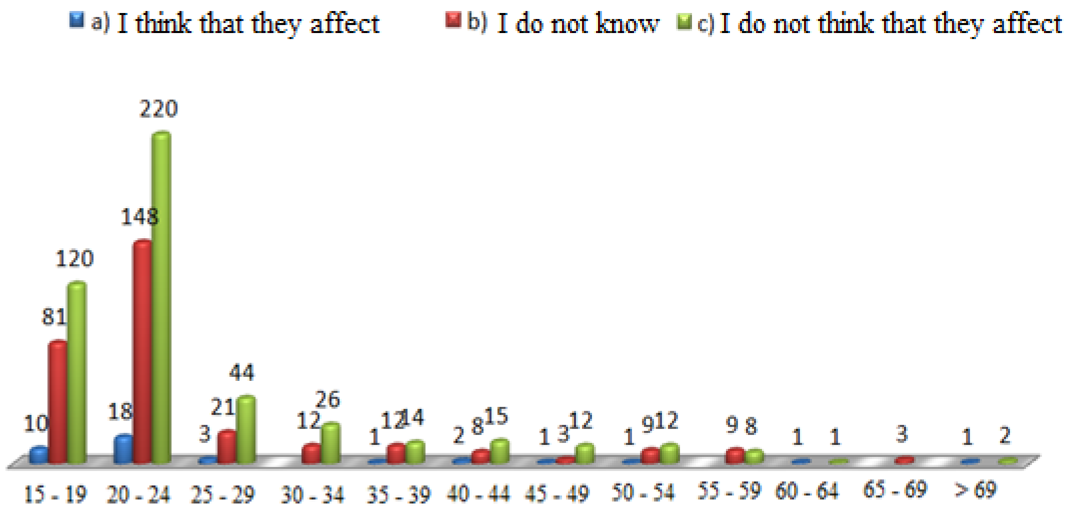

Figure 9 – Impact of product delivery purchased online to traffic congestion in residential zone according to surveyed users by age groups

Specifically, 57.9%, or 465 customers believes that delivery vehicles do not obstruct traffic, 37.3% or 305 customers said they did not know, while 4.7%, that is 48 respondents think that vehicles obstruct traffic in residence area. Those respondents who believe that vehicles do not obstruct traffic give answers like – I do not notice them, the distribution is done when there is not so many other vehicles, number of delivery vehicles is negligible in comparison with other vehicles, stopping time on one place is very short and the like. While those who think that they are still obstruct traffic state that they illegally park, unnecessarily stopping traffic, do not follow traffic rules and the like.

In order to obtain a clear picture of answers to this question statistic of answers was made by age groups of respondents as shown in Figure 9. Statistic show that in all groups of respondents there is a large percentage of those who do not know if delivery vehicles affect traffic congestion and traffic jams. This is a real situation that can be changed by educating all participants in traffic about possible consequences of excessive use of cars as well as the benefits of using public transport.

3.4 System of reverse logistics in online shopping

In order to more easily understand importance of parcel return, or reverse logistics in the following table are listed different reasons for initiating the same.

Table 2 – The reasons for the existence the reverse logistics system

The reason for setting up the reverse logistics system	**General example when using the reverse logistics system**
Returning goods which was bought on credit or returning goods for a refund money	The goods do not meet user expectations, return to refund money
Return the short-term rental and long-term rental products (leasing)	Return of goods which were leased in agreed day (rent-a-car)
Return to manufacturer for reprocessing	Return the used car alternator to manufacturer for processing and resale
Returning goods in the warranty period	Returning TV due to malfunction
The system "old for new"	Seller receives/take used car that is being prepared for resale
Products which were send to the company for improve or upgrade (innovation)	The old computer was send to the manufacturer to install the CD-ROM drivers
Product recall	Return the car to manufacturer, for example, due to faulty seat belt, made the wrong disc brake that threaten the safety of passengers and other road users, etc.
Products which are sent to the manufacturer for inspection and recalibration	Medical equipment were returned for review and recalibration measures
The products do not meet the manufacturer's warranty requirements to the customer	Returning TV when it not working as promised/specified

Returns of items also creates additional cost for distributors, and this study was to determine in which proportion of users make return of products and for what reason. Even 82.4% of respondents or 676 has never return ordered product, and 17.6% or 142 respondents responded that they did return product in some cases, and the main reason for returning product from the standpoint of users are:

- wrong product has been sent (incorrect size or product that is not ordered)
- defective product (product is damaged in transport because of poor packaging, the product is faulty – does not work) and
- poor quality of product (retailer promotes a high quality product that cannot be justified).

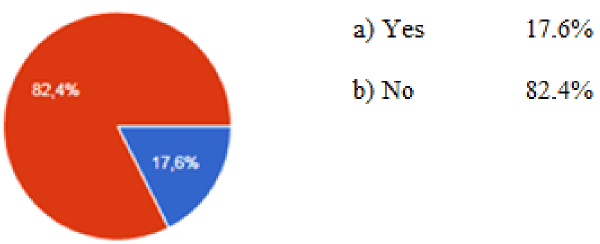

Figure 10 –Results of return products bought in online shops according to surveyed users

In Figure 11. it can be seen that each age group has a very similar answers, but they are negative to the question whether they return ordered product. Of 142 total respondents who answered that they did return ordered product 37 of them is in first age group (20 – 24 years old), while 37 of them are equally situated to other groups, with the exception in last three age groups (60 – 64, 65 – 69, more than 69) where the number is very small and does not exceed more than two positive answers to this question.

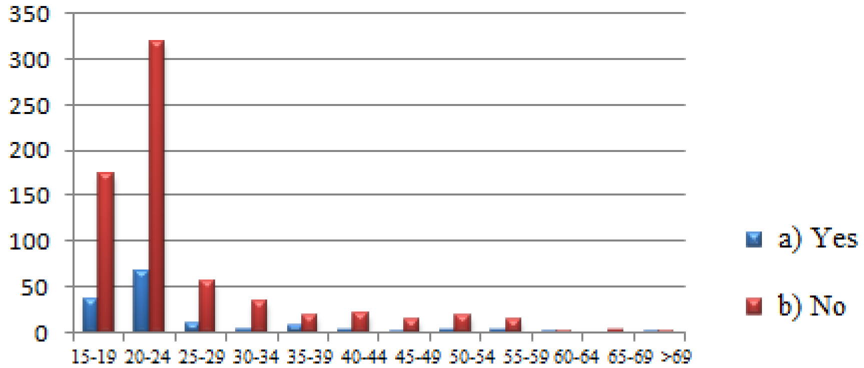

Figure 11 – Results of return products bought in online shops according to surveyed users by age groups

3.5 Analysis of business logistics operators in city logistics system

For the research purpose survey was made, which analyzes business of four companies engaged in distribution of parcels ordered over Internet services. Companies that participated in survey are the one with the highest share of parcel distribution in Republic of Croatia.

Table 3 – Displayed research on logistics operators in the city logistics system

Company/ Questions	Company 1	Company 2	Company 3	Company 4
1. In what way parcel distribution is taking place (ordered over internet)?				
	End user – Person	*End user – Person*	*End user – Distribution center*	*End user – Distribution center*
2. Who bears the cost of distribution to the end user?				
	Customer	*Customer*	*Sender*	*Sender*
3. What is time period from ordering to delivery to customer? (same day, 24 hours)				
	24h	*48h*	*24h*	*Over 48h*
4. Types of products to be distributed most frequently (a), medium intensity (b) and very rare (c)?				
a)	*Clothes, footwear, fashion accessories*	*Electronic devices*	*Food and households supply*	*Other*
b)	*Food and households supply*	*Clothes, footwear, fashion accessories*	*Electronic devices*	*Electronic devices*
c)	*Books and multimedia*	*Food and households supply*	*Books and multimedia*	*Books and multimedia*
5. In which period of day you make distribution of Internet orders (for example 09:00-13:00, 14:00-16:30)?				
	8.00 am to 5.00 pm	*4.30 am to 8.00 pm*	*8.00 am to 5.00 pm*	*9.00 am to 7.00 pm*
6. Do you give customer option for choosing time of delivery, if so, in which periods?				
	No	*Yes: 8 am – 8 pm*	*No*	*Yes: 4pm – 6 pm*
7. In your opinion, what are most common problems encountered in distribution products ordered online?				
	Wrong address, recipient is not at home in delivery time and there is no ready money to pay for the package	*The recipient is unavailable*	*The recipient was not at home at the delivery time*	*Lack of customer education about IT services*
8. How do you solve problem of "failed" delivery (this implies a problem that occurs when customer is not at home at the time of delivery)?				
	Delivery will be repeated (3 times)	*The package is left at a nearby post office*	*Delivery will be repeated (once)*	*Delivery will be repeated (3 times)*

9. How often product returns from customer occurs, and what is the share of returns in total number of deliveries (on monthly basis)?				
	<5 %	*<20 %*	*<10 %*	*<20 %*
10. Most common reasons for returning products?				
	The recipient is absent, incorrect address, the recipient refuses accept package, lack of money	*The recipient is absent*	*The recipient is absent, lack of money*	*The recipient refuses to accept package*
11. Do you charge returns and all activities needed for return shipments?				
	No	*No*	*No*	*Included in the product price*
12. Does it come to damaging products in return flows?				
	< 5 %	*< 5 %*	*< 5 %*	*<5 %*
13. Who estimates that can returned product be back in distribution flow?				
	The system - defined procedure	*Nobody*	*Contracting Party - sender*	*Contracting Party - sender*
14. Returns product from end users are processed always by the same employees?				
	No	*No*	*Yes*	*Yes*
15. In what way do you notify customers about product delivery (E-mail, by phone)?				
	E-mail, text messenger	*E-mail, call, text messenger*	*E-mail, text messenger*	*E-mail, call*
16. In what way customer takes ordered product?				
	Directly from the driver	*Directly from the driver or in person at a nearby post office*	*Directly from the driver*	*Directly from the driver*
17. Is there a possibility of communication between customer and driver in terms of product delivery?				
	Yes	*No*	*No*	*Yes*
18. Is there a possibility of shipment tracking by customer?				
	Yes	*Yes*	*Yes*	*Yes*
19. Based on practice examples what are most common city areas where distribution of online orders takes place?				
	Confidential information	*The whole city*	*Do not keep records*	*The whole city*
20. What are the most common problems during parcel deliveries?				
	Wrong address, the buyer gave up of buying	*The recipient is absent*	*Buyer withdrew from the buying, incorrectly ordered*	*Wrong address*
21. In relation to total goods flow of company, how much (percentage) Internet distribution makes?				
	We do not have information	*30 %*	*25 %*	*We do not have information*
22. From an economic point of view, what proportion of company profit (in percentage) is achieved from distribution parcels ordered online?				
	Confidential information	*Confidential information*	*10 %*	*We do not have information*
23. Due to the share that distributions parcels ordered over Internet has in your business, what is the number of transport vehicles intended for Internet distribution (for example 5/10) and what is their load capacity and mark these types of vehicles?				
	All vehicles are in use	*We do not have information*	*9/10*	*All vehicles are in use*
24. Vehicles				
	Vehicles load capacity to 3.5 tons, Vehicles load capacity to 7 tons	*Vehicles load capacity to 800 kg, Vehicles load capacity to 3,5 tons*	*Vehicles load capacity to 800 kg, Vehicles load capacity to 7 tons*	*Vehicles load capacity to 3.5 tons, Alternative fuel vehicles*
25. What type of transport vehicles are you using for city center and what for the other city areas?				
	Combined	*Light delivery vehicles*	*Light delivery vehicles*	*Light delivery vehicles*
26. How do you optimize distribution channel (vehicle routing)?				
	Making routes on daily basis	*According to streets*	*Making routes on daily basis*	*Zone routing*
27. What are delivery vehicles occupancy rates (in percentage)?				
	80-90 %	*70 %*	*70 %*	*There are not rules - depends on the day*
28. How do you solve problems of empty runs (if you have any)?				
	We do not have them	*We do not have them*	*We do not have them*	*We do not have them*

29. How is the parking of delivery vehicles regulated in city areas?				
	Where available, parking is paid (daily, monthly, yearly)	*No way*	*In the center we enter during the morning hours when the deliveries are allowed*	*Paying parking*
30. Are you thinking about introducing "smart" systems (or value added services) for distribution parcels ordered online and which systems would it be?				
	The planned introduction of parcel machine	*No*	*We are introducing network parcel machine and pay the ransom package by credit and debit cards*	*Currently not*
31. Have you submitted a proposal to city government about distribution system? If yes, what was the proposal?				
	No	*No*	*No*	*No*
32. How important are citizens thoughts about realization of your services?				
	5	*3*	*5*	*4*
33. What is your opinion about cooperation of logistics operators and city government?				
	1	*2*	*3*	*2*
34. Does city government inspire use of smart distribution systems in your city, if so, in what way?				
	No	*No*	*No*	*I do not know*
35. What is your opinion about cooperation between logistics operators and citizens?				
	4	*3*	*3*	*3*

3.6 Goods flow map

In the second phase of study map of goods flows was created with the aim of improving efficiency of parcels distribution and return flows in Zagreb city center. Since logistics operators could not give data on movement of their delivery vehicles, while city of Zagreb does not implement measures for improving urban logistics system field, counting of number and types of delivery vehicles in city center has been made. The study included counting of numbers of delivery vehicles in time beyond defined time by "Decision on regulation of traffic in Zagreb". For the purposes of the project study included three different areas. First area connects central part of Zagreb with its western part, or Ilica Street in length from British square to Selska Street. Second area includes city center, from Eugen Kvaternik square to Drago Ibler square. Third area includes streets in central part of the city (Gundulićeva street, Medulićeva street, Mesnićka street, Kačićeva street, Jurišićeva street, Plamotićeva street, Praška street, Kurelčeva street, Kaptol street, Nova Ves street, Zvonarička street, Nikola Tesle street, Gajeva street, Gundulićeva street, Masarykova street, Preradovićeva street, Nikole Šubića square).

Counting of delivery vehicles was conducted by recording – taking photographs on a total of 15 intersections within the first area, six intersections within second area and 16 intersections in the third area. First area, also the first demonstration zone of project, is determined on section of the Ilica Street from British square on the east, from first to fifteenth intersection Ilica – Selska – Sveti Duh Street in a total length of about 1.7 km. Each intersection represents one counting spot on which during six working days (Monday – Sunday) in period from 18 to 23 May 2016 counting was conducted. Interval of counting vehicles for each of the six working days was defined and it was from 7:00 to 10:00 hours.

Same methodology was used for second area, which includes Vlaška Street from Eugen Kvaternik square on east side, first intersection to sixth intersection Vlaška Street – Drago Ibler square, in total length of 1 km. Each intersection represents one counting spot on which, during three working days (Monday – Wednesday) in period from 27 to 29 June 2016 counting was conducted. Interval of counting vehicles for each of the three working days was defined and it was from 7:00 to 10:00 hours.

Same methodology was used for third area, in Gundulićeva street, Medulićeva street, Mesnićka street, Kačićeva street, Jurišićeva street, Plamotićeva street, Praška street, Kurelčeva street, Kaptol street, Nova Ves street, Zvonarička street, Nikola Tesle street, Gajeva street, Gundulićeva street, Masarykova street, Preradovićeva street and Nikole Šubića square.

Each intersection represents one counting spot on which, during four working days (Monday – Friday, not including Wednesday) in period from 5 to 9 November 2016 counting was conducted. Interval of counting vehicles for each of the four working days was defined and it was from 7:00 to 10:00 hours.

Map of goods flow on three simulated areas includes number of delivery vehicles on each intersection and street and it is only available as online version.

Table 4 – The total number of delivery vehicles in the first area

Total vehicles_18.05._Ilica	222	295	305	301	261	279	291	321	256	266	159	222	152	241	155
Total vehicles_19.05._Ilica	222	295	311	305	271	279	293	320	263	270	158	222	152	241	155
Total vehicles_20.05._Ilica	417	502	480	440	413	446	465	489	369	345	180	240	179	238	129
Total vehicles_21.05._Ilica	415	488	483	441	424	459	437	435	400	377	199	231	185	274	134
Total vehicles_22.05._Ilica	455	558	547	498	487	507	497	481	387	410	282	301	259	330	214
Total vehicles_23.05._Ilica	208	245	231	237	242	264	308	321	221	198	79	101	80	125	64
Number of intersections	*15*	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
Total	**1939**	**2383**	**2357**	**2222**	**2098**	**2234**	**2291**	**2367**	**1896**	**1866**	**1057**	**1317**	**1007**	**1449**	**851**

Table 4 – The total number of delivery vehicles in the second area

Total vehicles_27.06._Vlaška	*425*	*294*	*443*	*323*	*333*	*424*
Total vehicles_28.06._Vlaška	*384*	*289*	*458*	*337*	*350*	*458*
Total vehicles_29.06._Vlaška	*355*	*258*	*488*	*405*	*397*	*374*
Number of intersections	*1*	*2*	*3*	*4*	*5*	*6*
Total	**1190**	**871**	**1372**	**1051**	**1105**	**541**

Table 6 – The total number of delivery vehicles in the third area

Total vehicles_5.11._Centre	149	341	107	182	149	27	95	206	188	88	55	73	422	184	327	207
Total vehicles_6.11._Centre	199	432	125	241	179	24	92	240	210	121	75	80	395	342	218	300
Total vehicles_8.11._Centre	112	226	78	145	111	28	80	167	191	133	86	80	155	199	207	319
Total vehicles_9.11._Centre	175	331	105	200	195	33	83	236	236	142	91	101	361	207	345	267
Number of intersections	*16*	*15*	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
Total	**635**	**1330**	**415**	**768**	**634**	**112**	**350**	**849**	**825**	**484**	**307**	**334**	**1333**	**932**	**1097**	**1093**

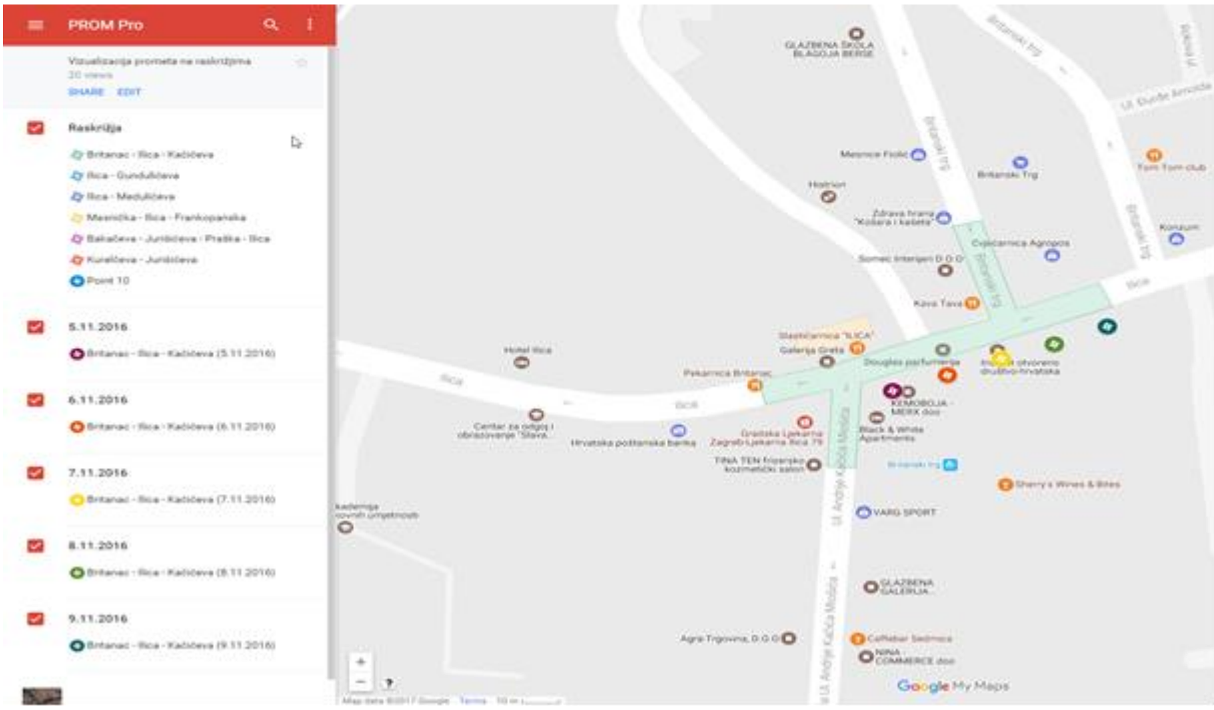

Figure 12 – Goods flow map for the third area

4. BUDGET SPENDING

Total funds allocated for research purposes amounts to 24.000,00 kn. In first year of research, studies have been realized on the distribution and return flows of parcels in city logistic system, and presentation of scientific work entitled "Greening the Supply Chain by Reverse Logistics Process Modeling" at international conference "Annual International Conference on Transportation“ held in Greece in period from 8 to 11 June 2015.

In the same period a meeting relating to the project Horizon 2020 was organized, with certain participants in previous WBC-INCO NET Brokerage Event, held in organization Hellenic Republic, Ministry of Education, Lifelong Learning and Religious Affairs, General Secretariat for Research And Technology.

In the same year of research, collaboration with Università di Genova, DIME Dipartimento di Ingegneria Meccanica, Energetica, Gestionale e dei Trasporti has been initiated, which resulted with the project proposal titled „Coordinated Strategies for Multimodal Freight Eco Distribution in CE Metropolitan Areas“ in the „Interreg CENTRAL EUROPE, Cooperating on transport to better connect CENTRAL EUROPE“. Unfortunately, the proposal was not accepted by EU.

Project entitled „Optimization of Parcel Flows in the City Logistics System“ has been applied at the tender of University of Zagreb, short-term financial support for research for 2015., which is in the status of development.

In second year of research, research about number of delivery vehicles in city area of Zagreb was conducted, as described in section 3.6.

Table 7 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	The organization and coordination of research distribution and reverse flow of parcels in the system of city logistics (field research)	7000,00	Conducting field research about the distribution and return flows of parcels in the city logistics system	7000,00
2.	Analysis of the data collected	2000,00	Analysis of the data collected	2000,00
3.	Presentation of Scientific Work „Greening the Supply Chain by Reverse Logistics Process Modelling“	6000,00	Presentation of Scientific Work „Greening the Supply Chain by Reverse Logistics Process Modelling“	6000,00
4.	Research technical-technological and organizational aspects of parcels logistics flows	4000,00	Conducting field research on technical-technological and organizational aspects of parcels logistics flows	4000,00
5.	Map of parcels flows within the area of the City of Zagreb	5000,00	Map of parcels flows within the area of the City of Zagreb	5000,00

5. RESULTS

Results derived from this project can be classified:

- cooperation with logistics operators involved in distribution and revers flows of parcels ordered Internet services,
- analysis of ordering products from online stores from user's perspective, logistics operators and city government,
- cooperation with scientific institutions outside Republic of Croatia,
- defining technical, technological and organizational factors and their interaction in implementation distribution and reverse flows of parcels shipping in city center of Zagreb,
- establishing the methodology for defining logistics flows in system of city logistics in observed area,
- defining real data about logistics flows of parcels within the area.

5.1 Including students in project development

By including students in research activities resulted in graduate thesis associated with the object and purpose of proposed project. Graduation thesis derived from this project are:

- Špoljarić, K.: Identification of the Logistic Processes of Parcels Ordered in Internet Business on the Zagreb Area, 2016., mentor: Rožić Tomislav
- Černetić, S.: Optimization of Distribution Process of Parcel Consignments Using Method of Transport Means Load Capacity Analysis, 2016., mentor: Rožić Tomislav
- Rihtarić, M.: Reverse logistics activities organization in Croatian waste management, 2015., mentor: Bajor Ivona
- Klongsungsorn, P.: Reverse logistics Warehouse Process Optimization, 2016., mentor: Bajor Ivona
- Stankeric, O.: Comparative Analysis of Reverse Logistics Activities and Incineration for Greening Waste Management, 2016., mentor: Bajor Ivona

Also, from project activities, research papers have been published with students at international conferences:

- Rogić, K., Bajor, I., Rihtarić, M.: Reverse Logistics Activities in Waste Management, Faculty of Transport and Traffic Sciences, ZIRP 2015, Zagreb, 2015., ISBN: 978-953-243-073-8
- Rihtarić, M., Klongsungsorn, P., Bajor, I.: Reverse logistics Warehouse Process Optimization, Faculty of Transport and Traffic Sciences, ZIRP 2016, Zagreb, 2016, ISBN: 978-953-243-081-3

5.2 Cooperation with industry and academia

With this project cooperation with relevant logistics operators associated with city logistics has been made. Besides the cooperation on project, cooperation was continued through the activities of professional practice for students of Faculty of Transport and Traffic Sciences, agreement on joint cooperation in projects, and writing a final thesis in logistics fields.

5.3 Project applications

Table 8 – Overview of submitted project proposals

Nr.	Funding scheme	Project name	Budget	Status
1.	Interreg CENTRAL EUROPE, Cooperating on transport to better connect CENTRAL EUROPE	Coordinated Strategies for Multimodal Freight Eco Distribution in CE Metropolitan Areas		Rejected
2.	University of Zagreb, Prijava za kratkoročnu financijsku potporu istraživanju za 2015	Optimization of Parcel Flows in the City Logistics System		Accepted

5.4 Published papers

Presentation of scientific paper entitled „Greening the Supply Chain by Reverse Logistics Process Modelling“ on international conference „Annual International Conference on Transportation“, held in Greece in period from 8 to 11 June, 2015.

6. CONCLUSION AND FUTURE WORK

This project particularly researched methods of deliveries of required products to end users, but also their satisfaction with all distribution aspects. It is interesting to note that some results of study show need for further involvement of end users in process of distribution and reverse flows of products ordered over Internet. Reasons for this is that people in age groups between 15 and 29 years old believe that delivery vehicles involved in distribution and revers flows does not endanger traffic safety and do not cause an increase in environmental pollution. Also, they consider Internet shopping a future of buying products, but on the other hand they don’t think this will cause negative effects in traffic congestion in cities, even though it is scientifically and empirically proven. This implies the implementation of education to most common age groups in process of ordering over Internet about aspects of city logistics, and possibility of inclusion nongovernmental organizations in education process.

Logistics operators seek to implement supply at the right time and right place in shortest possible time. For such system cooperation with customers and city government is required. In future, operators should dedicate to stronger connection with customers, providing quality and innovative services, without neglecting financial and time component.

In particular, it should be noted insufficient willingness city of Zagreb for a clear definition of city logistics system. In other words, currently in Zagreb there is no clearly defined plan for development and regulation of city logistics, and in particular delivery vehicles entering city center. In further research of sustainable mobility in Zagreb is necessary to examine in more detail, particularly problem elated to parking spaces intended for delivery vehicles.

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COGNITIVE APPROACH TO THE ERGONOMIC ASSESSMENT OF FACTORS FROM THE GROUP "HUMAN FACTOR" OF TRAFFIC PARTICIPANTS

ABSTRACT

In this project it will be researched how the factors of permanent and/or temporary disturbance from the working and/or the traffic environment, and non-harmonized psycho-physical characteristics and condition of the drivers with the requirements of the traffic situation, may negatively affect the factors from the group "human factor", which will lead to the appearance and/or increased physical, mental and sensory driver's workload, as well as the reduction of the driver's performance level, and consequently safety and reliability studied traffic process of goods' transport and/or passengers' transport will be reduced. Therefore, with the design of the working environment in transport means and/or the traffic environment it can be pre-programmed - the increase of driver's workload, subjective feelings of discomfort and fatigue, a lack of comfort, potentially hazardous situations, because the principles of psychophysiology of work and age-sex determinants of cognitive-motor function have not been respected. Cognitive approach to the research will include the field and laboratory studies of many factors from group ''human factor'' for engine drivers in Croatia, tram drivers in Zagreb and road drivers in the Zagreb county which affects the driver's capability, as well as driver's performance.

KEY WORDS:

cognitive approach; ergonomic assessment; human factor, performance, workload

1. INTRODUCTION

After traffic accidents, during classical behaviourist approach to the study of statistical objective risk, based on depth studies of damaged vehicles, place of accident and participants, the factors of traffic accidents are classified according to their shares into three standard groups of factors, with all their overlaps between three standard groups of factors: human factor (H), transport means (TM) and traffic environment (TE). Therefore, in accordance with the standard scientific methodology [1], a total share of human factor H include a pure share of human factor H, as well as a share of all overlaps between human factor H and other two groups of factors: H with TM, H and TE, and finally H with TE and TM. In 1982 [1] Rumar by summing two long years and independent studies of Road Research Laboratories in Great Britain and the USA with highly matching results, found extreme domination of the factors from the group "human factor" with a share of 95% in Great Britain and 94% in the USA.

Classical behaviourist approach to the study of statistical objective risk measured by total share of human factor H in traffic accidents cannot give as answer on the very important question, in accordance with the new cognitive approach to the researching of human role in traffic: How basic factors such as age, sex, occupation (of professional or amateur driver because of different level of practice and experience), and finally level of formal and/or periodic education of respondents (a general formal education trough the life and/or knowledge of traffic rules) affect on driver's capability and driver's behaviour in traffic?

Näätänen and Summala [2] were among the first who rejected the concept of statistical risk as a determinant of driver's behaviour.

According to Ray Fuller [3], it is important to distinguish between three basic uses of the term risk: objective risk, subjective risk estimate and the feeling of risk, with definitions as follow:

- Objective statistical risk, that is usually determined from analysis of accident data, it is the objective probability of being involved in a traffic accident.
- Subjective risk estimate (ratings of a statistical risk) refers to the driver's own estimate of the (objective) probability of collision and represent the output of a driver's cognitive process.
- Driver's feeling of risk represents an emotional response to a threat.

For the practical application of this psychological model in traffic it is very important what psychologists consider as a threat to drivers, which can result with driver's emotional response, such as a feeling of risk. According to the recent general theory of driver's behaviour, such us Fuller's task – capability interface model (TCI model) from 2005 [3], the driver's feeling of risk, instead of referring to the risk of collision, refers to the difficulty of the driving task (i.e. task difficulty), which implies that drivers might use feeling of risk as a measure of task difficulty. Simplified: because driver's task difficulty is also closely related to the driver's choice of speed, feelings of risk which enable the driver to maintain the task difficulty level within preferred boundaries by choice of speed. The task difficulty is likened to a great majority of authors with mental workload.

According to Figure 1, when the driver's capability exceeds the task demand (C>D), the task is easy. When the driver's capability C and the task demand D are equal (C=D), a critical speed is reached, therefore the driver's acts are on the borders of his capability and the task is very difficult, and only in that specific moment feelings of risk become equal to ratings of statistical risk. When the driver's capability is lower than the task demand (C<D), then the task is per definition too difficult and the driver cannot handle it, and therefore the consequence is loss of control of the vehicle.

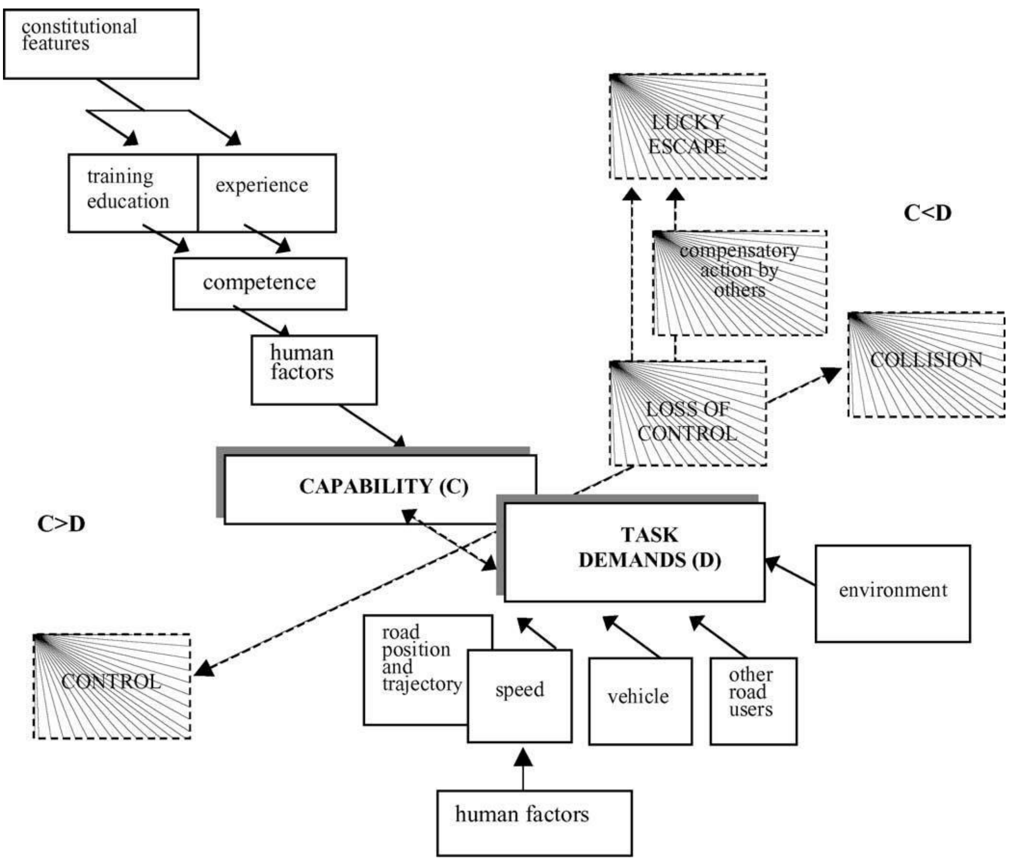

Figure 1 – Open dynamic TCI model of "task demand – driver's capability" interface
Source: Taken from Fuller, R. *2005. [3]*

Because the task demand, according to Fuller [3] does not depend on its complexity, co-authors of this paper believe that the model in Figure 1 for road drivers, who change gears and directions in the same time, is applicable, with an upgrade, also to the engine drivers and tram drivers because their task demand as well as task difficulty depend dominantly on the choice of speed.

Fuller argued [3]: "Driver capability is initially limited by biological characteristics of the driver, such as information processing capacity and speed, reaction time, physical reach, motor coordination and flexibility and perhaps strength. Together these biological characteristics and characteristics acquired through training and experience determine the upper limit of competence of the driver. However, competence of human factor is not necessarily what is delivered at any moment of time because the capability is vulnerable to plenty of human factor variables. These include factors of attitude, motivation, effort, fatigue, drowsiness, time-of-day, drugs, distraction, emotion and stress."

For example, an inadequate design of control panel and/or cabin can be one of the important reasons for occurrence of all type of driver's workload (physical, mental and sensory). Because driver's task difficulty (i.e. mental workload) among other things dominantly depends on the driver's choice of speed [3], frequently used commands which have to be manually served (by hands), on the locomotive or railcar control panel which needs to be arranged mainly within the range of normal arm reach in the central 90%, using a multi-purpose controller which contains several important and frequently used related functions associated with the change of speed for serving by one hand, whenever possible [4].

Furthermore, arrangement of frequently used commands outside of normal arm reach and/or driver's exposure to excessive doses of cabin audible noise can negatively influence the driver's performance.

For example, for the respondents exposed to the different sound pressure level (SPL) of audible traffic noise in dB(A) during the testing and/or exposed to different percentage share in (%) of daily recommended dose *D* of audible traffic noise which was accumulated before the testing in laboratory conditions, performance can be measured by the two most important parameters of driver's performance, accuracy and reaction time, using by, for example, next recent methods:

- simulator in laboratory conditions [5], and the goal is to correctly perform several consecutive complex elements while observing flight instruments readout,
- reaction meter CRD4 in laboratory conditions in the "Laboratory for Applied Ergonomics in Traffic and Transport" [6], on the two groups of several tests of cognitive functions of different levels of complexity:
  - tests of operative thinking (light signal identification and sound signal discrimination),
  - tests for measuring the time of classical types of psychomotor reactions (stimulus can be light or sound/release or keystroke).

Third, old and basic but very important method of performance measurement which is currently carried out on road vehicles drivers in the City of Zagreb is:

- paper pencil test of performance, such us: "Knowledge of traffic rules and regulations", and the goal is to correctly and as quickly as possible make a solution of test,

Traffic audible noise can be powerful distraction from the working and/or traffic environment. Furthermore, our past research confirms that traffic audible noise can significantly affect diesel traction engine driver's health. Permanent threshold shift (PTS) analysis of 44 randomly sampled male diesel traction engine drivers in Republic of Croatia (In Croatian, Republika Hrvatska; RH) were conducted [7].

It is important to recognize the difference between healthy hearing, age-related hearing loss and noise-induced hearing loss, because noise-induced hearing loss can be easily recognized by the typical notch at frequency of about 4 kHz [8], according to presented in Fig. 2.

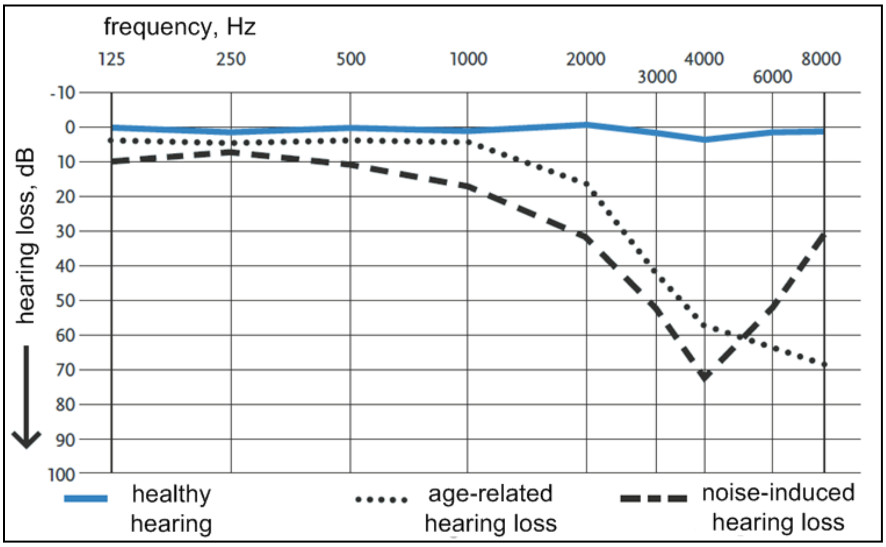

Figure 2 – Tipical audiograms for healthy hearing, age-related hearing loss and noise-induced hearing loss
Source: Taken from Coles R.R.A et al., *2000. [8]*

Mean audiogram of the right ear is presented in Fig. 3, and mean audiogram of the left ear is presented in Fig. 4, both of them for three groups of respondents related to working age. Typical notch can be very easily recognized for all of groups of respondents in Fig. 3 and Fig. 4. as well as higher hearing threshold for the groups with higher number of working age.

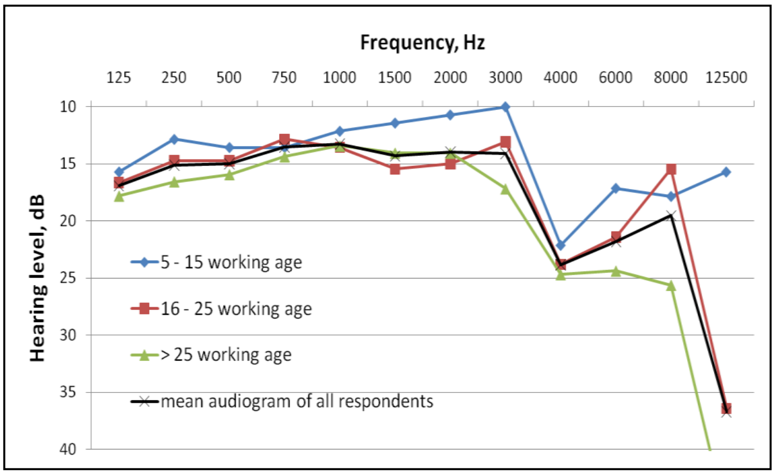

Figure 3 – Mean audiogram for three groups of respondents (right ear)
Source: Taken from Ivošević, J. et al. *2014. [7]*

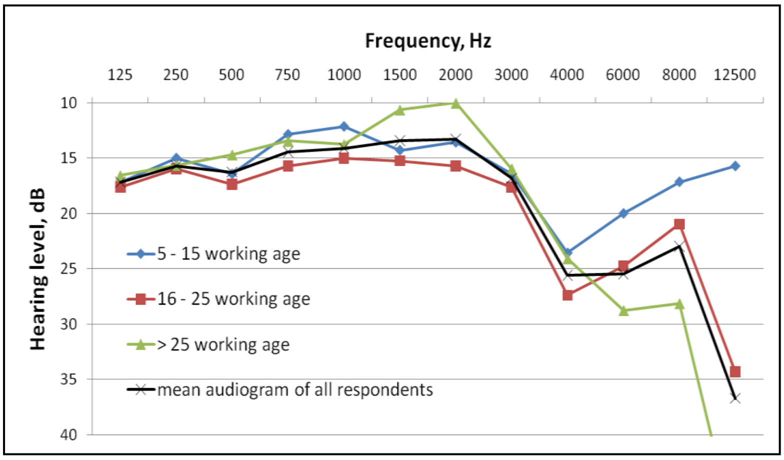

Figure 4 – Mean audiogram for three groups of respondents (left ear)
Source: Taken from Ivošević, J. et al. 2014. [7]

2. RESEARCH GOAL AND MOTIVATION

In accordance with the considerations in the chapter Introduction; the basic hypothesis and sub-hypotheses have been set up.

Basic hypothesis: using of specific parameters with numerical values, based on specific measurements and analysis, it is possible to prove that the factors of permanent and/or temporary disturbance from the working and/or the traffic environment, and non-harmonized psycho-physical characteristics and condition of the drivers with the requirements of the traffic situation, may negatively affect the factors from the group "human factor", which will lead to the appearance and/or increased physical, mental and sensory driver’s workload, as well as the reduction of the driver’s performance level, and consequently safety and reliability studied traffic process of goods' transport and/or passengers' transport will be reduced.

Sub-hypotheses: factors of permanent and/or temporary disturbances from the cognitive perception of traffic participants can be traffic parameters and/or design factors of working environment (driver's cab, vehicle) and/or the factors from the traffic environment (all outside of the vehicle), and mismatch of the psychophysical characteristics and states of traffic participants with the requirements of the traffic situation. Therefore, with the design of the transport means and/or the traffic environment it can be pre-programmed - the increase of driver's workload, subjective feelings of discomfort and fatigue, a lack of comfort, potentially hazardous situations, because the principles of psychophysiology of work and age-sex determinants of cognitive-motor function have not been respected.

First, very important goal envisaged with this project is continuous research that has been started at the two scientific projects of Ministry of Science Education and Sport (In Croatian, Ministarstvo znanosti, obrazovanja i športa; MZOŠ), in the period from 2007 to 2013, as follows:

- "Cognitive ergonomics in the function of traffic safety increase", project managers prof. Jasna Jurum-Kipke PhD and prof. Zdravko Toš PhD,
- "Parameters of the ecological impact on the development of infrastructure and traffic systems", project manager prof. Tino Bucak PhD.

The bigger number of researchers on this project were also researchers on the two mentioned scientific projects of MZOŠ.

A part of the measurement equipment for the next two laboratories under the names "Laboratory for Applied Ergonomics in Traffic and Transport" and "Laboratory for Aircraft Emissions" at Faculty of Transport and Traffic Sciences (FPZ) was co-financed with these two scientific projects.

Due to the needs of support for the cognitive approach to the researching it has been established cooperation with fellow psychologists from the Department of Psychology, Croatian Studies (HS).

In practice, there is a close collaboration of two laboratories, "Laboratory for Applied Ergonomics in Traffic and Transport" [6] and "Laboratory for Aircraft Emissions" [9], in the areas of joint research and exchange of measuring equipment.

This project is linked to the strategic research directions of the FPZ sciences because:

- improvement of the curriculum for course of graduate studies at FPZ under the name "Ergonomics in Traffic and Transport" is based on learning through our own researches,
- research infrastructure was created,
- competences of multidisciplinary research group has increased.

3. RESEARCH ACTIVITIES

3.1 Research activities which are finished

3.1.1 Research activities which are finished for engine drivers in Croatia

In order to analyse the intensity of perceptual speed (PS) and selective attention (SA) decline in ageing railroad engineers, but also its possible specificities and to indicate its main causes (which all have important implications for the safety of passengers and transport of goods), we conducted the examination of 103 male drivers of the Croatian Railways, ages 25-59, assigned to 4 age groups, distinguished by specific functional characteristics of professional drivers.

Concerning the PS (measured individually by two equivalent paper-and-pencil tests) the data showed the absence of speed-accuracy trade-off effect, as well as the absence of age-related changes in PS inter-individual variability and number of errors [10]. On the other hand, statistically significant nonlinear PS decline with increasing age is evident in Fig. 5.

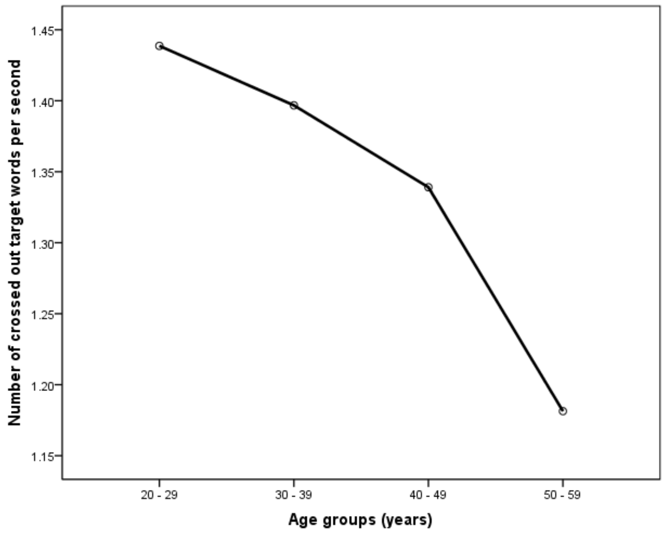

Figure 5 – Age-related changes of PS magnitude in four observed age groups
Source: Taken from Žebec, M.S. et al., 2016. [10]

The only significant decline was found among the two youngest age groups and the oldest group of railroad engineers, indicating mainly similar patterns as those found in the general population. The observed PS decline with increasing age may be due to differences in life styles, exposure to different kind of risk factors during life or neurobiological changes that accompany advanced age.

Concerning the SA, measured individually by two forms of the Stroop test - the 1st, verbal uncoloured (50 subjects), and the 2nd, verbal coloured (52 subjects) paper-and-pencil form – and expressed by interference time, the data [11] showed that the interference variability across age groups was homogenous at the 1st Stroop form, but not at the 2nd one; (2) the mean number of errors in the 1st Stroop form is as expected, very low with positive asymmetric distributions and homogenous variability, while in the 2nd one, errors are evident only for the 30-39 age group; (3) for the 1st Stroop form, a significant difference in SA interference time was found between the 40-49 and 50-59 age groups, the latter showing a higher interference (Fig. 6.); (4) for the 2nd Stroop form, no significant effects of age on SA interference were found.

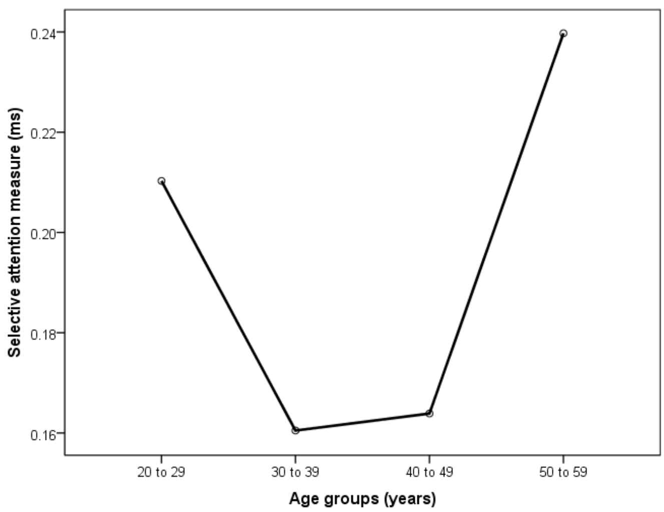

Figure 6 – Age-related changes of selective attention magnitude in four observed age groups in the lexical version of the Stroop test
Source: Taken from Žebec, M.S. et al., 2016. [11]

Non-coloured SA operationalization mostly proved the expected non-linear SA ageing deterioration, showing that at 20-49 years age range there were nonsignificant decrements, which became significant after the age of 50. Nevertheless, coloured (red-green) SA operationalization indicated age-related SA decrement through whole 20-59 age period, but didn't reach significance, probably because of specific red-green traffic differentiation experience. Such a kind of "everyday SA training", together with the similar SA exercise and certain number of health and working conditions interventions aimed to preserve SA neurological base (mostly concerned with environmental factors, working shifts and life style habits), presents an expert field for SA improvement.

The collected data are re-analysing by using some additional information of the raw data (errors are divided into slips and mistakes, relative positions of the slips and mistakes are observed, intra-individual variability of the responses has been calculated) in order to answer the questions on age-related changes of the dynamics indicators of SA-system.

From the measured anthropometric measures in the central 90% from the sufficient and random sample of 50 engine drivers the range of normal and maximal reach of arm has been defined using statistical methods for the entire population in *RH* [4]. The correlation dependence of lumbar moment M_{ly} on the Body mass index (BMI) has been proven in the hypothetically most unfavourable statistical seating working position (situation when the frequently used and manually serving commands are arranged in the maximum arm reach) , and based on the really measured anthropometric measures.

Amounts of lumbar moments M_{ly} according to expression (1) have been obtained by the reduction of all the body segment gravities F_{gzi} fom segmental masses m_i into the origin of the coordinate system xy in Fig. 7.

$$M_{ly} = \sum_{i=1}^{n} F_{gzi} \cdot x_i \qquad (1)$$

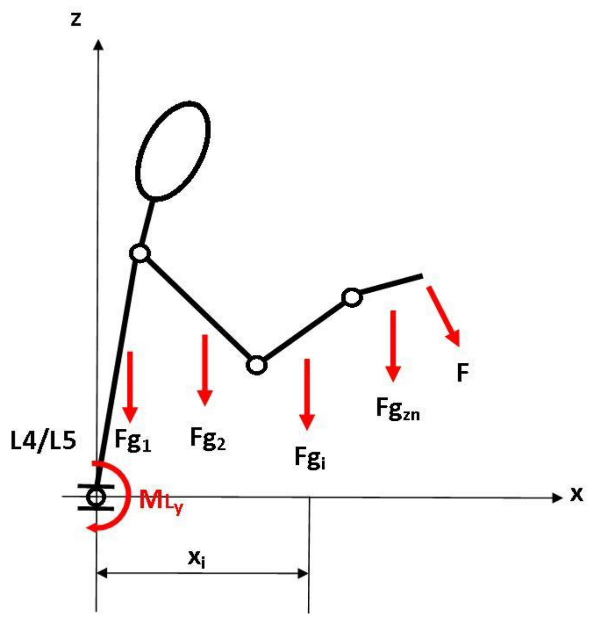

Figure 7 – Two-dimensional stick model of the respondent in sagital plane
Source: Taken from Jurum-Kipke et al., 2007. [12]

In compliance with the considerations of Mairiaux et al. [13], or Muftić et al. [14], the origin of the coordinate system xy represents also the point of reduction L4/L5 of the lumbar moment M_{ly} to the level between the fourth (penultimate) and fifth (last) lumbar vertebra in the mobile part of the spine viewed from above downwards.

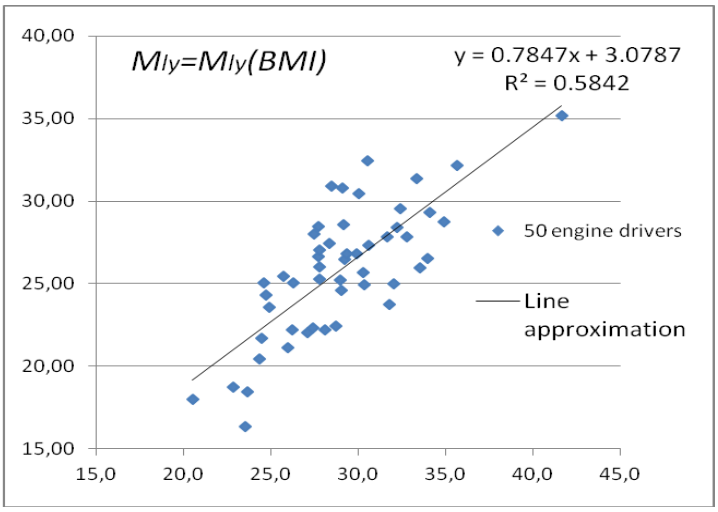

Figure 8 – Regression function $M_{ly}=M_{ly}(BMI)$ based on the actually measured anthropometric measures from the random and sufficient sample n = 50
Source: Taken from Sumpor, D. et al., 2015 [4]

Lumbar moment M_{ly} according to regression function (2) from the diagram in Figure 8 has an acceptable correlation dependence $M_{ly}=M_{ly}(BMI)$ of medium strength, with correlation coefficient R = 0.764.

$$M_{ly} = 0.7847 \cdot BMI + 3.0787 \qquad (2)$$

BMI calculated according to the formula (3), which contains two of the most important static anthropometrical measures standing height *h* and body mass *m*, is an indicator of possible overweight because of excessive mass *m* in relation to the standing body height *h*.

$$BMI = \frac{m}{h^2} \qquad (3)$$

Generally considering, during the analysis of the measured body sizes on the largest possible sample, it is necessary to investigate the influence of the following significant five group of factors of the human body sizes [15, 16, 17, 18]:

- **Sex:** males are higher than females at the same ages,
- **Age:** relative change in height with age for both sexes,
- **Ethnic differences**: belonging to the different races and to the different national groups in the different part of word,
  - racial differences are basically genetic and they can be disregarded in the anthropometry, therefore racial affiliation is not mentioned as a separate group of factors,
  - it is necessary to take into account the morphological differences caused by phenotype (F_v),
  - for example black people in the USA are morphologically different in relation to the black people in Africa despite the same genotype (G_v),
- **Socioeconomic factors:** between people having different occupation and between people having different level of formal education,

- **Demographic factors**: within the same ethnic affiliation in the different part of country (for example morphological differences between people in Dalmatia and Slavonia).

After maturity the body dimensions of both genders begin to decrease with age which is illustrated in Fig. 9.

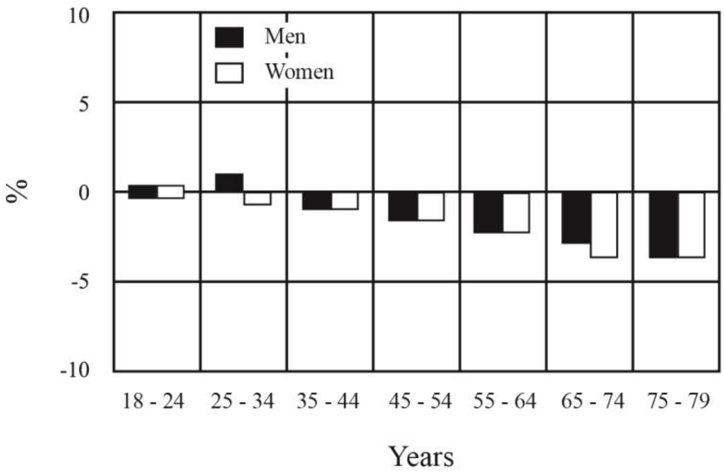

Figure 9 - Relative changes in body stature depending on age and gender, for men and women at the age of 18 to 79
Source: Taken from National Center for Health Statistic, 1965. [19]

In the next step a total of 25 anthropometric measures important for the engine driver's cab design was taken from a sample of 51 male engine drivers from all parts of Croatia, from which 5 and 95 percentiles along with central 90 % were determined [20].

Figure 10 shows some typical anthropometric measures in the sagittal plane with labels by Kroemer and Muftić [14]. Label 19 was added by co-authors.

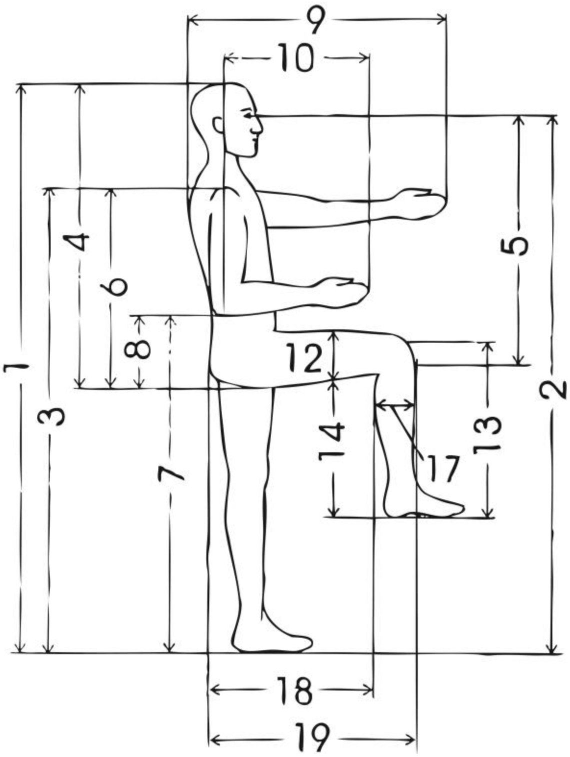

Figure 10 – Showing typical anthropometric measures in the sagittal plane by Kroemer
Source: Complemented taken from Muftić, O., 1999. [14]

The age of respondents significantly affect body height, what is confirmed by the results shown in Table 1, and probably affect other anthropological measures that are functionally dependent on the body height $h_i=f(h)$.

Table 1 – Body height and mass of male engine drivers in Croatia depending on age groups

Anthropometric measures	Symbol (unit)	age groups									
		all sample (*n = 51*)		up to 29 years (*n = 9*)		from 30 up 39 years (*n = 13*)		from 40 up 49 years (*n = 18*)		from 50 up 59 years (*n = 11*)	
		M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Body height	*h (cm)*	178.9	5.7	177.2	6.0	180.6	6.2	178.6	6.1	170.8	37.3
Mass*	*m (kg)*	91.9	14.1	81.4	13.9	96.5	12.9	91.2	11.3	87.9	22.1

Source: Taken from Mikulčić, M. et al., 2015. [20]

According to scientific findings that body height decreases with age, subjects were divided by age into four groups. Results from Table 2 show that between forty two respondents older than 30 years we have between 72.73 and 92.31 percent of overweight and obesity person, considering to the amount of *BMI*.

Table 2 – Number and percentage share of male respondents according to the amount of BMI index depending on age groups

Age groups		**all sample**	**up to 29 years**	**from 30 up 39 years**	**from 40 up 49 years**	**from 50 up 59 years**
Number of respondents		***n = 51***	***n = 9***	***n = 13***	***n = 18***	***n = 11***
Normal body mass	*n*	10	4	1	2	3
***BMI** = 18.5-24.9*	*%*	19.61	44.44	7.69	11.11	27.27
Overweight	*n*	24	4	7	10	3
***BMI** = 25-29.9*	*%*	47.06	44.44	53.85	55.56	27.27
Obesity	*n*	17	1	5	6	5
BMI ≥ 30	*%*	33.33	11.11	38.46	33.33	45.45
Overweight and	*n*	41	5	12	16	8
obesity *BMI ≥ 25*	*%*	80.39	55.55	**92.31**	**88.89**	**72.73**

Source: Taken from Mikulčić, M. et al., 2015. [20]

Arithmetic mean $M_r = \overline{h_i / h}$ of ratios *hi/h* calculated according to the formula (4) and harmonic mean H_r of ratios *hi/h* calculated according to the formula (5) for individual anthropometric measures h_i in relation to the standing height h are the same for all age groups, with minor deviations.

$$M_r = \overline{{}^{h_i}\!/_{h}} = \frac{1}{n} \cdot \sum_{i=1}^{n} \frac{h_i}{h} \tag{4}$$

$$H_r = \frac{n}{\sum_{i=1}^{n} \frac{1}{x_i}} = \frac{n}{\sum_{i=1}^{n} \frac{1}{\left(\frac{h_i}{h}\right)}} \tag{5}$$

Mathematically considered, the sample of drivers from this study is sufficient (all sample with more than 30 respondents). Because of insufficient and unequal number of respondents in age groups, for the final conclusions the research should be repeated with a larger sample, taking into account amounts of *BMI* within each age group.

For the design of the driver's working environment in a new locomotive or railcar cabins adjusted to the targeted drivers' population, the calculated arithmetic mean $\overline{h_i / h}$ of ratios hi/h should be used in the future. Using the arithmetic mean $\overline{h_i / h}$ of body segments ratios *hi/h* other anthropometric measures *hi* can be easily and quickly calculated from the standing body height *h*, if known amounts of standing body height *h* for 5 and 95 percentiles. The research was taken whether it was possible to use body ratios *hi/h* for the design of driver's cab in new vehicles adapted to the target population of drivers, in future only by knowing standing height and mass span in the central 90%.

If we know the arithmetic mean *M* and sample standard deviation *SD*, we can calculate 5 centile and 95 centile for all anthropometric measures, according to formulas (6) and (7) taken from Kroemer and Grandjean [15].

$$5{,}0 \cdot c = M - 1{,}65 \cdot SD \tag{6}$$

$$95{,}0 \cdot c = M + 1{,}65 \cdot SD \tag{7}$$

Table 3 – Engine drivers' body segments ratios and anthropometric measures in all sample

Anthropometric measures	Symbol	Label by Fig. 10	all sample *(n = 51)* *M* cm (kg*)	*SD* cm (kg*)	Percentiles *5 %* cm (kg*)	*95 %* cm (kg*)	Ratio $\overline{h_i/h}$	H_r
Body height	h	1	178,9	5,7	169,5	188,2	/	/
Mass*	m		91,9	14,1	68,7	115,1	/	/
Range of horizontally outstretched arms	h_{11}	11	181,0	7,3	169,0	193,1	1,01	1,01
Eye height in standing position	h_2	2	167,9	5,4	159,1	176,8	0,94	0,94
Shoulder height in standing position	h_3	3	147,1	6,2	136,9	157,3	0,82	0,82
Elbow height in standing position	h_7	7	111,3	4,6	103,7	118,8	0,62	0,62
Leg length	h_n		99,3	4,6	91,7	107,0	0,56	**0,55**
Normal arm reach (from the rear side of the elbow to the middle of a clenched fist)	h_{ndr}		35,5	2,0	32,2	38,8	0,20	0,20
Maximum arm reach (from the rear side of the acromion to the middle of a clenched fist)	h_{mdr}		64,7	3,7	58,6	70,9	0,36	0,36
Sitting height to vertex	h_4	4	90,6	3,4	85,0	96,3	0,51	0,51
Eye level in sitting posture	h_5	5	80,1	3,2	74,8	85,4	0,45	0,45
Shoulder level in sitting posture	h_6	6	61,2	2,8	56,5	65,8	0,34	0,34
Elbow level in sitting posture	h_8	8	25,0	3,5	19,2	30,7	0,14	0,14
Knee height in sitting posture	h_{13}	13	54,5	2,2	50,9	58,0	0,30	0,30
Foot length	h_{sd}		26,4	1,2	24,3	28,4	0,15	0,15
Ankle joint height	h_{sv}		9,3	0,9	7,7	10,8	0,08	**0,07**
Horizontal reach of outstretched arm	h_{hdr}	9	77,1	4,8	69,1	85,1	0,43	0,43
Length of forearm and hand (from rare side of the elbow to the tip of the middle finger)	h_{10}	10	48,2	1,9	45,1	51,3	0,27	0,27
Arm length (from acromion to the tip of the middle finger)	h_r		77,6	3,4	71,9	83,2	0,43	0,43
Hand length	$h_{š}$		20,0	1,1	18,2	21,8	0,11	0,11
Below knee height in sitting posture	h_{14}	14	44,5	1,8	41,5	47,4	0,25	0,25
Bi-acromial range (shoulder width)	$h_{šr}$	15	40,3	2,5	36,2	44,5	0,23	**0,22**
Bi-iliocristal range	$h_{šb}$		30,2	3,2	24,9	35,6	0,17	0,17
Length from the back below the knee	h_{18}	18	54,6	3,1	49,5	59,8	0,31	**0,30**
Length from the back to the top of the knee	h_{19}	19	64,5	3,4	58,9	70,1	0,36	0,36

Source: Taken from Mikulčić, M. et al., 2015. [20]

3.1.2 Research activities which are finished for female students of Zagreb University

A total of 25 anthropometric measures were taken from a sample of 68 female students of Zagreb University, up to 29 years of age, from all parts of Croatia, central 90 % of which were determined by using calculated amounts for 5 and 95 percentiles [21]. Arithmetic mean and harmonic mean of body ratios h_i/h and functional dependence $h_i=f(h)$ for individual anthropometric measures h_i in relation to the standing body height h were also determined. Calculated arithmetic mean $M_r = \overline{h_i / h}$ of female students body ratios h_i/h will be compared with results of many simultaneous researches for other populations of respondents such us:

- male engine drivers from Croatia for all age groups on increased sample,
- male and female tram drivers from Zagreb for all age groups
- male students of Zagreb University up to 29 years of age.

3.2 Research activities which are in progress.

3.2.1 Research activities which are in progress for tram drivers in the city of Zagreb

All PS and SA measurements, conducted at engine drivers are planned to be replicated on tram-drivers, but also supplemented with some additional psychological instruments needed to explain the possible causes of the observed findings. PS and SA measurements are being conducted at the moment.

Arithmetic mean $M_r = \overline{h_i / h}$ and harmonic mean H_r of body ratios h_i/h and functional dependence $h_i=f(h)$ for individual anthropometric measures h_i in relation to the standing body height h will be also determined, for male and female tram drivers from the city of Zagreb, for all age groups. Field measurement of anthropometric measures are being conducted at the moment.

Researchers are recording percentage share in (%) in relation to the daily recommended dose D of audible traffic noise for all models of trams in the city Zagreb at the moment, in accordance to the guidelines of *National Institute for Occupational Safety and Health* (NIOSH) from the Unites States of America (USA) [22], which are same with the European Union (EU) law requirements in this area. NIOSH criterion for maximum daily noise dose *D* that respondent is allowed to accumulate is 85 dB(A) during the normalized time period of 8 hours, with low of change of 3dB(A).

3.2.2. Research activities which are in progress for road drivers in the city of Zagreb

Researchers are conducting the pencil-paper tests of driver's performance under the name "Knowledge of traffic rules and regulations". More than 1200 test were done.

3.3 Research activities which will be conducted

3.3.1 Research activities which will be conducted for male students of Zagreb University

Arithmetic mean $M_r = \overline{h_i / h}$ and harmonic mean H_r of body ratios h_i/h and functional dependence $h_i=f(h)$ for individual anthropometric measures h_i in relation to the standing body height h will be also determined, for male male students of Zagreb University. Measurement of anthropometric measures are planed in the following six months.

3.3.2 Research activities which will be conducted for engine drivers from Croatia

Researchers will record percentage share in (%) of the daily recommended dose D of audible traffic noise for all models of locomotives and railcars in Croatia, in accordance to the guidelines of NIOSH from USA [22], which are same with the EU law requirements in this area. Measurement are planned in the following twelve months.

Audiograms of both ears of electric traction engine drivers will be recorded, for random and sufficient sample of respondents. Measurement are planned in the following twelve months.

3.3.3 Research activities which will be conducted for tram drivers in the city of Zagreb

Audiograms of both ears of male and female tram drivers in city of Zagreb will be recorded, for random and sufficient sample of respondents. Measurement are planned in the following four months.

3.3.4 Research activities which will be conducted for road drivers in the Zagreb county

Base of pests of a large insurance company and MUP base of participants in accidents in the Zagreb county (for the last few years, 6 or more) will be analyzed according to the following independent variables: age, gender, vehicle category, date and time of an accident, the day of the week and month of traffic accidents, power of vehicles which has caused a traffic accident in (kW), (also not limited). Measurement are planned in the following six months.

3.3.5 Complex research draft in the laboratory conditions in purpose to measure a performance of respondents

The last and the most important research activity in accordance with the recent cognitive approach to the research will be implementation of several complex research drafts at the Reaction meter CRD4, for several groups of respondents with different characteristics of several human factor variables, in laboratory conditions and the "Laboratory for Applied Ergonomics in Traffic and Transport" [6].

Reactionmeter CRD4, which is usually used for the purpose of practical laboratory classes for graduate students on the course Ergonomics in Traffic and Transport, during this project will be used for the purpose of performance measurement of different respondents (traffic participants or students).

During the classes on the course Ergonomics in Traffic and Transport students will be trained for serving Reactionmeter CRD4. Afterwards, a part of the students in role of student associates will participate in performance measurement of real respondents in laboratory conditions.

Reactionmeter CRD4 enables measuring of different cognitive functions, and contains tests for the following measurements:

I) Tests of thinking (stimulus can be: light or sound, keystroke buttons by hands and/or pressure foot's pedals by legs):

- operative thinking (light signal identification),
- operative thinking (sound signal discrimination)

II) Tests for measuring the time of classical types of psychomotor reactions (stimulus can be: light or sound, release or keystroke):

- tests of simple reaction time,
- tests of disjunctive reaction time,
- tests of the choice of reaction time.

Measurements of performance will be in the first phase carried out within young and healthy subjects (students under 29 years of age), and in the second phase on the different participants, in traffic, with different work and rest conditions, as well as with different characteristics of several human factor variables (engine drivers, tram drivers, bus drivers for public transport of passengers), because value of Perception-Response Time (PRT) according to the results from scientific literature dominantly depends on age, sex, type of stimulus (sound or light), type of serving (keystroke or release), as well as on the occupation of respondents (different level of respondents competence due to the influence of education, training and experience).

Examples of possible independent variables which will define a number of groups in experiment (number of groups is equal to the number of experimental conditions):

- sex (male/female),
- levels of complexity (tests of simple reaction time or tests of operative thinking),
- two different levels of traffic audible noise SPL in dB(A) emitted in the laboratory, in accordance with the worst value of equivalent traffic audible noise levels L_{ekv} which were measured and recorded in tram cabins in the city of Zagreb and/or in the Diesel locomotive cabins in the Republic of Croatia,
- exposed to the different percentage share in (%) of daily recommended dose D of traffic audible noise, which was accumulated by respondents before the testing in laboratory.

4. BUDGET SPENDING

Table 4 – Planned and realized activities with budget overview for 2015

First cycle (2015)			
Planned activity	**Planned budget (VAT included)**	**Achieved**	**Cost (VAT included)**
1. Purchase of software: IBM SPSS softver Statistics 22.0, Valicon academic analytical solution + NVivo program for qualitative analysis	13.200, 00 KN	IBM SPSS software Statistics - license for one year 23,67 %	3.125, 00 KN
2. Purchase of small measuring equipment	107.617, 70 KN	*Small and medium Lafayette anthropometers* 4, 75%	5.107, 50 KN
3. Purchase of paper-pencil tests: SPM Plus tests of general intellectual abilities	4.616,50 KN	100 %	4.616,50 KN
4. Scientific production	19.500, 00 KN	**0 %**	0, 00 KN
5. Purchase of laptops (3 pieces) for field measurements	12.000, 00 KN	**0 %**	0, 00 KN
6. Costs of the fieldwork	7.500, 00 KN	*(per diem)* 2 %	150, 00 KN
7. Purchase and installation of equipment for achieving optimal environment conditions in LzPeP	18.393, 10 KN		0, 00 KN
8. Fieldwork of students researchers (FPZ i HS)	unforseen	Conducted psychological tests and measured anthropomeasures	1.989, 00 KN
	Total: 182.827, 34 KN		Total: 14.988, 00 KN

Table 5 – Planned and realized activities with budget overview for 2016

Second cycle (2016)			
Planned activity	**Planned budget (VAT included)**	**Achieved**	**Cost (VAT included)**
1. Scientific production in foreign CC, SCI and SCIE scientific journals (2-3 papers)	12.500, 00 KN	One paper was published in the international SCIE scientific journal (other sources of funding)	/
2. Scientific production at international scientific symposiums (3 papers): Ergonomics 2016 -Focus on synergy	12.000, 00 KN	Conference fee for 1 paper at Ergonomics 2016 -Focus on synergy Conference (a total of 3 papers were published)	1.540, 55 KN
3. Costs of the fieldwork and establishment of cooperation (*per diem*, fuel, road tolls, local ride, travel orders)	2.500,00 KN	1. researchers' *per diem* 2. fuel 3. Travel order - Faculty of Maritime Studies Rijeka	750, 00 KN 100, 31 KN 790, 00 KN
4. Fieldwork of students researchers (FPZ and HS): 10 students x 40h x 25KN/h x 1,17	11.700, 00 KN	Implementation of the pencil-paper tests under the name "Knowledge of traffic rules and regulations"	1.997,50 KN
5. Small measuring equipment: Metrel tripod A 1159 for device Metrel Poly MI 6401 EU	1.262, 00 KN	Other sources of funding	0, 00 KN
6. Small measuring equipment: dictaphone Olympus WS-833 (159,90 EURos)	1.218, 50 KN	/	/
7. Prezentation	unforeseen		129, 00 KN
8. Membership fees of researchers in the scientific societies	unforeseen	Membership fees in the Croatian Acoustic Society	600, 00 KN
		Membership fees in the Croatian Ergonomics Society	675, 00 KN
9. Other materials (for the needs of the ordinary business)	unforeseen	Measuring tapes Rechargeable batteries	110, 00 KN 156, 00 KN
10. Replacement parts for measuring equipment	unforeseen	Reserve pedals for serving by legs (reactionmeter CRD4)	1.231,25 KN
	Total: 41.180, 00 KN		Total: 8.079, 06 KN

Budget overview for 2016 is not finished, because research activities in accordance with the planned and described in section 3.2 are still in progress.

From Table 4 and Table 5 it can be seen that the available funds are not sufficient for the planned scope of research.

5. RESULTS

5.1 Involvement of students

Next four papers were published during the 2015 together with students associates, who have been involved in conduction of researching, in results processing and finally in a scientific publication.

First paper is for female respondents students of graduate studies at FPZ and all the other papers are for respondents engine drivers from RH.

[10] Žebec, M. S., Crnko, I., Sumpor, D.: Selective attention of Croatian railroad engineers from 25 to 59 years of age: Empirical findings and implications, Book of Proceedings of the 6th International Ergonomics Conference „Ergonomics 2016 – Focus on synergy“,

Sušić, Aleksandar et al. (ed.), Croatian Ergonomics Society, June 15 – June 18, 2016, Zadar, pp. 413-426, ISSN: 1848-9699

[11] Žebec, M. S., Palavra, V., Sumpor, D.: Perceptual speed of Croatian railroad engineers from 25 to 59 years of age: Empirical findings and implications, Book of Proceedings of the 6th International Ergonomics Conference „Ergonomics 2016 – Focus on synergy“, Sušić, Aleksandar et al. (ed.), Croatian Ergonomics Society, June 15 – June 18, 2016, Zadar, pp. 427-440, ISSN: 1848-9699

[20] Mikulčić, M., Modrić, M., Sumpor, D.: Application Possibility of Engine Drivers' Body Segments Ratios in Designing the Cab' Working Environment in Croatia, Proceedings of the 26th DAAAM International Symposium on Intelligent Manufacturing and Automation, *DAAAM 2015*, Zadar, 21st – 24th October 2015, Published by DAAAM International, Katalinić, B. (ed.), Vienna, 2015, pp. 842-848, ISSN: 1726-9679

[21] Sumpor, D., Mikulčić, M., Modrić, M.: Female Students' Body Segments Ratios, Book of Proceedings of the 6th International Ergonomics Conference „Ergonomics 2016 – Focus on synergy“, Sušić, Aleksandar et al. (ed.), Croatian Ergonomics Society, June 15 – June 18, 2016, Zadar, pp. 323-330, ISSN: 1848-9699

Matea Mikulčić univ.bacc.ing.traff., who has been a student of graduate studies at FPZ and who was a co-author of paper under the name "Application Possibility of Engine Drivers' Body Segments Ratios in Designing the Cab' Working Environment in Croatia", had been awarded for the best oral presentation of paper in English at the 26th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM 2015, which took place in Zadar, Croatia, from 21st to 24th of October 2016.

Based on conducted researches, it has been improved and corrected the list of proposed topics of obligatory student's seminar papers and/or possible topics of graduate works for course Ergonomics in Traffic and Transport (also not limited):

1. Factors of Ergonomic Assessment from the Group "Human Factor"
2. Cognitive Approach to the Analysis of Statistical Objective Risk of Traffic Accidents
3. Human Factor in the TCI dynamic Interface „Task Demand - Capability of Driver“
4. Ergonomic Analysis of Static Sitting Position of Traffic Participants
5. Impact of a Range of Static and Dynamic Anthropometric Measures of Drivers in Sitting Static Working Position on Workload in the Lumbar Part of Spine on Level L4/L5
6. Body Mass Index BMI of Drivers in Sitting Static Working Position as a Factor of Workload in the Lumbar Part of Spine on Level L4/L5
7. Ergonomic Assessment of the Impact of Arrangement and Positioning of Frequently Used Commands for Manual Serving on the Control panel to the Performance and Workload of the Driver
8. Application of Descriptive Statistics and Harmonic Analysis on the Cabin Working Environment Design
9. Noise Impact on the Workload and Performance of Traffic Participants in the Combined Transportation
10. Traffic Audible Noise in Urban Environment as a Factor of Driver´s Disturbance
11. Impact of Climatic Factors of Comfort on the Traffic Participants Workload
12. Impact of Shift Work Organization and Night Work on the Workload
13. Ergonomic Assessment of Work and Rest Conditions of Traffic Participants
14. Impact of Driver's Assistance Systems on the Driver's Ability.
15. Impact of Autopilot Using on the Pilot's Ability, Competences and Basic Flight Skills

16. Impact of Daily Circadian Rhythms on the Workload and Performance of Traffic Participants
17. Ergonomic Assessment of Disturbance Factors from the Working and Traffic Environment
18. Factors of Influence on the Temporary Psychophysical Readiness of Driver
19. Factors of Fatigue Occurrence and Impact of Fatigue on Driver Performance
20. Factors of Physical, Psychological and Sensory Workload of Traffic Participants
21. Ergonomic Assessment of Passenger Seat Comfort in Traffic Means
22. Ergonomic Assessment of Passenger Seat Comfort in Aircraft
23. Factors of Driver's Perception-Response Time
24. Factors of Driver's Performance
25. Ergonomic Assessment of Pilot's Working Ability Factors
26. Ergonomic Assessment of the Air Traffic Controllers' Workplace
27. Cockpit Ergonomic Factors Analysis
28. Ergonomic Assessment of Engine Drivers´ Workplace in Croatia
29. Ergonomic Assessment of Tram´s NT 2200 Cabin produced by Crotram
30. Working Conditions of Tram Drivers Comparison within Different Trams of ZET Operator in the City of Zagreb
31. Ergonomic Assessment of the Workplace on Computer Work
32. Ergonomic Assessment of the Counter Workplace

In 2015 Matea Mikulčić univ. bac. ing. traff. defended the undergraduate thesis under the title “Mechanics of Solid Bodies Applied to the Skeleton of Engine Driver” at the Faculty of Transport and Traffic Sciences, University of Zagreb.

The students of the FPZ participated at the 6th International Conference Ergonomics, ERGONOMICS 2016 - Focus on Synergy in Zadar, with a four scientific papers, which were written in co-authorship with the lecturers of the FPZ studies, presenting the results of the research in the area of applied ergonomics and applied acoustics and traffic. For some of them, those were the first experiences in the paper presentation at a scientific symposium. The students of the FPZ actively participated in the Technical committee and they worked successfully all four days at the official board of the Conference. ERGONOMICS 2016 – Focus on Synergy, which was organized by the Croatian Ergonomics Society (CES), was a joint project with Faculty of Transport and Traffic Sciences (FPZ), University of Zagreb.

5.2 Cooperation with academia in EU

On the course "Ergonomics in traffic and transport", which has been performed in English, in the last two academic years students of graduate studies from abroad (Erasmus +) have been involved in real researches in the "Laboratory for Applied Ergonomics in Traffic and Transport", during the conducting of the laboratory exercises, which are part of the auditory exercises.

Students from abroad (Erasmus +) in the academic year 2015/2016:

- Panudda Klongsungsorn
- Arun Gurung

Students from abroad (Erasmus +) in the academic year 2016/2017:

- Valtteri Laaksonen
- Johannes Raiha
- Jaakko Pietila

5.3 Planned and realized achievements based on learning through their own researches

Based on learning through their own researches have been conducted activities in two main directions:

- Improvement of the curriculum for course of graduate studies at FPZ under the name ""Ergonomics in traffic and transport".
- Preparation for proposing a new elective course on doctoral studies at FPZ, under the possible names ""Human factors in traffic" or “Factors of driver's performance in traffic”

5.4 Obtained additional projects and funding

Table 6 – Overview of accepted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	Support for scientific and artistic research in 2015 of the University of Zagreb	Factors of the Tram Drivers' Workload in the City of Zagreb, the number of research TP138	Ergonomic Assessment of Factors from the Group "Human Factor" of Tram Drivers in the City of Zagreb	12.471,18 KN

Realization of this project, which was finished in the percentage share of 20%, dominantly depends on available funding. Ergonomic assessment of factors from the group "human factor" of tram drivers in the city of Zagreb has been continued on this project.

5.5 Published papers

Papers [4, 5] were published in scientific journals.

Papers [10, 11, 20 and 21] were published with co-authors students associates from FPZ or HS in the Proceedings of two international scientific Conferences.

Short explanations of scientific contribution in all the mentioned papers are given in the chapters 1. and 3.1.

6. CONCLUSION AND FUTURE WORK

From the comparison of research activities which are finished, research activities which are in progress and planed research activities with the analysis of budget overviews for 2016 and 2015 it can be seen that the available funds at this project are not sufficient for the planned scope of research.

Generally considering, realization of this ambitious and complex project, which was finished in the percentage share of 30%, dominantly depends on available funding. In the first step, in relation to the available funds, it is necessary to publish several papers in scientific journals with the purpose of acquiring necessary competence of researchers. In the next step, it is necessary to apply for additional research projects that enable more intense funding.

There is also a lack of workforce for faster conduction of research, because the involvement of students associates in research work requires mentors' extra effort in the next two very important segments: training for handling with measurement equipment and team work during the treatment of results and scientific publication.

Future work will include all segments of this project which are not finished in the last two years, and which are planed, explained, partially conducted and partially completed in accordance to planed as in this paper, which is explained in details in chapters 3.2. and 3.3.

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RESEARCH ON THE SAFE APPLICATION OF CONTEMPORARY INFORMATION AND COMMUNICATIONS EQUIPMENT IN TRAFFIC ENTITIES

ABSTRACT

Today's operating systems in the field of distribution, logistics, taxi service, etc., include interactive participation of drivers in the transport process, navigation of vehicle/drivers in an unfamiliar area, remote vehicle diagnostics, etc. A prerequisite of such management is interactive mobile communications of vehicles/drivers with other participants of the transport processes in real time. For that, is required to use devices and services of mobile communication systems. Depending on the business functions, implies the use of specific applications, navigational charts, etc. However, when using these devices and services, the driver is not fully focused on the road, which significantly increases the possibility of traffic accidents. While there are many different types of driver distraction, it was, according to previous research presented in this paper, the use of mobile terminal devices is one of the most dangerous because it requires visual, acoustic and cognitive attention of the driver. For this reason, the goal of this research, which was conducted in collaboration between employees of the Department of Information and Communications Traffic and Department of Traffic Accident Expertise was to determine the safety aspects of the application of mobile terminal devices in the traffic environment and evaluate their impact through the reaction time of drivers of road vehicles. Results obtained in this study will be used as the basis for further research in this area but also in the implementation of traffic and technical expertise that are conducted at the Department of traffic and technical expertise, and where as a possible cause of a traffic accident occurs the use of terminal devices while driving.

KEY WORDS:

Distracted driving; Reaction time; Traffic safety; Terminal devices; Information and Communication traffic

1. INTRODUCTION

Today, mobile terminal devices are used every day by people of all ages. The advancement of technology, mobile devices provide an increasing number of services and functionalities, which have attracted a large number of users. Almost every user has at his side a mobile device at any time. Conducted research have shown that drivers often while driving using their mobile terminal devices in several different ways (talking, writing and reading messages, browse web pages, etc.), although this is prohibited by the Law. The reason for the prohibition are the consequences of using mobile terminal devices while driving, which is usually manifested by extending the reaction times of drivers, which in the worst case can cause a traffic accident. For this reason, and because these is the data that can be very useful for the implementation of traffic and technical expertise, this study was initiated.

2. RESEARCH GOAL AND MOTIVATION

The primary motivation for this project was the lack of relevant research that showed the influence of reaction time of drivers using a mobile terminal device while driving. The research was proposed in accordance with the strategic program of scientific research for the period 2012.-2017. [1] and results of the project will certainly enhance future traffic and technical expertise which is performed at the Faculty of Transport and Traffic Sciences.

Although there were no available relevant studies that defined the reaction time of drivers while using mobile terminal devices in the traffic environment, there is a number of other studies that have shown driving habits when using mobile terminal devices. University of Utah [2] revealed that the drivers using text messaging while driving, are eight times as likely to participate in a road accident as those who do not use. While the University of Virginia conducted several research and shown that drivers who use text messaging while driving, have a 23 times greater chance of being involved in a car accident. Their research has shown that the younger drivers are the population using the most text messaging while driving.

Pew Research Center in 2009 [2] published a study on the use of messaging service of the young drivers while driving. The results showed that 26% of drivers from 16 to 17 in the year (in the US driver's license can be obtained at 16 years) have written a message while driving, and 48% of children from 12 to 17 years said they were riding with a driver who was texting while driving. The NHTSA study from 2012 [3] about making and answering calls from mobile devices, showed that more calls were received while driving than were dialed by driver. Categorically, it can be observed that men more often use a mobile device for receiving and making calls. Also, one can see that the most calls are received by people age 21-24 years while the least calls are received by people 65+ years. Most calls are made by people 25-34 years old (38%), while at least calls are made by people 65+ years old (6%).

In another large NHTSA study from 2012 [2] conducted on 6016 samples, drivers were divided into two main categories; drivers having a distraction tendency while driving, and drivers that do not have distraction tendency while driving. In the sample, 33% of drivers were in the first category and 67 in the second. Drivers in the first category (prone to distraction), were of wealthier social status, typically younger and better educated than drivers from second category (not prone to distraction). More than half of drivers under 35 were classified as drivers tend to distraction, while only 5% of drivers over 65 were classified into the same group. Also more than half of the respondents with a distraction tendency have an income of $ 100,000 a year, while 26% have lower incomes than $ 15,000 a year. From this it can be seen that drivers with higher incomes are more likely to use mobile devices while driving. Drivers with only a high school education are less likely to use mobile phones while driving, only 1/3 of them, compared with drivers of university education from which half of them uses mobile devices while driving. This finding makes sense, because people with a university degree have higher salaries than those with only a high school education.

In this study [2] frequency of travel is more than four of five drivers who drive every day or almost every day, 13% of people said they drive only a few days a week, while less than 4% of drivers drive a couple of times a month. Most drivers who use mobile devices while driving belong to the group of people that drive every or nearly every day while very small number of them are people who drive a car a couple of times a week [4]. Also nearly half of drivers (48%) are answering calls while driving, while 2 out of 5 drivers never answer a call while driving. More than half of drivers who answered the call continued talking while 17% of them warn the they are driving and will call later, 14% of them passes the mobile device to a companion in the car, and about 11% of them stops by the road in order to have a conversation.

About 24% of drivers makes a call while driving, what is even worse option then receiving a call, because to make the call driver must find a person in phonebook and dial, what distracts driver's attention from the road.

Sending messages while driving is most dangerous activity, because in addition to reducing the very concentration on driving, driver must also look away from the road, what is the worst combination of distraction while driving. Interestingly, the vast majority of people support severe punishment of people who use mobile phone while driving, but also use their own mobile device while driving. In a study [2], it was shown that drivers under 29 years most frequently use mobile device while driving. In analysis [4], it was concluded that sending messages during driving have effects on driver's actions needed to successfully operate the vehicle [4]

In Croatia, the campaign against the use of mobile devices on the road is very poor and should be improved to raise the awareness of the dangers of using mobile phones while driving. But this should be done in a good way and carefully, not through advertisements by the road that are also distracting the driver [5].

Within the study [6], significant differences are visible in the amount of fines provided for the offense of use of mobile devices while driving. Important differences are visible in the amount of the fine provided for the offense of using mobile devices while driving.

Money fines in the Republic of Croatia are 2 times lower than in Slovenia. Approximately 30.9% of respondents believe that the fine is not high enough, it is considered appropriate by 57.3%, while it is considered too strict by 15.4% of respondents. According to the survey, over 70% of people is phoning while driving, of which over 25% do it frequently. Every other driver reads received messages, and over 40% of drivers write messages while driving [7]. These numbers are higher than those from studies in the United States, because there is a much larger campaign against the use of mobile devices while driving, so drivers are aware of the dangers that can be caused by this type of distraction while driving. In the Slovenian research, when taking into account all ways of using mobile devices while driving, almost all respondents use a mobile device while driving.

3. RESEARCH ACTIVITIES

Research on the use of mobile terminal devices while driving, and measuring the reaction time of drivers was conducted in collaboration of two Department of the Faculty of Transport and Traffic Sciences, Department of Information and Communications and Traffic and Department of Traffic Accident Expertise.

The employees of Department of Traffic Accident Expertise, Željko Šarić, PhD and Goran Zovak, Assoc. prof, coordinated and prepared all the phases of the above research, conducted the survey on using mobile terminal devices and analyzed the scientific literature about the ways to measure the reaction times of drivers. They conducted the supply of equipment for the vehicles in which the examination was carried and together with other co-workers conducted experimental measurements to ensure the successful implementation of the project / research. They collected all the necessary information and at the end of measurement processed the results.

The employees of Department of Information and Communications, Dragan Peraković, Assoc. prof and Siniša Husnjak, mag.ing.traff., analyzed the possible application of terminal devices and applications as well as information - communication support to drivers during testing. They prepared terminal equipment for measuring and designed and synchronized system for communication between vehicles using the Arduino UNO Rev3 devices. In addition to, they actively participating in all other phases of the research.

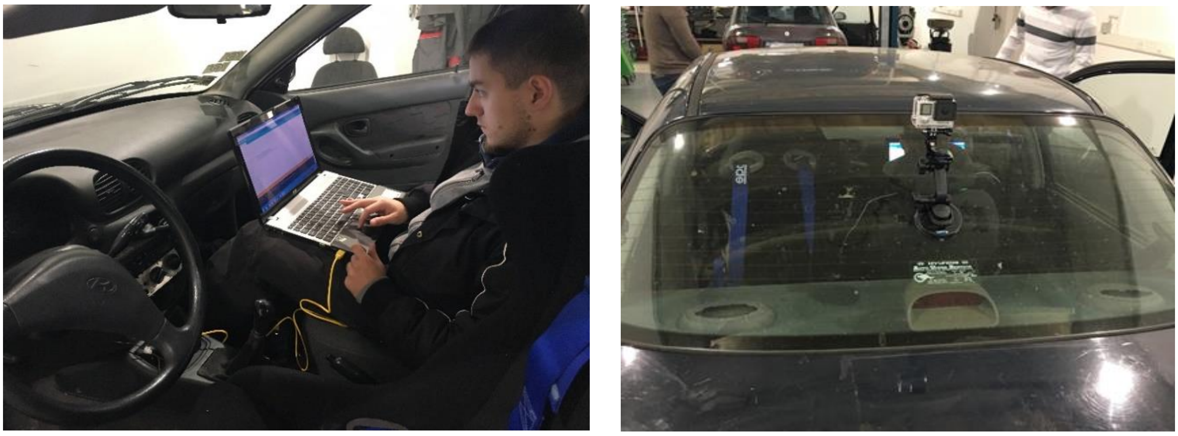

Figure 1 – Preparation of vehicles for testing

The project/research was implemented in several phases. In the first phase of the study data was collected on traffic accidents in the Republic of Croatia to give a general overview of the current state of road safety. Special attention has been focused on information about the causes of traffic accidents and the proportion of traffic accidents which cause was the use of the terminal device. The first phase of this research also included the analysis of research scientific and professional literature in the area of influence of terminal devices to reaction time of drivers. Also, the methodologies of testing the reaction times of drivers in road transport was analyzed.

The second phase of research focused on the development and implementation of the survey in which was tried to obtain the knowledge of how road users using the mobile terminal devices while driving, how and whether is the use of mobile terminal devices while driving lead them to possible incidents in traffic.

The third phase of the research included the analysis and evaluation of the results obtained from the survey. The equipment needed for examination was prepared and also the database in which was entered the test results. The target group and the method of implementation of testing was defined. Also, experimental measurements in order to eliminate possible negative impacts on the performance of research was carried out.

In the fourth stage of the research, examination and measure of the reaction times of drivers while using terminal devices was carried out. The measurement was carried out using two vehicles moved one after the other. Vehicles has been equipped with systems for monitoring the dynamics of the vehicle, electronic device Arduino UNO Rev3, GO PRO and high speed cameras, terminal equipment and other specialized equipment (Figure 2).

Figure 2 – Installed measuring equipment in vehicles for testing

In the first vehicle, there was a driver who was at that precise moment suddenly reacted by breaking on what the respondent, which was a driver in the second vehicle, had to react by intense braking. During the ride, the respondent at one point had to answer the mobile terminal device and answer a few questions but just at that moment when the vehicle in front of him was breaking and that forced the respondent to respond again. Devices installed in both vehicles gauged all time activation of braking devices and lighting devices that are used as an indicator to observe sudden danger. Cameras mounted in the vehicle followed the movement of the driver and his reactions while other equipment installed in the vehicle followed the dynamics of the vehicle, speed and stopping distance. It should be noted that respondents were not informed about the type, manner and purpose of the tests in order to achieve more relevant results.

The most important role in this measurement had the Arduino UNO Rev3 device which was merged with signal of braking system of the car to recorded moments of pressure of the brake pedal. How Arduino does not have a built-in clock with which can measure the time there was used additional module DS3231 Real Time Clock (RTC) which very accurately measures the time and in the case of a lack of power supply, has the ability to memorize time using the built-in battery. Each time when the Arduino device gets power, he started counting from zero in microseconds and milliseconds. How this internal clock is reset each time when the Arduino is off and is not synchronized with an external clock is was necessary to use any RTC module.

The measurement platform for providing tests were based on the communication between the Arduino devices and vehicles as shown with sequential UML diagram at Figure 3. Arduino was connected to the light of the car's braking system, so at the moment of pressing the brake pedal, power comes and based on that voltage is generated that Arduino record as a signal. Time lag between pressing the brake pedal and generating voltage is irrelevant in this case because of the very high speed movement of electrons in a wire, and it can be said that the point at which the brake pedal is pressed and the moment in which the Arduino recorded signal is the same moment.

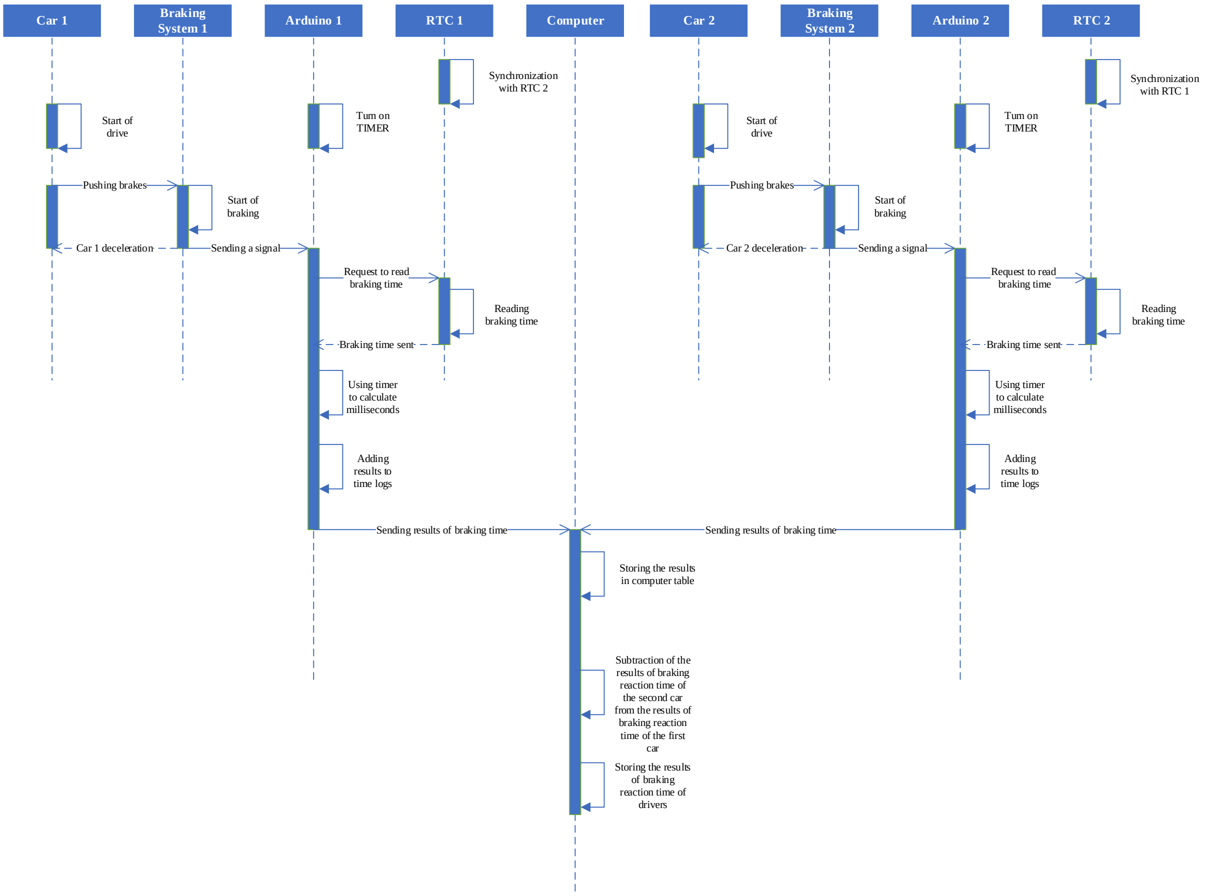

Figure 3 – UML diagram of the measurement platform for testing process.

The test is carried out under strictly controlled conditions because there was possibility of the collision of vehicles that were involved in a test due to emergency braking. After the test, in the last phase of the project, results were analyzed, also and the data about vehicle dynamics and driver behavior.

4. BUDGET SPENDING

Table 1 shows planned and realized activities with budget overview of this research in period of two years.

Table 1 – Planned and realized activities with budget overview.

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	Equipment for measuring and testing	79.000,00 kn	Go Pro Camera, Bluetooth devices, Terminal devices, DaschCam, Memory cards, Suction Cup Camera Mount, Cam holders	12.941,00 kn
2.	Organization of tests and conducting experimental tests.	5.000,00 kn	Education at the seminar for working with testing equipment	3.406,51 kn
3.	Conducting tests and measurements at the training ground	30.000,00 kn	Participation in seminars and gathering experience with the implementation of similar research	11.046,94 kn
4.	Publication papers	2.000,00 kn	4th Research Conference in Technical Disciplines, 2016, Slovakia	525.00 kn
	TOTAL	**116.000,00**		**27.923,65 kn**

5. RESULTS

The result of the project/research can be divided into two parts corresponding to the cycles of the project application. In the first cycle, in addition to the analysis of scientific and technical literature, specific research on the frequency of use mobile terminal devices while driving and habits of drivers in the Republic of Croatia were also carried out. The results of this part of the project were analyzed and processed in order to be the basis for the second cycle of implementation of this project.

In the second cycle, based on the actual operations and research, in the first part, model was set to implement examination about how the mobile terminal devices extent the reaction time of drivers. The necessary equipment was supplied and was accessed to the design and implementation of a model that could allow synchronized operation of both vehicles in order to obtain accurate measurement results. After trial testing and calibration of model test was carried out. Testing was carried out in several different terms and since the previous tests showed good results, it was decided to continue testing to collect as many samples and ensure the best possible relevance of the results.

5.1 Involvement of students

The research group of student from two Departments of Faculty of Transport and Traffic Science was established in order to implement the above phases of research, (Department of Information and Communications and Traffic and Department of Traffic Accident Expertise) which resulted in the following works:

- Drača, Igor: Impact of using mobile devices on road traffic safety, Thesis (Department of Traffic Accident Expertise, mentor Željko Šarić, PhD),
- Milković, Ivana: Research of the negative effects of usage of mobile devices in traffic, Final work, (Department of Information and Communications and Traffic, mentor Dragan Peraković, Assoc. prof.).

During the next period, in order to increase the sample of respondents and ensure even greater relevance, it is planned to carry out a few more tests on reaction time of drivers when using mobile terminal devices, so it is expected a few more thesis and final works to be made in this academic year.

5.2 Cooperation with industry and academia

During implementation of the project within the course Theory of the Vehicle Movement and Traffic Accident Expertise and Safety, graduate students had the opportunity to visit ORYX Centre for Safe Driving where they could try and personally operate the vehicle during certain distraction while driving.

5.3 Project applications

Based on spent budget, the experience and the results achieved in the first year of this research following projects have been submitted.

Table 2 – Overview of submitted project proposals.

Nr.	Funding scheme	Project name	Budget	Status
1.	The National Program of Road Safety 2016	The impact of using mobile devices on the driving behavior	548.500,00 kn	Evaluation of project application
2.	The National Program of Road Safety 2016	Technical inspection of fatal traffic accidents locations in the function of identifying black spots	480.000,00 kn	Evaluation of project application.
3.	The National Program of Road Safety 2015	Technical analysis of traffic accidents with motorcycles	480.000,00 kn	Rejected

Project *The impact of using mobile devices on the driving behavior*
Project description:

The goal of the proposed project *The impact of using mobile devices on the driving behavior* is to improve the prevention of using of mobile devices for drivers and to reduce the negative impact on the behavior of the driver while driving.

Project *Technical inspection of fatal traffic accidents locations in the function of identifying black spots*
Project description:

The proposed project will include an overview of all locations of traffic accidents with deaths in order to determine whether the specified locations are the hazardous locations where the lack of roads and its infrastructure is the eventual cause of traffic accidents. This way of identifying hazardous locations would enable a more efficient approach to rehabilitation because of recognizing of possible disadvantages of the road immediately after the first traffic accident with deaths and there will not be a period of three years, as before, for analysis of statistical data in order to identify possible dangerous place.

Project *Technical analysis of traffic accidents with motorcycles*
Project description:

The goal of the proposed project Technical analysis of traffic accidents with motorcycles would be to determine the most common causes of traffic accidents with motorcycles. All traffic accidents with killed motorcyclists would be analyzed, extraordinary technical inspection of motorcycles would be carried out and protective driver gear would be checked in order to give more relevant insight into the current state.

5.4 Obtained additional projects and funds

The project idea was enrolled within the Support program of the University of Zagreb (2015).

Table 3 – Overview of submitted project proposals.

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	Support program of the University of Zagreb	The impact of using terminal devices on the reaction time of drivers	Objectives are equal to the project idea within Prom-pro	5.540,53 kn

5.5 Published papers

Research on the impact of using mobile devices use on road traffic safety which was implemented in the first cycle of the project, resulted in the production of the thesis, which results were later published and presented through work:

- Šarić, Ž., Kunštek, A., Drača, I.: The impact of using mobile devices on road traffic safety, RCITD - Proceedings in Research Conference in Technical Disciplines, 2016. p. 67-73 (ISBN: 978-80-554-1271-9)

Results of other tests, particular those carried out in the second cycle of the project will be announced in the coming period as the part measurements and tests which have not been fully completed yet.

6. CONCLUSION AND FUTURE WORK

The development of technology has a major impact on people. Although today's mobile terminal devices are very useful in many everyday situations, provide access to numerous information, enables easy communication with other people and the fun, are not completely harmless. In addition to radiation that cause, they also affect on the safety of the users themselves, but also on other people. The use of mobile terminal devices while driving, tends to decrease the concentration, the extension of time to respond, change the path of movement and reduction of attention to the environment. Researchers conducted in the context of this project confirmed and evaluate the negative impact of terminal devices on road safety and emphasized the need for further research that would include evaluation of the impact of different types of services of terminal devices on the reaction time of drivers. Dissemination of the final results, except for the purposes of traffic accident expertise, will serve to inform the general public about the possible dangers and consequences arising from the use of terminal devices while

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ORGANIZATION OF HEMS OPERATIONS IN THE REPUBLIC OF CROATIA

ABSTRACT

Organization of HEMS service in the Republic of Croatia is not at a satisfactory level, from organizational as well as legal point of view. Regardless the great progress in the construction of transport infrastructure in recent years, sever number of injured people die or is permanently incapacitated due to insufficient first aid promptitude. By using helicopters and with better system organization, that number could certainly reduce.

In this paper, HEMS operations are theoretically defined, technical and technological helicopter features and equipment used for medical flights are described and proposition of organizational structure of helicopter emergency medical services in the Republic of Croatia is given.

KEY WORDS:

HEMS; helicopter; fleet; emergency; heliport; operative centre

1. INTRODUCTION

Helicopter Emergency Medical Service (HEMS) is the helicopter flight with the purpose of providing emergency medical assistance at places where the necessity of immediate and rapid transportation of medical personnel, medical supplies (equipment, blood, organs, and medications), sick and injured people exists.

Although a significant progress was made in the last decade, especially in the construction of road infrastructure, transport of sick and injured people requiring urgent medical transport by road is still not at a satisfactory level. Thereto, the data show that in spite of significant reduction in the number of traffic accident deaths, the Republic of Croatia is still in the European top by the number of people who died in traffic accidents on 100.000 inhabitants. As a logical choice for organizing more rapid and efficient connection system of all parts of the Republic of Croatia, aviation imposes as the fastest and therefore the best way to transport the injured, sick and other people who need emergency transport.

Military helicopters are currently used for the purpose of HEMS operations in the Republic of Croatia; however, this way of conducting HEMS operations is not at a satisfactory level from organizational or the legal point of view. HEMS system in Croatia has to be organized in accordance with the current European regulations of medical aviation. Equipment and aircraft must meet the safety criteria and ability for providing complete care to the injured and sick people.

Emergency medical aviation, primarily helicopters, increase the efficiency of the response to emergency medical cases and allow faster access to big medical centres that provide specialist and sub-specialist medical treatment. The experiences of countries (Germany, Austria, Switzerland, USA and United Kingdom) that have a vell-developed system of air emergency medical assistance indicate that almost immediate accessibility of medical staff and fast transport after the injury reduce the mortality by 35% to 52%. [1]

2. RESEARCH GOAL AND MOTIVATION

The fundamental purpose of this research is to reduce number of casualties and heavily injured in traffic accidents and other accident types where instantaneous first aid and evacuation speed to the hospital are of vital importance. The aim is to specify international standards and recommendations for establishment of HEMS system, determine the influential factors and relevant elements for its dimensioning, compare HEMS systems at national levels and make assessment of the specific requirements of local surroundings.

Although scientific and professional studies on this topic already exist, it is necessary to point out that no study has resulted in a model that was accepted in practice and results of most of the research cannot be applied in today's conditions due to elapsed period of time (e.g. fleet composition). Namely, HEMS system in the Republic of Croatia actually still does not exist (adequate fleet, operative centers, financing method, civil operator, etc.), but medical care is improvisatory performed by Croatian army helicopters.

From previous research in the field of intervention aviation and the use of helicopters for the purpose of emergency medical services in the Republic of Croatia, great contribution to this issue was given by Vukotić [2] by series of articles on emergency heliports which resulted in the book "Intervention heliports" in which the establishment of intervention heliports is explained, their use, equipment and labeling and it gives many useful technical and operational information, characteristics of intervention helicopters as well as conditions for patient transportation, etc.

Hereafter are listed some of the scientific papers that analyze HEMS operations issue and possibilities for appliance of HEMS operations in the Republic of Croatia. Papers of authors Galović et al. [3] and Steiner and Missoni [4], analyze technical characteristics and performance of intended helicopter fleet adjusted to specific requirements for intervention actions and give proposal for helicopter transport coverage with four operative centers. Steiner et al [5] analyse the possibilities of organization a national Search and Rescue (SAR)/Emergency Medical Service (EMS)/DISASTER management centers in Croatia. Zagorec [6] in his master's thesis analyzes the possibility of using the aircraft fleet for multipurpose, ie, for the purpose of HEMS, SAR and firefighting (FF) service. Other papers [7, 8, 9] analyze the current state of helicopter application in medical purposes in the Republic of Croatia, provide an overview of the fleet composition and system organization of European largest HEMS operators and ultimately give the proposal for more qualitative system organization in terms of fleet composition and accommodation of operative centers.

From numerous scientific papers dealing with HEMS system organization issues in the world, papers of author Wigman et al. [10] can be sorted out which provide an overview of dispatch criteria for trauma cases used by HEMS organizations within Europe, and search for similarities and differences, between countries and HEMS stations. In papers of authors Taylor et al. [11] and Akhtari et al. [12] a systematic review of economic evaluations of HEMS is given, in order to determine the economic cost of HEMS and the associated patient-centred benefits. a systematic review of economic evaluations of HEMS, in order to determine the economic cost of HEMS and the associated patient-centered benefits Paper [13] analyses the cost of HEMS in New South Wales and investigate the factors linked with the variation in the costs, coverage and activities of HEMS. Authors de Jongh et al. [14] evaluates the effect of the HEMS on trauma patient mortality and the effect of prehospital time on the association between HEMS and mortality.

Topic relevance is evident according to strategic objectives and action plans set out in a document "Development strategy of Faculty of Transport and Traffic Sciences of University of Zagreb" for the period from 2012 up to 2017. This especially implies to professional activities and connections with the enterprise – strategic objective 4 – measures 4.1. and 4.2. In addition, topic relevance is also evident from measure 4 (Promoting and innovation research) which is defined in a document "Strategic programme of scientific research at the Faculty of Transport and Traffic Sciences for the period from 2015. up to 2020.".

3. RESEARCH ACTIVITIES

An analysis of current state was made and guidance proposal for HEMS operations development in the Republic of Croatia is given. In the calculation of HEMS fleet choice, special attention was given to the selection of optimal aircraft (helicopter), whereat their performance should meet specific requirements of the region. Organizational structure of the HEMS system is proposed and optimal heliport locations which evenly cover whole Croatian territory by their mutual distances. Associate professor Andrija Vidović, PhD, was in charge for the development of this activity.

Statistical analysis on the number of casualties and injured in traffic accidents in the past few years (5-10 years) is also made. That number is set in correlation with World Health Organization's statistical indicators on the number of traffic accidents which cause death at the accident scene, during the transport to the health institution or 30 days after the accident. Emergency medical care's data analysis on number of persons who could have survived if they had been transported to hospital within a "golden hour", who are not directly traffic accidents victims can be an upgrade of this project assignment. Professor Sanja Steiner, PhD, was in charge for the conduction of this measure.

Analysis of existing European HEMS operators is made regarding fleet composition and number, flight and medical staff composition, operative centres location, number of heliports, system's financing method, etc. Preposition for a model that would correspond best to the specific Croatian requirements is wrought on the basis of aforementioned data. Arijana Modić, M Eng Traff, was in charge for the conduction of this activity.

A team of students (Igor Dulikravić, Tomislav Banić, Antun Meić Sidić and Matej Šmejkal) was in charge of conducting a comparative analysis of technical helicopter features that are commonly used in operations of largest European HEMS operators and on the basis of multi-criteria analysis, drafting the selection proposal of optimal helicopter for Croatian requirements. In addition, data on location topology of existing heliports in Croatia are collected. Data on the number and heliport topology were used as the basis for drafting location proposal for new heliports/operative centers.

4. BUDGET SPENDING

Of the realized activities which were planned, the funds are spent on parting to scientific-professional congress “HEMS Congress” (Table 1). The congress was attended by international experts in the HEMS field, helicopter manufacturers and representatives of HEMS operators, emergency medical cares, polices, firefighters, coast guard, etc. Besides discussion about medical and technical aspects of HEMS operations organization on the example of several operators, rescue services’ representatives have also demonstrated fire drills. The conference was very useful for getting broad and practical knowledge on system organization, fleet composition, medical and technical equipment, medical and flight personnel composition, etc., from operators who have perennial experience in HEMS.

Table 1–Planned and realized activities with budget overview

Nr.	Planned activity	Planned budget	Achieved	Cost
1.	Literature expenses (1st and 2nd year)	2,000	-	-
2.	Allocated research, Split Airport, travel, accommodation and daily allowance expenses	2,500	-	-
3.	Field research – interviewing or/and survey	2,200	-	-
4.	Organization of the event/scientific workshop – expenses for preparation, organization and promotion materials (1st and 2nd year)	6,000	-	-
5.	Scientific Congress HEMS Congress 2015, 14-16.05.2015., Massa, Italy,	6,900	Y	7,451
6.	Publication of research results in one of the journals A or B category – publication expenses for two papers (1st and 2nd year)	6,000	-	-

Other planned activities such as field research in Split as well as interviewing and surveying were not realized largely due to inability of achieving qualitative cooperation and necessary data provision by Ministry of Defence.

As for the paper publications and professional events/workshops organization, the same will be possible to realize after obtaining data which were not available during the project such as data on the average intervention duration, crew alert plan, times between receiving a call to helicopter take-off, intervention reasons (pregnancy, traffic accident, heart attack or stroke, etc.), distribution of intervention to primary and secondary transport, etc.

For qualitative publication of papers, it will be necessary to include emergency medical care data on the total number of casualties that are not direct victims of traffic accidents – heart attacks, strokes and other types of trauma.

5. RESULTS

5.1 Current state of HEMS system

The efficiency of rapid patients’ transport by emergency road vehicles in the Republic of Croatia is still not at a satisfactory level. Aggravating circumstances are traffic congestions, isolation of island inhabitants, low population density, inaccessibility of certain areas, etc. The results are inadequate response times, late first aid and subsequent specialist treatment of accident consequences causing death of a large number of casualties during transport from accident site to the hospital. The solution is the application of aviation as the fastest and best way to transport the injured, sick and other people who need emergency transport.

Regularity of using helicopters of the armed forces, equipment, licences of people who work out of military organization, insurance, payment and other elements that constitute the system are doubtful. Exploiting armed forces' helicopters in commercial purposes is not possible because armed forces are not legal entity or have an agency which would represent them and do not pay taxes. Operational capabilities of helicopters of the armed forces and of the Ministry of internal affairs are limited to a modest amount of accurate ones, lack of designated equipment and maladjusted configuration, especially military, helicopters for performing tasks of medical transportation.

Probability of survival increases proportionally to the reduction of time required for transportation of people to the hospital. In 65% of fatal accidents, death occurs within first 25 minutes. Up to 14 minutes after the accident occurrence, number of further complications which cause death affects 20% of the treated victims. After 28 minutes upon the accident occurrence, consequences and complications, including death, appear in 80% of the cases [15].

The losses from traffic accidents and incidents in the Republic of Croatia amount from 1.5% to 2% of Gross Domestic Product (GDP) of which 60% is related to injured people and 40% is related to material damage. In 2015, 348 persons died at Croatian roads – 210 (60.3%) persons died at the accident scene, 32 (9.2%) persons during transportation to the health institution, and 106 (30.5%) persons in the period of 30 days after the accident [16]. It can be concluded that 39.7% of the injured die on the way to the hospital or in the hospital, which suggests the need for establishing a faster and more efficient transport to the hospital. Statistical data imply that with the qualitative organization of HEMS operations, number of casualties due to late first aid could be diminished by one third – in 2015th 46 lives could have been saved – in the last 10 years more than 600 persons.

Data available by Ministry of Defence show that the price of a one-hour flight with a military helicopter is 48.000 kn. Helicopter transportation costs 8.5 million euros on a yearly basis for the transportation of little more than 500 patients. With the implementation of specialized helicopters for the same amount, in far better conditions, 2.500 patients could be transported. It is estimated that this service would cost 1.75 € per capita annually. In the European Union helicopter takes-off within three minutes after the call, while in Croatia the expectancy of military helicopter approval often lasts 40 to 60 minutes.

In year 2015, a pilot project financed from EU projects for establishing civil HEMS in Croatia was initiated. The project lasted 4 months and during that time 219 persons have been transported. Those were mainly patients with trauma (46), heart attack (47) and stroke (17) and emergencies of pregnant women (14) and children (14). Project limitation was that the helicopters were operative in the period from 6 a.m. until 6 p.m. In afterward projects of this type, it is necessary for the helicopters to be operational 24 hours a day.

Military helicopters are used for the purpose of medical transportation in the Republic of Croatia. Helicopters MIL MI-8 MTV 1 and MI 171-Sh from the Croatian Air Force fleet, apart from advantages such as high loading capacity, stability, possibility of transporting a big number of rescuers and equipment because of the spacious cabin, also features significant drawbacks when used for the purposes of administering emergency medical transport. Helicopters do not comply with the European civil flight regulation No 965/2012 on Air operations EU-OPS (Annex V, Part SPA, Subpart J), i.e., it has not been civil registered, it is not equipped with necessary medical equipment for administering medical help, emergency transmitter, pontoons for emergency landing on water. [17] They are not equipped with communication instruments for direct communication with the police, fire brigade, vessels, ambulance, search reflector, it does not have adequate winch designed for two persons, it has a large diameter of the main rotor, the cabin noise level is very high, and there is no intercom connection between the flight and the medical crew. Helicopter Bell 212 owned by MUP (Ministry of the Interior) complies partially with the technical requirements; however, the equipment is not adequate nor is the level of noise for civil requirements, which are the reasons, among others, why it was withdrawn from production. Three helicopters Bell 206 are not to participate in medical operations since they are single-engine ones, and EU-OPS regulations require twin-engine helicopters to be used for these purposes. Nova flota helikoptera H135 (2) i AW139 (2) se ne smije upotrebljavati za zadaće HEMS-a, već se koriste isključivo za potrebe nadzora granica.

5.2 Fleet selection

Helicopter represents an irreplaceable means in search and rescue operations, firefighting and emergency medical assistance due to its characteristics that allow safe flying at low altitudes and low speeds, small landing and take-off areas, hovering possibilities, equipping with latest communication and navigation instruments, usage of additional fuel tanks, etc. Apart from facilitating work to rescue services and emergency medical assistance, a helicopter is a means that increases largely the chances for survival of the victims or reduces the negative consequences that may result from long transport to the medical institution. The rescue operation using a helicopter at the same time represents the most complex and difficult rescue operation which very often requires action in adverse weather and night conditions and in the areas which are often far from the stipulated safe landing areas.

The plan to buy, i.e. purchase adequate helicopters has to be made in detail, analysing the needs of the system and economic efficiency of the entire investment. However, in purchase planning, several conditions have to be met regardless of the higher investment costs if an efficient system is to be established. The requirements that are set as obligatory to be fulfilled is for the helicopter to have two engines with sufficient spare power to operate in conditions of high ambient temperatures, sufficient space to transport two victims/injured, systems for flying in all meteorological conditions. It has to be fitted with instrumental flying instruments, day and night, have sufficient flying speed (not less than 200km/h) so that it covers its area in such a way that the flight to the boarding place and the transport of the victim to the hospital do not take more than 1 hour, high-located main and tail rotors (preferably with a tail rotor in an isolated housing). It has to have pilot space separated from the area for transporting patients, it has to have safety belts for the crew, medical staff, and patients, it has to have life vests, possibility of fast start-up, communication instrument for direct communication between the pilot, emergency doctor, auxiliary staff with the doctor at the accident site. Boarding and disembarking of patients on stretchers have to flow smoothly and should not disturb the patient's comfort. External dimensions of helicopters have to be as small as possible in order to enable landing on as many places as possible. This refers especially to landing in urban areas that are space-limited and on the buildings of minor hospitals that have no heliports. It is important to limit the helicopter weight in order to improve the performance and to reduce the impact of rotor operation. This may be special obstacle in the vicinity of the accident site and in urban areas where there are usually many passive observers. It is necessary to reduce the impact of vibrations and noise to the minimal level.

It is important to make the selection of fleet whose performances need to satisfy the specific requirements of single operative areas. In the function of configuration characteristics, for operative areas of greater heights above sea level, specific-purpose means of higher climbing speeds and flight peaks have to be selected and in the function of climatic characteristics for operative areas of higher values of mean air temperatures the means of greater propulsion power are necessary. Although the best solution is to use the helicopter precisely for the defined purpose, the current economic situation in the Republic of Croatia and the obvious shortage of helicopters used for emergency aviation indicate the need to use helicopters as multi-purpose operative.

For the HEMS operative purposes, in the world today, the following models are mostly used (technical data for most used helicopters in HEMS operations can be seen in Table 2): Eurocopter EC 135 (H 135), Eurocopter EC 145, AgustaWestland AW 109, MBB/Kawasaki BK 117 B2, McDonnell Douglas MD 900 Explorer, AS 365, Bell 222 B and Bell 412 HP. Each of these models showed its quality during several years of their implementation in rescue actions. If it were assumed that helicopters are of European production or later models, optimal helicopters would be AgustaWestland AW 109 and Eurocopter helicopters (now part of Airbus Helicopters), AS 365-NG, EC 135 (H 135) or EC 145 (H145), or combination of these two models. Regardless of the number of ordered helicopters and of the manufacturers, it is essential that all the helicopters are manufactured by the same manufacturer in order to ensure fleet standardization which eventually results in substantial reduction in the costs of purchase, maintenance, and training of the flight and auxiliary crew. For the Republic of Croatia, the best solution for a long-term period would be combined purchase of 6 to 10 Eurocopter (Airbus) models EC 145 and EC 135. EC 145, namely, is bigger (it has the biggest cabin in the class), which provides transport and treatment of several persons if necessary, whereas EC 135 could be used for the transport operations of fewer injured / patients. The fleet should consist of 60% models EC 145 and 40% EC 135 models. Helicopters of the H135 family add up to 50% of the European fleet, while the H145 family is represented with 20%. [18]

Table 2 – Technical specifications of most frequently used helicopters in HEMS operations

Helic./Spec.	**EC 145**	**H 135 (EC 135)**	**BK 117 B2**	**MD 900 Explorer**	**AW 109**	**AS 365-NG**
Number of engines	2	2	2	2	2	2
Max. power per engine	550 kW	473 kW 498 kW	527 kW 560 kW	485 kW	320 kW	625 kW
Cruising speed	246 km/h	254 km/h	248 km/h	250 km/h	250 km/h	269 km/h
Max. operative altitude	6,000 m	6,095 m	3,000 m	6,000 m	4,570 m	5,825 m
Range	680 km	620 km 635 km	540 km	550 km	600 km	792 km
MTOM	3,585 kg	2,980 kg	3,350 kg	2,835 kg	2,600 kg	4,300 kg

Source: [18, 19, 20, 21]

5.3 Locations of operative centres

HEMS is usually organized in such a manner that the state territory is covered by a distribution of helicopter bases which cover the entire state, so that the operation radius allows arrival of helicopters to the accident site within 20 to 30 minutes, and the transport of the injured to the hospital within one hour. The plan of EMS service was projected by dr. William Cowley who invented a phrase „golden hour"– if ill or injured person is transported in hospital inside first hour from the time when accident has occurred, the chance of surviving is very high. The delay within the first hour after the accident not only reduces the chances for survival but results also in other harmful consequences – the costs of treatment and medical rehabilitation increase, as well as the losses due to unnecessary invalidity and similar. The efficiency of emergency operations can be increased by overlapping of the operative areas, thus increasing the effective operative coverage of the area, i.e. reducing the time necessary for intervention.

Recommendations indicate the importance of connecting medical helicopters with the clinical-hospital centres at the expense of helicopter operation radius. The solution would be to divide the Republic of Croatia into four Operative centres with their areas of responsibility regarding the existing four clinical-hospital centres. Regarding also the existing infrastructure for helicopter handling, the division system of the Republic of Croatia to Operative centres would include the Main Operative Centre Zagreb with helicopters accommodated at the airport Lučko, Operative centre Rijeka with helicopters located at the airport Krk, Operative centre Osijek with helicopters at the airport Čepin and the Operative Centre Split with helicopters at the airport Resnik. An even better solution would be the addition of a fifth operative centre, Operative Centre Dubrovnik with helicopters at the airport Ćilipi, which, apart from the four proposed operative centres, would fully meet the requirement of covering the Croatian territory. For an even better coverage of the area, especially during the tourist season, one helicopter with three crews could be accommodated in the alternative operative centre Zadar with the headquarters at the Zemunik Airport. Location of centres and action radius is shown on Figure 1. The helicopter for this alternative operative centre can be provided from the operative centre Zagreb or from the operative centre Split in case the model with five operative centres is applied. More qualitative solution is to arrange helicopter accommodation within a clinical hospital centres, but due to deficiency of all necessary licences for existing heliports and the fact that all clinical hospitals do not have heliports, the paper presents a proposal for helicopter accommodation to nearby airports. On the other hand, as it is likely that a potential new fleet would not be used for HEMS needs exclusively but would be multipurpose accommodation at airports seems like a logical solution.

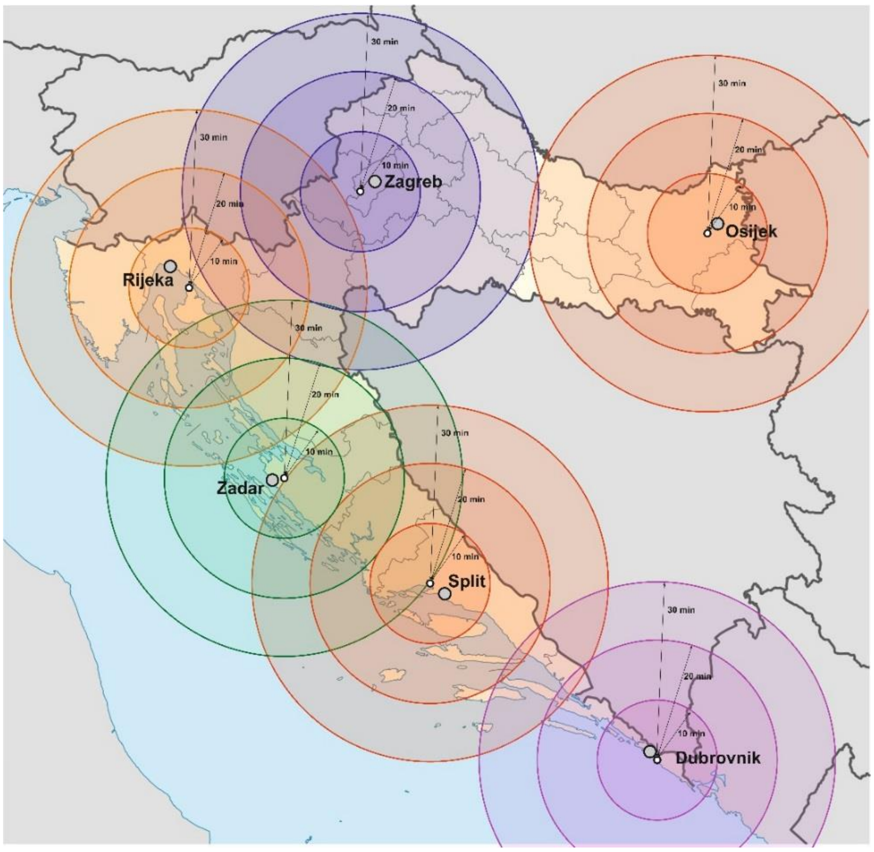

Figure 1 – Proposal of the locations of operative centres [8]

5.4 Organization of the system

A barrier to a more successful functioning of HEMS and SAR operations in the Republic of Croatia consists in a very complicated and bureaucratized system of issuing helicopter take-off clearances. In order to dispatch a helicopter to a rescue operation, many factors to justify the dispatch to perform the task have to be satisfied. Since this is an expensive operation, it is necessary to determine that the helicopter is the only transport means which can perform the rescue operation on time. Through good organization of transport which results in good connection of local and regional centres of medical points which provide emergency interventions, a responsible and correct decision can be made within a short period of time about who requires the helicopter transport. National Protection and Rescue Directorate (Državna uprava za zaštitu i spašavanje) has been established which should manage and coordinate all the activities in case of catastrophes and major accidents. The Agency was developed by the reorganization of the previous Centre for Monitoring and Alerting and the free telephone number 112 for reporting catastrophes and accidents has been introduced by the Republic of Croatia in compliance with EU, but the existing emergency services (police, fire brigade, and ambulance) still have different phone numbers (192, 193, and 194 respectively). The National Protection and Rescue Directorate has the task to perform interventions of various purposes – search and rescue, medical care, fire fighting, reconnaissance, coordinating the national plan with relevant ministries, organization of the main coordination centre which combines different emergency services. As part of the main coordination centre the communication and information centre is also organized with a single phone number for the needs of all types of interventions. The main coordination centre manages further coordination of intervention tasks, depending on the location and type of accident, the task is assigned to local coordination centres. The main operative centre would take care of the organization and coordination as well as system management. The helicopters and the crew would be available 24 hours at their central airports. The important task of the agency is the choice of optimal specified-purpose transport means, equipment and logistics. Apart from the government administration operative the emergency operative can be supported by the non-governmental organizations – professional societies and private enterprises. The realization of coordinated cooperation of the military and civil field of operation is of extreme importance. It is necessary to establish a training centre for specialized staff. The professionally qualified operative teams for various types of interventions can be sent to emergency humanitarian or commercial missions abroad.

Regarding organization, the system has to be unique, efficient, with fast and reliable communication channels and decision-making system. For the operation of HEMS services in the Republic of Croatia coordination of several sectors is necessary, including: The Ministry of the Interior, Croatian Army, Mountain Rescue Service, clinic and hospital centres and County Alerting Centres. The equipment and aircraft have to satisfy the flight safety criteria and the possibilities of providing full care for the injured and the patients. Besides, they have to be in compliance with the European regulations that refer to aviation and the health care system.

The organization of the system would be such that the call for the helicopter would be sent by the medical staff, ambulance at the accident site or hospital, by making the calls, depending on their location, directly to the relevant operative centre for the respective area thus shortening the procedure and the time for reaction.

The provision of medical assistance services by means of an emergency medical helicopter results in the system which charges such services from various organizations. The helicopter services of medical assistance are financed from the state budget and the local authorities, through state insurance funds, medical funds, and private insurance societies, automobile clubs, mountaineering societies and private enterprises. The initial capital to establish the HEMS operative is ensured by the state. Apart from urgent transport and treatment of the injured from the accident site, the financial profit of HEMS service can be realized through additional services such as the transport and treatment of the diseased/injured between the hospital centres, transport of organs, blood and blood plasma and drugs, by urgent transport of physicians if necessary and by transporting the victims of foreign nationality to their central hospitals. Besides, because of the helicopter distribution the service could provide their services also beyond the borders of the Republic of Croatia.

The past research of the problems regarding the use of helicopters for medical transport/treatment services and the proposals of concretized models for the establishment of the system in the Republic of Croatia, either as an autonomous system or as a segment of the system of wider civil protection, are sufficient base for the full implementation of the system. The assumptions for the operationalization of the proposed model primarily refer to the institutional and legal coordination, both due to the integration in the wider region and equal participation in regional and international missions, optimization of operative procedures through centralization of operative management functions, of more rational usage of technical and personnel resources, increase of system efficiency and due to the social care manifestation for the lives of citizens.

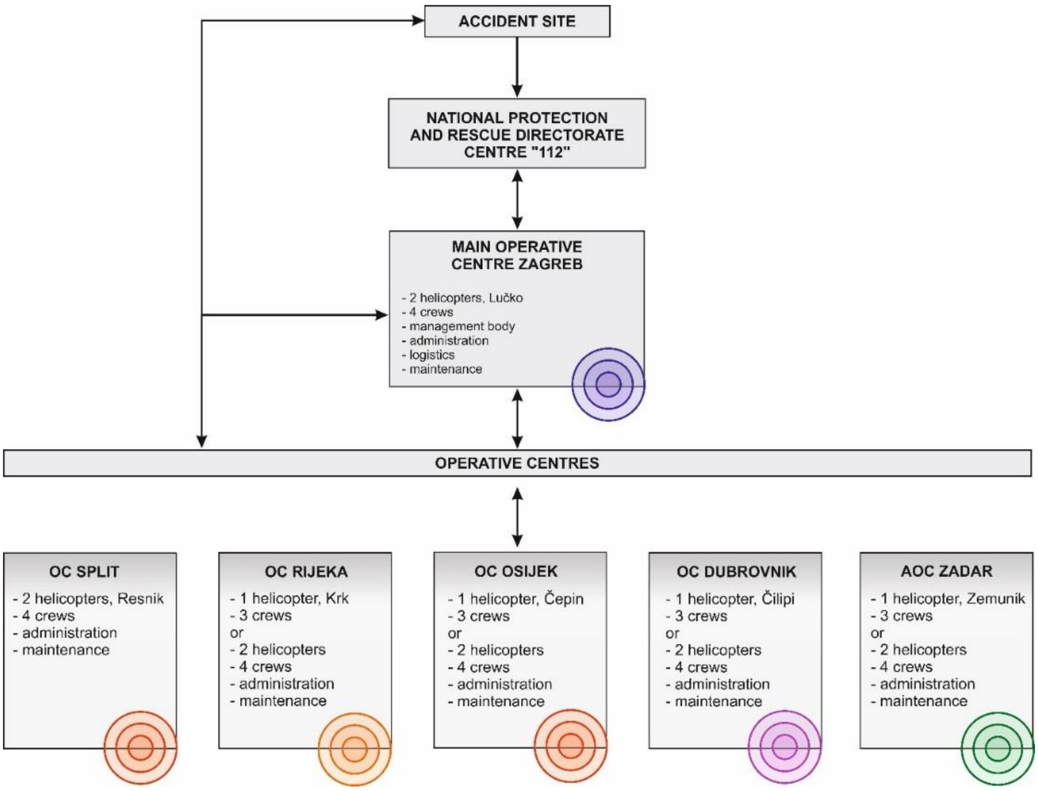

Figure 2 – Simplified scheme of the HEMS system organization [8]

5.5 Involvement of students

Five air transport graduate students were involved into development of this project. Students' tasks are defined in Chapter 3.

The student task was to make a comparative analysis of technical helicopter features that are commonly used in operations of largest European HEMS operators and on the basis of multi-criteria analysis draft the selection proposal of optimal helicopter for Croatian requirements.

It is expected that part of the students who participated in this project will find a motivation for writing a master's thesis on this subject, and an application for Rector's award for the academic year 2016/2017 is planned. Creating a mutual conference paper for conference IMSC 2017 is also planned.

5.6 Obtained additional projects and funds

As the research extension of the project PROM-PRO, in 2015th a project Grants to scientific and artistic research financed by University of Zagreb was applied and accepted. Table 3 gives a short overview of project and allocated funds.

Table 3 – Overview of submitted project proposals

Nr.	Funding scheme	Name of project or grant	Short description	Budget
1.	Support programme for scientific and artistic research of University of Zagreb	Organization model of HEMS operations in the Republic of Croatia	The proposed research belongs to the category of development research which will represent the real overview of actual HEMS (Helicopter Emergency Medical Service) operations' condition in the Republic of Croatia in order to develop guidelines for more qualitative system organization in the terms of fleet composition, location of operative centres and heliports and the organizational structure of HEMS operations itself.	3,861.89

6. CONCLUSION AND FUTURE WORK

It is necessary to approach to the modernization of organization and equipment of emergency medical assistance. It does not have to be an expense, but significant effects of treatment cost reduction and other exterior costs (caused as an outcome of frequent death and injuries) could be expected. The system in organizational terms has to be unique, efficient, with fast and reliable communication and decision making system.

Equipment and aircraft must meet the safety criteria and enable provision of complete care to the injured and sick people and have to be in accordance to all European regulations concerning aviation and health.

There are situations in which only the helicopter gives hope to patients and the injured. In the Republic of Croatia, at the accident site, the fatalities amount to 60.3% of the total number of fatalities, during transport to the medical institution 9.2% and during the first 30 days of medical treatment 30.5%. [16] Precisely the fact that before arriving to the medical institution almost one fourth of the total number of victims loses their lives is the main argument for the introduction of medical aviation.

For system financing, state budget funds can be used as well as state insurance funds, health care funds, private insurance companies, automobile club funds, upon the model of most HEMS operators in the world.

Only one case of avoiding permanent disability economically justifies organization and financing of rescue service, including helicopter usage. If helicopter emergency service in Croatia at this moment reduces patients' residence in intensive care for two days by case, it justifies its existence.

The establishment of HEMS system is not an additional cost but improvement, through the expected reduction in the number of fatalities and treatment costs. Indirect costs which result from temporary or permanent loss of working capability, are also reduced. The human effect of rescuing human lives is difficult to measure by means of objective economic units, whereas the subjective character does not need to be specially emphasised.

As the analysis of potential number of people who could survived if the HEMS system had been organized more qualitative included only traffic accident victims, for future analysis which would accurately indicate all the benefits of the HEMS operations implementation, people who died from other causes such as heart attacks and strokes should be taken into account.

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