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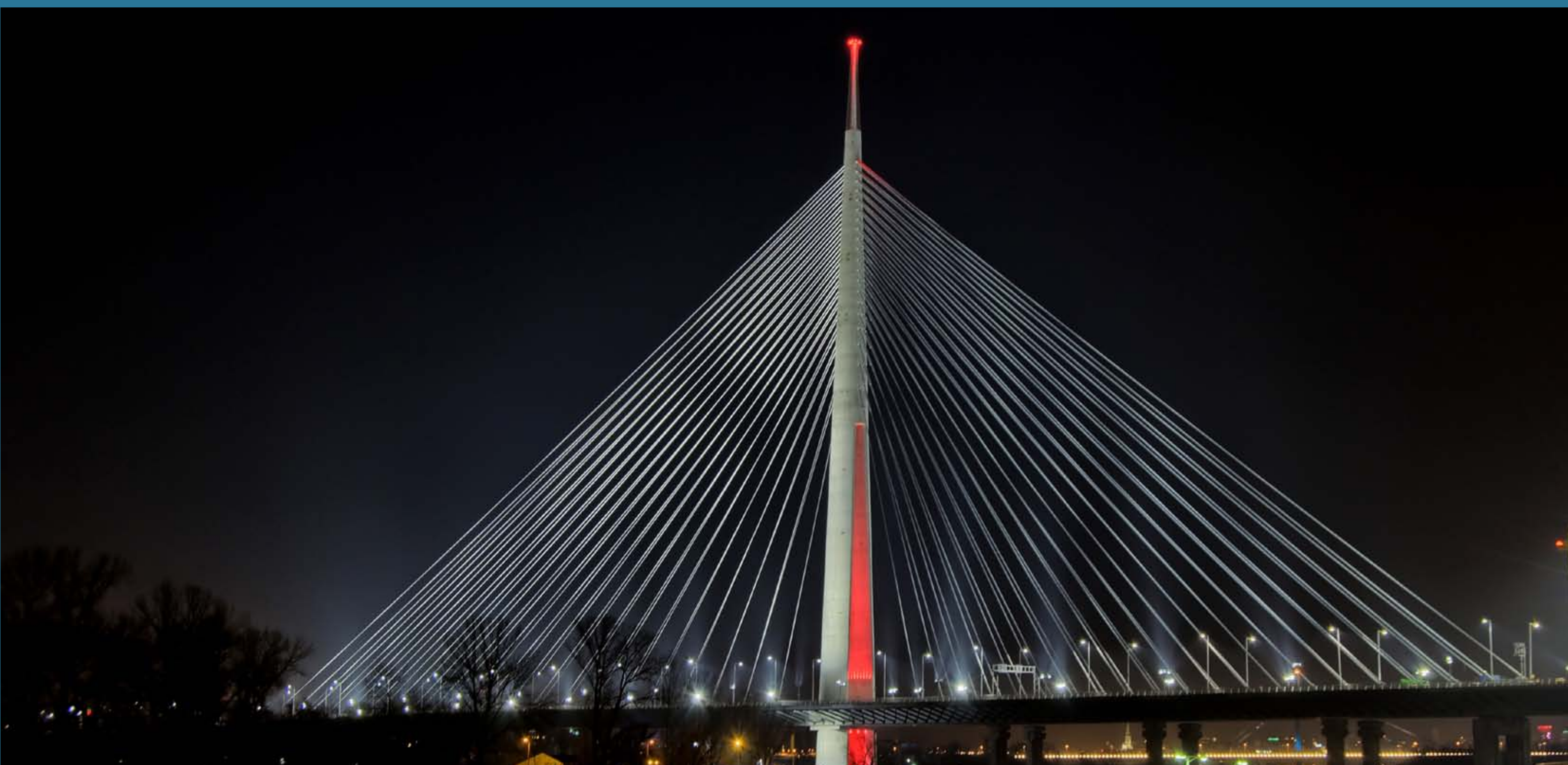

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ICTTE Belgrade 2012 Conference Director's Speech

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

I am delighted to welcome you to Belgrade and to the International Conference on Traffic and Transport Engineering, 2012. It is a pleasure to be here with you today at the beginning of this two-day conference on traffic and transport engineering.

This conference presents the perfect example of globalization in transportation industry. Nothing illustrates this better than the number of papers from more than 20 countries worldwide. I hope that many conclusions made here will be the key drivers of future development in global transport sector for passengers, cargo and infrastructure.

Naturally, we are ready to share our experience of creating what we think is the world's largest and most successful example of transportation industry in all transport modes.

By providing essential transport links, between ourselves, our companies, universities and countries, we are vital part of global community for integrating and connecting regions all over the world.

International Conference on Traffic and Transport Engineering, ICTTE Belgrade 2012, will be the first conference organized by Scientific Research Center Ltd and its International Journal for Traffic and Transport Engineering (IJTTE). My special thanks and encouragement in their work go to our dear colleagues and friends, key speakers, as well as to our partners: City Net Ltd., South-East Europe Transport Observatory (SEETO), "Kirilo Savić" Institute and Innovation Center - Faculty of mechanical engineering, University of Belgrade. And finally, I would like to mention great support from Center for the promotion of science, and Faculty of transport and traffic engineering, University of Belgrade thanks to which we are jointly hosting this conference.

I wish us all fruitful exchanges during these two days; constructive, testing ideas and identification of the steps we will be taking in the future.

Thank you for your attention.

ICTTE 2012 Director
Dr Olja Cokorilo

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Session 1: Transport Optimization Problems

ASSIGNMENT OF FLOATING BULK HANDLING CRANES IN INLAND WATERWAYS: A COMPARISON OF DIFFERENT METAHEURISTIC TECHNIQUES

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Abstract: In this paper floating bulk handling cranes have been assigned to serve vessels placed in nodes within inland waterways. In order to utilize handling devices efficiently, and to minimize the waiting time, as well as the total service time of vessels, it is necessary to consider assignment of handling equipment to unloading locations and orders of servicing different unloading locations. Assignment of handling devices is very complex combinatorial optimization problem. It can be considered as a binary mathematical programming model. Such approach is appropriate only for small instances of the problem, but larger instances can not be solved in a reasonable amount of computing time. Another way is to apply some of the well-known metaheuristic techniques and to achieve good (near-optimal) solution at a reasonable computational cost. In this paper we apply several metaheuristic approaches to solve the problem. In particular the metaheuristics under consideration are: simulated annealing, genetic algorithm, tabu search and bee colony optimization. The metaheuristics are compared in terms of simplicity by considering their number of parameters and solution quality. Solution quality comparisons are being made over the same problem instances.

Keywords: handling devices, assignment, metaheuristic techniques

1. Introduction

In this paper one phase of gravel distribution by inland water transportation is considered. After loading and transport, vessels are unloaded by floating bulk handling cranes. Nodes are locations within inland waterways where unloading process is carried out usually by relatively small number of handling facilities. Providing efficient and cost effective service of loaded vessels requires appropriate allocation plan for handling cranes. In order to utilize handling devices efficiently, and to minimize the waiting time, as well as the total service time of vessels, it is necessary to consider assignment of handling equipment to unloading locations and orders of servicing different unloading locations.

In this paper static assignment problem is considered where all tasks service ready times are already known when the scheduling plan is determined.

Allocation planning of handling devices for barge unloading is very complex combinatorial optimization problem. It can be solved by binary mathematical programming but only for small instances of the problem. Since larger instances can not be solved in a reasonable amount of computing time, different approach is required. Good (near-optimal) solution at a reasonable computational cost could be achieved by application of some of the well-known metaheuristic techniques.

In this paper several metaheuristic approaches were applied to solve the problem. In particular we considered and compared in terms of simplicity four metaheuristics: simulated annealing, genetic algorithm, tabu search and bee colony optimization. The metaheuristics are compared by considering their number of parameters and solution quality. Solution quality comparisons are being made over the same problem instances. The metrics that could provide meaningful information without access to the optimal solution for the problem instances are the goal function value and the computing time of the algorithms.

The goal of this paper is to start the decision support system development. The system might be used by a dispatcher when it is necessary to make decisions in real time situations.

2. Problem description

The problem of handling devices allocation to loading/unloading tasks may be introduced in the following way. For a given collection of barges find a set of assignments to minimize the sum of the service times including waiting for service and handling devices transfer times.

The problem of this type may be considered as dynamic handling devices scheduling problem, where tasks service ready times are known after the beginning of the planning interval, or as static problem, where all tasks are already known when the scheduling plan is determined. In this paper, only static problem is studied [Vidović and Vukadinović (1996)].

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3. Description of the metaheuristics

In this section, the basic principles of each metaheuristic under consideration are briefly described. For a general description the reader is referred to [Beasley (1993)] and [Lučić and Teodorović (2001)].

3.1. Simulated Annealing

The principle of the Simulated Annealing (SA) metaheuristic is deduced from the physical annealing process of solids. Kirckpatrick et al. (1983) and Cerny (1985) proposed the use of SA for combinatorial problems. Their work is based on the research of Metropolis et al. (1953) in the field of Statistical Mechanics.

As far as our implementation is concerned, the following choices have been made. In order to determine the value of the initial temperature, T_{begin}, it is computed by solving the expression:

$$P_a = e^{-\frac{\Delta C}{T_{begin}}}$$

and hence:

$$T_{begin} = \frac{-\Delta C}{\ln P_a}$$

Here ΔC represents the average deterioration value, which is computed as the cumulative value of the values of all worsening moves possible from the initial solution, divided by the number of moves that have caused a deterioration of the objective function value. Parameter P_a represents the acceptane fraction, i.e. the ratio of those accepted to the total number of generated moves. The cooling function we use for the reduction of the temperature is a simple geometric function. The temperature at iteration t, T_t, is obtained from the temperature of the previous iteration as follows:

$$T_t = R \cdot T_{t-1}$$

where R represents the cooling rate.

Parameters of the SA are:
Acceptance fraction (P_a): This is the percentage of accepted moves obtained when performing 30 move cycles on the initial solution. This parameter is used to fix the initial temperature. Here the value assigned to this parameter is 0,8.

Cooling rate (R): This is the fraction by which the temperature is reduced in the geometric temperature function. Here the value assigned to this parameter is 0,9.

3.2. Genetic algorithm metaheuristic

Genetic Algorithm was conceived by Holland (1995). GA is a population-based evolutionary heuristic, where every possible solution is represented by a specific encoding, often called an individual. Usually GA is initialized by a set of randomly generated feasible solutions (a population) and then individuals are randomly mated allowing the recombination of part of their encoding. The resulting individuals can then be mutated with a specific mutation probability. The new population so obtained undergoes a process of selection which probabilistically removes the worse solutions and provides the basis for a new evolutionary cycle. The fitness of the individuals is made explicit by means of a function, called the fitness function, which is related to the objective function to optimize. The fitness function quantifies how good a solution is for the problem faced.

In GAs individuals are sometimes also called chromosomes, and the position in the chromosome are called genes. The value a gene actually takes is called an allele (or allelic value). Allelic values may vary on a pre-defined set that is called allelic alphabet.

Let P be a population of N chromosomes (individuals of P). Let $P(0)$ be the initial population, randomly generated, and $P(t)$ the population at time t. Then the GA generates a new population $P(t+1)$ from the old population $P(t)$ applying some genetic operators.

The four basic genetic operators are:

1. Reproduction: An operator which allocates in the population $P(t+1)$ an increasing number of copies of those individuals with a higher fitness value than the population $P(t)$ average.

2. Parent selection: The parent chromosomes are selected randomly according to their fitness ratio. This method is similar to roulette wheel selection.

3. Crossover: A genetic operator is activated with a probability p_c . It takes as input two chosen individuals (parents) and combines them to generate two offspring. In this approach we use two point crossovers based on a random process. In our permutation GA a crossover may generate infeasible children. In order to keep feasibility crossover operation is performed as it is explained in Drenovac (2012).

4. Mutation: An operator that causes, with probability p_m, the change of an allelic value of a randomly chosen gene. In this approach we randomly select two vertices and change their positions.

Parameters of the GA metaheuristic are:

N: This parameter indicates the size of population and here the value assigned to this parameter is 50.
p_m This parameter indicates the crossover rate probability and here the value assigned to this parameter is 1.
p_c This parameter indicates the mutation rate probability and here the value assigned to this parameter is 0,01.

3.3. Tabu search metaheuristic

Tabu search (TS) was conceived by Glover (1986). The idea behind the TS is to start from a random solution and successively move it to one of its current neighbors. Each time a move is performed and linked, the pairs of nodes are added to the tabu list that includes inhibited moves. From a given solution, not all neighbors can usually be reached.

A new candidate move in fact brings the solution to its best neighbor, but if the move is present in the tabu list, it is accepted only if it decreases the objective function value below the minimal level so far achieved (aspiration level). This process is repeated until a stopping criterion is reached. The stopping criterion of this algorithm is reaching the limited number of iterations between the current iteration and iteration in which the best solution is reached.

Parameters of the TS metaheuristic are:

Length of tabu list (L): This parameter indicates the size of the tabu list and is considered a fixed number. Value assigned to this parameter here is 5.

Long term memory (G): This parameter determines whether or not a long-term memory is used. In this paper implementation with long-term memory is applied. Frequency is weighted by G broadening the foundation for selecting preferred moves. Value assigned to this parameter here is 5.

3.4. Bee Colony Optimization

The Bee Colony Optimization (BCO) is inspired by bees' behavior in the nature. The basic idea behind the BCO is to create the multi agent system (colony of artificial bees) capable to successfully solve difficult combinatorial optimization problems.

Lučić and Teodorović (2001) were the first who used basic principles of collective bee intelligence in solving combinatorial optimization problems. Population of artificial bees searches for the optimal solution. Every artificial bee generates one solution to the problem. The algorithm consists of two alternating phases: forward pass and backward pass. During each forward pass, every bee is exploring the search space.

Having obtained new partial solutions, the bees return to the hive and start the second phase, the so-called backward pass. During the backward pass, all bees share information about the quality of the solutions (i.e. the value of objective function). During the backward pass, every bee decides with a certain probability whether it will advertise its solution or not. The bees with better solutions have more chances to advertise their solutions. The remaining bees have to decide whether to continue to explore their own solution in the next forward pass, or to start exploring the neighborhood of one of the solutions being advertised. Similarly, this decision is taken with a probability, and therefore better solutions have higher probability of being chosen for exploration.

The two phases of the search algorithm, forward and backward pass, are performed iteratively, until a stopping condition is met. The possible stopping conditions could be, for example, the maximum total number of forward/backward passes, the maximum total number of forward/backward passes without the improvement of the objective function, etc.

The BCO algorithm parameters whose values need to be set prior the algorithm execution are as follows:

B - The number of bees in the hive. Value assigned to this parameter here is 10.

NC - The number of constructive moves during one forward pass. Values assigned to this parameter here are 0 or 1.

4. Framework for the metaheuristics

In this section we define framework for all metaheuristics that are used for solving this problem.

4.1. Initial solution

We assume a random initial solution. This will help evaluate the methods under study here based on their merits alone, and independent of initial solution.

4.2. Solution representation

Solution of the problem represents the scheduling order. In SA, GA and TS every solution is shown with one vector. The length of the vector is the number of loading/unloading locations plus the number of handling devices minus one. Elements of this vector show the assigned device for each location as well as the frontier between location queues for every device. In BCO the partial solution consists of already chosen locations.

Problem definition, datasets and cost function are common to all the algorithms. All algorithms are executed on one computer.

4.3. Neighbor solution

A neighbor solution is a feasible solution, and in SA, GA and TS it is obtained by random alternation of two elements of the solution vector. In BCO, the solution is generated partially.

5. Comparison

Four different metaheuristics were chosen to solve the problem and to compare solutions. The metaheuristics that we chose were: simulated annealing, genetic algorithm, tabu search and bee colony optimization. The general reasons for selecting these metaheuristics are popularity, applicability and handling high dimensionality. Eight instances of different size have been selected for comparison.

Meaningful metric for algorithmic complexity is the number of parameters used in the algorithm. Parameters are the configurable components of an algorithm that can be changed to alter the performance of that algorithm. Each major type of metaheuristic has a number of parameters that must be set before the algorithm execution. In chapter 3 (Description of the metaheuristics) we listed basic parameters required for selected metaheuristics. Metaheuristics SA, TS and BCO have two parameters while GA has three. We chose one parameter set and run the algorithms.

To compare two algorithms in terms of solution quality, a metric to represent the solution quality is needed. In this discussion of the potential metrics to be selected, we assume that solution quality comparisons are being made over the same problem instances.

Comparisons over different instances are generally weaker, as the instances being compared often have different structures and almost certainly have different optimal values and difficulties. Of course, the best metric to use in solution quality comparison is the deviation of the solutions returned by the algorithms from optimality. Finding the average percentage error over all problems is common practice, as this strategy gives equal weight to each problem instance. However, using this metric requires knowledge of the optimal solution for every problem instance tested. This is a presupposition that likely cannot always be made. If optimal solutions are available for every problem instance tested upon, the problem instances being considered are likely not large enough, since exact algorithms can provide solutions in reasonable runtimes. This introduces the need for new metrics that can provide meaningful information without access to the optimal solution for all (or potentially any) problem instances. Two popular metrics that fit this description are deviation from best-known solutions for a problem and deviation between the algorithms being compared.

While it is necessary that a metaheuristic demonstrate good solution quality to be considered viable, having a fast runtime is another critical necessity. If metaheuristics did not run quickly, there would be no reason to choose these approaches over exact algorithms.

There are other forms of computational complexity comparison that do not rely on runtimes. One of the most intriguing is counting the number of representative operations the algorithm uses. In this scheme, the number of a selected set of bottleneck operations is compared without any regard for the total execution time of the algorithms being compared.

In this paper the metrics for comparing the algorithms are goal function value and runtimes of the algorithms.
In order to demonstrate the proposed metaheuristics, the following example was tested.

There are three handling devices and nine nodes to be served. Handling devices move at the same speed which is 5 km/h. Their unloading productivities are 100 tons/h, 150 tons/h and 200 tons/h respectively. The nodes have demand shown in Table 1.

Table 1
Demand in loading/unloading locations

Node	1	2	3	4	5
Demand	4000	3000	5000	6000	2000
Node	6	7	8	9	
Demand	3000	2000	2000	5000	

Transportation network with distances between network nodes is given in Figure 1.
Handling devices are placed at the depot node.

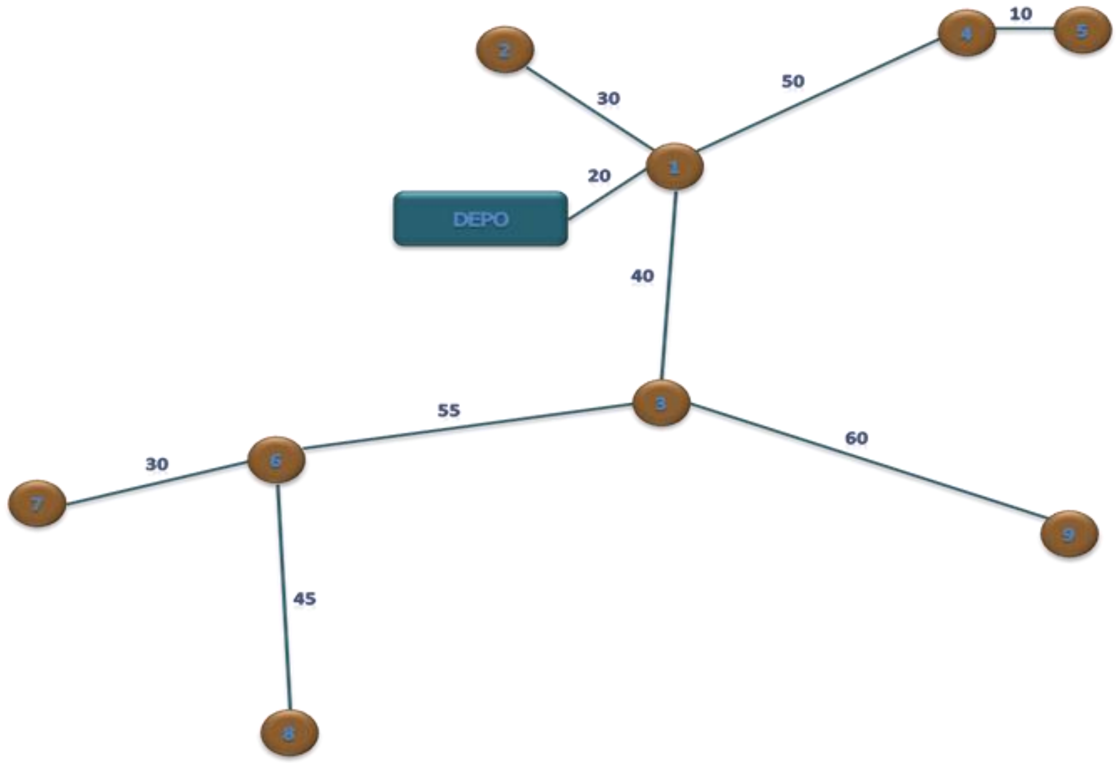

Fig. 1.
Example of transportation network

We composed instances choosing the nodes from transportation network as it is shown in the first column of Table 2. Comparison of the metaheuristics is given in Table 2.

Table 2
Comparison of the metaheuristics

Set of nodes	SA (h)	CPU time (s)	GA (h)	CPU time (s)	TS (h)	CPU time (s)	BCO (h)	CPU time (s)
1,2	**54**	0,555	**54**	19,016	**54**	0,753	**54**	0,622
1,2,3	**107,667**	0,836	**107,667**	19,234	**107,667**	0,968	**107,667**	0,798
1,2,3,4	**173,333**	1,362	**173,333**	19,020	**173,333**	1,482	**173,333**	1,129
1,2,3,4,5	**221,607**	2,205	**221,607**	19,526	**221,607**	2,375	**221,607**	1,328
1,2,3,4,5,6	**304,667**	3,346	**304,667**	21,189	**304,667**	3,860	**304,667**	1,516
1,2,3,4,5,6,7	**385,667**	5,481	**385,667**	21,111	**385,667**	6,521	**385,667**	1,678
1,2,3,4,5,6,7,8	**483**	8,584	496,333	21,833	**483**	9,389	488	1,996
1,2,3,4,5,6,7,8,9	**609,333**	12,391	629	22,483	**609,333**	13,251	620,667	2,309

We made a simple comparison of the final solution values and the computing time of the four metaheuristics. The runtime of the metaheuristics highly depends on values assigned to the parameters. The best solution of the four metaheuristics at each time point are printed in bold face.

As it is shown in the Table 2, we gained the best solution from the SA and the TS at every time points. Therefore, the SA and the TS got the first place and then the GA and the BCO are in the second. The BCO reaches better results than other metaheuristics in terms of runtime. Since the computing times of the metaheuristics are very reasonable, each of them is acceptable for solving the problem in real time.

6. Conclusion

In this paper floating bulk handling cranes have been assigned to serve vessels placed in nodes within inland waterways. The problem is solved by four well-known metaheuristic techniques: simulated annealing, genetic algorithm, tabu search and bee colony optimization. One of the main goals of this paper is to attempt an unbiased comparison of the performance of implementations of the metaheuristics on handling device allocation problem. The metaheuristics are compared by considering their number of parameters, solution quality and runtime of the algorithms. Problem definition, datasets and cost function are common to all algorithms. All algorithms are executed on the same computer. We did not find any other study that attempts to compare between the four metaheuristics under consideration here.

We compared the results of them on eight small instances. Since the simple comparison of the final solution of the four metaheuristics without taking into account the runtime is not appropriate, we used dynamic comparison. The initial solution for all metaheuristics are completely random.

The results showed that the SA and the TS algorithm worked slightly better compared to the GA and the BCO. The BCO reached better results than other metaheuristics in terms of runtime. Since the computing time of all metaheuristics is very reasonable, each of them is acceptable for solving the problem in real time.

Another research direction might be a comparison between the algorithms according to parameters different than those considered in this paper. Additional research opportunity might be the usage of a real data set.

References

Azimi, Z. N. 2004. Comparison of metaheuristic algorithms for examination timetabling problem, *J. Appl. Math. & Computing* 16 (1-2): 337 – 354.

Beasley, J.; Dowsland, K.; Glover, F.; Laguna, M.; Peterson, C.; Reeves, C.; Soderberg B. 1993. *Modern Heuristic Techniques for Combinatorial Problems*, (ed. by Reeves), Halsted Press, 320 p.

Cerny, V. 1985. A Thermodynamical approach to the travelling salesman problem: An efficient simulation algorithm, *Journal of Optimization Theory and Applications* 45: 41–51

Davidović, T.; Šelmić, M.; Teodorović D. 2009. Scheduling Independent Tasks: Bee Colony Optimization Approach, In *Proceedings of the the 17th Mediterranean Conference on Control and Automation, MED'09, Thessaloniki, Greece, June 24-26*, 1020-1025.

Drenovac, D. 2012. Assignment of floating bulk handling cranes in inland waterways by genetic algorithm, *YU INFO*, Kopaonik (in Serbian)

Gendreau, M.; Potvin, J. 2003. *Handbook of metaheuristics.* Springer Science+Business Media, LLC, 648 p.

Glover, F. 1986. Future paths for integer programming and links to artificial intelligence, *Computers & Operations Research* DOI: 13: 533-549.

Holland, J. 1995. *Adaptation in Natural and Artificial Systems*, University of Michigan Press, Ann Arbor, MI, 228 p.

Kirkpatrick, S.; Gelatt, C. D.; Vecchi, M. P. 1983. Optimization by simulated annealing, *Science* 220: 671–680.

Lučić, P.; Teodorović, D. 2001. Bee system: modeling combinatorial optimization transportation engineering problems by swarm intelligence. In: *Preprints of the TRISTAN IV Triennial Symposium on Transportation Analysis, Sao Miguel, Azores Islands, Portugal*, 441–445.

Metropolis, N.; Rosenbluth, A. W.; Rosenbluth, M. N.; Teller, A. H.; Teller, E. 1953. Equations of State Calculations by Fast Computing Machines, *Journal of Chemical Physics* 21: 1087-1092.

Rossi-Doria, O.; Sampels, M.; Birattari, M.; Chiarandini, M.; Dorigo, M.; Gambardella, L.; Knowles, J.; Max Manfrin, M.; Mastrolilli, M.; Paechter, B.; Paquete, L.; Stutzle T. 2002. *A comparison of the performance of different metaheuristics on the timetabling problem*, Technical Report, Istituto Dalle Molle Di Studi Sull Intelligenza Artificiale, 23 p.

Vidović, M.; Vukadinović K., 2006. Allocation planning of handling devices for barges unloading. In *Proceedings of EWGT International Joint Conference Bari, Italy*, 740-747.

THE RENUEWIBLE ENERGY ON SHIP: SIMULATION AND OPTIMIZATION

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Abstract: International Maritime Organization (IMO) decisions with respect to measures to reduce the emissions from maritime greenhouse gases (GHGs) suggest that the collaboration of all major stakeholders of shipbuilding and ship operations is required to address this complex techno-economical and highly political problem efficiently. Safe, secure and efficient shipping on clean ocean requires the development of appropriate design, operational knowledge and assessment tools for energy efficient design and operation of ships.The major research issues in the renewable power arena involving power generation, storage, transformation and distribution, and the issues associated with micro grids such as limited power generation for a specific set of loads, are the same issues seen in shipboard implementation of electric distribution technologies.This paper analyzes the effects of efficient shipping using solar panel system, wind or fuel cells by using genetic algorithm.

Keywords: efficiency, renewable power, power management system on ship.

1. Introduction

Maritime transport is an important mode of transport from the European Union with over 90% of its external trade and some 43% of its internal trade going by sea. The maritime sector is also important from an economic point of view. Maritime companies belonging to European Union nationals control one third of the world fleet and some 40% of EU trade is carried on vessels controlled by EU interests. The environmental record of maritime transport is mixed. On the one hand, sea shipping is relatively climate friendly. Emissions of greenhouse gases per amount of transport work are low compared to other modes. In absolute terms, greenhouse emissions from shipping are significant. Emissions of greenhouse gases from sea shipping are rising due to the increase in the global trading of goods. Currently, fuel originating greenhouse gases from shipping are not subject to any policy measures. On the other hand, sea shipping is an important source of air pollutants. Especially in coastal areas and harbors with heavy traffic, the contribution of shipping emissions to air pollution is substantial.

The IMO's Energy Efficiency Design Index (EEDI) will require new ships to meet a minimum level of energy efficiency: ships built between 2015 – 2019 will need to improve their efficiency by 10 percent, rising to 20 percent between 2020 and 2024, and 30 percent for ships delivered after 2024. However, after intense negotiations, efforts led by China, Brazil, Saudi Arabia and South Africa resulted in a waiver for new ships registered in developing countries. If countries choose to apply the waiver for a newly delivered ship, application of the EEDI is delayed for 6.5 years from the January 1, 2013 entry into force of the regulation. There is a significant danger that many ship owners will elect to have their new ships flagged in countries that provide a waiver. The first guaranteed effective date of the EEDI as a global shipping efficiency standard would thus be 2019. Environmental NGOs (Non-Governmental Organizations) caution that because the standard only applies to ships replacing older ones at the end of their very long lives (typically 30 years), and because the waiver will defer implementation for many new ships. The full effects of today's decision will take a very long time to have any significant impact.

2. Sustainable energy

Sustainable shipping in marine technology usually refers to sustainable energy. Sustainable energy has two key components: energy efficiency and renewable energy. With respect to the provision of shipboard energy, near term sustainability is primarily about achieving two objectives: reducing fossil fuel oil consumption reducing airborne emissions, particularly CO_2.

What is increasingly acknowledged however is that significant reductions in both fuel oil consumption and CO_2 emissions can be achieved using a number of current or relatively near term operational and technical measures.

Such measures are focused on reducing energy demand and using alternative sources of energy. Renewable energy sources is divided into traditional renewable energy sources like biomass and large hydropower installations, and the "new renewable energy sources" like solar energy, wind energy, geothermal energy, etc.

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A renewable resource is a natural resource with the ability to reproduce through biological or natural processes and replenished with the passage of time they will never run out. This fact shows that renewable sources should be exploited much more and that there is no need to worry about the energy after fossil fuels cease to exist. Development of renewable energy sources (especially from wind, water, sun and biomass) is important because a couple of reasons: Renewable energy sources have major role in decreasing of emissions of the carbon dioxide (CO_2) into atmosphere; Increased proportion of renewable energy sources enhances energetic viability of the energy system; It also helps to enhance energy delivery security by decreasing dependency on importing energetic raw materials and electrical energy; It is expected that renewable energy sources will become economically competitive to conventional energy sources in middle till longer period. Off grid renewable energy technologies satisfy energy demand directly and avoid the need for long distribution infrastructures. A combination of different but complementary energy generation systems based on renewable energies or mixed (with a backup of Liquefied Petroleum Gas /diesel/gasoline generator), is known as a hybrid power system. Hybrid systems capture the best features of each energy resource. Hybrid systems can provide a steady community-level electricity service, such as marine, village or lighthouse, electrification, offering also the possibility to be upgraded through grid connection in the future. Furthermore, due to their high levels of efficiency, reliability and long term performance, these systems can also be used as an effective backup solution to the public grid in case of blackouts or weak grids, and for professional energy solutions, such as telecommunication stations or emergency rooms at hospitals. When designing a hybrid system, it is important to choose a good combination of components, their dimensions and determine a good strategy to manage the system that would be reliable and economical for long time. A large number of resources will result in large investment costs, while a system with a small number of components can result in the interruption of electricity supply in the electricity system. Climatic conditions may affect the choice of renewable energy sources. For example, photovoltaic hybrid systems (photovoltaic modules-diesel-battery) are ideal in areas with warm climates and in areas where there is big number of sunny hours. In this paper, the system is defined as a combination of components (PV generator, batteries, diesel generator) and control variables.

2.1. Hybridization options in marine applications

There are many combinations of hybridization options. An effective power plant hybridization option is wind turbines and solar panels like on Fig. 1. This is an easy plug and play option to the DC Power Grid concept. Solar panels are virtually maintenance and are ideal for charging storage batteries (Fig. 2). There are designed to convert sunlight into electricity. The current and power output of a solar panel or photovoltaic module is approximately proportional to sunlight intensity. At a given intensity, a module's output current and operating voltages are determined by the characteristics of the load. If that load is a battery, the battery's internal resistance will dictate the module's operating voltage. Wind turbines and solar panels can be mounted in various configurations onboard a wide variety of vessels to harness wind and solar energy which is very abundant out at sea. The type of vessel will determine the best configuration for optimizing the available energy.

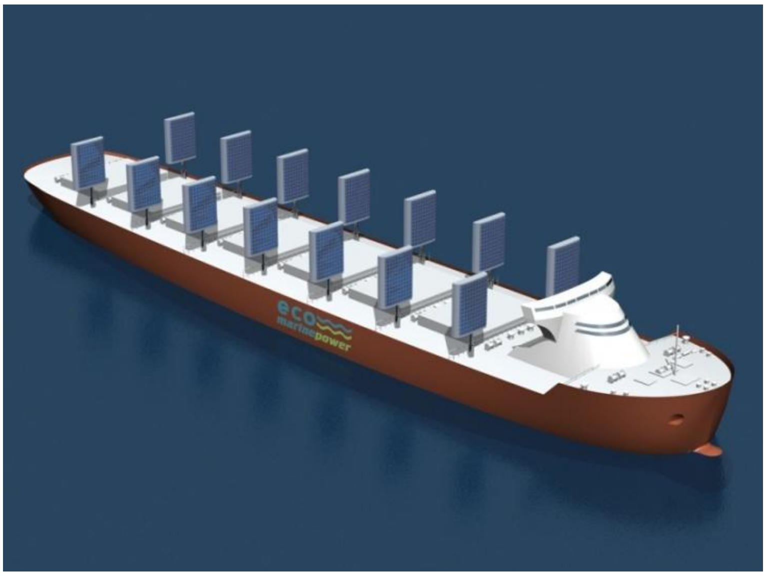


Fig.1.
Aquarius Eco Ship
Source: http://www.ecomarinepower.com

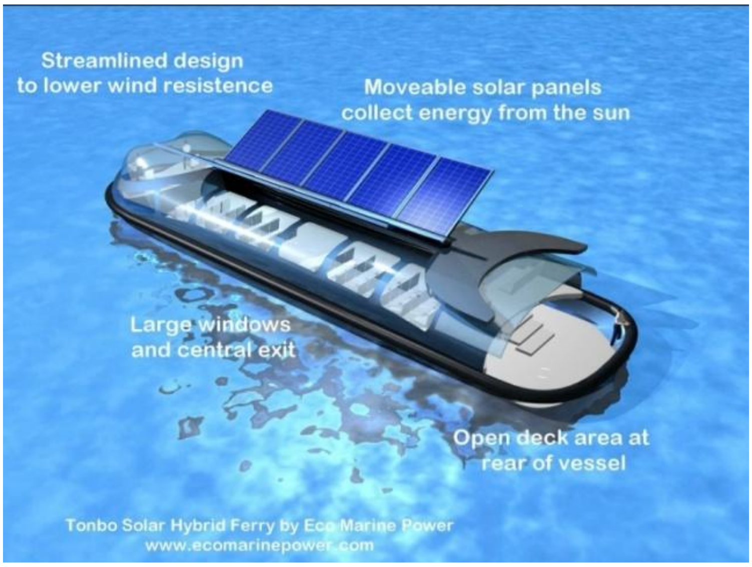


Fig.2.
Solar Ferry Concept
Source: http://www.ecomarinepower.com

Fuel Cell technology could also be integrated as part of a hybrid solution for example, propulsion systems in conjunction with combustion engines. This technology using natural gas as fuel offers ultra low emissions and high thermodynamic efficiency which makes for an excellent application for coastwise shipping, inland waterway and offshore applications and operations inside the North American Emission Control Areas. The high operating temperature of Solid Oxide Fuel Cell or SOFC technology enables co-generation where the high value exhaust heat can be utilized in marine applications to produce electricity, steam and cooling—even freezing, depending on the vessel type. Recovery of the waste heat which is a byproduct of the chemical reaction can raise the efficiency to as high as 90%. Additional byproducts of the chemical reaction include water, electricity and small amounts of NO_2 depending on the fuel source. Fuel Cell benefits include high efficiency (40-60%), ultra low emissions, low noise, no vibrations, co-generation, fuel flexibility, high part load efficiency, high reliability and availability. Marine Fuel Cell Units can be installed on many types of vessels including offshore, short sea feeder, ferries and others. These highly efficient units can be operated with LNG or methanol and in the future with diesel oil. The power range and quality is sufficient for application as auxiliary power units for hotel load, power for harbor mode, hybrid solution for propulsion together with ship's main engines and main power source offshore vessels using dynamic positioning. Smaller vessels such as ferries and tugs could also benefit from fuel cell technology as the main power supply. Typically fuel cells don't respond well to transient loads, which could be a problem when being applied to propulsion. However hybridization of a prime mover can improve transient response. High exhaust temperatures of the units make for an opportunity to add waste heat recovery systems for improved efficiency.

Power plant hybridization is also possible using lithium polymer ion batteries. These batteries have been used for commercial and military marine applications. A typical battery bank will include a battery management system with connecting cables and communication harnesses to the vessel systems. The battery modules can be combined to produce megawatts of power that can replace a prime mover. These battery banks can act as the sole energy source for low load situations, handle peak loads without starting standby generators and act as an energy buffer. This energy buffer will optimize fuel consumption, emissions, lifecycle cost and transient response to power demands. This is especially important for gas engines which have slower transient response than their diesel counterparts. Auxiliary drives can easily be integrated in the DC grid system using inverter units for auxiliary motors lowering system size and power consumption. The batteries themselves are 100% biodegradable. The *Emerald Ace*, on Fig. 3, is equipped with a hybrid power supply system combined with a solar power generation system and lithium-ion batteries. Conventional vessels use diesel-powered generators to produce electricity while they are on berth. But on the *Emerald Ace*, the solar power generation system generates electricity while the ship is under way and stores it in the lithium-ion batteries. The diesel-powered generator is completely shut down when the ship is in berth, and the batteries provide all the electricity the ship needs, resulting in zero emissions at the pier.

Another hybridization option is the use of super capacitors. Super capacitors can provide stability and efficiency to the DC grid. A super capacitor can provide a few seconds to a minute of reactive power in cost effective package. A 20 foot container can provide 1MW of power for 1 minute. Super capacitors have a longer life than lithium battery banks and are ideal for shipboard application because of their superior high power charge/discharge cycling with lifetimes over a million charge/discharge cycles at 100% depth of charge.

Fig.3.
Hybrid car carrier Emerald Ace
Source: http://www.mol.co.jp/opensea

2.2. HOGA (Hybrid Optimization by Genetic Algorithms)

HOGA (Hybrid Optimizations by Genetic Algorithms), the program used in this article, simulates and optimizes the hybrid PV-Diesel system using Genetic Algorithms (GA). HOGA is simulation and optimization program developed in C++ for Hybrid Renewable systems for generation of electrical energy (DC and/or AC) and /or hydrogen. The program calculates the optimal system design and allows the user to evaluate the electro-economic and technical feasibility of a large number of technologies. Basic principle is to minimize the total Net Present Cost (NPC) of the system. GA researches combination of resources by using cost values to satisfy the load and finds the system, among the combinations, which can satisfy the demand (Dufo-López, 2005).

Genetic algorithms are used in computers to carry out simulations for breeding, mutation, and selection that are present in nature. All possible solutions provided by genetic algorithms to any given problem are thus presented as "individuals" within a certain species. Each individual is actually a combination of the variables ("genes") to be optimized (in this case, the variables or "genes" correspond to the hybrid system components and to the variables utilized for the system control strategy). Those variables or genes are integers (number of PV panels, codes for panel types...). The structure of the variables or genes is called "genotype", whereas any concrete combination of variables or genes in the genotype is called individual or "phenotype".

3. Experimental model

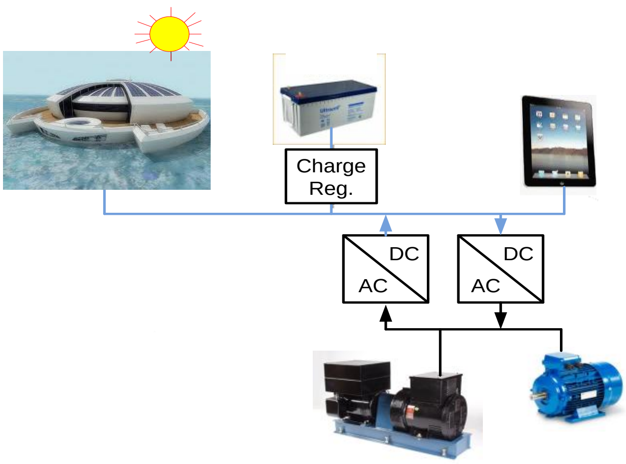


Fig. 4.
Hybrid energy model

For this experiment the motor ship which sails along the Adriatic coast has been analyzed, for example connecting the city of Split and place on the island Hvar. The system from the Fig. 4. has been optimized. The program optimizes both the configuration of the physical components and their control strategy.

In order to select the appropriate solar panels it is necessary to know the solar radiation by month to appropriate area (in this case the island of Hvar). The solar irradiation of the island Hvar is shown on the Fig. 5. The average daily irradiation on a horizontal surface value is 4.29 kWh/m^2. As the photovoltaic panels used are two-axis solar cracking devices, the average daily irradiation value is 4.73 Wh/m^2. Irradiation is very similar in the different geographical points in a given area or region; therefore, different case studies in which irradiation varies are not considered.

Fig. 5.
Monthly irradiation

Load (kW) during the day observing schedule is shown on Table 1.

Table 1
Load profiles

Hour	AC Load (kW)
00:00 - 01:00	194,00
01:00 - 02:00	194,00
02:00 - 03:00	194,00
03:00 - 04:00	194,00
04:00 - 05:00	194,00
05:00 - 06:00	194,00
06:00 - 07:00	194,00
07:00 - 08:00	369,00
08:00 - 09:00	369,00
09:00 - 10:00	454,00
10:00 - 11:00	422,00
11:00 - 12:00	422,00
12:00 - 13:00	422,00
13:00 - 14:00	330,00
14:00 - 15:00	330,00
15:00 - 16:00	454,00
16:00 - 17:00	422,00
17:00 - 18:00	422,00
18:00 - 19:00	369,00
19:00 - 20:00	369,00
20:00 - 21:00	454,00
21:00 - 22:00	194,00
22:00 - 23:00	194,00
23:00 - 00:00	194,00
Hourly average AC load	314,50
Max Ac Load Activate	454,00

Assumptions include:

- 5% annual real interest rate;
- The annual general inflation rate considered is 3%.
- The lifetime of the system considered is 25 years, same as the estimated lifetime of the photovoltaic generator.
- Fixed initial costs of installation, engineering, etc. are 2% of the initial investment.

Hybrid energy system components

The proposed hybrid system consists of the following:
Sanyo HIT Power 220 watt solar panels are connected in series parallel. Maximum Power Voltage is 42.7 V and Maximum Power Current 5.17 A. Maximum number of panels in parallel is 160. The installation cost of PV arrays is 625 € and annual O&M cost is 0.5% of the acquisition costs. The lifetime of the PV arrays are taken as 25years. The loss factor considered is 1.2.

The battery set includes the original Sinopoly LiFePO4 3,2 V Cells with capacity 200 Ah, nominal voltage of the cell is 3,2 V and the operational voltage is 2,8 - 3,7 V. Maximum number of batteries in parallel is 54. Cost of one battery is 210€ with O&M cost of 20€.

Number of possible Diesel generators in parallel can be between 1 and 3 (commercial AC Diesel generators 350 kW, with prices: 4657 € and O&M cost: 50 €).

When discharging electricity, each unit supplies electricity to a DC-AC converter with a 250V DC bus, boosts it to DC700V in the converter, converts it into AC450V (output power: 480kW) with an inverter and supplies the electricity to the inside of the ship. The inverter cost is 250h/kW nominal power (commercial data). The lifespan is 10 years, and the efficiency depends on the output power. O&M cost is included in the photovoltaic generator cost.

For charging the batteries, AC450V electricity is supplied to the unit, and it is converted to a direct current in the charger of the unit.

Computational results

By using the developed program, a system located in vessel has been designed and optimized. The implemented Multi-Objective algorithm is in charge of finding the designs which manage to simultaneously minimize the cost of the system and the pollutant emissions.

There have been realized several executions of the design program, determining the best values of the parameters, evaluating convergence and computational time for the Genetic Algorithm. The parameters used in this case are the following: Number of Generations is 20. Population is 25. Crossing probability is 0,7. Mutation rate is 0.02.The set of possible solutions of a Multi-Objective optimization problem, in which two objectives (cost and CO_2 emissions) are minimized. The 3 solutions that have been selected are marked. Their characteristics appear in Table 2.

Table 2
The characteristics of possible solutions

Nº	Cost(NPC) (€)	Emision (kgCO2/yr)	Unmet Load (KWh/yr)	No.Pan.p	P. Pan. (Wp)	No.Bat.	Cn Bat (Ah)	P.Gen. (VA)	P.Inv. (VA)
1	41442280	1557714	17312,0	136	220	15	200	350000	480000
2	41487444	1555041	15297,7	136	220	13	200	350000	480000
3	4148924	1558071	17067,3	136	220	15	200	350000	480000

In Table 2 Solution 2 is the one with the highest cost and the lowest emissions. Fig. 6. shows the characteristics of Solution 2 compared with characteristics of diesel generator-only power systems.

The level cost of energy for this renewable system is 44% lower than for the diesel generator (ie. 0.6 €/kWh vs. 1.07 €/kWh). During the system lifetime (25 years), AC Generator Fuel Cost savings of over 23666830 € is achieved for the renewable system. In addition, the renewable system reduces CO_2 emissions by 43%, removing almost 1,162 tones of CO_2 from the atmosphere annually.

DC Voltage: 240 V; AC Voltage: 450 V					
Renewable Power System			**Diesel Generator**		
COMPONENTS					
5 PV Panels serial x 136 Panels parallel, 220 W	Ptotal = 149,6 kWp				
75 Batteries serial x 13 Bat. parallel, 200 Ah	E total = 624 kWh				
AC Generator, rated power	350 kVA		2* AC Generator, rated power	350 kVA	
Inverter	480000 VA				
Battery Charge Regulator, current = 914 A					
Rectifier, 8175 W					
Cost summary			**Cost summary**		
Total System Costs (NPC):	41.487.444 €		Total System Costs (NPC):	74.039.608 €	
Levelized Cost Of Energy:	0,6 €/kWh		Levelized Cost Of Energy:	1,07 €/kWh	
AC Generator Fuel Costs:	31.683.186 €		AC Generator Fuel Costs:	55.350.016 €	
Electrical			**Electrical**		
Component	Production (kWh/yr)	Fraction %	Component	Production (kWh/yr)	Fraction %
PV	974338	32%			
2**350 kW AC Diesel	1923969	63%	2**350 kW AC Diesel	2813327	100%
Battery	147470	5%			
Total	3045777	100%	Total	2813327	100%
Emissions			**Emissions**		
Total CO_2 emissions:	1555041 kg CO_2/yr		Total CO_2 emissions:	2716633 kg CO_2/yr	
Emissions generated by AC generator:	1492839 kg CO_2/yr		Emissions generated by AC generator:	2607966 kg CO_2/yr	

Fig. 6.
Renewable vs. diesel generator-only power systems for a hypothetical remote community
Source: Made by authors

The daily values of electricity required by the load, the energy supplied by the hybrid power -PV-diesel-battery system and the energy absorbed and provided by the battery banc are shown in Fig. 8. for an annual average solar radiation equal to 1,74 kWh/m^2.

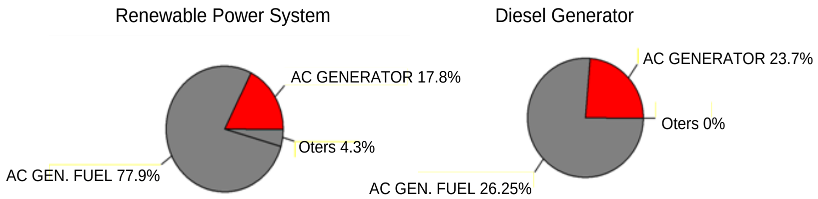
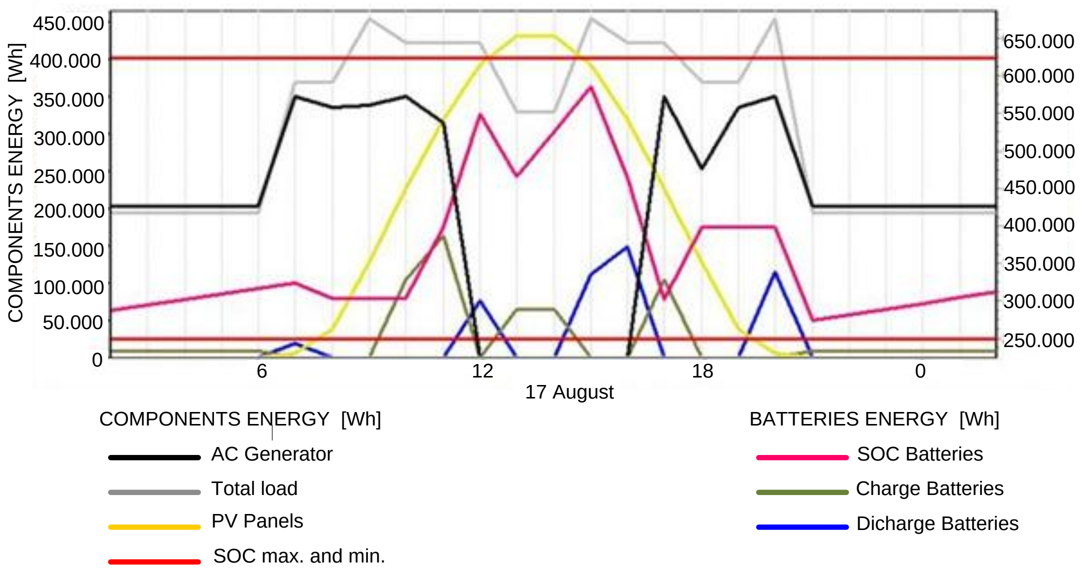
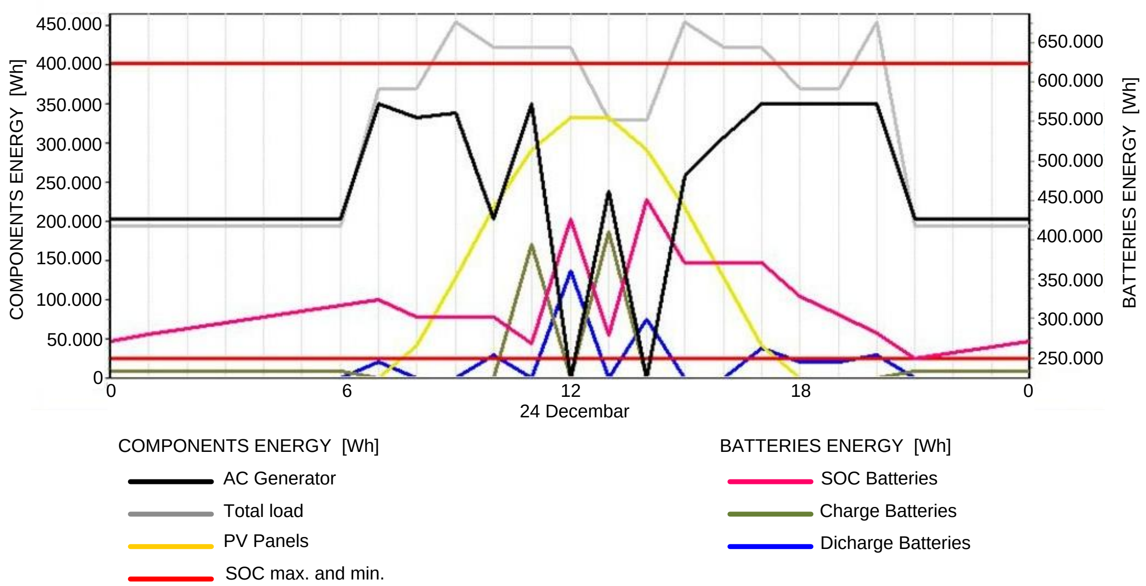


Fig 7.
Distribution of total system costs
Source: Made by authors in computer program HOGA



a)



b)

Fig. 8.

The simulation of daily values of electricity required by the load: a) summer time; b) winter time

Source: Made by authors in computer program HOGA

4. Conclusion

Multiple diesel generators are used on vessels to meet their average and peak power demands. While diesel generators may have a relatively favorable capital cost, they have exceptionally high operating costs due to their low efficiency, combined with the high cost of transporting diesel fuel to remote sites, often under very difficult circumstances. Diesel fuel prices are expected to increase further in the coming years. In addition, diesel generators create greenhouse gas (GHG) emissions that are harmful to local residents and the environment.

The shipping industry is focusing on a future based on sustainable, clean energy.

The shipping industry is setting an agenda for improvement and innovation. The environmental impact alone can drastically affect the world's CO_2 emissions, since the shipping industry currently puts out 3-4% of the world's total, and could lead the industry to becoming a global innovator in clean energy technology and international trade practices.

Seamen, serving hybrid energy systems (power management system) will certainly require additional knowledge and training that will be required to provide either through specific courses.

The vessels to be built in the near future will be different from the previous construction of ships. Better management of travel will reduce the number of voyages, cargo, or in ballast. Vessels must be efficient in terms of fuel efficiency with better engines and lower emissions. It is important to note that the construction of such vessels of less ports and infrastructure must serve them.

Through a dialogue between ship owners and charterers, shipbuilders, engineers, service providers, banking, insurance, and classification industries that will be encouraged by the Sustainable Shipping Initiative, shipping has a unique opportunity to make improvements in the way it operates. It stands to gain much in the way it is viewed in the public eye, as well as the way it operates and prepares for a sustainable future for all.

References

Atkinson, G. 2011. A Marine Renewable Energy Solution for Modern Ship. Available from internet: <http://www.ecomarinepower.com/>.

Detweiler, G.H., 2011. Offshore Renewable Energy Installations. Available from internet: <http://www.uscg.mil/proceedings/spring2011/articles/19_Detweiler.pdf>.

Dufo-López R.; Bernal-Agustín JL.; Rivas-Ascaso, D.M. 2006. Design of Isolated Hybrid Systems Minimizing Costs and Pollutant Emissions, *Renewable Energy,* DOI: http://dx.doi.org/10.1016/j.renene.2005.11.002, 31(14): 2227-2244.

Dufo-López R.; Bernal-Agustín JL. 2005. Design and control strategies of PV-Diesel systems using genetic algorithms, *Solar Energy* DOI: http://dx.doi.org/10.1016/j.solener.2004.10.004, 79(1): 33-46.

Fowler, P.; Kurtalj, N.; Miri, M. 2006. Energy Sustainability: Island of Hvar, Croatia – Final Report. Available from internet:
<*http://homerenergy.com/webcastdownloads/Patrick_Fowler/Island_of_Hvar_Croatia_Renewable_Energy_Potential_Final_Presentation_2006.pdf*>.

Krcum, M.; Gudelj, A.; Juric, Z. 2004. Genetic Algorithm Application in the Optimization of the Ship´s Electric Power System Load, In Proceedings of the *10th IEEE International Conference on Methods and Models in Automation and Robotics (*MMAR) World Conference, Miedzyzdroje, Poland: 201-206

Krcum, M.; Gudelj, A.; Žižić, L. 2010. Marine Applications for Fuel Cell Technology, In Proceedings of the *International Conference of Transport System (ICTS), Portorož, Slovenia*

Streeter, B. 2010. Marine transport and Energy, Mare Forum 20101., Loyds Register. Available from internet: <http://www.mareforum.com/ENERGY_TRANSPORTATION_USA_2010_PAPERS/STREETER.pdf>.

<http://www. solartown.com>.

<http://www.ev-power.eu>.

MIP-HEURISTICS FOR MINIMUM COST BERTH ALLOCATION PROBLEM

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Abstract: The dynamic minimum cost berth allocation problem (BAP) is considered with an aim to minimize the total costs of waiting and handling, as well as earliness or tardiness of completion, for all ships. BAP can be presented as the Mixed Integer Linear Program (MILP) with a large number of 0-1 variables, making it suitable for the application of Mixed Integer Programming (MIP) heuristics. Three well known MIP heuristics have been applied: local branching, variable neighborhood branching and variable neighborhood decomposition search for 0-1 MIP, where the last one performs the best. In the computational experiments, the results of the above mentioned MIP heuristics with the CPLEX commercial solver within the same CPU time limit are compared. For small size examples, variable neighborhood decomposition search for 0-1 MIP heuristic method was able to find optimal solutions for all instances and to outperform CPLEX regarding computation times. The results for medium size test examples indicate that the complexity prevents this problem from being efficiently treated by any of the three general purpose solution methods considered in this paper.

Keywords: Container ship, berthing, mixed integer formulation, meta-heuristics.

1. Introduction

A container terminal (CT) in a sea port can be described as open system of container flow with sea-side interface. This interface is quayside with loading and unloading of vessels. After arrival at the port, a container vessel is assigned to a berth equipped with quay cranes (QCs) to load and unload containers. Various types of container vessels have to be served at the quayside. In order to compete in this environment, a CT should be organized efficiently. One issue of seaside operations planning is the assignment of quay space and service time to vessels that have to be unloaded and loaded at a CT (Bierwirth and Meisel, 2010; Imai, et al., 2003). This problem is commonly referred to as the berth allocation problem (BAP).

BAPs can be classified as discrete or continuous, as well as static or dynamic (Meisel and Bierwirth, 2009). In the discrete case, the quay is partitioned into a number of sections, called berths, and each berth can serve one vessel at a time. Moreover, time could also be partitioned into discrete units allowing using integer arithmetic for calculation of the objective function value. In the continuous case a calling vessel can be placed at any position, with the restriction to avoid overlapping with other vessels and time is also considered continuous. In a static BAP it is assumed that all vessels arrive to the container terminal in advance, namely before any berth becomes available. If the vessels can arrive at any time during the planning horizon (although having *a priori* knowledge of their arrivals), then it has to be dealed with dynamic BAP.

In recent years, an ever increasing number of papers on CTs considering BAP have appeared. In most of them crane resources were either ignored (assuming that each berth is equipped by a crane) (Guan and Cheung, 2004; Kim and Moon, 2003; Wang and Lim, 2007) or treated separately within the second stage of problem solving (Park and Kim, 2003). Moreover, different authors considered different objectives to be minimized within the solution of BAP. In some of the papers the total of waiting and handling times was minimized (Bierwirth and Meisel, 2009; Imai, et al., 2001), while in the others the minimization of total costs for waiting and handling as well as earliness or tardiness of completion was considered as the objective (Hansen, et al., 2008). Solution approaches can also be distinguished: while minority of authors was developing exact methods (Oğuz, et al., 2009) usually for some special cases of the problem, in most of the papers heuristic (e.g. Lagrangean relaxation (Imai, et al., 2001), Branch-and-Bound-based heuristic (Bierwirth and Meisel, 2009)) and meta-heuristic methods (genetic algorithm (Nishimura, et al., 2001), tabu search (Cordeau, et al., 2005), variable neighborhood search (Hansen, et al., 2008)) were used.

The dynamic minimum cost BAP are considered in the case when QC resources are ignored and propose the application of heuristic methods based on the Mixed Integer Programming (MIP) formulation of the problem.

Three state-of-the-art MIP-based methods have been tested: Local Branching (Fischetti and Lodi, 2003), Variable neighborhood Branching (Hansen, et al., 2006) and Variable Neighborhood Decomposition Search for 0-1 MIP (Lazić, et al., 2010).

Those experiments show that the best performing among them is Variable Neighborhood Decomposition Search for 0-1 MIP. Here is presented the comparison results with respect to the CPLEX commercial solver (ILOG, 2008).

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The rest of this paper is organized as follows. BAP is described and formulated as integer linear program in section 2. The section 3 contains a brief overview of used MIP-based heuristic. Experimental evaluation of MIP-heuristic efficiency is presented in section 4. The last section contains concluding remarks.

2. Dynamic Minimum Cost Berth Allocation Problem

BAP represents one of the major CT operations planning problem (Bierwirth and Meisel, 2010; Imai, et al., 2003). It consists of assigning a berthing position and a berthing time to every vessel incoming to be served within a given planning horizon with and aim to minimize some objective. In this paper the minimization of berthing cost as well as the costs of earliness and tardiness of each vessel is considered. The main assumption is that the number of QCs is equal to the number of berths and therefore QC scheduling problem can be avoided.

Typically, the decisions are made with respect to the different arrival times, lengths, and handling times of vessels. The handling (operation) times are usually assumed to be fixed and known in advance. As shown in Fig. 1, a solution to BAP can be depicted in a space-time-diagram. Both coordinates are assumed to be discrete (space is modeled by the berth indices while the time horizon is partitioned into segments in such a way that berthing time of each vessel is represented by an integer). The height of each of the rectangles corresponds to the length of a vessel (expressed by the number of berths) and the width corresponds to the needed handling time. The lower-left vertex of a rectangle gives the berthing position and berthing time of a vessel and it is referred as *the reference point* of a vessel (marked by the index of vessel in Fig. 1). A berth plan is *feasible* if the rectangles do not overlap (see Fig. 1).

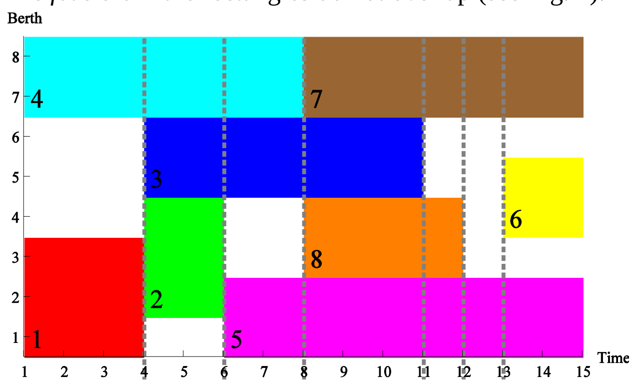

Fig. 1.
An example of BAP solution
Source: Kordić, S. PhD Thesis (in progress)

2.1. Problem Description

The input parameters of BAP are: The total number of vessels (l); The total number of different berthing positions (m); The total number of time segments (T); The expected time of arrival (ETA_k) of vessel k. ETA is a kind of agreement between carriers and the terminal operator regarding the arrival time of vessels. Thus, berthing earlier than the promised berthing time causes the corresponding vessel to speed up, which in turn causes the extra consumption of fuel, and berthing later than the promised berthing time may incur complaints from carriers; The total operation time (a_k) of vessel k if only one QC operates on it during the berthing; The length (b_k) of vessel k expressed as the number of berths. Assuming that each berth is equipped with a crane, the time required to unload and load all the cargo for vessel k equals $\lceil a_k / b_k \rceil$; The due time for the departure (d_k) of vessel k; The least-cost berthing location of the reference point (s_k) of vessel k; The container handling cost (c_{1k}) per unit distance of vessel k from the least-cost berthing location; The penalty cost (c_{2k}) of vessel k per unit time of arrival before ETA_k; The penalty cost (c_{3k}) of vessel k per unit time of arrival after ETA_k; The penalty cost (c_{4k}) of vessel k per unit time of delay beyond the due time d_k.

The goal is to minimize the total penalty cost which includes: the penalty induced by missing the least-cost (preferred) berthing location of the reference point; the penalties induced by the actual berthing earlier or later than the expected time of arrival and the penalty cost by the delay of the departure after the promised due time.

The last three terms have impacts on the objective function provided that they are positive. More precisely, the objective function can be expressed in the following form:

$$\sum_{k=1}^{l}\{C_{1k}\sigma_k + C_{2k}(ETA_k - At_k)^+ + C_{3k}(At_k - ETA_k)^+ + C_{4k}(Dt_k - d_k)^+\}$$

where

$$\sigma_k = \sum_{t=1}^{T}\sum_{i=1}^{m}\{|\, i - s_k \,| : \text{vessel } k \text{ occupies possition } (j,i)\}$$

and

$$(a-b)^+ = \begin{cases} a-b, & \text{if } a > b \\ 0, & \text{otherwise} \end{cases}$$

2.2. Mathematical Programming Formulation

Although containing some non-linearities (expressed by absolute values, positive components, conditional expressions), BAP can be formulated as Mixed Integer Linear Program (MILP). Therefore, it is possible to apply well known optimization software (like CPLEX, ILOG 2008) to obtain optimal solution for small size problem instances and MIP-based heuristic methods for the larger ones.

In order to develop MILP for BAP, let us introduce the following decision variables:

- binary variables x_{ijk}, z_{ijk} and v_{jk} defined as follows

$$x_{jik} = \begin{cases} 1, & \text{if the berth } i \text{ is allocated to vessel } k \text{ at time } j, \\ 0, & \text{otherwise} \end{cases}$$

$$z_{jik} = \begin{cases} 1, & \text{if the reference point of vessel } k \text{ is } (j,i), \\ 0, & \text{otherwise} \end{cases}$$

$$v_{jk} = \begin{cases} 1, & \text{if vessel } k \text{ is processed at time } j, \\ 0, & \text{otherwise} \end{cases}$$

- integer variables (taking values 1, 2,…, T)
  At_k - The Berthing position of vessel k on the time axis;
  Dt_k - The completion (departure) time of vessel k.

Moreover, let us perform some preprocessing. First, it is obvious that it is possible to calculate array $H_k = \lceil a_k / b_k \rceil$ in advance. Now, matrices $E1_{kj}$, $E2_{kj}$, $D1_{kj}$, and Zb_{ki} can be introduced and defined as follows:

$$E1_{kj} = \begin{cases} c_{2k}(ETA_k - j), & \text{if } ETA_k > j, \\ 0, & \text{otherwise} \end{cases}$$

$$E2_{kj} = \begin{cases} c3(j - ETA_k), & \text{if } j > ETA_k, \\ 0, & \text{otherwise} \end{cases}$$

$$D1_{kj} = \begin{cases} c_{4k}(j + H_k - d_k), & \text{if } j + H_k > \mathrm{d_k}, \\ 0, & \text{otherwise} \end{cases}$$

$$Zb_{ki} = \sum_{r=i}^{i+b_k-1} B_{kr}$$

where

$$B_{kr} = \begin{cases} H_k * c_{1k}(r - s_k) & \text{if } r > s_k, \\ H_k * c_{1k}(s_k - r) & \text{otherwise.} \end{cases}$$

In this way most of the problem non-linearities have been extracted into preprocessing phase.

The only part to be linearized is the one describing continuity in vessel berthing time and space (the fact that vessel must be assigned to neighboring b_k berths and successive H_k time slots - represented by the rectangle in space-time diagram in Fig. 1).

Based on the formulation presented in (Park and Kim, 2003) and the preprocessing scheme, BAP can be formulated as follows (Eq. (1) – Eq. (17)):

$$\min \sum_{k=1}^{l}\sum_{i=1}^{m}\sum_{j=1}^{T} z_{ijk}(Zb_{ki} + E1_{kj} + E2_{kj} + D1_{kj}) \tag{1}$$

s.t.

$$\sum_{k=1}^{l} x_{ijk} \le 1, \qquad i = 1,2,\ldots,m; \quad j = i+1,\ldots,T \tag{2}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{T} z_{ijk} = 1, \qquad k = 1,2,\ldots,l \tag{3}$$

$$\sum_{i=1}^{T}\sum_{i=1}^{m} j * z_{ijk} = At_k, \qquad k = 1,2,\ldots,l \tag{4}$$

$$\sum_{i=1}^{T}\sum_{i=1}^{m} j * z_{ijk} + H_k = Dt_k, \qquad k = 1,2,\ldots,l \tag{5}$$

$$\sum_{k=1}^{l}\sum_{i=1}^{m} x_{ijk} \le m, \qquad j = 1,2,\ldots,T \tag{6}$$

$$\sum_{j=1}^{T}\sum_{i=1}^{m} x_{ijk} \ge a_k, \qquad k = 1,2,\ldots,l \tag{7}$$

$$\sum_{i=1}^{m} x_{ijk} \le M * v_{jk}, \qquad j = 1,2,\ldots,T; \quad k = 1,\ldots,l \tag{8}$$

$$\sum_{i=1}^{m} x_{ijk} \ge v_{jk}, \qquad j = 1,2,\ldots,T; \quad k = 1,\ldots,l \tag{9}$$

$$(j+1)v_{jk} \le Dt_k, \qquad j = 1,2,\ldots,T; \quad k = 1,2,\ldots,l \tag{10}$$

$$(j_2 - j_1 + 1) \le \sum_{j=j_1}^{j_2} v_{jk} + M(2 - v_{j_1k} - v_{j_2k}), \qquad j_1 = 1,2,\ldots,T-1; \quad j_2 = 2,\ldots,T\,(j_1 < j_2); \quad k = 1,2,\ldots,l \tag{11}$$

$$v_{jk} \le \sum_{i=1}^{m}\sum_{j_1=1}^{j} z_{ij_1k}, \qquad j = 1,2,\ldots,T; \quad k = 1,2,\ldots,l \tag{12}$$

$$\sum_{i=1}^{i_1-1}\sum_{j=1}^{T} x_{ijk} + \sum_{i=i_1+b_k}^{m}\sum_{j=1}^{T} x_{ij_1k} \le M\left(1 - \sum_{j=1}^{T} z_{i_1jk}\right), \qquad i_1 = 2,\ldots,m-b_k; \quad k = 1,2,\ldots,l \tag{13}$$

$$\sum_{i=1+b_k}^{m}\sum_{j=1}^{T} x_{ij_1k} \le M\left(1 - \sum_{j=1}^{T} z_{ijk}\right), \qquad k = 1,2,\ldots,l \tag{14}$$

$$\sum_{i=1}^{m-b_k}\sum_{j=1}^{T} x_{ij_1k} \le M\left(1 - \sum_{j=1}^{T} z_{(m-b_k+1)jk}\right), \qquad k = 1,2,\ldots,l \tag{15}$$

$$b_k - \sum_{i=1}^{m} x_{ijk} \le M(1 - v_{jk}), \qquad j = 1,2,\ldots,T; \quad k = 1,2,\ldots,l \tag{16}$$

$$x_{ijk}, z_{ijk}, v_{jk} \in \{0,1\} \tag{17}$$

The objective function, given by Eq. (1), aims to minimize the weighted sum of the berthing cost components (the cost depending on the distance from the Berthing location of a vessel to the preferred location, the penalty cost incurred by Berthing earlier or later than the expected time of arrival (ETA), and the penalty cost incurred by the delay of the departure beyond the desired due time). Only one vessel can occupy a single berth at a time according to constraints (2). Constraints (3) restrict the number of referent positions to one per vessel. Constraints (4) and (5) define the values of variables determining the berthing times for each vessel. Constraints (6) are to assure that the number of available berths is not exceeded.

Operation time of each vessel is controlled by constraints (7). Constraints (8) and (9) define correspondence between variables v_{jk} and x_{ijk}. Constraint (10) relates the departure time Dt_k to variables v_{jk}. Because v_{jk} is 1 if at least one crane serves vessel k during time segment j that is between time j and j+1, the departure time of vessel k must be greater than equal to j + 1. Invalid values of v_{jk} 's are eliminated by constraints (11) and (12), i.e. the vessel is processed only if at least one berth is assigned to it within given time segment. Constraints (13) through (16) imply that only x_{ijk} within a rectangle can take value 1. In all relevant cases M represents large enough constant.

As can be seen from the above MILP formulation, the problem complexity with respect to the number of variables is $O(mlT)$. More precisely, in order to solve the problem it is necessary to determine values for $lT(2m+1)$ binary variables, $2l$ integer ones and to calculate objective function value (which is floating point number in general case). For solving such a complex MIP problem, MIP-based heuristic methods are proposed, which have proven their efficiency in the recent literature.

3. MIP Heuristics

According to the mathematical formulation provided in Section 2, BAP presented in this paper is the special case of the 0-1 MIP (Eq. (18)):

$$\min\{c^T \xi \mid \xi \in X\}, \tag{18}$$

where $X = \{\xi \in R^{|N|} \mid A\xi \le b,\ \xi_j \ge 0 \text{ for } j \in N, \xi_j \in Z \text{ for } j \in \mathcal{G}, \xi_j \in \{0,1\} \text{ for } j \in \mathcal{B}\}$ is the feasible set, N is the set of indices of all variables, $\mathcal{G} \subseteq N$ is the set of indices of general integer variables and $\mathcal{B} \subseteq N$ is the set of indices of binary variables, $\mathcal{B} \cap \mathcal{G} = \emptyset$, $\mathcal{B} \neq \emptyset$. Indeed, all problem constraints and the objective function are linear, and the set of binary variables $\{x_{ijk}, z_{ijk}, v_{jk} \mid 1 \le i \le m, 1 \le j \le T, 1 \le k \le l\}$ is non-empty. Therefore, it is possible to tackle this problem by using 0-1 MIP solution methods. Three well known heuristics for 0-1 MIP problem have been applied: Local branching (LB) (Fischetti and Lodi, 2003), Variable Neighborhood Branching (VNB) (Hansen, et al., 2006) and Variable Neighborhood Decomposition Search for 0-1 MIP (VNDS-MIP) (Lazić, et al., 2010). Since the best results were obtained by VNDS-MIP they are briefly described below, with introducing some notations first.

Let P be a given 0-1 MIP problem as defined in (18). The linear relaxation $LP(P)$ of problem P is obtained from P by releasing the integer requirements on ξ. Let ξ and η be two arbitrary integer feasible solutions of P and $J \subseteq \mathcal{B}$. The partial distance between ξ and η, relative to J, is defined as $\delta(J, \xi, \eta) = \Sigma_{j\in J}|\xi_j - \eta_j|$. Now the following subproblem notation for $k \in \mathcal{N} \cup \{0\}$: $P(k, \xi^0) = (P \mid \delta(\mathcal{B}, \xi^0, \xi) \le k)$ can also be introduced.

The neighborhood structures $\{ \mathcal{N}_k \mid k = k_{\min},\ldots,k_{\max}\}$, $1 \le k_{\min} \le k_{\max} \le |\mathcal{B}|$, can be defined knowing the distance $\delta(\mathcal{B}, \xi, \eta)$ between any two solutions $\xi, \eta \in X$. The set of all solutions in the k-th neighborhood of $\xi \in X$ is denoted as $\mathcal{N}_k(\xi)$, where

$$\mathcal{N}_k(\xi) = \{\eta \in X \mid \delta(\mathcal{B}, \xi, \eta) \le k\}.$$

From the definition of $\mathcal{N}_k(\xi)$, it follows that $\mathcal{N}_k(\xi) \subset \mathcal{N}_{k+1}(\xi)$, for any $k \in \{k_{\min}, k_{\min}+1, \ldots, k_{\max} - 1\}$, since $\delta(\mathcal{B}, \xi, \eta) \le k$ implies $\delta(\mathcal{B}, \xi, \eta) \le k + 1$. It is trivial to conclude that, if the neighborhood $\mathcal{N}_{k+1}(\xi)$ is completely explored, it is not necessary to explore neighborhood $\mathcal{N}_k(\xi)$.

Variable Neighborhood Decomposition Search (VNDS) (Hansen, et al., 2001) is a two-level VNS (Mladenović and Hansen, 1997) scheme for solving optimization problems, based upon the decomposition of the original problem. Recently, VNDS has been implemented for solving 0-1 MIPs (Lazić, et al., 2010) and it was named Variable Neighborhood Decomposition Search for 0-1 MIPs (VNDS-MIP). The approach proposed by (Lazić, et al., 2010) is a VNDS based diving strategy, which combines linear programming (LP) solver, MIP solver and Variable Neighborhood Descent (VND) based MIP solving method (VND-MIP) in order to efficiently solve a given 0-1 MIP problem. In this paper a slightly improved version of the original method presented in (Lazić, et al., 2010) has been used.

Namely, we decided to introduce objective cuts in case of an improvement in order to reduce the search space. In addition, if the current incumbent solution cannot be improved by examining all subproblems generated with respect to the current linear relaxation solution $\overline{x}$, pseudo-cut $\delta(B(\overline{x}), x, \overline{x}) \ge 1$ is added to change the linear basis and the whole process is reiterated.

Input parameters for VNDS-MIP are 0-1 MIP problem P, integer d which controls the size of the subproblems generated within VNDS-MIP, initial integer feasible solution x and the maximum neighborhood size k_{vnd} within VND-MIP. Starting from incumbent integer feasible solution x of P and an optimal solution $\overline{x}$ of $LP(P)$, variables are ranked in the non-decreasing order of their absolute values of the difference between the values of x and $\overline{x}$.

Subproblems within VNDS are obtained by successively fixing a certain number of variables in that ranking. In this way, the subproblem involves the free variables which are furthest from their linear relaxation values. Then these subproblems are solved exactly or within the CPU time limit by, for example, CPLEX solver. The subproblems are changed by the hard fixing of the variables according to VNS rules.

It was noted that CPLEX solver requires a lot of CPU time to find the first feasible solution required also at the beginning of VNDS-MIP. Therefore, the *single neighborhood diving* heuristic (Lazić, et al., 2011) is used for finding initial feasible solutions. This heuristic is based on the systematic hard variable fixing (diving) process, according to the information obtained from the linear relaxation solution of the problem. In the next section the comparison results between VNDS-MIP and CPLEX commercial solver within the same CPU time limit are presented.

4. Experimental Evaluation

To evaluate the efficiency of VNDS-MIP two sets of test instances for BAP have been treated: the first set is containing artificially generated problems and the second is the set of real life instances proposed in (Changa, et al., 2010). VNDS-MIP is compared to CPLEX 11.2 optimization software (ILOG, 2008). VNDS-MIP is coded in C++ programming language for Linux operating system and compiled with gcc (version 4.1.2) and the option -o2. Both CPLEX and MIP heuristic are executed on Intel Core 2 Duo CPU E6750 on 2.66GHz with RAM=8Gb under Linux Slackware 12, Kernel: 2.6.21.5.

The results for the first set of test examples are summarized in Table 1. For all examples number of berths and time horizon are fixed, while number of vessels is varied from 6 to 15 and it is represented in the first column of Table 1. The numbers of binary and integer variables are given in the second and third column, respectively. The objective function value for an optimal solution (the total berthing and earliness-tardiness cost) is given in the fourth column. It is obtained by both solution methods. The remaining 2 columns contain CPU times required by CPLEX and VNDS-MIP to reach the optimal solution, respectively. As can be seen from Table 1, in most of the cases VNDS-MIP was able to obtain optimal solution within the smaller amount of CPU time.

Table 1
Computational results - artificial test problems: m=8,T=15

l	**#variables**		**OPT COST**	**CPU Time**	
	bin	**int**		**CPLEX**	**VNDS-MIP**
6	1530	12	380	0.06	0.02
7	1785	14	665	20.53	90.66
8	2040	16	745	18.91	10.28
9	2295	18	780	20.88	28.27
10	2550	20	1070	35.19	15.00
11	2805	22	1325	644.98	46.25
12	3060	24	1375	129.76	145.94
13	3315	26	1415	379.64	1383.44
14	3570	28	1485	635.40	362.62
15	3825	30	1845	4588.20	15.06
av.				647.35	209.75

The second set of examples consists of the real-life instances generated starting with the example taken from (Changa, et al., 2010) characterized by 21 vessels, 12 berths and 54 time units within the time horizon. This instance is further extended by adding new vessels; up to 28 (see Fig. 2).

Table 2 contains results for the examples from the second set. In this table the optimal values of the objective function are not included because CPLEX CPU time required to solve these instances to optimality was quite large.

For example, it took 14274sec=3h 57min 54sec for CPLEX to solve the smallest instance with 21 vessels and obtain the objective function value 4779.

Therefore, for the remaining examples the authors did not try to find an optimal solution. Instead, the same time limits for both methods used have been defined (CPLEX and VNDS-MIP) and in Table 2 the best obtained results are reported.

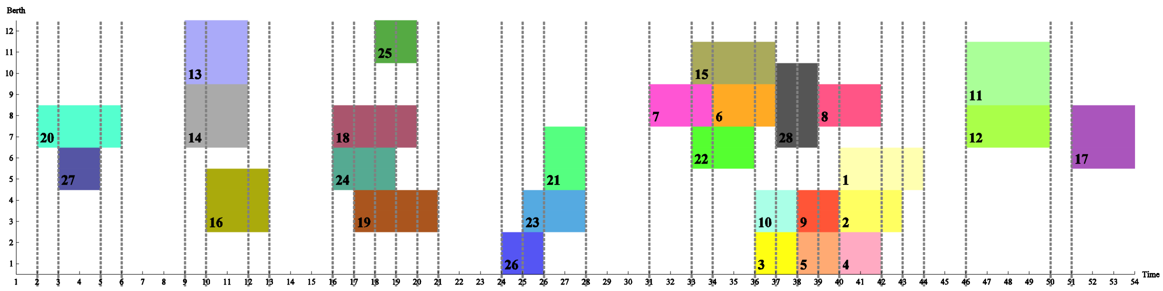

Fig. 2.
An example of real-life BAP solution
Source: Changa, et al., 2010

Table 2 is organized as follows. Number of vessels is presented in the first column. Columns 2 and 3 contain the best objective function value and the corresponding CPU time obtained by CPLEX solver, respectively. Same data connected with VNDS-MIP heuristic are given in columns 4 and 5. The specified time limit for each example is presented in the last column of Table 2. From the presented results it can be seen that for smaller examples (up to 24 vessels), VNDS-MIP results dominate the ones obtained by CPLEX with respect to both, solution quality and CPU time. For larger test instances (25-28 vessels) CPLEX is able to find better solutions. VNDS-MIP obviously faced the problem of being trapped in some worse local minimum.

Table 2
Computational results – real life test problems: m=12, *T*=54

	CPLEX		VNDS-MIP		T. Limit
l	**COST**	**CPU Time**	**COST**	**CPU Time**	**(sec.=hours)**
21	24562	3698.41	15424	494.30	3600.00= 1h
22	16334	7434.44	10108	961.13	7200.00= 2h
23	96549	7404.73	14110	1207.77	7200.00= 2h
24	6594	7429.48	9521	1609.55	14400.00= 4h
25	13262	18709.60	91620	1569.54	18500.00= 5h
26	26614	18716.10	77439	24742.42	18500.00= 5h
27	26679	18638.50	69143	3215.10	21600.00= 6h
28	8418	44530.70	63249	7779.35	43200.00=12h
av.	27376.50	15820.24	43826.75	5197.39	15750.00=4.375h

From these results it can be concluded that this problem is too complex to be efficiently treated by any of the general purpose solution methods that have been tested. This identifies the need for developing dedicated methods that will include all available *a priori* knowledge about this problem.

5. Conclusion

The Berth Allocation Problem (BAP) with an aim to minimize the total costs for waiting and handling as well as earliness or tardiness of completion, for all ships is considered. The problem is formulated as a mix-integer linear program. The complexity analysis of this problem is performed as well as the experimental evaluation of MIP-based exact and heuristic solution methods. For small size examples, heuristic method was able to find optimal solutions for all instances and to outperform CPLEX regarding computation times. The discouraging results for medium size test examples direct the further research to the development of dedicated (combinatorial–based) methods that will include all available knowledge about the considered problem.

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References

Bierwirth, C.; Meisel, F. 2009. A fast heuristic for quay crane scheduling with interference constraints. *Journal of Scheduling*, DOI: http://dx.doi.org/10.1007/s10951-009-0105-0, 12(4): 345-360.

Bierwirth, C.; Meisel, F. 2010. A survey of berth allocation and quay crane scheduling problems in container terminals. *European Journal of Operational Research*, DOI: http://dx.doi.org/10.1016/j.ejor.2009.05.031, 202(3): 615-627.

Changa, D.; Jiang, Z.; Yan, W.; He, J. 2010. Integrating berth allocation and quay crane assignments. *Transportation Research Part E*, DOI: http://dx.doi.org/10.1016/j.tre.2010.05.008, 46(6): 975-990.

Cordeau, J.F.; Laporte, G.; Legato, P.; Moccia, L. 2005. Models and tabu search heuristics for the berth-allocation problem. *Transportation Science*, DOI: http://dx.doi.org/10.1287/trsc.1050.0120, 39(4): 526-538.

Fischetti, M.; Lodi, A. 2003. Local branching. *Mathematical Programming*, 98(2): 23–47.

Guan, Y.; Cheung, R.K. 2004. The berth allocation problem: models and solution methods. *OR Spectrum*, DOI: http://dx.doi.org/10.1007/s00291-003-0140-8, 26(1): 75-92.

Hansen, P.; Mladenović, N.; Perez-Britos, D. 2001. Variable Neighborhood Decomposition Search. *Journal of Heuristics*, 7(4): 335-350.

Hansen, P.; Mladenović, N.; Urošević, D. 2006. Variable neighbourhood search and local branching. *Computers& Operations Research*, 33(10): 3034–3045.

Hansen, P.; Oğuz, C.; Mladenović, N. 2008. Variable neighborhood search for minimum cost berth allocation. *European Journal of Operational Research*, DOI: http://dx.doi.org/10.1016/j.ejor.2006.12.057, 191(3): 636-649.

ILOG. 2008. Cplex 11.2 reference manual. ILOG AMPL CPLEX System, Ver. 11.0, User's guide.

Imai, A.; Nishimura, E.; Papadimitriou. S. 2001. The dynamic berth allocation problem for a container port. *Transportation Research Part B*, DOI: http://dx.doi.org/10.1016/S0191-2615(99)00057-0, 35(4): 401–417.

Imai, A.; Nishimura, E.; Papadimitriou, S. 2003. Berth allocation with service priority. *Transportation Research Part B*, DOI: http://dx.doi.org/10.1016/S0191-2615(02)00023-1, 37(5): 437-457.

Kim, K.H.; Moon, K.C. 2003. Berth scheduling by simulated annealing. *Transportation Research Part B*, DOI: http://dx.doi.org/10.1016/S0191-2615(02)00027-9, 37(6): 541–560.

Lazić, J.; Hanafi, S.; Mladenović, N. 2011. Single Neighbourhood Diving for MIP Feasibility. (*Submitted for publication*).

Lazić, J.; Hanafi, S.; Mladenović, N.; Urošević, D. 2010. Variable neighbourhood decomposition search for 0-1mixed integer programs. *Computers and Operations Research*, http://dx.doi.org/10.1016/j.cor.2009.09.010, 37(6): 1055-1067.

Meisel, F.; Bierwirth, C. 2009. Heuristics for the integration of crane productivity in the berth allocation problem. *Transportation Research Part E*, DOI: http://dx.doi.org/10.1016/j.tre.2008.03.001, 45(1): 196-209.

Mladenović, N.; Hansen, P. 1997. Variable neighborhood search. *Computers and Operations Research*, DOI: http://dx.doi.org/10.1016/S0305-0548(97)00031-2, 24(11):1097-1100.

Nishimura, E.; Imai, A.; Papadimitriou, S. 2001. Berth allocation planning in the public berth system by genetic algorithms. *European Journal of Operational Research*, DOI: http://dx.doi.org/10.1016/S0377-2217(00)00128-4, 131(2): 282-292.

Oğuz, C.; Narin, Ő. 2009. Solving Berth Allocation Problem with Column Generation. In Proceedings of the *Multidisciplinary International Conference on Scheduling : Theory and Applications* (MISTA 2009), Dublin, Ireland: 744-747.

Park, Y.M.; Kim, K.H. 2003. A scheduling method for berth and quay cranes. *OR Spectrum*, DOI: http://dx.doi.org/10.1007/s00291-002-0109-z, 25(1): 1-23.

Wang, F.; Lim, A. 2007. A stochastic beam search for the berth allocation problem. *Decision Support Systems*, DOI: http://dx.doi.org/10.1016/j.dss.2006.06.008, 42(4): 2186-2196.

APPLICATION OF DIFFERENT LEARNING ALGORITHMS FOR THE PREDICTION OF POWER OF INLAND PUSHBOATS

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Abstract: This paper analyzes different learning algorithms for assessment of ship powering performance. Ship speed through water data have been used as an inputs in artificial neural networks and propulsion shaft torque data have been used as an outputs. Five different learning algorithms have been applied in order to get relationship between pushboat power and convoy speed. Data are acquired over several years on many different pushed convoys. It was shown that trained neural networks can be used for the prediction of ship power and in the same time plenty of room was left in the length of training neural networks.

Keywords: Artificial neural network, shaft power, speed through water, relative error

1. Introduction

Determination of power required to propel ship is an essential part of building a ship. When the ship is put into operation it is considered that the power of his main engine(s) corresponds to the given power required for predicted ship speed. Such power is most commonly associated with the corresponding ship speed and drought which is arranged in advance of the construction of the ship. However, during the operation of a ship for a long period of time it is possible to appear changes on the hull and propulsion. These changes will inevitably affect the changes in the speed-power ratio over the same transport capacity and thus directly will increase the required power of the main engine for the same speed of the ship.

The most common reasons for the change of main engine power are propeller cavitations and changes that occur at the ship hull. Therefore, assessing the changes of the powering characteristics and detecting the decline in the overall ship performance are the most important things that the crew and the captain are obliged to know over the one or more periods of time. During these periods the ship's captain and crew remain unknown about the degree of decline or weakening in the overall ship performance. Since the operation of the ship is affected by various external factors (wind, waves, water depth, water temperature changes, etc.) it is not difficult to conclude that the ship will rarely, or never navigate in the same external conditions. On the other hand, these external factors are very difficult to measure accurately, and it is almost impossible to find the same situation in two different periods of time.

Changes of speed/power ratios over few percent a year is impossible to determine with the traditional methods for ship resistance (and therefore the effective power of ship) calculation (Marchal et al. 1996). Traditional methods include the use of empirical and numerical equations that are based on model tests carried out at model tanks and full-scale trials performed over a measured distance. Since the tests were done at certain navigation and hydrological conditions on the waterway, experiential methods are used to meet these requirements of navigation. In real, everyday operation, ships or pushed convoys will navigate in different conditions, for example, different ballast, drought etc.

Applied research in this paper refers to the pushed convoys which, on inland waterways, consist of pushboat and group formations of barges. Results of tests refer to different pushboats and their convoys.

This paper will discuss and analyze data obtained during the experimental tests and speed/power measurements performed on pushboats that were in convoys. The subject of the analysis will be the following variables of ship propulsion: shaft power and sheep spid through water. Because of the relationship which occurs between the main dimensions of the ship and the ship resistance (and thus effective power of ship) ratios between the main dimensions of the convoys will be considered too.

Experiential methods give accurate results in some cases, but in most cases give a rough estimate of the effective power of the ship. The method presented in this paper, apply artificial neural networks for predicting pushboat shaft power in relation with ship speed through water.

Artificial neural networks are modeled by a nonlinear relationship between the input variables (convoy speed, convoy capacity and ratios between main dimensions of convoy) and one output variable (shaft power of the pushboat). It is possible to model the nonlinear relationship between input and output data, and the interrelationship of input data.

The database, obtained by speed/power measurements, is not divided by different barge formations. This is not an accurate estimate of the shaft power for different convoys. Therefore, the obtained solution can be applied to previously tested convoys.

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This approach to problem solving can be justified by the ability of artificial neural networks to adapt easily to the new data, so it will be possible in the future to upgrade the entire model with minimum effort.

2. Literature review

Over the last two decades there has been done extensive research in the field of artificial neural networks for predicting relationships between various data related to the ship. Neural networks have been widely used in the field of shipbuilding and transportation systems.

Couser et al. (2004) investigated the accuracy of ANNs as prediction tools for hull resistance. The goal of the investigation was to determine a predictive model for residuary resistance, based on input values of Froude number, Separation-Length ratio, Breadth-Draught and Slenderness ratio. The data used for the investigation originated from a series of tank tests. The authors demonstrated that a combination of Genetic Algorithms and Artificial Neural Networks could be used as an optimization tool for catamaran design parameters.

Bertram and Mesbahi (2006) designed SWATH (small water plane area twin hulls) Ship Design Formulae Based on Artificial Neural Nets. They concluded that the Neural Network approach allows more general curve fitting than classical regression analysis based on simple polynomial expressions. However, they pointed out that results are highly dependent on how well the input parameters are chosen. Extrapolation is particularly risky. The Artificial Neural Network formulae appeared in paper proved to be an excellent first estimate aiding preliminary SWATH design.

Pedersen and Larsen modeled the operation of the ship TORM MARIE propulsion system and got predictions with a relative error of less then 2.7% using a single layer neural network. With the classical methods relative error was more than 5%. They carried out four different states with the following input variables: ship speed, relative wind speed and direction, air temperature and sea water temperature (Pedersen and Larsen, 2009).

Abdel Naby et al. (2008) and others explored various techniques of artificial neural networks for the prediction of resistance coefficients of river barges. They relied on experiments obtained from the model tests that were carried out in the ship model basin in Duisburg.

Ortigosa et al. (2009) presented a neural network approach to two resistance's components prediction. Multilayer perceptron has been trained with generated data and experimental data to provide an estimation of the form coefficient and the wave's coefficient as function of hull geometry coefficients and the Froude number. Results obtained with Neural Networks technique were compared with Holtrop and Mennen's method (1982) for estimating the form factor and the wave's coefficient. They found that the quality of the prediction with the neural networks was improved over the entire range of data.

The contribution of the paper is a completely new procedure for predicting shaft power of the pushboats, as well as the training data with multiple learning algorithms.

3. Artificial Neural Networks

Artificial neural networks stores data during a learning process and then reproduces these data during a recall process that makes them very usable in the field of interpolation. Artificial neural networks are non-linear function with the capability of mapping multi-dimensional input/output data sets as:

$$f: X \rightarrow Y$$

where:

- f – non-linear function,
- $X = (x_1, x_2, \ldots, x_n)$ – real input vector,
- $Y = (y_1, y_2, \ldots, y_m)$ – real output vector (see Fig. 1).

An ANN structure consists of several layers that includes input layer, output layer and one or more hidden layer between these two (see Fig. 1) although there is rarely more then two hidden layers. Each layer consists of several nodes. The values of the previous layer are weighted, summed up and are transformed by a function, before passed on to the next layer.

In the paper, this function is a sigmoid function. Network has feed-forward architecture with one or more hidden layers. Input units have identity activation function; all other units have sigmoid activation function. Provided data are automatically normalized, both input and output, with a linear mapping to the range (0, 1). Each input and output is treated separately (i.e. linear map is unique for each input and output). Function minimized during training is a sum of squared errors of each output for each learning pattern.

Training was performed with use of several optimization schemes including: standard back propagation with momentum (Vukadinović et al., 1997), Rprop learning algorithm (Riedmiller and Braun, 1993), conjugate gradient algorithm (Nocedal and Wright, 1999), constrained version of quasi-Newton method of Broyden, Fletcher, Goldfarb, and Shanno (algorithm is called L_BFGS_B), Tnc algorithm and genetic algorithm based optimization (Nash, 2000). Input and output data are normalized between 0 and 1:

Normalized value = (Real value -Min. Value)/(Max. value - Min. value)

After sufficient training non-linear mathematical relationship between input and output data is determined and input and output data is de-normalized to their real values.

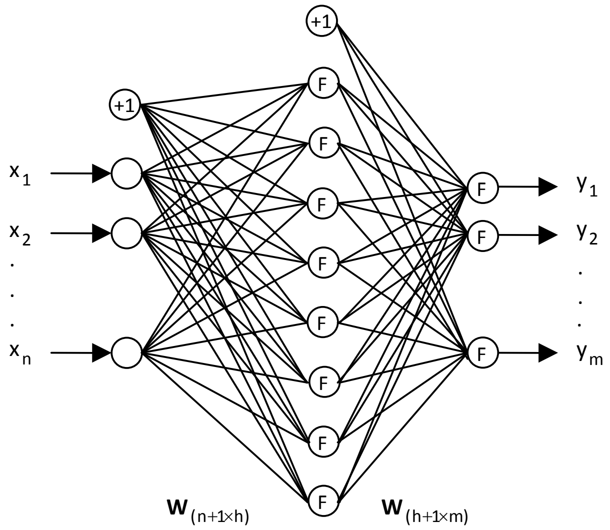

Fig. 1.
General structure of an Artificial Neural Network

4. Experimental Data

Periodic speed/power measurements are the only reliable method to determine ship powering characteristics. This hull powering assessment is accomplished through standardization trials. Standardization trials are conducted on every new ship and represent the optimum performance capabilities of every new ship. Trials are reflected in speed/power characteristics for ship (Čolić, 2006).

Measurements are performed on a predetermined section of the waterway and under normal conditions of navigation. The resulting data represent the performance characteristics for the entire class of ships and are referred to each ship in the class.
However, the usefulness of these data decreases by the time due to ship aging.

Speed/power measurements included the following measurements: the measurement of the shaft power resulting in propulsion shaft torque data (obtained from torsion meters) and measurements of ship speed through water resulting in ship speed data (obtained from ship equipment). Ship speed measurements are obtained from the Global Positioning System (GPS).

Measurement of the power of propeller shaft was done by torsion meter which was set up on both shafts at the stern of the ship and at the highest engine load as well as several lower loads for continuous operation.

Convoy speed through water was determined by a hydrometric wing, which was set to the side of the leading barge(s) but closer to the bow of the convoy. During the measurement the hydrometric wing was submerged to a depth of approximately 0.8 meters while it was away from the leading barges about 3.5 meters at the same time. Thus it can be considered that the hydrometric wing was operated in relatively undisturbed water.

All tests and measurements were carried out for different pushed convoys. Pushed convoy refers to the combined formations of barges and pushboats, and all pushboats have twin propellers.

Propulsion shaft torque data and convoy speed through water data were collected and combined into a single database. Input data included:

1. convoy beam-to-length ration (B/L),
2. convoy medium drought-to-beam ratio (T/B),
3. slenderness ratio ($L/V^{1/3}$)
4. Froude number (F_n).

Output data included pushboat shaft power (P_D). All input and output data are normalized between 0 and 1. The data has been collected over the years and for the 17 different pushboats and 40 different formations of barges where the total number of data increased to 194 (Čolić, 2006).

5. Results

In this study, a multilayer neural network with the feed-forward multi-layer perceptron (one input layer two hidden layers and one output layer) is used. Number of nodes in the first of two hidden layers changed from 6 to 9. The number of neurons in the second hidden layer was constant and was eighth. Each layer was added by an additional "noise".

Training of the neural network was performed by back-propagation algorithm (Vukadinović et al., 1997), Rprop learning algorithm (Riedmiller and Braun, 1993), conjugate gradient algorithm (Nocedal and Wright, 1999), constrained version of quasi-Newton method of Broyden, Fletcher, Goldfarb, and Shanno (algorithm is called L_BFGS_B), Tnc algorithm and genetic algorithm based optimization (Nash, 2000). Node activation functions are logistic or sigmoid curve. Weights are determined by the delta rule, i.e., by the difference between the actual and desired outputs. Level of error wasn't given, and the learning process is completed through a number of iterations. In order to complete learning process (by back-propagation algorithm) in a shorter period of time, learning rate (the intensity of learning) and momentum factor are set to values that guarantee fast reaching errors less than 10%.

Two decisions were made regarding the hidden layers: the number of hidden layers and the number of nodes in each of them. Firstly, there is no theoretical reason to use the network with more than two hidden layers. Secondly, the neural network with two hidden layers can represent any nonlinear relationship (Heaton, 2008).

Number of nodes in the hidden layers is very carefully determined. Given that the data set was very complicated, it was considered that the network should not have a small number of nodes, because they do not correctly detect all signals. Otherwise, the network would not be able to train well all nodes in the hidden layer. Another problem with excessive number of nodes is increasing the time of publishing the results with the increasing number of nodes, which in overall challenges neural network technique as optimal.

There are a lot of rules about the number of nodes in the hidden layer, but they (the rules), in fact, represents the starting point in determining the optimal number of nodes (Heaton, 2008). Finally, the optimal network architecture was discovered through many network training and according to minimum error during and after the training.

Training and testing is done in software application written in Python. The results of each of the five different neural networks are estimated on the basis of the relative sum of the errors squared (Eq. (1)) and mean of the relative error (Eq. (2)) (Pedersen and Larsen, 2009):

$$\tilde{\sigma} = \frac{\sum_{i=1}^{n}(P_D - P_D^{test})^2}{\sum_{i=1}^{n}(P_D^{test})^2} \tag{1}$$

$$\tilde{\omega} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{P_D - P_D^{test}}{P_D^{test}}\right| \tag{2}$$

where:

P_D - values of the propeller shaft obtained by experimental measurements (kW)
P_D^{test} - values of the propeller shaft obtained by testing the neural network (kW)
n - number of data set that was tested

Every dataset has been trained with the different learning algorithm four times and with different number of hidden units in the first and second hidden layer. Number of units in the first hidden layer is varied from 6 to 9 and in the second hidden layer varied from seven to eight. Thus, trained neural networks had following number of hidden units in the first and second hidden layers: 6,9; 7,9; 8,9 and 7,8. Tables 1-8 shows the relative sum of the errors squared, mean of the relative errors and their mean values for the four different tested results, as well as maximum difference between measured shaft power and shaft power obtained from training neural network. Results from standard back propagation algorithm weren't shown because of the big errors in results.

Tables 1 and 5 noted that L_BFGS_B and RPROP algorithm give the best results. Errors are lower than 5% for relative sum of the errors and mean error of all relative errors is about 16 %.

As for the training results, all four algorithms are good choice because errors are lower than 1% for relative sum of the errors and mean error of all relative errors is lower than 10%. If looking at the last columns in all of the Tables from 1 to 8 there can be found very big variations in the values for the tested data. All variations come from inadequate number of training iterations and suggest more training iterations to be done. For the L_BFGS_B and RPROP learning algorithms it is possible to be done more iteration which will extend time for training network, but will also give more accurate results. For the rest of learning algorithm it is showed that the extension in iteration will not automatically mean improved accuracy of results.

Table 1
Results and related errors to tested data done after L_BFGS_B learning algorithm

Number of tested data	**Number of units in hidden layers**	**Testing sets (N)**	**Relative sum of the errors squared, $\tilde{\sigma}$**	**Mean of the relative error, $\tilde{\omega}$**	$\tilde{\bar{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\bar{\varpi} = \frac{1}{N}\sum_{N=1}^{4}\omega$	**$\lvert P_D - P_D^{test}\rvert_{max}$ (kW)**
53	6,9	1	0.049	0.107	0.034	0.162	734
35	6,9	2	0.035	0.106			158
53	6,9	3	0.010	0.163			718
53	6,9	4	0.042	0.272			533
35	7,9	1	0.012	0.109	0.040	0.264	134
53	7,9	2	0.088	0.368			441
53	7,9	3	0.0094	0.087			113
53	7,9	4	0.052	0.493			246
53	8,9	1	0.0083	0.048	0.0206	0.115	289
53	8,9	2	0.040	0.164			237
53	8,9	3	0.015	0.119			141
53	8,9	4	0.019	0.128			148
53	7,8	1	0.024	0.122	0.024	0.121	248
35	7,8	2	0.023	0.120			123
35	7,8	3	0.041	0.165			128
35	7,8	4	0.0075	0.077			96

Table 2
Results and related errors to trained data done after L_BFGS_B learning algorithm

Number of trained data	**Number of units in hidden layers**	**Training sets (N)**	**Relative sum of the errors squared, $\tilde{\sigma}$**	**Mean of the relative error, $\tilde{\omega}$**	$\overline{\tilde{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\overline{\omega} = \frac{1}{N}\sum_{N=1}^{4}\omega$	**$\lvert P_D - P_D^{test}\rvert_{max}$ (kW)**
124	6,9	1	0.0037	0.055	0.008	0.068	70
142	6,9	2	0.0052	0.065			172
124	6,9	3	0.0182	0.088			480
124	6,9	4	0.0051	0.064			144
142	7,9	1	0.0040	0.060	0.0029	0.0465	113
124	7,9	2	0.0027	0.045			70
124	7,9	3	0.0021	0.037			80
124	7,9	4	0.0028	0.044			136
124	8,9	1	0.0054	0.068	0.0055	0.0645	120
124	8,9	2	0.0073	0.061			190
124	8,9	3	0.0032	0.051			108
124	8,9	4	0.0060	0.078			120
124	7,8	1	0.0063	0.071	0.00605	0.067	213
142	7,8	2	0.0060	0.069			87
142	7,8	3	0.0085	0.080			129
142	7,8	4	0.0034	0.047			86

Table 3
Results and related errors to tested data done after CONJUGATE GRADIENT ALGORITHM learning algorithm

Number of tested data	**Number of units in hidden layers**	**Testing sets (N)**	**Relative sum of the errors squared, $\tilde{\sigma}$**	**Mean of the relative error, $\tilde{\omega}$**	$\overline{\tilde{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\overline{\omega} = \frac{1}{N}\sum_{N=1}^{4}\omega$	**$\lvert P_D - P_D^{test}\rvert_{max}$ (kW)**
53	6,9	1	0.017	0.099	0.0269	0.0955	117
35	6,9	2	0.026	0.097			90
53	6,9	3	0.006	0.064			132
53	6,9	4	0.058	0.119			718
53	7,9	1	0.065	0.125	0.04174	0.1368	718
53	7,9	2	0.021	0.116			200
53	7,9	3	0.032	0.120			144
53	7,9	4	0.046	0.185			81
53	8,9	1	0.126	0.354	0.1237	0.3600	718
35	8,9	2	0.081	0.583			79
35	8,9	3	0.014	0.115			102
35	8,9	4	0.274	0.388			735
35	7,8	1	0.013	0.102	0.02675	0.1358	86
53	7,8	2	0.075	0.290			72
35	7,8	3	0.008	0.085			75
35	7,8	4	0.008	0.064			164

Table 4
Results and related errors to trained data done after CONJUGATE GRADIENT ALGORITHM learning algorithm

Number of trained data	Number of units in hidden layers	Training sets (N)	Relative sum of the errors squared, $\tilde{\sigma}$	Mean of the relative error, $\tilde{\omega}$	$\bar{\tilde{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\bar{\omega} = \frac{1}{N}\sum_{N=1}^{4}\omega$	$\lvert P_D - P_D^{test}\rvert_{max}$ (kW)
124	6,9	1	0.001	0.031	0.0028	0.0441	58
142	6,9	2	0.002	0.043			71
124	6,9	3	0.002	0.045			79
124	6,9	4	0.004	0.056			106
124	7,9	1	0.0009	0.022	0.0017	0.0320	69
124	7,9	2	0.002	0.036			69
124	7,9	3	0.002	0.035			52
124	7,9	4	0.001	0.033			72
124	8,9	1	0.001	0.025	0.0023	0.0392	74
142	8,9	2	0.003	0.049			69
142	8,9	3	0.002	0.043			71
142	8,9	4	0.002	0.037			67
142	7,8	1	0.002	0.036	0.0024	0.0419	72
124	7,8	2	0.002	0.042			82
142	7,8	3	0.002	0.042			71
142	7,8	4	0.003	0.046			92

Table 5
Results and related errors to tested data done after RPROP learning algorithm

Number of tested data	Number of units in hidden layers	Testing sets (N)	Relative sum of the errors squared, $\tilde{\sigma}$	Mean of the relative error, $\tilde{\omega}$	$\bar{\tilde{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\bar{\omega} = \frac{1}{N}\sum_{N=1}^{4}\omega$	$\lvert P_D - P_D^{test}\rvert_{max}$ (kW)
53	6,9	1	0.051	0.160	0.0426	0.1538	703
53	6,9	2	0.069	0.199			804
53	6,9	3	0.011	0.085			88
53	6,9	4	0.038	0.169			339
35	7,9	1	0.010	0.084	0.0241	0.1045	147
53	7,9	2	0.017	0.126			364
53	7,9	3	0.059	0.133			247
35	7,9	4	0.009	0.073			187
53	8,9	1	0.051	0.120	0.0854	0.2350	522
53	8,9	2	0.110	0.257			493
53	8,9	3	0.106	0.403			321
35	8,9	4	0.072	0.158			395
53	7,8	1	0.055	0.199	0.0720	0.2193	406
35	7,8	2	0.085	0.246			363
35	7,8	3	0.032	0.149			82
35	7,8	4	0.114	0.281			523

Table 6
Results and related errors to trained data done after RPROP learning algorithm

Number of trained data	**Number of units in hidden layers**	**Training sets (N)**	**Relative sum of the errors squared, $\tilde{\sigma}$**	**Mean of the relative error, $\tilde{\omega}$**	$\tilde{\tilde{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\overline{\varpi} = \frac{1}{N}\sum_{N=1}^{4}\omega$	**$\|P_D - P_D^{test}\|_{max}$ (kW)**
124	6,9	1	0.004	0.059	0.0036	0.0500	114
124	6,9	2	0.001	0.037			69
124	6,9	3	0.003	0.052			97
124	6,9	4	0.004	0.050			115
142	7,9	1	0.003	0.044959	0.0026	0.0415	95
124	7,9	2	0.002	0.038			81
124	7,9	3	0.003	0.041			127
142	7,9	4	0.002	0.040			62
124	8,9	1	0.002	0.03	0.0025	0.0415	59
124	8,9	2	0.002	0.044			88
124	8,9	3	0.002	0.039			79
142	8,9	4	0.002	0.044			98
124	7,8	1	0.002	0.040	0.0045	0.0514	83
142	7,8	2	0.005	0.058			148
142	7,8	3	0.002	0.043			71
142	7,8	4	0.007	0.063			192

Table 7
Results and related errors to tested data done after TNC learning algorithm

Number of tested data	**Number of units in hidden layers**	**Testing sets (N)**	**Relative sum of the errors squared, $\tilde{\sigma}$**	**Mean of the relative error, $\tilde{\omega}$**	$\tilde{\tilde{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\overline{\varpi} = \frac{1}{N}\sum_{N=1}^{4}\omega$	**$\|P_D - P_D^{test}\|_{max}$ (kW)**
35	6,9	1	0.088	0.268	0.0896	0.2078	330
53	6,9	2	0.049	0.169			467
53	6,9	3	0.163	0.217			597
53	6,9	4	0.056	0.176			801
35	7,9	1	0.013	0.095	0.0906	0.2335	177
35	7,9	2	0.051	0.120			482
53	7,9	3	0.155	0.324			167
53	7,9	4	0.142	0.394			470
35	8,9	1	0.089	0.156	0.1164	0.3700	392
53	8,9	2	0.141	0.224			692
53	8,9	3	0.140	0.871			969
53	8,9	4	0.093	0.227			1260
53	7,8	1	0.112	0.472	0.1252	0.3527	714
53	7,8	2	0.102	0.120			610
35	7,8	3	0.187	0.541			644
53	7,8	4	0.098	0.276			890

Table 8
Results and related errors to trained data done after TNC learning algorithm

Number of trained data	Number of units in hidden layers	Training sets (N)	Relative sum of the errors squared, $\tilde{\sigma}$	Mean of the relative error, $\tilde{\omega}$	$\overline{\tilde{\sigma}} = \frac{1}{N}\sum_{N=1}^{4}\tilde{\sigma}$	$\overline{\varpi} = \frac{1}{N}\sum_{N=1}^{4}\omega$	$\lvert P_D - P_D^{test}\rvert_{max}$ (kW)
142	6,9	1	0.001	0.027	0.0017	0.0311	79
124	6,9	2	0.002	0.035			81
124	6,9	3	0.002	0.039			56
124	6,9	4	0.000	0.022			70
142	7,9	1	0.002	0.040	0.0023	0.0371	69
142	7,9	2	0.002	0.041			77
124	7,9	3	0.002	0.039			122
124	7,9	4	0.001	0.027			80
142	8,9	1	0.001	0.033	0.0012	0.0242	64
124	8,9	2	0.001	0.018			92
124	8,9	3	0.001	0.021			84
124	8,9	4	0.001	0.023			68
124	7,8	1	0.001	0.030	0.0019	0.0357	74
124	7,8	2	0.001	0.038			79
142	7,8	3	0.002	0.040			74
124	7,8	4	0.001	0.033			65

Standard backpropagation algorithm was performed on the measured data but results are far below the standards obtained from four previous algorithms. The key for the learning process in backpropagation algorithm is in the number of iterations that should be performed and that are time-consuming. In this paper these results will not be presented and compared with those obtained from four previous algorithms.

The prediction error distribution is illustrated in Fig. 2 – Fig. 5. The majority of errors in predicted shaft powers are between 0 and 200 kilowatts. For all of the tested data normal distribution fits the histogram very well.

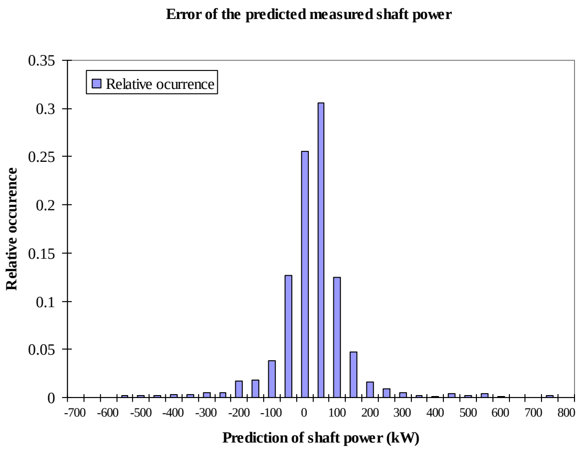

Fig. 2.
Relative distribution of the predicted errors for tested data with L_BFGS_B learning algorithm

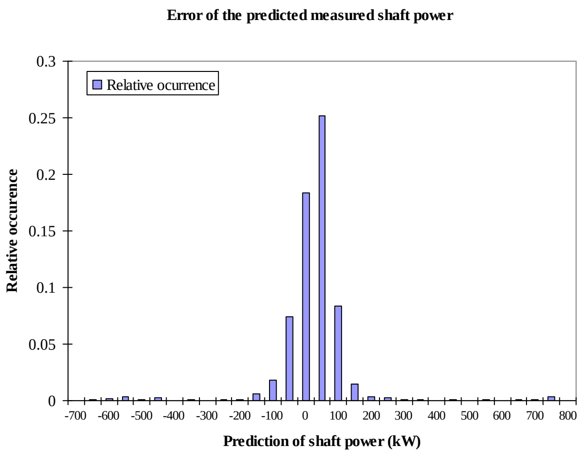

Fig. 3
Relative distribution of the predicted errors for tested data, with conjugate gradient learning algorithm

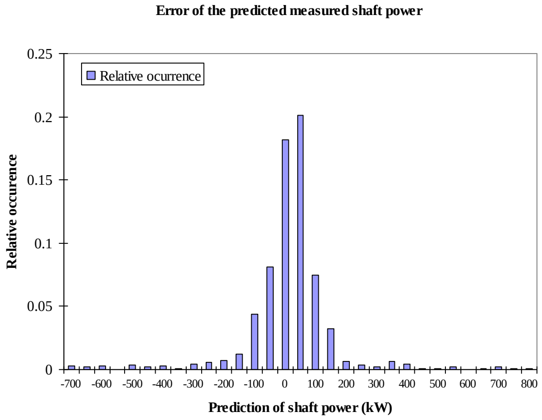

Fig. 4.
Relative distribution of the predicted errors for tested data with RPROP learning algorithm

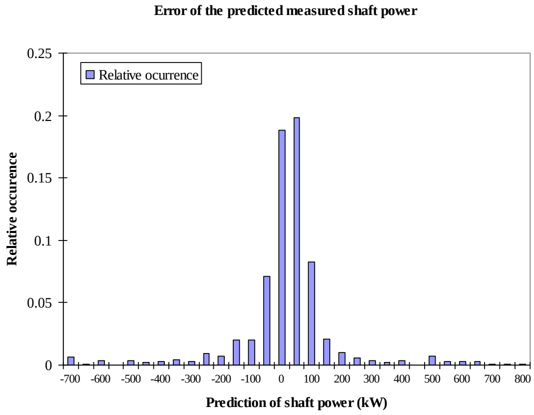

Fig. 5.
Relative distribution of the predicted errors for tested data with TNC learning algorithm

6. Conclusion

This paper showed that it is possible to train experimental data with artificial neural networks. Trained data errors are less than 1% in the relative sum of the errors squared $\tilde{\sigma}$ and less than 10% in mean of the relative error ω. Remaining data are tested and solutions differed from one to another learning algorithm. These errors range from a few percent up to 10% in the $\tilde{\sigma}$ errors and up to 16% in ω error. The best results are obtained from RPROP and L_BFGS_B algorithms. It would be possible to achieve even better results if the learning algorithms were let work over a longer period of time or with more iterations.

Variations in the error of shaft power are not large, but the maximum values in the difference between measured shaft power and predicted shaft power are big and can be corrected by increasing the number of iterations for training the network. Relative distributions of the predicted errors for tested data fit normal distribution.

In this study the possibility of using the standard backpropagation algorithm is also investigated. However, the results were not good for a given number of iterations and these results were not discussed. However, acceptable results in this domain can be achieved by increasing the number of iterations and period of time for network training. The genetic algorithm was used for calculation of the initial weights of branches in neural networks.

This research has also shown that the success of a learning algorithm is closely related to the selection of algorithm as well as to number iterations used in training data.

References

Bertram, V.; Mesbahi, E. 2006. SWATH Ship Design Formulae Based on Artificial Neural Nets, In Proceedings of the *5th International Conference on High Performance Marine Vehicles*, Launceston, Australia. 479p.

Čolić, V. 2006. *The study of navigational, energetics and propulsion characteristics of Danube pushboats (in Serbian)*, University of Belgrade, Faculty of Transport and Traffic Engineering.350p.

Couser, P.; Mason, A.; Smith, C.R.; Von Konsky, B.R. 2004. Artificial neural networks for hull resistance prediction, In Proceedings of the *3rd International Conference on Computer Applications and Information Technology in the Maritime Industries (COMPIT)*, Siguenza, Spain. 480p.

Heaton, J. 2008. *Introduction to Neural Networks for Java*, 2nd Edition, Heaton Research Inc., St. Louis, 417p.

Holtrop, J.; Mennen, G.G.J. 1982. An approximate power prediction method, *International Shipbuilding Progress*, 29(335): 166-170.

Maged, M. Abdel Naby.; Heba, W.L.; Adel, A.B.; Ahmed, H.E. 2008. Investigation of various artificial neural networks techniques for the prediction of inland water units' resistance, *Ships and Offshore Structure* 3(3): 247-254.

Marchal, J.L.J.; Shen, Y.D.; Kicheva, D. 1996. An Empirical Formula to Estimate the Resistance of a Convoy in a Restricted Waterway, *Journal of Ship Research*, 2(40): 107-111.

Nash, S. 2000 A survey of truncated-Newton methods, *Journal of Computational and Applied Mathematics*, DOI: http://dx.doi.org/10.1016/S0377-0427(00)00426-X, 124(1-2): 45–59.

Nocedal, J.; Wright, S. 1999. *Numerical Optimization*. Springer. Series in Operations Research. 634p.

Ortigosa, I.; Lopez, R.; Garcia, J. 2009. Prediction of Total Resistance Coefficients using Neural Networks, *Journal of Maritime Research*, III(VI): 15-26.

Pedersen, B.P.; Larsen, J. 2009. Modeling of ship propulsion performance, *World Maritime Technology Conference (WMTC)*, Mumbai, India: 1-10.

Riedmiller, M.; Braun, H. 1993. A direct adaptive Method for faster backpropagation learning: The RPROP algorithm. *In* Proceedings of the *IEEE International Conference on Neural Networks*. IEEE Press: 586–591.

Vukadinović, K.; Teodorović, D.; Pavković, G. 1997. A neural network approach to the vessel dispatching problem, *European Journal of Operational Research*, DOI: http://dx.doi.org/10.1016/S0377-2217(96)00237-8, 102(3): 473-487.

THE CONTAINER TRANSPORTATION PROBLEM: MODEL AND SOLUTION METHODS

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Abstract: This paper studies the traffic control of automated guided vehicles (AGVs) moving in seaport terminals. These unmanned vehicles are used in terminal operations for transfer containers between ships and storage locations on the shore. The moving of vehicles can be described as the set of discrete events and states. Some of these states can be undesirable such as conflicts and deadlocks. It is necessary to apply adequate control policy to avoid deadlocks and block the vehicles' moving only in the case of dangerous situation. This paper focuses on design AGV transport system with no conflicts and deadlocks. Vehicles have to be stopped only in the case of dangerous situation. The final goals of this design are normally related to optimization of processing time or minimization the number of AGVs involved while maintaining the system throughput. The container transport system is modeled as a MRF_1 class of Petri net with disjoint sets of resource and job places. The authors use a method for calculating control places which control conflicts and restrict level deadlocks. The model is tested using computer simulation.

Keywords: container transport, control conflicts, no deadlock, Petri net

1. Introduction

A container terminal provides the interface between different transport means, therefore handling equipment is very important. It is important to guarantee fast operations to reduce delays in delivering goods to ships, trains and trucks, and consequently to reduce sea, road or railway transport time. For this reason, the container terminal management must constantly measure productivity on all subsystems, on berth, yard and in acceptance-delivery zone. To achieve the best results, analysis, design, and control are necessary, possibly through flexible and adaptable modeling techniques and advanced simulation tools.

Basically, the main processes which determine the system effectiveness are: unloading containers from a vessel to internal transfer vehicles, moving containers from ship to stack; stacking containers in an assigned position; moving containers from stack to ship; loading containers from internal transfer vehicles to the vessel; transport of containers to other modes (railway, road). All the above processes need several shared and reusable resources to fulfill the tasks involved in handling and transporting containers: quay cranes, yard cranes, transport vehicles such multi trailers or automatically guided vehicles (AGVs), straddle carriers, yard stacking deposits, automatic stacking cranes, railway tracks, human operators.

In this paper, a container terminal configuration similar to the terminal of Port Koper (Slovenia) is considered. The terminal layout considered throughout this paper is displayed in Fig. 1. This terminal consists of three quay cranes (Cr1), 1 automated stacking crane (Cr2) and 1 mobile crane (Cr3) which unloads containers from vehicles and loads them on the train. To design a highly efficient automated container terminal AGV system is deployed to transport containers within the terminal area. AGVs are means for horizontal transport of containers between the stacking area and the quay, and they are unable to load or unload themselves. It is only possible to deal with a static transportation problem in which all the transportation jobs are ready to be picked up at the beginning of a planning horizon. It is assumed that the number of containers to be moved between two locations is determined at the beginning of the planning horizon, and travel times between locations as well as loading and unloading times are deterministic and known in advance.

Generally, the container transportation systems (CTS) can be described as discrete event system (DES), which consists of discrete states and events. These events and states are normally observed by the container terminal managament system (CTMS). Some of these states, such as conflicts and deadlocks, are undesirable (even dangerous). In this view, CMTS should implement supervisory policy which has to ensure that the process does not get into any of forbidden states (AGV collision or deadlock of vehicles) and that it performs in accordance with the given requirements (Charbonnier, et al., 2001).

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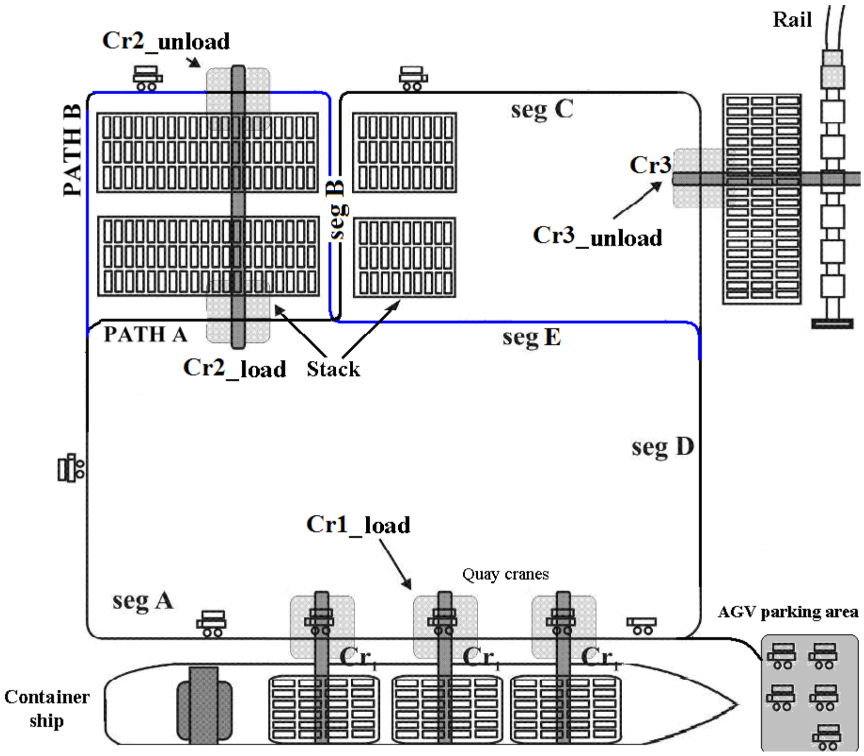

Fig. 1.
Layout of the Container Terminal

Discrete event systems are growing in popularity and complexity. This is motivating the use well organized methodologies to avoid failures and to optimize performance. In this paper, the main goal is to achieve conflict and deadlock free transshipment of containers within the terminal area. Petri net theory is used for modeling CTS and designing appropriate supervisor. For simulation, analysis and control of CTS, MRF_1 class of Petri net (MRF_1PN) is used (Bogdan & Lewis, 1997). This tool is based on a matrix formulation for DES (Lewis et al., 1998). The supervisor is maximally permissive and consists of minimal number of control places. To avoid deadlock, it is necessary to control markings in every critical subsystem by adding additional control places. P-invariant method is used to calculate deadlock prevention control places (Bogdan & Lewis, 1997; Kezić and Gudelj, 2010). Using matrixes, computer program in Matlab is written for simulation and control CTS. Using this technique it is possible to plot versus time various performance measures and as results some of plots are presented in Section 3.

2. Petri Nets and Deadlock Avoidance

Petri nets formalism is a graphical and mathematical tool adapted to the modeling of the main features of discrete event systems (Gallego et. al, 1996). Basically, Petri net is a bipartite graph consisting of two types of nodes, places and transitions, connected by arcs.

Place - transition P/T Petri net is a 6-tuple (Murata, 1989) (Eq. (1)):

$$PN = (P, T, \mathbf{I}, \mathbf{O}, w, \mathbf{m_0}) \tag{1}$$

where:

$P = \{p_1, p_2, ..., p_n\}$ is set of places, $T = \{t_1, t_2, ..., t_n\}$ is set of transitions, $\mathbf{I}: P \times T \rightarrow \{0,1\}$ is set of input arcs from places to transitions, $\mathbf{O}: T \times P \rightarrow \{0,1\}$ is set of output arcs from transitions to places, $w: \mathbf{I}, \mathbf{O} \rightarrow \{1, 2, 3, ...\}$ is a weight function, $\mathbf{m}_0$ is initial marking.

Places and transitions $v \in P \cup T$ are calling nodes and denote states and events in the DES. Given any node *v*, let $\bullet v$ and $v \bullet$ respectively denote the pre-set and post-set of *v* in usual way, i.e. the set of nodes that have arcs to and from *v*, respectively.

An available resource or an ongoing job in DES is indicated by tokens in respective places. A transition $t \in T$ is enabled at a marking $m(p)$ $iff\_\forall p \in \bullet t, m(p) \geq w(I(p,t))$ ($\bullet t$ is a set of input places to transition *t*, and $w(I(p,t))$ is weight of the arc between *p, t*). A transition *t* that meets the enabled condition is free to fire. When a transition *t* fires, all of its input places lose a number of tokens, and all of its output places gain a number of tokens. In a Petri net PN with *m* places and *n* transitions, the incidence matrix **W** is a $n \times m$ matrix defined by (Eq. (2)):

$$\mathbf{W} = \mathbf{O} - \mathbf{I} \tag{2}$$

where the elements a_{ij}^{+} and a_{ij}^{-} of **O** and **I** are:

$$a_{ij}^{+} = w(I(p_i, t_j))\_if\,(p_i, t_j) \in I\_and\_a_{ij}^{+} = 0\_otherwise$$

$$a_{ij}^{-} = w(O(t_j, p_i))\_if\,(t_j, p_i) \in O\_and\_a_{ij}^{-} = 0\_otherwise$$

The matrices **I** (input matrix) and **O** (output matrix) provide a complete description of the structure of a Petri net. If there are no self loops, the structure may be described by **W** only. The incidence matrix allows an algebraic description of the evolution of the marking of a Petri net. The marking of Petri net changes from marking $m_k(p)$ to marking $m_{k+1}(p)$ (Eq. (3)):

$$m_{k+1}(p) = m_k(p) + \mathbf{W}^{\mathbf{T}} \cdot \boldsymbol{\sigma}. \tag{3}$$

$\boldsymbol{\sigma}$ is a transition vector which is composed of non-negative integers that correspond with the number of times a particular transition has been fired between markings $m_k(p)$ and $m_{k+1}(p)$.

Siphon S is the set of Petri net places for which it is true that each transition having an output arc from the set also has an input arc into the set ($\bullet S \subseteq S\bullet$). Once the siphon becomes empty, it will always remain empty. More about the structure of a Petri net can be found in (Bogdan and Lewis, 1997).

Deadlock prevention supervisor design begins with the container terminal system modeling by using MRF_1PN, which is a subclass of P/T Petri net specially designed for analysis of multiple re-entrant flow lines flexible manufacturing systems (MRF system), where each part type $k \in \Pi$ is characterized by predetermined sequence of jobs $J^k = \{J_1^k, J_2^k, ..., J_{L_k}^k\}$, with at least one resource for each job.

In definition of MRF_1PN, the place set $P = R \cup J \cup J_{in} \cup J_{out}$ contains all places, the set R contains all resources, J_{in}*,and* J_{out} *contain* units arrivals and finished units, and set J contains all job places. The set of transitions *T* can be partitioned as $T = \cup_{k \in \Pi} T^k$, where $T^k = \{t_1^k, t_2^k, ..., t_{L_k+1}^k\}$, with $t_i^k = \bullet J_i^k = J_{i-1}^k \bullet$, for $i \notin \{1, L_k\}$; while $t_1^k = \bullet J_1^k = J_{in}^k \bullet$ and $t_{L_k+1}^k = \bullet J_{out}^k = J_{L_k}^k \bullet$. Transition *t* is said to be job (resource) enabled if $m(\bullet t \cap J) > 0$ and $m(\bullet t \cap R) > 0$. For any $r \in R$, define the job set $J(r)$ as the set of jobs using *r*, and resource loop $L(r) = r \cup J(r)$. Given a set of resources $Q \subset R$, define the job set of Q as $J(Q) = \cup_{r \in Q} J(r)$. Denote $R(J_i^k)$ the resources used by job J_i^k.

The system described in section 2 belongs to the class of MRF_1PN (Bogdan et al., 2006). MRF_1PN guarantees that (i) there are no self loops, (ii) each unit-path has a well defined beginning and an end, (iii) every job requires one and only one resource with no two consequent jobs using the same resource, (iv) and (v), there are no choice jobs and no assembly jobs, (vi) there are shared resources. In MRF_1PN, for any two $r_i, r_j \in R$, r_i is said to wait r_j, denoted $r_i \rightarrow r_j$, if the availability or r_j is a immediate requirement for the release or r_i, i.e., $\bullet r_i \cap r_j \bullet \neq \varnothing$, or equivalently, if there exists at least one transitions $t \in \bullet r_i \cap r_j \bullet$.

Any set of resources is called circular wait *CW*, if among the set of resources $r_a, r_b, ..., r_w$ exist wait relations among them such that $r_a \rightarrow r_b \rightarrow \ldots \rightarrow r_w$ and $r_w \rightarrow r_a$. *CW* relations are characteristic among shared and non-shared resources in MRF_1PN and contain at least one shared resource.

Deadlock in the MRF_1 is connected with the system condition called circular blocking *CB*, which is a consequence of the existence of circular wait relations *CW* among resources in the system. A *CW* is said to be in *CB* if (i) $m(CW)=0$; and (ii) for each $r \in CW, \forall p \in J(r)$ with $m(p) \neq 0$, $p\bullet \in CW\bullet$. Avoiding *CB* is necessary but generally not sufficient for deadlock-free dispatching policy. To prevent deadlock in MRF_1PN, *CB* conditions must be first avoided, which are closely related to the critical siphon. A critical siphon *S* is a minimal siphon that does not contain any resource loop. The next step is to find sets of job places, so called critical subsystems $J(CW)$, which are very important in deadlock prevention.

A *CW* is in *CB* at any $m_0 \in \Re(m)$ if and only if siphon S_{CW} becomes empty. The siphon is empty if and only if $m(J_0(CW))=m_0(CW)$; To avoid deadlock it must be ensured that the $m(S_{CW})\neq 0$ by applying constraint $m(J_0(CW))<m_0(CW)$ to the set $\Re(m_0)$. The token sum in the critical subsystem $J_0(CW)$ must be limited above $m_0(CW)-1$. To avoid such first level deadlocks control places must be connected to the transitions before and after any critical subsystems $J_0(CW)$ which make sure that the token sum in the critical subsystem $J_0(CW)$ is limited to (Lewis, et al., 1998) (Eq. (4)):

$$J_0(CW)\leq m_0(CW)-1 \tag{4}$$

3. Petri Net Model of Container Transportation System

In this chapter, the container transportation system .is modeled as a MRF_1 class of Petri net with disjoint sets of resource and job places. Each container job involves the loading of a container onto the AGV, the movement of the AGV to the destination of the container, and the unloading of the container from the AGV. An AGV can be assigned one job at a time. After completing a job, an AGV can start another job. The following assumptions are used in this study:

- Every AGV serves more than one QC. That is, any one AGV is not dedicated to one QC.
- All AGVs are in their functions at the same and they can carry only one container at a time.
- Navigational AGV will be modeled with a constant speed, without acceleration or deceleration.
- Time needed to travel from one to another point in the AGVS is dynamic and it will be retrieved from the schedule.
- The time for a loading/unloading container is generated and given. This time must be taken into consideration for all types of cranes as it affects the waiting time of AGVs.
- What needs to be taken into account is the average time that elapses from the moment they pass QC AGV to the container until the moment the next container is lifted. This time will be defined as a resource setup time.

These automated guided vehicles will transport the containers along a predefined path. To increase the efficiency of AGVs, and reduce their waiting time, it is envisaged that there are two circular paths of the moving of AGVs. First, the path A, would be from the quay cranes to the stock crane on the storage area, to the rail station and return to the coastal area. The second path B, would be from the quay cranes to the storage area and back to the quay side. So in order to reduce the waiting path, B would be an alternative route. The paths consist of several segments. Along the segment A, vehicles transport containers from the shore crane to a specific location in the storage where the containers are disposed of. Thereafter, the AGV drives along the segment B to a position where it will load a container from a stack and along the segment C it will transport the container to the rail station. After unloading the container, empty vehicle goes along the segment D to the place where it waits for the next job to be done. If the AGV vehicle doesn't load a container to be transferred to the railways, then after unloading containers at the warehouse, an empty vehicle goes along the segment E to the parking lot.

A set of jobs in the system is (Eq. (5)):

J={CR1load_A, transA_A, CR2unload_A, transB_A, CR2load_A, transC_A, CR3unload, transD_A, CR1load_B, transA_B, CR2unload_B, transB_B, transE_B, transD_B}. (5)

Set of resources $R=\{Cr1,Cr2,Cr3,segA,segB,segC,segD,segE\}$ involves all cranes and segments. If a particular resource is occupied in a moment of time, and if there are AGVs waiting to use them, then these vehicles wait for the availability of the occupied resource at the exit of the resource where they are in the moment of time.

When the resource becomes available, it is occupied by awaiting vehicles. The moving of the vehicles through the system is limited due to the capacity of resources. Resource type *k* has a limited capacity of *R(k)* at any point in time. Cranes' capacities are $R(Cr1)=3, R(Cr2)=R(Cr3)=1$. Segment's capacities are defined by the number of vehicles that can drive long these segments and these capacities are *R* (segA)=5, *R*(segB)=1, *R*(segC)=4, *R*(segD)=1, *R*(segE)=4.

Fig. 2 shows PN model of proposed CTS with control places. The places are related to MRF_1 Petri net and they represent jobs and resources.

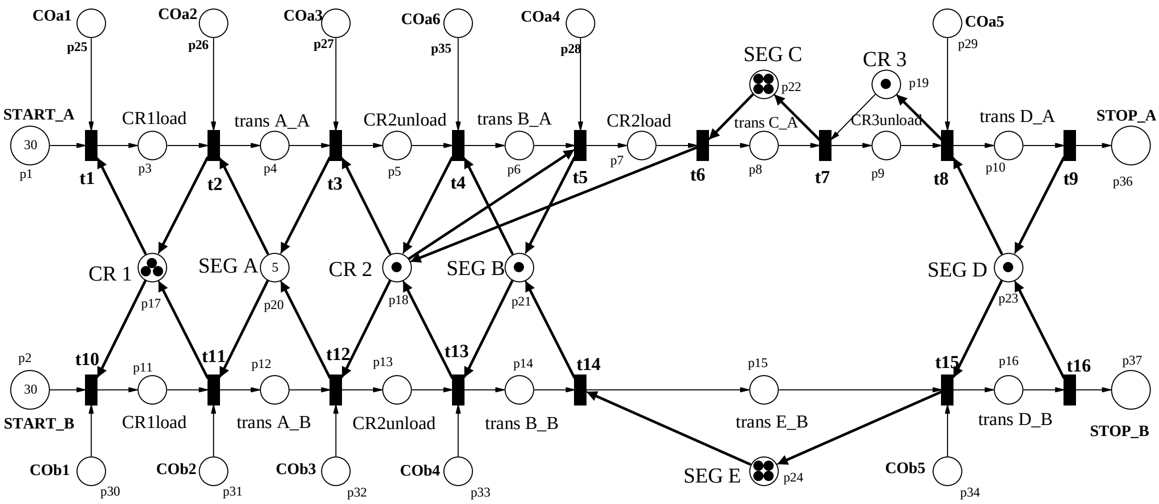

Fig. 2.
MRF_1 Petri Net Model of AGV-Container Terminal System
Source: Made by authors, Visual Object Net ver 2.7, http://www.paramsoft.de

The number 30 in input places represents the number of tokens indicates the container number which will be transported along path A (path B) by AGVs. The set of output places $\{p_{36}, p_{37}\}$ represents the container's destinations. The set of all places that represent jobs in the system is $\{p_3 - p_{16}\}$, and the set of places that represent availability of resources is $\{p_{17} - p_{24}\}$. The meaning of the places is given in Table 1 and Table 2.

Control places $p_{25} - p_{35}$ belong to the supervisor which ensures the conflict and deadlock free operation of the net.

Table 1
The Meaning of Job Places with and Associated Processing Times (Min)

PATH A			PATH B		
Places	**Meaning**	**Time**	**Places**	**Meaning**	**Time**
p_3	Crane CR1 loads a container from the ship on the AGV	1	p_{11}	CR1 loads container from the ship on the AGV	1
p_4	Along segment A, AGV transport container to the storage	1.5	p_{12}	AGV drives along the segment A to the storage	1.5
p_5	CR2 unloads the container from AGV and puts it on the stack	2	p_{13}	CR2 unloads the container from the AGV and put it on the stack	2
p_6	Empty AGV drives along segment B to the position on the storage	0	p_{14}	Empty AGV drives along segment B	0
p_7	CR2 loads the container on the AGV	2	p_{15}	Empty AGV drives along segment E	0
p_8	Full AGV drives along the segment C	0	p_{16}	Empty AGV drives along segment D to the parking lots	0
p_9	CR3 unloads the containers from the AGV	2			
p_{10}	Empty AGV drives along the segment D	0			

Table 2
The Meaning of Resource Places and Set-Up Times for Resources (Min)

Places	Meaning	Time
p_{17}	Quay crane CR_1 is available	1
p_{18}	Stacking crane CR_2 is available	1
p_{19}	Mobile crane CR_3 is available	1
p_{20}	Segment A is available	0
p_{21}	Segment B is available	0
p_{22}	Segment C is available	0
p_{23}	Segment D is available	0
p_{24}	Segment E is available	0

3.1. Timed Simulation

As distinguished from many authors, dynamic behavior of CT system is taken into account. In reality CT, any resource requires nonzero times for performing jobs. In our PN, these times are associated to places p_3–p_{16} for jobs and they are defined by following *PNtimes* vector (Eq. (6)):

PNtimes = [0 0 1 1.5 2 0 2 0 2 0 1 1.5 2 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]'. (6)

Initial times for places p_6, p_8, p_{10}, p_{14}, p_{15}, p_{16} are zero. Namely, these times correspond to times that are required when/if the vehicle exceeds a certain segment of the terminal and these times depend on the distance of the terminal (matrix D) and on whether AGV is full or empty (speed limits are different for the two cases). So, times for these places are calculated as follows (Eq. (7) – Eq. (9)):

$$D = [\begin{matrix} 0 & 445 & 495 & 545 & 866 & 893 & 0 & 0 & 0 \\ 0 & 0 & 50 & 100 & 421 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 50 & 371 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 321 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 27 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 680 & 258 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 260 & 360 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 100 \\ 0 & 70 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{matrix}];$$

ve=330; *vf*=180; % speed limit of empty/full AGV (m/min) (7)

PNtimes(6,1)=D(5,6)+10)/*ve*; *PNtimes*(8,1)=*D*(6,7)/*vf*; *PNtimes*(10,1)=*D*(7,9)/*ve*; (8)

PNtimes(14,1)=*D*(5,6)/*ve*; *PNtimes*(15,1)=*D*(6,8)/*ve*; *PNtimes*(16,1)=*D*(8,9)/*ve*. (9)

The token in places p_4 (p_{12}) means that AGV has taken a container from the quay crane and transports it to the stock. The distance which AGV has to pass depends on the position of the quay crane, so the times for the places p_4 and p_{12} are determined dynamically as follows (Eq. (10)):

PNtimes(4,1)=D(d2+1,5)/vf; PNtimes(12,1)=D(d2+1,5)/vf; (10)

where d_2 is the order number of associated crane.

Each place $p_3 - p_{19}$ is divided in two parts: input part mi, where tokens are positioned as the place input transitions fire; end part mf, where token is moved from the part mi after the time associated with that place has lapsed, and the token becomes available to fire the place output transitions. These associated times to the places (jobs and resources) request the subroutine which computes elapsed times and whose currently ongoing jobs are complicated and whose resources are released. Now it is possible to compute different performance measures such as wasted times, delays, resource percent utilization and so on.

3.2. Conflict and Deadlock Resolution

The first problems that must be solved are conflicts. Conflicts arise when the AGVs which drive in different directions try to occupy the same shared resources with limited capacity (a crane or a segment) $\{p_{17}-p_{24}\}$. In this situation the transitions t_1, t_{10}; t_2, t_{11}; t_4, t_{13} and t_8, t_{15} can be in conflict (the both transitions are enabled at the same time). A conflict between the three transitions t_3, t_5, t_{12} is possible when three vehicles require the same crane (the resource p_{18}). In case of conflict, random dispatching is used.

The second problem is how to produce the design of a deadlock free supervisor. Fig. 3 shows the cyclic deadlock.

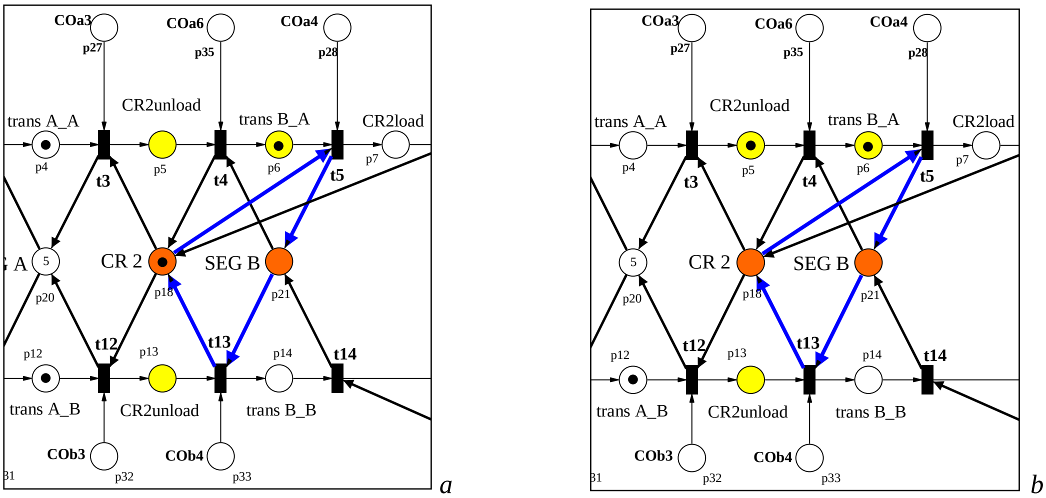

Fig. 3.
A Circular Deadlock Form by the Vehicles

The circular waiting occurs when there are two vehicles waiting for each other to release the shared resource. The circular waiting can be determined from PN graph (Fig. 3a). The pair $CW=\{CR2, SEG\_B\}$ is the circular wait and each place has one token. It is obviously, there are three jobs that are waiting for the crane CR2. The token in place p4 indicates that AGV from direction A is waiting for CR2 crane to unload a container from it. The token in p6 shows that there is another AGV vehicle waiting for crane CR2 to load a container for transport to the rail, while the existence of token in the place p12 means a vehicle that goes to the direction of B is waiting for crane to unload a container from it. Since there is only one crane CR2, it is necessary to determine which job will be to get crane CR2. If CR2 is assigned to the place p_5, the transition T3 fires and token moves from the place p_4 to p_5 (Fig. 3b). Now it is clear that no transition can fire. The problem is that resources CR2 and SEG_B waiting for each other to be release. How this is not possible to happen, the system is in deadlock state. Similar would be happened if the crane is assigned to p_{13}. Thus, resources SEG_B and CR2 are in infinite circular waiting.

During the control of AGV system it is very important to predict the existence of circular waits, as it causes AGVs' waiting for cranes. This is unacceptable because the congestion occurs in the system, or delays in performing tasks. To avoid such a situation, matrix approach described in (Lewis et al., 1998) has to be applied. It is necessary to determine the tasks that belong to the circular waiting and critical subsystem.

Step 1: There is 1 *circular wait* $C_1=\{p_{18}, p_{21}\}$ and job set which belongs to simple circular wait is the set

$J(C_1)=\{p_5, p_6, p_7, p_{13}, p_{14}\}=\{CR2unload\_A, transB\_A, CR2load, CR2unload\_B, transB\_B\}$.

Step 2: There is 1 critical subsystem

$J_0(C_1)=\{p_5, p_6, p_{13}\}=\{CRunload\_A, transB\_A, CR2unload\_B\}$.

Step 3: The initial marking of C_1 is $m_0(C_1)=2$.

From the circular wait the *circular blocking CB* has to be found. The *CB* exists if the token sum in the critical subsystem is equal to the number of resources in *CW*: $m(J_0(C_1))=m_0(C_1)$.

Hence, to avoid the first level deadlock it is necessary to apply the equation (4) and the control places COa3, COb3, COa4, COb4 maintain the number of tokens in critical system to maximum 1 (less than initial marking in *CW*).

Fig. 4 shows MATLAB code for the circular deadlock avoidance. The vector x should be considered as a proposed transition vector (*line* 2) and *multoa* is derived Matlab function for computing matrix "and/or" multiplication. *mtest* is the PN marking vector after x has been fired (*line* 3). Mainly, equation (4) has been applied by lines 4, where m_0 is initial number of tokens. If it results in true values, the deadlock is detected, the procedure has to block the token input in the critical subsystem and allow the token output from it. It is solved by adding or removing tokens from the control places COa3, COa4, COb3, COb4 (*line* 5-8).

```
1.    %   Deadlock avoidance subroutine
2.      x=multoa(not(F), not(not(mf)));
3.      mtest=(mf+mi)+(W'*x); %
4.       if (mtest(5)+ mtest(6)+ mtest(13) > (m0(18)+ m0(21)-1))
5.          mf(COa3)=0;    mf(COb3)=0;
6.          mf(COa4)=1;    mf(COb4)=1;     end
```

Fig. 4.
Deadlock Avoidance Subroutine

The deadlock prevention supervisor which applies this control policy for container's moving through the container terminal system is verified using computer simulation and P-time PN. The results are shown in Fig. 5 and Fig. 6.

Fig. 5 shows number of vessels in input and output places. It is observed that all jobs are finished because all containers came to the output places in both directions. It is possible to see that the last container comes to the destination 293.6 time units from begging of containers moving through the system. Fig. 6 shows the circular wait from situation (Fig. 3) which happened at time t=265.2 (*No* is number of tokens in particular place). There are three jobs that are waiting for the crane CR2. Logical „1“ in control places disables firing of transitions (means green light, while logical „0“ means red light“). To avoid system deadlock the supervisor applies the control policy shown on Fig. 4 (control places COa4 and COb4 have the logical value 1. CR2 is assigned to the place p_7 and job CR2load executes after the job transB_A is finished (Fig. 3b) and the container's moving through the system is able.

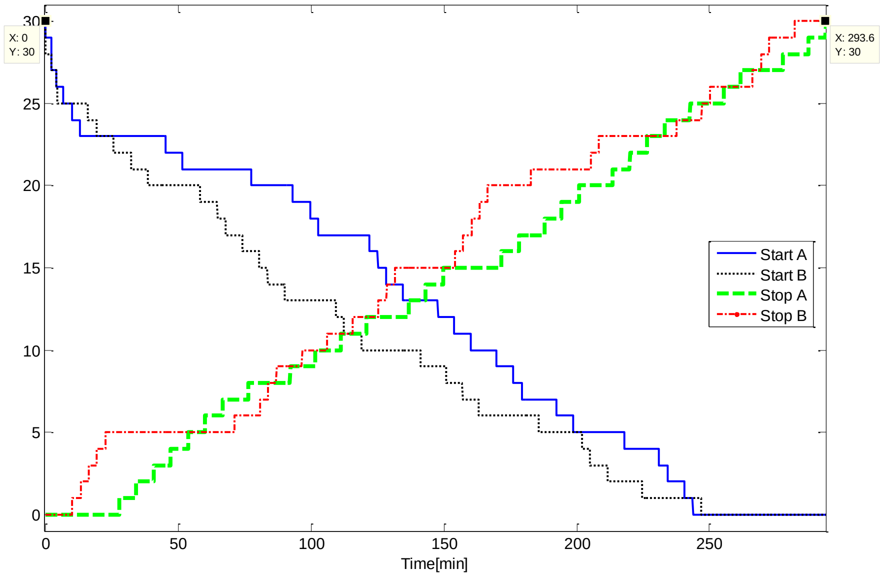

Fig. 5.
Number of Containers in Input and Output Places

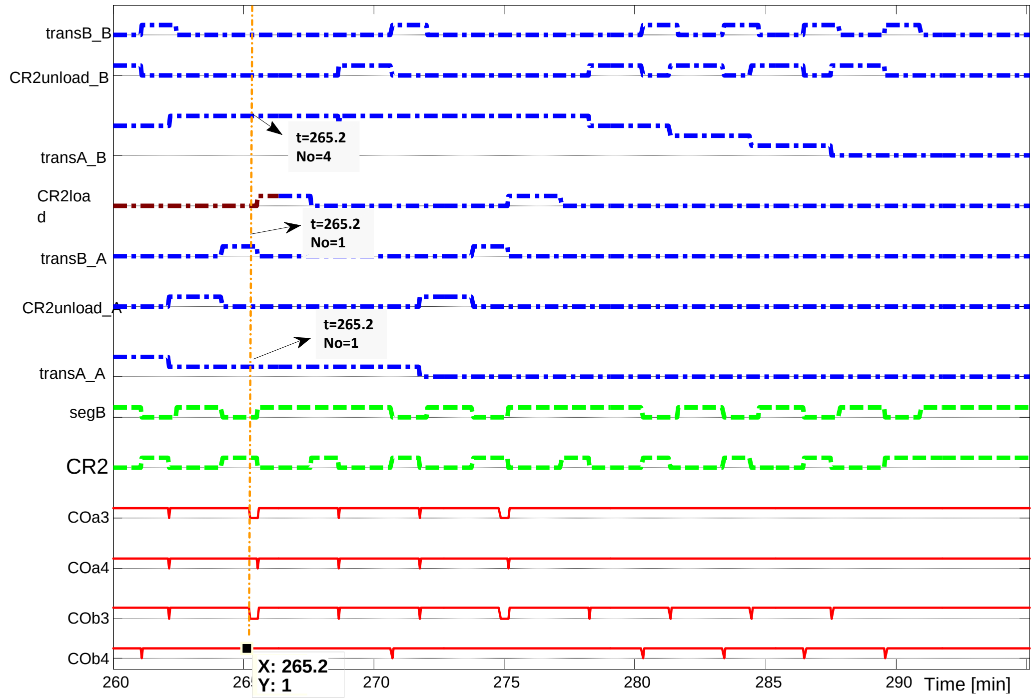

Fig. 6.
Deadlock Free Container Transshipment with Supervisor

4. Conclusion

The authors propose the method for creating a suitable Petri net model of complex terminal system using MRF_1 type of flowline system Petri net, and then circular waits and critical subsystems are found. The authors propose the addition of control places to the Petri net, which forms a supervisor. Conflicts and the first level deadlock can be avoided by adding control places, which disable firing of particular transitions and limit the number of vessels in critical subsystems. The controller is verified using a P-timed Petri net model and computer simulation by using Matlab environment. Future research will be focused on to develop an algorithm to find the optimal number of AGVs for the same problem.

References

Bogdan, S.; Lewis, F.L. 1997. Matrix approach to deadlock avoidance of dispatching in multi-class finite buffer reentrant flow lines. In Proceedings of the *IEEE International Symposium on Intelligent Control*: 397–402.

Bogdan, S.; Lewis, F.L.; Kovačić, Z.; Mireles, J. 2006. *Manufacturing systems control design – A matrix-based approach*, Springer. 320 p.

Charbonnier, F.; Alla, H.; David, R. 2001. The Supervised Control of Discrete-Event Dynamic Systems, *IEEE Transactions on Control Systems Technology*, 7(2): 175–187.

Gallego, J.L.; Farges, J.L.; Henry, J.J. 1996. Design by Petri nets of an intersection signal controller, *Transportation Research Part C: Emerging Technologies*, 4(4): 231-248.

Kezić, D.; Gudelj A. 2010. Design of river system deadlock avoidance supervisor by using Petri net, *PROMET – Traffic & Transportation, Scientific Journal on Traffic and Transportation Research* 22(3): 215-221.

Lewis, F.; Huang, H.; Tacconi, D.; Gurel, A.; Pastravanu, O. 1998. Analysis of deadlocks and circular waits using a matrix model for discrete event systems. *Automatica*, 34(9): 1-19.

Murata, T. 1989. Petri Nets: Properties, Analysis and Applications. In *IEEE Proceedings*, 77(4), 541-580.

INFLUENCE OF CONTAINER SHIP CAPACITY ON TERMINAL OPERATIONS IN SMALLER CONTAINER PORTS

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Abstract: Nowadays container terminals represent a key part of ports, tasked with providing efficient, rapid, and reliable manipulation of container units. On the other hand, rapidly increasing international trade has led to the construction of ever larger container ships. Due to the problems that arise in the ports that accept large ships, we created a model which makes it easier for the ports to prepare themselves for the reception of these larger container vessels. The model consists of six subsystems which are related to the sea, coast and storage areas. The connection between them is strong, as their characteristics interact with one another. The model was tested on the port of Koper and has proved to be reliable. Because of its generality it is also suitable for use in other smaller ports that in the future want to increase the capacity of existing container terminals.

Keywords: Maritime container terminals, container ship capacity, container terminal operations, port optimization.

1. Introduction

As the primary means of maritime transport, the container industry has been the most affected by globalization. The average annual growth rate of container use from 1990 to 2010 was 8.2%. This led to an increase in global port throughput, which in 2010 reached 531.4 million TEUs, with an increase of about 526% over the last twenty years (Unctad, Review of Maritime Transport 2011). Container terminals have therefore become a more important part of the port system, and they must be specially built and equipped facilities for transhipment of containers between sea and land (or vice versa) transport providing efficient, rapid, and reliable manipulation of cargo container units.

Meanwhile, rapidly increasing international trade and increasing demand for maritime container transport has led to the construction of ever larger container ships. Today, the largest ship on the marker reaches 14,770 TEUs; in the next few years ships are expected to reach capacities of 18,000 TEUs (Unctad, Review of Maritime Transport 2011). This will lead to capacity problems for container terminals, which will not have adequate equipment for the reception of such ships; yet at the same time ship-owners will demand facilitation of rapid transhipment and reduced costs.

As the biggest ships can only operate between a few major ports in the world, which have appropriate conditions for receiving such capacities, ship-owners will in the future still operate on the 'hub and spoke' principle (Nedyalkov and Andreeva 2011). Small ports will therefore be specialised in receiving feeder ships; nevertheless they will also have to increase their terminal capacities to be able to accept larger container ships.

2.Container terminal productivity

For increased market competitiveness and optimal functioning of the container terminal, constant measuring of terminal productivity is of crucial importance. Container terminals can be divided into three subsystems: the berth subsystem, storage subsystem and subsystem of the handover area (Beškovnik and Twrdy 2010). Though each has its own purpose, to function as an efficient whole a high level of interaction and consistency between them is necessary.

In defining the efficiency of a container terminal and its subsystems different productivity indicators can be used. The indicators clearly show the productivity of each subsystem and the efficient use of existing infrastructure, off-loading capacity of mechanisation and labour force (Beškovnik and Twrdy 2010).

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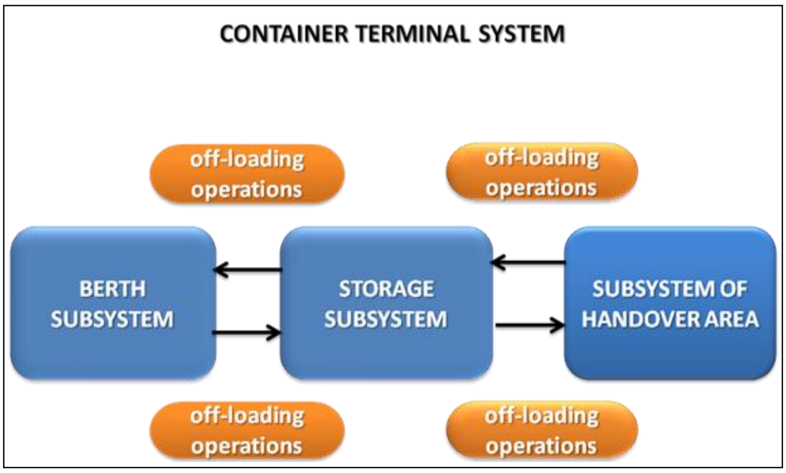

Fig. 1.
The container terminal subsystems
Source: (authors)

Today, one of the greatest challenges for smaller container ports is the constant increase of container vessel size, since many terminals do not have adequate facilities to keep pace with these trends. If they will want to follow those market trends they will have to increase capacities at individual points of the terminal. The most important elements to define the terminal vessel capacity are sea depth, berth length, number of gantry cranes, and storage capacity. The terminal productivity parameters most relative to vessel capacity are therefore (Le Griffin and Murphy, 2006):

- Number of TEU per berth length,
- Number of TEU per berth container crane,
- Number of TEU per hour of each berth container crane,
- Number of TEU per 1,000 m^2 of container yard.

Given the current state of traffic in individual ports and container traffic growth trends worldwide, it was necessary to re-define the container terminal capacity and create a model on the basis of which it is possible to make decisions about optimizing container terminals in terms of ship capacity.

3. The link between ship size and operations

For economic reasons, or, more precisely, for the achievement of an economy of scale, ship-owners today prefer to use large container vessels with a capacity of 10,000 TEUs or more on their routes around the world. According to Sys et al., (2008) with the increase of ship capacity, the amount of freight carried increases, resulting in lower costs per unit of cargo. Unit costs are thus the main factor influencing the choice made by ship-owners regarding the size of container vessels used on a given route (Sys et al. 2008). Various analyses have shown that big container ships have more advantages for ship-owners than disadvantages; the construction of even larger and more efficient container ships in the future is therefore to be expected.

3.1. Container fleet trends

The container ship fleet is the fastest growing maritime fleet. Until the economic crisis, the annual growth of the fleet was 13%, and in 2011 reached 184 million dwt. Today the container fleet covers approximately 13% of the world shipping fleet. The orders for new container ships in recent years have risen despite the recession, although with a lower growth rate. These orders were made for both larger and smaller container ships. Of all the ships delivered in 2010, 29 of them had a capacity over 10,000 TEUs (Unctad, Review of Maritime Transport 2011). According to the forecasts of Williams (2011), the container fleet is expected to reach approximately 19 million TEUs in 2014, while in 2010 the fleet amounted to 14 million TEUs (Williams, 2011). The largest container ships, with a capacity of 14,000 TEUs or more, are now mostly employed between Europe and the Far East, where the largest cargo exchange is made and where the ports have adequate facilities to accept them. The construction of ever larger container ships led also to a growing demand for feeder vessels of which size is in the last years also increasing due to market trends. This represents a major problem for many smaller container ports (Unctad, Review of Maritime Transport 2011). The link between ship size and port operations is very strong. On the main routes ship-owners are choosing bigger container vessels as this allows them to reduce shipping costs.

The ports that can accept such large container ships are therefore in a position of advantage in comparison with the ports that do not have adequate facilities. The ports that do not have the facilities to accept larger container ships will have to optimize their existing container terminals in order to become more competitive on the market.

4. Container terminal optimization in terms of ship capacity

As mentioned before, the connection between vessel capacity and port operations is very strong. The pressure from the market trends is increasing day by day and ports have to follow them if they want to remain interesting for ship-owners. Since the construction of new terminals represents such a large financial investment, ports are in the first phase deciding to increase the capacity of existing terminals in order to be able to accept larger ships. The biggest problem in achieving this goal represents the decision about the terminal parts that need to be optimized, so we created a model (Fig. 2) which facilitates the adoption of such decisions.

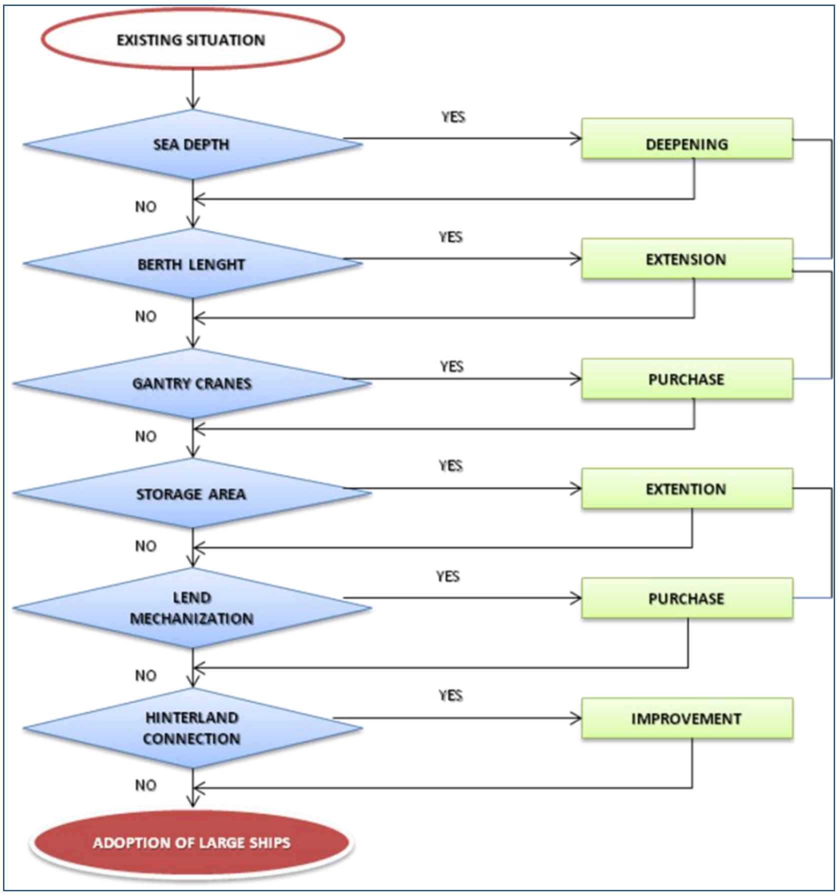

Fig. 2.
Container terminal optimization model
Source: (authors)

The model is based on the six parts of the terminal that define the operational ship-to-shore system which determines the quality of service when a ship is in the port. The first three components represent the berth subsystem which directly defines the size of the ships that can enter a port, while the other three components belong to the storage subsystem and the subsystem of the handover area, which influences the size of the ship that can be received in port indirectly.

With the model we can therefore determine if the individual part of the terminal capacity is in sufficient condition for the reception of the wanted ship size, or the capacities are insufficient and require optimization.

4.1. Application of the model to the port of Koper

Luka Koper is the main northern Adriatic container port, whose current annual throughput capacity is 600,000 TEUs. In the last ten years the container terminal recorded a constant growth in container throughput, and in 2011 reached a record throughput of 589,314 TEUs, which represents a 24% growth compared to the year 2010 (476,731 TEUs) (www.luka-kp.si/slo/).

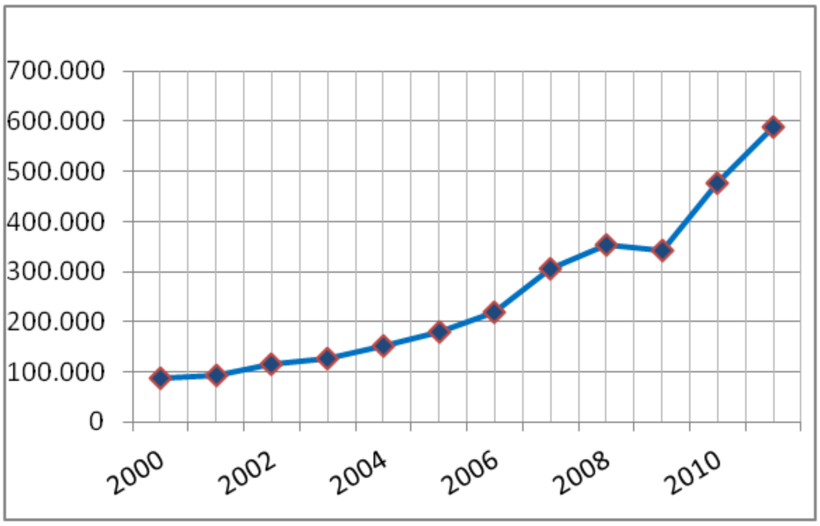

Fig. 3.
Container throughput in the port of Koper
Source: (authors)

The terminal has three berths with a total quay length of 596 meters. It is equipped with four post-Panamax and four panamax cranes and storage areas to the extent of 18 acres. The depth of the sea at the terminal is limited to 12 meters (slightly more at high tide).

The terminal belongs therefore to the class of smaller container terminals whose business is limited to one direct line to the Far East, a few direct lines with the Mediterranean, but mostly represented by feeder lines (Stojakovič and Twrdy 2010). The largest container ships currently entering the terminal have a capacity of 6500 TEUs; however the acceptance of such a large ship in port often represents a problem due to the shallow draft of the terminal.

The current capacities of the terminal are sufficient for reception of one larger vessel (up to 300 meters in length) and one smaller vessel (up to 200 meters in length) at the same time. If the port wants to increase this capacity and be more competitive on the marketplace it is of vital importance to establish new direct lines with larger container vessels. With the existing terminal facilities the port is actually able to have more direct lines with large ships, but the ships should not meet at the terminal, which due to the unforeseen delays in schedules and long unloading times (2-3 days) often represents a problem. To avoid those problems in the port of Koper it is absolutely necessary to increase the existing terminal capacities. We used the previously described model (Fig. 2) to solve the mentioned problem.

For decision making on the basis of the model we used the vessel of capacity 6,000 TEUs. After careful analysis, we came to the conclusion that this capacity is the most appropriate for the port of Koper, since there are sufficient cargo flows and the ship size would be interesting enough for the ship-owners to include the port of Koper in a direct line.

Requirements for the acceptance of 6000 TEU ships (Sys et al., 2008):
- Sea depth 13-14 m
- Channel depth 13-14 m
- Berth length 350 m
- Terminal area 16 ha per berth
- Gantry cranes post-panamax (45 m outreach)

4.2. Model solution

The proposed model was tested on the case of Luka Koper before and after the purchase of new container cranes, as we wanted to see the situation with two larger container vessels entering the port simultaneously.
Before the purchase of the new cranes, the quay was 300 meters long with two berths and had just four panamax container cranes.

With the model, we found that in addition to sea depth, the quay length and inadequate container cranes also represent a problem. Before purchasing the post-panamax cranes it was therefore necessary to extend the pier by 300 meters.

Minor problems were also noted on the land side of the terminal, where it was necessary to change the storage system (especially for empty containers). After the successful optimization of the terminal in 2009 it became possible to accept ships of capacities up to 6,500 TEUs.

In the next steep we used the same model for testing the adoption of two larger ships in the port at the same time. To be able to accept two ships of 6,000 TEUs simultaneously, the port of Koper would require optimization of the container terminal at all points of the model. The sea depth would certainly have to increase by a meter or two. The number of berths is sufficient; but it would still be necessary to extend the pier by at least 150 meters in order to provide smooth throughput operations for both ships. The ideal enlargement of the quay may even be 200 meters, but due to the geographical constraints of the port this would represent a problem. The extension of the terminal quay would also result in the need to purchase new quay cranes. The current number of cranes is sufficient for the current terminal capacities, as when the largest ship arrives the four post-panamax cranes are available to attend her, while the other four panamax cranes are used to serve smaller ships at the terminal. With the current terminal capacities the reception of two large ships simultaneously would cause delays, an extension of the time the ship spends at the terminal which would result in increasing costs. For optimal handling of such circumstance from three to five post-panamax cranes are necessary. The port of Koper would therefore have to purchase at least two new post-panamax cranes. The increased throughput at the berth subsystem would certainly affect the functioning of the other two subsystems, which is why in our case the port would have to increase the storage capacity. The current capacities are now barely sufficient, while with the increase of cargo flows the storage area would be too small. They would have to increase the area by approximately 25-30%, regardless of which the storage problem would be solved for just a short time. Current mechanization at the storage area might be sufficient even after the enlargement of the area, but there would exists real risks of delays, which would consequently mean a loss of port efficiency and the risk for losing customers. It would be absolutely necessary to optimize the hinterland connections of the port of Koper. The link from the port to its hinterland is possible by road and rail traffic, although the capacities are already fully exploited. Therefore, the arrival of larger ships in the port and the increased number of container ships handled in the port would require the construction of another railway track.

5. Conclusions

In the near and distant future world container traffic will continue to increase, with consequences for all ports. The problems that smaller container ports will have to face will be related mostly to the vessel size, as this will affect their productivity. Since the construction of new terminals represents significant financial investment and the physical expansion of terminals is often not possible due to urban centers in the immediate hinterland of the port, we can conclude that the ports will in the first phase decide to increase the capacity of existing terminals. The appropriate optimization will be possible only with the right decision about the terminal areas that have to be improved in order to facilitate acceptance of larger ships in the port. The model presented in this article was created to facilitate those decisions. The tests made on the port of Koper gave us satisfactory results. We can therefore conclude that in the port of Koper investments in handling equipment, optimization of existing facilities, deepening of the sea and other investments have became necessary if the port wants to improve its productivity and be able to accept two (more) larger ships at the terminal simultaneously.

References

Beškovnik, B.; Twrdy, E. 2010. Planning organization and productivity simulation tool for maritime container terminals, *Transport* 25(3): 293-299.

Le Griffin, H.D.; Murphy, M. 2006. Container terminal productivity: Experiences at the ports of Los Angeles and Long Beach, NUF Conference. Available from internet: <http://www.metrans.org/nuf/documents/Le-Murphy.pdf>.

Nedyalkov, T.; Andreeva, T. Trends in the container shipping and need of a new generation container terminals and container vessels. Available from internet: <http://mech-ing.com/journal/Archive/2011/3/32_Todorin%20Nedqlkov.pdf>.

Port of Koper. Available from internet: <http://www.luka-kp.si/slo/>

Sys, C.; Blauwens, G.; Omey, E.; Van de Vorde, E.; Witlox, F. 2008. In search of the link between ship size and operations, *Transportation Planning and Technology*, 31(4): 435-463.

Stojaković, M.; Twrdy, E. 2010. Opportunities for the increase of cargo handling capacity at the container terminal in the port of Luka Koper. In *Proceedings of the 13th International Conference on Traffic science (ICTS)*, 7.

Unctad, Review of Maritime Transport 2011. Available from internet: <http://unctad.org/en/Pages/Home.aspx>

Williams, M. 2011. Containership Supply Outlook. *In Proceedings of the 4th Annual Med Freight conference.*

EVALUATION OF MOTORWAY RELIABILITY BASED ON THE IDENTIFICATION OF SPOT SPEED STOCHASTIC PROCESSES. THE CASE OF A22 MOTORWAY, ITALY

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Abstract: The evaluation of motorway reliability is a subject of great interest for researchers of traffic engineering. For easy recognizable reasons, this subject is very important in theoretical studies and for applications, e.g. evaluation of capacity and traffic control on motorway. In this paper the different conceptions of reliability in technical and scientific literature are compared with the following definition: reliability of traffic stream, for a time interval T, is “the conditioned probability that level of speed spot process does not decrease during T as far as the section in which limit density is reached, given that the level at instant zero is equal to the average speed corresponding to the flow rate in condition of stable flow”. Then, a criterion to calculate the motorway reliability is presented. The speed spot time-series are divided into sequences of events of random and homogeneous traffic processes. For every process one can calculate two parameters: flow rate and density; then, one can obtain the relationships between the parameters of spot speed processes and vehicular density. Using these relationships and a simulation procedure of spot speed process, one can obtain a formulation of the reliability of a traffic flow running along the offside lane of a motorway carriageway. Thus, through this formulation and the measurements of flow rate and speeds, one can evaluate the probability of instability on the carriageway under investigation. On the other hand, with an inverse procedure one can calculate the capacity of one lane in this way: putting close to 1 the reliability value and considering a 15 minutes time interval, the obtained flow rate represents capacity. In the paper, the procedure explained is used to provide, in real time, the approaching of the instability on the carriageway and to calculate the carriageway capacity for the A22 Brenner Motorway (Italy).

Keywords: reliability, speed process, motorway.

1. Introduction

A system is usually said to be reliable if it is suitable to perform, in life cycle, tasks for which it was designed. For engineers “*the reliability of an item is the probability that it will adequately perform its specified purpose for a specified period of time under specified environmental conditions*” (Leemis, 1995).

The first systematic knowledge on reliability was developed in the 40s of last century and applied in aviation and military (Henley and Kumamoto, 1981; Shaw et al., 2003). Starting from the same period, the probabilistic approach has been increasingly used in other areas of industrial engineering (mechanical, chemical, nuclear, software communications, etc.) (Modarres et al., 1999; Ushakov anda Harrison, 1994). From few decades reliability has also acquired more and more importance in civil engineering (Kottegoda and Rosso, 1997; Mauro, 2010), particularly in structural engineering (Madsen et al., 2006). Reliability has played and is of increasing interest in transport engineering since the '70s and up to now. In transportation engineering, reliability is mainly relates to the travel time, with reference to journey time and traffic flow conditions of a road link, i.e. the levels of service (LOS) corresponding to it.

In both cases the same information on the fundamental characteristics of traffic flow are used. In addition, the user's perspective is always assumed. In fact, a given LOS is directly connected to a journey that users can perform within an acceptable time. Finally, reliability calculations of travel time and traffic conditions are based on similar assumptions and pursue overlapping aims. On the close relationship between travel time reliability and measurement of effectiveness of service may refer to Chen et al. (2003).

An evaluation of the reliability of an uninterrupted-flow facility can be also carried out considering the reliability of traffic flow running along lanes. Whereas the reliability of the traffic flow is the likelihood that a motorway link is not congested, this means that the travel time does not exceed levels considered acceptable.

The calculation of the reliability of a traffic stream implies the prediction of the traffic flow breakdown phenomenon (Elefteriadou et al., 1995; Persaud et al., 1998; Lorenz et al. 2001) or the traffic flow instability (Ferrari 1988; 1991a; Mauro, 2003, 2005, 2007). If breakdown analysis is used, reliability is calculated by characterizing capacity as a random variable.

If the analysis of traffic flow instability is used, reliability is calculated directly basing on observation in real time of the stochastic process of speeds implemented by users, sequentially observed in the link sections. In this case, capacity is deduced from the identified formulation of reliability.

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The first criterion has been recently developed by German researchers (Zurlinden, 2003; Brilon et al., 2005; 2007; Geistefeldt, 2011). Real world results from German motorways confirmed that the capacity distribution function is directly related to the reliability of traffic flow evaluated in a road cross section of the link. Thus, capacity is deduced from the identified formulation of reliability. If the aforesaid distribution function gives, indeed, the probability that, at a certain flow rate, capacity is reached or exceeded, that is a breakdown occurs, the complement to one of the same distribution function can represent the probability that traffic will not be interrupted (fluent traffic), that is the measure of reliability.

The second criterion (Ferrari, 1988, 1991a; Mauro, 2003, 2005, 2007) will be explained in the next sections with reference to more recent researches carried out on A22 Brenner Motorway, a 314 km long corridor, from Modena province, Italy, to Austrian-Italian border in the northern Italy, connecting Italy to Central Europe inside the European motorway corridor E45 (Göteborg-Gela).

4. A22 Brenner Motorway Reliability and Capacity

4.1. Process Characterization of Spot Speeds

Instability on a motorway carriageway is usually reached, first, on the offside lane, then it extends to other lanes. Thereby, carriageway capacity is defined as the flow rate which is accommodated by it, when the offside lane flow rate is equal to its capacity. Whereas the occurrence of instability conditions for a traffic stream on a motorway carriageway is closely related to instability conditions on its offside lane, the study of the speed process implemented by users may refer to the last one.

Considering that v_{t-1}, v_t, v_{t+1}… are speeds of vehicles passing at instants t-1, t, t+1… along the offside lane before the observation section; they are determinations of random variables, whose sequences are random processes. The sequences of numbers of vehicles (n_{i-1}, n_i, n_{i+1}…) passed during successive little time intervals Δ_t also represent realizations of random process. The following definitions can thus be introduced:

- the flow rate Q as the average of the successive n_i/Δ_t values recorded during a time period T; the sequence of n_i represents a realization of a first order stationary process during T. Otherwise T can be broken down into a succession of partial intervals T_1, T_2, … during which the process is stationary; in each one of these partial intervals, different flow rate values can be then calculated;
- the level $\overline{v}_t$ of the speed at the instant t is the conditioned mean of speed at this instant, given the previous realization of the process;
- traffic density D_t at the instant t is the ratio between the flow rate Q and the level $\overline{v}_t$ of the speed process.

The analysis of numerous speed sequences observed on different motorways (Breiman, Lawrence, 1977; Ferrari, 1988) has allowed to ascertain that the speed process recorded on a cross section of an offside lane on motorway is an autoregressive integrated moving average process of the first order ARIMA (0, 1,1) of the form (Eq. (1)):

$$v_t = v_{t-1} + a_t - \theta \cdot a_{t-1} \tag{1}$$

where:

a_t , a_{t-1} = shifts of the speed v_t from corresponding level $\overline{v}_t$;

θ = 1- λ, in which λ is a coefficient, ranging between 0 and 1 and measuring the influence of a_t, at a certain instant t, on the level $\overline{v}_{t+1}$ at the subsequent instant.

From Eq. (1) the relationship between speed levels $\overline{v}_t$ and $\overline{v}_{t-k}$ of the process at instants t and t-k can be obtained (Eq. (2)):

$$\overline{v}_t = \overline{v}_{t-1} + \lambda \cdot \sum_{j=1}^{k} a_{t-j} \tag{2}$$

It shows how the sequence of levels $\overline{v}_t$ starting from the instant t-k can be considered the result of a random walk generated by the variable $\lambda \cdot a_t$. Moreover, the shifts a_t, a_{t-1} are a sequence of random variables independent and identically distributed with zero mean and equal variance σ^2; so the process of Eq. (1) has two parameters: λ and σ^2, estimated on the process of Eq. (1), utilizing stationary.

For the time variation of level $\overline{v}_t$, if λ is low (or the dispersion σ^2 of a_t is small), Eq. (2) allows to deduce that the probability of significant deviations of $\overline{v}_t$ from a constant value is low; it follows that process of instantaneous speeds v_t can be considered stable. Conversely, if λ and σ^2 are both high, this probability is significant and the speed process is highly unstable.

Since the stability of the speed process has a fundamental role in system reliability for A22 Motorway data, the relationships between the parameters λ and σ^2, as well as the variables they depend on, were identificated; these considerations will result useful for applications to traffic flow control.

4.2. The Treatment and Analysis of Experimental Data on A22 Motorway

For implementing the model just described, experimental surveys were carried out at observation sections on the A22 Motorway in 2003, 2005 and 2007 (Mauro, 2003, 2005, 2007). Further model verification has been made in subsequent years up to now, under the procedures implemented for A22 Motorway and described in section 4.3.

The A22 Motorway is one of the principal axis of the Italian motorway network linking the Po Valley and the A1 Motorway with Austria and Germany (Bergmeister et al., 2004). For function and territorial position the Brenner Motorway is occupied, along its whole route, by high traffic volumes (of which 1/3 of heavy vehicles) and, on specific tracts, by intense seasonal tourist flows during holiday-times. Travelling traffic often causes serious delays to circulation also because the motorway features just two lanes in each travel direction. Moreover, A22 traffic is, in its components, growing in keeping with the national trend on motorway.

To identify speeds processes implemented by users on A22 Motorway, speed sequences were surveyed in a long time interval, during which flow rates varied within a wide range of traffic situations, while environmental conditions, traffic composition and driver behaviours were the same.

The analyses concerned the only offside lane at observation sections on A22 Motorway, with reference to the latest results of 2007, quite conform to those obtained in 2003 and 2005. A total of 544 realizations of processes ARIMA (0, 1, 1), implemented by sequences of vehicles, whose number N of observations in each of them varied 50 to 1,500 vehicles (in total 125,650 vehicles), were counted. Only daylight periods in which traffic was composed by passenger cars were selected, so that in them congested conditions could be observed. Table 1 summarizes information about the surveys conducted.

Table 1
Number N of realizations of processes ARIMA (0, 1, 1), time periods within which realizations occurred, and number of passed vehicles that generated them

Observation Section	Carriageway	Date	Period of analysis	N	Passed vehicles
S. Michele	southbound	8-18-2007	10:00 am – 8:00 pm	61	16,175
S. Michele	southbound	8-26-2007	7:00 am – 3:00 pm	57	11,375
S. Michele	southbound	9-1-2007	7:30 am – 9:00 pm	79	19,325
S. Michele	northbound	8-1-2007	5:30 pm – 8:30 pm	18	3,500
S. Michele	northbound	12-2-2007	10:00 am – 3:00 pm	32	7,500
Rovereto	southbound	1-6-2007	10:00 am – 4:30 pm	40	9,825
Rovereto	southbound	1-7-2007	10:00 am – 4:30 pm	37	9,875
Adige	southbound	1-6-2007	10:00 am – 5:00 pm	49	10,350
Adige	southbound	1-7-2007	9:00 am – 5:00 pm	46	10,725
Adige	southbound	7-29-2007	3:00 pm – 8:00 pm	35	7,225
Adige	northbound	8-5-2007	8:30 am – 3:00 pm	35	7,450
Adige	northbound	8-12-2007	7:30 am – 12:30 pm	28	4,700
Adige	northbound	12-26-2007	9:00 am – 3:00 pm	27	7,625

Considered the role of σ^2 in traffic flow stability analyses, the relationship between the variance σ^2 of shifts a_t and the density D was searched on each observation section (see Table 2). It was noted that the variance σ^2 is a decreasing linear function of the logarithm of the average density of each realization (see also Fig. 1).

All the straight lines $\sigma^2 = f(\ln D)$ pass through the same point having coordinates $\sigma^2 = 1.5\ m^2s^{-2}$ and $\ln D = 3.4$ (veh/km). The passing of the straight lines through the same point confirmed results of other experimental studies on the A14 Motorway, Italy, and the A12 Motorway, Netherlands (Ferrari, 1988; 1991a).

Fig. 2 shows regression curves for two observation sections. The point where the relationship σ^2 - lnD intersects the x-axis locates the value of average density beyond which there is not, at a high probability level, traffic flow: so it can represent a measure of the limit density D*. The relationship between σ^2 and lnD, and the value of D* are characteristics of each traffic stream. In accordance with results obtained by Ferrari (1988; 1991a), D* increases when the absolute value M of the angular coefficient of $\sigma^2 = \sigma^2(\ln D)$ decreases; D* is higher for traffic streams characterized by less values of dispersion of speed shifts and density being the same.

Further analysis focused on the relationship between the parameter λ and lnD. Table 3 reports regression lines (λ; lnD) obtained for A22 Motorway.

For the cases examined, the law of variation in average of the parameter λ as a function of density D, can be put equal to $\lambda = - 0.126 + 0.274 \ln D$, obtained in previous researches on motorway (Ferrari, 1988).

Table 2
Regression lines (σ^2; lnD); values of coefficient of determination R^2; Durbin–Watson statistics and results of autocorrelation in residuals

Observation Section (Carriageway)	Regression Line	R^2	DW	Autocorrelation in the Residuals
S. Michele(southbound)	$\sigma^2 = - 4.131 \cdot \ln D + 15.540$	0.487	2.00	no
S. Michele (southbound)	$\sigma^2 = - 4.313 \cdot \ln D + 16.140$	0.703	1.70	no
S. Michele (southbound)	$\sigma^2 = - 3.797 \cdot \ln D + 14.371$	0.626	1.82	no
S. Michele (northbound)	$\sigma^2 = - 6.137 \cdot \ln D + 22.398$	0.636	2.66	adverse
S. Michele (northbound)	$\sigma^2 = - 4.351 \cdot \ln D + 16.319$	0.789	2.33	no
Rovereto (southbound)	$\sigma^2 = - 4.502 \cdot \ln D + 16.854$	0.849	2.17	no
Rovereto (southbound)	$\sigma^2 = - 5.459 \cdot \ln D + 20.072$	0.883	2.28	no
Adige (southbound)	$\sigma^2 = - 4.352 \cdot \ln D + 16.258$	0.704	1.96	no
Adige (southbound)	$\sigma^2 = - 5.237 \cdot \ln D + 19.272$	0.821	1.45	positive
Adige (southbound)	$\sigma^2 = - 4.647 \cdot \ln D + 17.320$	0.763	2.12	no
Adige (northbound)	$\sigma^2 = - 3.976 \cdot \ln D + 15.057$	0.657	1.77	no
Adige (northbound)	$\sigma^2 = - 4.130 \cdot \ln D + 15.496$	0.572	2.61	adverse
Adige (northbound)	$\sigma^2 = - 3.542 \cdot \ln D + 13.496$	0.839	1.77	no

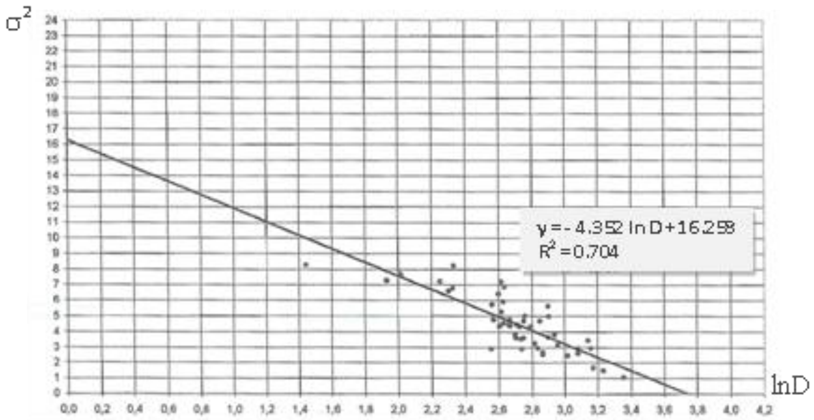
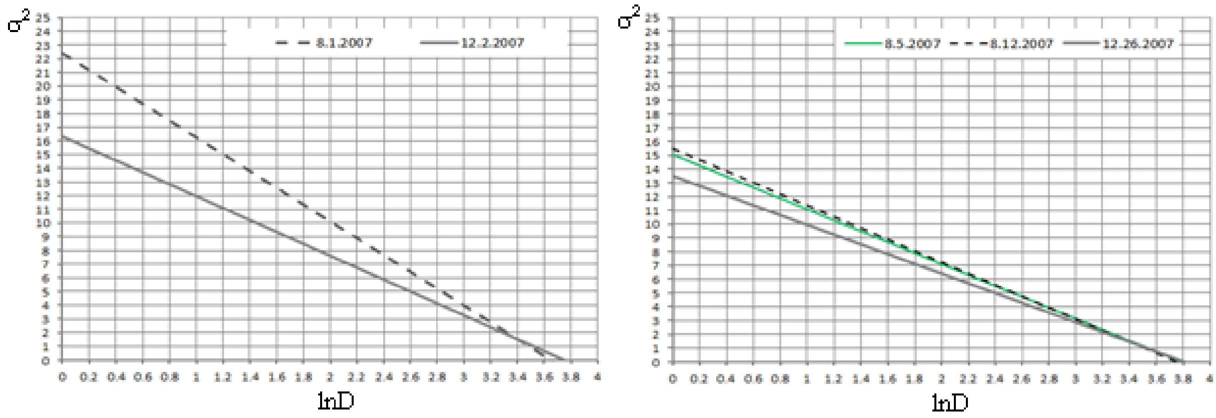


Fig. 1.
Relation σ^2-lnD for the Adige observation section (southbound carriageway) on 1.6.2007.



a) b)

Fig. 2.
Relationships σ^2 – lnD
(a) S. Michele section (northbound carriageway); (b) Adige section (northbound carriageway

Table 3
Regression lines (λ; lnD) and values of the coefficient of determination R^2

Observation Section (Carriageway)	Regression Line	R^2
S. Michele (southbound)	λ = 0.268·lnD - 0.128	0.707
S. Michele(southbound)	λ = 0.274·lnD - 0.130	0.723
S. Michele(southbound)	λ = 0.270·lnD - 0.123	0.585
S. Michele (northbound)	λ = 0.268·lnD - 0.121	0.812
S. Michele (northbound)	λ = 0.270·lnD - 0.124	0.778
Rovereto (southbound)	λ = 0.281·lnD - 0.129	0.769
Rovereto (southbound)	λ = 0.274·lnD - 0.122	0.719
Adige (southbound)	λ = 0.281·lnD - 0.123	0.818
Adige (southbound)	λ = 0.275·lnD - 0.129	0.766
Adige (southbound)	λ = 0.273·lnD - 0.122	0.789
Adige (northbound)	λ = 0.270·lnD - 0.127	0.704
Adige (northbound)	λ = 0.266·lnD - 0.129	0.789
Adige (northbound)	λ = 0.266·lnD - 0.125	0.758

4.3. Traffic flow Reliability of the A22 Brenner Motorway

The A22 Motorway is equipped with capture system of data needed to real-time estimations of reliability in a congruent number of motorway sections. This tool is proving particularly useful, together with other information technology tools useful to forecast traffic demand, for controlling the motorway and in perspective for other applications related to the containment strategies of traffic congestion.

Considering a traffic stream travelling along the offside lane of a motorway stretch without entries and exits, observed in a cross section of this lane, featured by a constant flow rate Q and by a given relationship σ^2 = f (ln D); random variations of speed level $\overline{v}_t$ produce random variations of the density D_t (see section 4.1). As shown by experimental observations, the occurrence of traffic flow instability conditions for a vehicular stream on motorway is a random event connected to realizations of level $\overline{v}_t$ of the speed process implemented by users. The probability that this event does not occur is defined in a prefixed period of observation T as the reliability of this traffic stream, relatively to this period. So the reliability Φ of a traffic stream relative to the time interval T is the conditioned probability that level $\overline{v}_t$ does not decrease during T, as far as the section where limit density is reached, given that the level at instant zero is equal to the average speed $\overline{v}_0$ corresponding to the flow rate Q in conditions of stable flow. From results reported in section 4.2, following a numerical simulation of the random walk, Ferrari (1991a) and Mauro (2003) proposed for the reliability the regression equation of Φ on Q (veh/h), T (min), M (m^2 km s^{-2}) (Eq. (3)):

$$\Phi = 1 - 19.80 \cdot \left(\frac{Q}{10000}\right)^{8.82} \cdot T^{1.933} \cdot M^2 \quad (3)$$

where Q is the flow rate of the lane; T is the selected observation period; M is the absolute value of the angular coefficient b of the relationship σ^2 = a+b·ln D. Eq. (3) can allow, when implemented in a suitable sequential procedure, the recognition of approaching of instability in the considered traffic stream, i.e. the real-time prediction of congestion and, therefore, the set-up (and the implementation) of control strategies of the traffic flow. From Eq. (3) it can be obtained the traffic flow rate on a lane, which has probability Φ of not showing instability phenomena over a period of time T (Eq. (4)):

$$Q = 10000 \cdot \left(\frac{1 - \Phi}{19.80 \cdot T^{1.933} \cdot M^2} \right)^{\frac{1}{8.82}} \tag{4}$$

Taking a reliability value close to unity (usually Φ = 0.90) and a conventional period T of 15 minutes, the volume defined by Eq. (4) is the capacity of the lane; it depends on the properties of the traffic flow, represented by the coefficient M. In a motorway, instability is generally reached firstly on the offside lane, then on the other lanes. Therefore, capacity of the carriageway is the flow rate which is accommodated by it, when the flow rate on the offside lane is equal to its capacity. The value of M to be used in Eq. (4) has to be estimated by analysing the speed process. For traffic flows on A22 Motorway, lanes and carriageways capacities were evaluated as follows:

- by Eq. (4), having chosen T = 15 min, Φ = 0.90, and M as the absolute value of the angular coefficient of the linear fitting σ^2 = a + b·ln D, capacities of the passing lane ($Q = C_{pass}$) were estimated;
- from the least square analysis of the flow rates data referred to examined days, relations $Q_{pass} = f(Q_{carr})$ were calibrated. Then, solving the equation $C_{pass} - f(Q_{carr}) = 0$, the value Q_{carr} was obtained, that represents the carriageway capacity C_{carr};
- by extension, the right-lane capacity C_{right} was assumed as the difference $C_{carr} - C_{pass}$.

Table 4 shows capacity values, obtained following the procedure just described, and the critical density values D*, calculated solving with respect to D the equation: a + M · ln D = 0; this last comes from σ^2 = a + M·ln D, considering equal to zero the variance of speed differences.

Table 4
Capacity values for right lane, passing lane and carriageway for A22 Motorway

Observation Section	M	D* [veh/km/lane]	C_{right} [veh/h]	C_{pass} [veh/h]	C_{carr} [veh/h]
S. Michele (southbound)	4.131	43.03	1,190	2,199	3,389
S. Michele (southbound)	4.313	42.19	1,081	2,177	3,258
S. Michele (southbound)	3.797	44.03	1,157	2,241	3,399
S. Michele (northbound)	6.137	38.46	843	2,010	2,853
S. Michele (northbound)	4.351	42.55	1,103	2,173	3,276
Rovereto (southbound)	4.502	42.25	1,191	2,156	3,347
Rovereto (southbound)	5.459	39.52	1,258	2,064	3,322
Adige (southbound)	4.352	41.92	1,179	2,173	3,352
Adige (southbound)	5.237	39.65	1,286	2,084	3,369
Adige (southbound)	4.647	41.56	1,215	2,141	3,355
Adige (northbound)	3.976	44.12	903	2,218	3,121
Adige (northbound)	4.130	42.61	804	2,199	3,002
Adige (northbound)	3.542	45.16	1,139	2,277	3,416

D* is a limit value of the density: over D* the flow is possible only if vehicle speeds measured at a road section exhibit the same value, without fluctuating around their average value.
D* usually depends on the observed traffic flows: D* increases when M decreases, as well as, the passing lane capacity increases as M decreases (see Table 4).

The relationships between Φ and Q relative to the full range (0, 1) of Φ, are graphically represented in Fig. 3, in correspondence of various values of M and for a time period T = 15 min (frequently assumed as the maximum time interval characterised by a constant flow rate). Each line, representing the relationship between Φ and Q corresponding to a given M value, is made up of two parts: in the first part Φ = 1 for a wide range of Q, then progressively decreases; in the second part, a sharp drop of Φ occurs as Q increases.

The transition point between two patterns of Φ = f(Q) is located in correspondence of a Φ value which ranges from 0.90 to 0.95 and it is higher for lines with greater values of M. This range of Φ values singles out a critical interval for the reliability of a traffic stream: when Φ is located within this interval the reliability is still good, but a little increase of the flow rate Q and/or of the M coefficient, unavoidable in real traffic operations, can produce a sharp increase in probability of instability of the traffic flow. For instance, it can be noted in Fig. 3 that an increase of flow rate Q from Q = 2,000 to Q = 2,100 veh/h produces a decrease of reliability Φ from Φ = 0.90 to Φ = 0.85 in a traffic stream characterised by M = 6.137 $m^2 kms^{-2}$ (S. Michele section, northbound carriageway, 8-1-2007); a decrease of Φ from Φ = 0.89 to Φ = 0.67 takes place in a traffic stream having flow rate Q = 2,300 veh/h, as a consequence of an increase of M from M = 3.542 (Adige section, northbound carriageway, 12.26.2007) to M = 6.137 m^2 kms^{-2} (S. Michele section, northbound carriageway, 8-1-2007).

For what it has been said about the relationships between Φ and Q (given the characteristics of traffic streams through the absolute values M), Φ = 0.90 can be assumed to estimate capacity, and as threshold value for real-time estimations of a traffic stream.

The availability of a formulation of reliability allowed, indeed, the development of a procedure for real-time estimations of the probability that, in a time interval T within which forecasts are calculated, instability conditions of the traffic flow for a traffic stream can be recorded (Mauro, 2003). In this way, sequences of Q, Φ, M and v were built by data surveyed on A22 Motorway. Fig. 4 shows an example where the successions of Q, Φ and M are shown (within periods of instability, successions of Φ and M were not reported, because in these conditions their determination is the result of a calculation, not having physical meaning).

Based on results obtained by analysing the evolution of traffic flows under examination, it can be seen thus that, until the value of reliability exceeds Φ = 0.90, the approaching of instability was not occurred within the time interval of forecast; the approaching of instability, however, regularly manifested as a result of determinations of Φ smaller or at most equal to Φ = 0.80, relating to two (or more) successive sequences of 50 vehicles. Thus, the stochastic approach provided new measures of traffic flow performances based on aspects of traffic reliability.

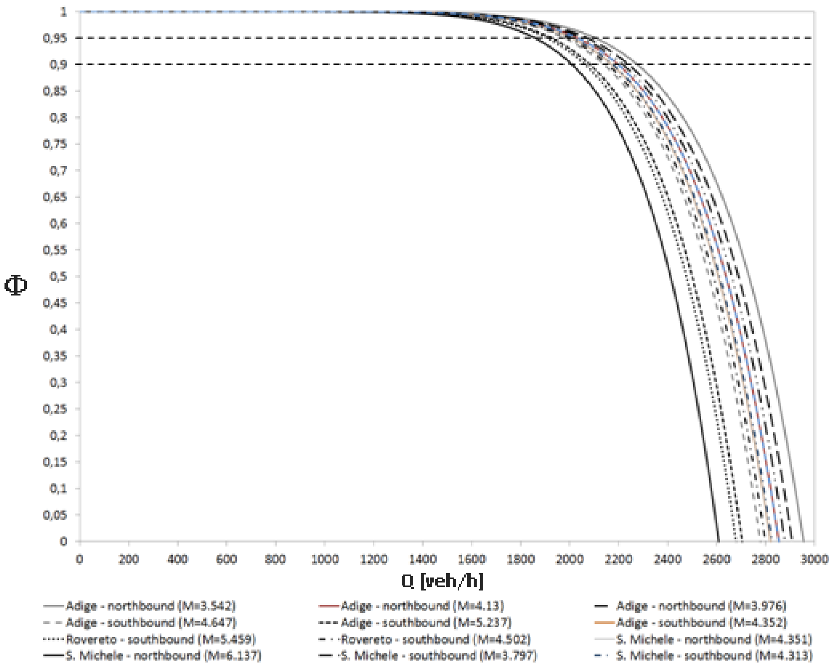


Fig. 3.
Relationships between Φ and Q, for each observation section

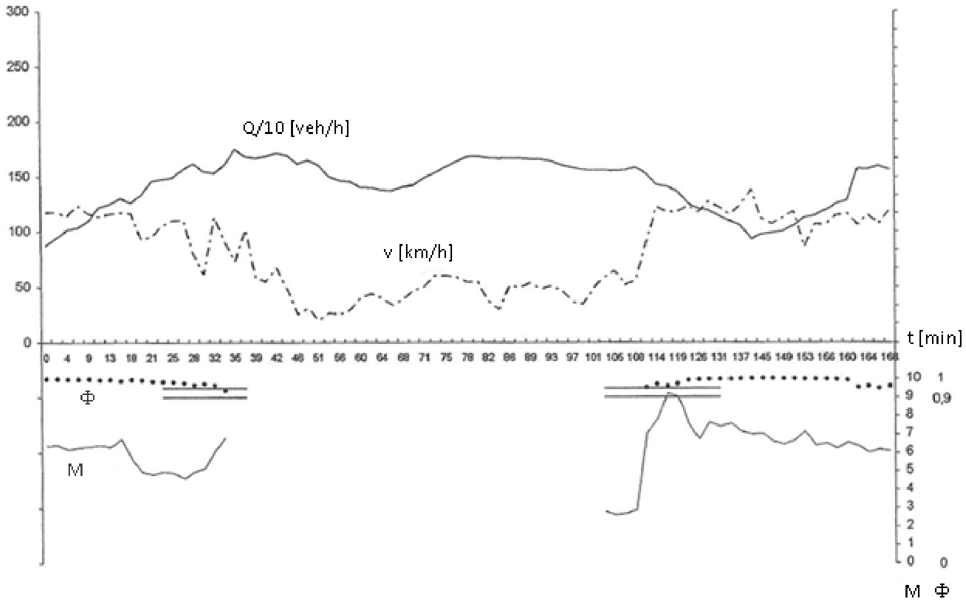


Fig. 4.
Sequences of Q, Φ and M for Rovereto section (southbound carriageway), on 1-6-2007 (from 10.35 am)

6. Conclusions

The criterion to calculate the motorway reliability here presented used the analysis of traffic flow instability and allowed to calculate reliability basing on observation in real time of the stochastic process of speeds implemented by users, sequentially observed in sections on A22 Motorway, surveyed in 2003, 2005, 2007 (Mauro, 2003; 2005; 2007). All properties highlighted for speed processes identified in the analyses may be considered in accordance with those explored in previous analyses of foreign and Italian motorways; they are important for applications, allowing estimating the reliability of a traffic stream. It must be said that on the A22 Motorway a system that allows, by remote, to obtain real-time measures of reliability in accordance with the model set out in the preceding sections, is currently operating.

At last, it has to be noted that the formulation of reliability used here was fully appropriated to forecast instability conditions only in one sample of conditions of traffic flow surveyed, as far as the latter may be regarded as extended and statistically significant. It follows that the verification cannot be considered fully exhaustive resulting necessary, for a complete judgment on predictive capability of this formulation, a systematic experimentation of the same on additional and different operating situations of interest for the A22 Brenner Motorway. In this way, the procedure above outlined was implemented in a calculation code with which to perform a further (and wider) validation of the relationship in Eq. (3) for predictive purposes of instability of the traffic flow. Overall, it is expected that prediction of traffic flow instability can offer potential for improved traffic engineering methodologies. Furthermore, it needs to be said that the above method differs from the calculation of the reliability of a traffic stream carried out through the prediction of the traffic flow breakdown phenomenon. While both approaches aimed at the calculation of reliability of a traffic stream (the traffic flow instability or the prediction of the traffic flow breakdown phenomenon) have the shape flexibility to fit a variety of data, it is believed that the procedure proposed for evaluating the probability of instability on the carriageway under investigation is significantly easier to use. However, in relation to the data availability, a further study is needed to better specify the differences between the two methods.

References

Bergmeister, K.; Benesperi, C.; Cavestro, R.; Mauro, R. 2004. New Information Technologies on the Brenner Freeway. In *Proceeding of the 2nd International SIIV Congress: New technologies and modelling tools for roads*: 1-12.

Breiman, L.; Lawrence, R. 1977. A simple stochastic model for freeway traffic. *Transportation Research,* DOI: *http://dx.doi.org/10.1016/0041-1647(77)90016-8*, 11(3): 177–182.

Brilon, W.; Geistefeldt, J.; Zurlinden, H. 2007. Implementing the Concept of Reliability for Highway Capacity Analysis. *Transportation Research Record,* DOI: http://dx.doi.org/10.3141/2027-01, 2027/2007: 1–8.

Brilon, W.; Geistefeldt, J.; Regler, M. 2005. Reliability of Freeway Traffic Flow: A stochastic Concept of Capacity. In Proceedings of the *16th International Symposium on Transportation and Traffic Theory*: 125 – 144.

Chen, C.; Skabardonis, A.; Varaiya, P. 2003. Travel Time Reliability as a Measure of Service. *Transportation Research Record*, DOI: http://dx.doi.org/10.3141/1855-09, 1855/2003: 74–79.

Elefteriadou, L.; Roess, R.P.; McShane, W.R. 1995. Probabilistic Nature of Breakdown at Freeway Merge Junctions. *Transportation Research Record* 1484: 80-89.

Ferrari, P. 1988. The reliability of motorway transport system. *Transportation Research Part B*, DOI: http://dx.doi.org/10.1016/0191-2615(88)90005-7, 22(4): 291-310.

Ferrari, P. 1991a. The control of motorway reliability. *Transportation Research Part A*, DOI: http://dx.doi.org/10.1016/0191-2607(91)90019-M, 25(6): 419–427.

Ferrari, P. 1991b. *Freeway capacity: reliability and control. Concise Encyclopaedia of Traffic Transportation Systems*. Pergamon Press, Oxford, UK, 1991.

Geistefeldt, J. 2011. Empirical Relation Between Stochastic Capacities and Capacities Obtained from the Speed-Flow Diagram. In *Greenshields Symposium "75 Years of the Fundamental Diagram for Traffic Flow Theory"*: 147-156.

Henley, E.J.; Kumamoto, H. 1981. *Reliability Engineering and Risk Assessment*. Prentice Hall, Inc. USA. 568 p.

Kottegoda, N.T.; Rosso, R. 1997. *Statistics, probability and reliability for civil and environmental engineers*. The Mac-Graw Hill Companies, Inc.USA. 735 p.

Leemis, Lawrence M. 1995, *Reliability: Probabilistic Models and Statistical Methods*. Prentice Hall, USA. 319 p.

Lorenz, M.; Elefteriadou, L. 2000. A Probabilistic Approach to Defining Freeway Capacity and Breakdown. In Proceedings of the *4th International Symposium on Highway Capacity*: 84-95.

Madsen, H.O.; Krenk, S.; Lind, N.C. 2006. *Methods of structural safety*. Dover Publications, Inc. USA. 416 p.

Mauro, R. 2003, 2005, 2007. Traffic analysis, development of models and systems for estimating reliability on A22 Motorway, Italy (*In Italian*). Technical report, part. I(2003), II(2005), III (2007) – Autostrada del Brennero, Trento, Italy.

Mauro, R. 2010. *Evaluation of roundabout reliability. In Mauro, R. Calculation of Roundabout*. DOI: http://dx.doi.org/10.1007/978-3-642-04551-6_5. Springer, 155 p.

Modarres, M.; Kaminskiy, M.; Krivstov, V. 1999. *Reliability Engineering and Risk Analysis. A Practical Guide*. Marcel Dekker, Inc. USA. 542 p.

Persaud, B.; Yagar, S.; Brownlee, R. 1998. Exploration of the Breakdown Phenomenon in Freeway Traffic. *Transportation Research Record* DOI: http://dx.doi.org/10.3141/1634-08, 1634/1998: 64-69.

Shaw, T. et al. 2003. Performance Measures of Operational Effectiveness for Highway Segments and Systems. NCHRPSynthesis 311, Available from internet: <http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_311.pdf>.

Ushakov, I.A.; Harrison, R.A. 1994. *Handbook of reliability engineering*. John Wiley & Sons, Inc USA. 664 p.

Zurlinden, H. 2003. Ganzjahresanalyse des Verkehrsflusses auf Straßen. Schriftenreihe Lehrstuhl für Verkehrswesen, Ruhr-Universität Bochum, Heft 27.

AN AIS METAHEURISTIC APPROACH FOR SOLVING MULTI-DEPOT VEHICLE SCHEDULING PROBLEM

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Abstract: Bus transit design is an important issue; many researchers developed different methods that have not been provided complete and accurate solution for it yet. The reason for this is huge problem and the number of parameters in the process of designing effective public transit network. Bus transit design can be considered a four-step process: 1–Route network designing, 2- Setting the timetables, 3- Bus Scheduling 4- crew scheduling. Objectives of optimization models from the viewpoint of passenger, operator and the community can be investigated. The purpose of this paper is the implementation of the third step of the above mentioned, to the route networks and timetables, obtained in stages 1 and 2, in a way that well-run system operator or the costs of public transport system is minimized, Because many costs of operator run at this stage their shows. The system has been optimized in a way that buses also serve all lines, minimizing deadhead trip times, or in other words, all the trips with the least number of fleet are serviced. Also in those functions, amortization costs and fuel costs of the busses can be considered as the values, we try to reduce costs to the lowest number. The approach for solving the multi-depot vehicle scheduling problem (MDVSP) has been proposed. For problem solving and optimization process, a metaheuristic method has been used, inspired of immune system (Artificial Immune System). The results of this study are compared with results of similar procedures on benchmarking examples and showed that the proposed model not only to have the ability to compete with these models, but even in some cases has better results.

Keywords: Multi-depot vehicle scheduling; Deadhead trip; Artificial Immune System

1. Introduction

In order to simplify the bus transit network design problem, some researchers and scholars have defined bus fleet network design as a four-phase process which includes network route design, setting timetables, scheduling vehicles to trips and crew assignment (Gavish et al., 1987). It is worth mentioning that Ceder and Wilson (1986), and Sadeh (1984) have divided bus network transit design to five steps whose overall scheme is similar to the classification offered. Its only difference is in considering two distinct bus frequencies setting phases and timetabling, which are considered as one in new definitions (Israeli and Ceder, 1989; Ceder, 2002). Still, another present problem in bus network design is that due to the greatness of the problem in bus network design is that due to the greatness of the problem and the plurality of parameters, usually each of the designing steps of network is completed separately and the output of each design phase, along with other related and required information, forms the input of the next phase and still, no comprehensive design which can cover all phases simultaneously and dynamically has been proposed. Bodin et al. (1982) have completed scheduling in such a way that they have considered trip time restricting as follows: "In a vehicle scheduling problem with length of path restriction (VSPLPR), restrictions are with the time the vehicle manages to run without having to return to depot for being serviced". In some cases, significant SDVS models are used.

These models only take the time difference between vehicles' arrival to and departure from depot into consideration, and hence the problem with these models is that one can not consider fuel consumption when using them. Authors have carried out single-depot vehicle scheduling in a simple problem known as minimum-cost-flow problem. This formulation has first been done by Bertosi et al. (1987). They showed how the issue of bus fleet scheduling can be changed to lanes into a minimum cost problem, provided that it is shown in form of a bipartite graph. Through changing the cost parameters, one can also change the problem to the following problems: (Minimum vehicle numbers-Minimum operational cost (which minimize deadhead trips and idle times) or a combination of both. No calculation results have been reported for this algorithm. Paixao and Branco (1988) have introduced a similar algorithm which minimizes the operational cost while the number of vehicles is fixed. Indeed, this algorithm is a refined form of Hungarian Algorithm. They have also extended this problem solving method to multi-depot condition as well. This algorithm is used in some real applications e.g. in a mass transit company in Portugal known as Rodoviaria Nacional. Using shortest-path problem, Del Amico et al. (1989) first devised a few novel formulations and then minimized the number of the vehicles in a multi-depot vehicle scheduling problem.

The foretold algorithm is done in a various phases, in each of which the new vehicle is determined.

In such a phase, a number of forbidden paths are identified and then a practical circuit is searched for in the network, which shall not pass from forbidden path and in order to improve calculation efficiency of the search for shortest path instead of whole network, a set of arcs are chosen.

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Changes and modifications have been applied so that the speed of computerized calculation is increased. Some of these changes are a new solution including changing a multi-depot to a single-depot problem. Researches by Dadona et al. (1995) have shown different research phases in different problems of vehicle scheduling: basic VSP- multi depot VSP- VSP with a fleet of different kinds- VSP with the maximum time restriction. Odoni et al. (1994) have offered a review of operation of research techniques in solving problems of urban public transportation. Particularly that they have concluded that there exist many connections among various parts of public transportation systems, from surface structure design phase to the phase of vehicle scheduling and assignment of the crew. Lobel (1998, 1999) have discussed the issue of vehicle scheduling in multi depot form and simplified it to a linear scheduling formulation, which can be solved through branch-and-cut method. A formulation for multi-commodity flow formulation has been introduced, which, unlike most similar formulations, is not arc-oriented. To solve the problem of lagrangean pricing, a column generation solution technique has been approached, which is based on two various lagrangian simplifications. Innovative methods have been used in the process to determine higher and lower limits of the answer, but the ultimate answer is proved that is the real optimal answer. F. Baita et al. (2000) in this study, a practical case has been studied and traditional method and two heuristical methods have been constructed.

A traditional method and an algorithm method based on logic programming and a method based on modified genetic algorithm have been used. In this method, a bus fleet with two types of busses used. In this research, urban transport system of Mestre in Italy has been examined. In fact this study has two ends: 1.comparing the classic method with newer and more flexible methods such as genetic algorithm and logic programming 2.attempts to make a system which can have operational use in real world, too. The result is that the results of the traditional AP procedure and logic programming method are almost the same and acceptable, but the solutions obtained from genetic algorithm method are weak and in a lower level. Haghani and Banihashemi (2002) introduced a new model for multi-depot vehicle scheduling problem and multi-depot vehicle scheduling problem with route time constraints. They added route time constraints to multi-depot vehicle scheduling in order to consider real world management problems like fuel consumption. Authors believe that compared to other present formulations this formulation decreases the problem size up to 40% without omitting possible answers of the problem. Furthermore, an exact solution method and two heuristic methods have been introduced to solve the problem of multi-depot vehicle scheduling with route time constraints. Although these methods can be applied to solve average-sized problems at a time, in big cities, we need to reduce the size of the problem calculations. In this study, two techniques have been offered to reduce the size of the problem and its calculations in the real world. Their case-study was mass transit administration in Baltimore. Final results of the applied model were compared with MTA scheduling results which were obtained in January 1989. Comparisons indicate that the suggested model's results are better than MTA scheduling in any aspect which include 7.9% in number of vehicles and 4.66% in operational time and 5.77% in directors' overall expenses. Haghani et al. (2003), in this study, a comparative analysis is based on three methods of vehicle scheduling, One of these methods is multi-depot and the other two are single-depot. The multi-depot model was actually proposed before by two authors (Haghani and Banihashemi) in 2000.

The other two single-depot models are derived from multi-depot and are in fact certain forms of this multi-depot form. This analysis was done as a blocked situation of the problem for MTA in the city of Baltimore, Maryland. Results obtained from the three methods were compared with each other and with the real MTA scheduling in Baltimore. These comparisons show that in certain conditions, a single-depot model has a better performance. In addition a sensitively analysis is done related to the two main parameters; the report of which is presented. The obtained results indicate that deadhead speed is a principal and Huisman and Wagelmans (2006), in their study, dynamic vehicle scheduling and assignment of the crew are examined and a solution is offered, which is formed by constant optimizing problem solving. Authors have tried to justify why considering such a dynamic method and comparing it with a static method can be useful. They have carried out a sensitively analysis on their own main hypotheses and have shown that trip time is exactly the same as it was before the operation. They have examined their model in a real system in Netherlands and in a big transportation company. Of course, regarding the complexity of vehicle scheduling and assigning crew, they have only solved some of the small problems with their dynamic method. Results indicate that the proposed method yields acceptable results in single-depot form. While in multi-depot form, the dynamic method proposed by authors does not work well. It is necessary to mention that the aim of this study is to reduce the total number of drivers and vehicles.

Torcel et al. (2009) have carried out vehicle scheduling through the minimum cost scheduling and by using a fleet which includes some different vehicles. They have done the scheduling through a mixed integer model and for one-way routes. In this system, daily route trip time for each vehicle exists as well scheduling is completed through using six heuristic algorithms and yields acceptable results.

2. Immune System Physiology

All living organism show the ability of some kind of defense against foreign attacks. Gradual evolution of various species which has happened as a result of appearance of vertebrate, has led to the evolution of the immune system of these elements. Immune system of the vertebrate, some of which are very interesting for some calculation abilities, are studied here. Immune cells are divided into to two major groups which are called B-cells and T-cells. Those two cell types are almost similar but only different in the methods of identifying anti-gens and in their functional roles. B-cells can identify anti-gens independently, like in blood flow, while T-cells need other helping cells to identify anti-gens (Goldberg et al., 1992).

The immune system of human body has a gland known as Thymus which is located behind the sternum and plays an important role in production of T-cells. After T-cells are produced they move toward the thymus gland and develop there. During this development, all T-cells which recognize familiar anti-gens, separate from other T-cells, a process which is known as negative selection. If a B-cell encounters an unfamiliar antigen with enough dependence, it multiplies and differentiates between influencing cells and memory cells. This process is known as clone selection. In contrast, if a B-cell recognizes a familiar antigen, it may be stopped, an issue which is proposed in the theory of immune network. Later, each of these processes, negative selection, clone selection and network theory, are explained and their calculation algorithms will be delivered (Goldberg et al., 1992).

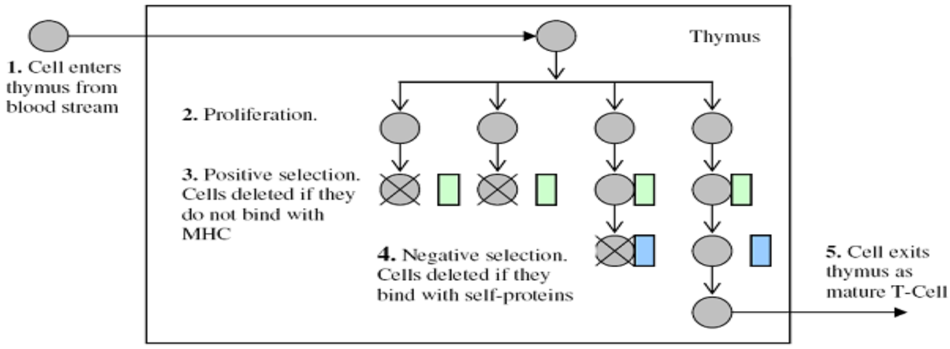

Fig. 1.
Antigen Maturing in Thymus

There are two types of Lymphocyte cells: (B) 64 and (T) 65, both of which originate from cells in Lymphocytes that develop in develop in marrow are B-cells and those which move to thymus and develop there are T-cells. Each of the two cell types has receptor molecules on their surface. These molecules are responsible to identify antidote patterns (antigen) in pathogens. In Fig. 2 T-cells and B-cells, which have separate receptor molecules in their surface, are shown. Receptors of the T-cell are called TCR and the receptors of the B-cell are BCR or antibody (Ab). B-cell maturing process as shown in Fig. 2 happens in a way that at first cell receptor adjusts the pattern related to host and the respective cell is deleted through negative choice. Therefore, the non-cloned cell is deleted. In the next phase, cell receptor adjusts alien antigen pattern (the non-similar cell of the previous stage), and therefore chooses it for cloning. Cell becomes active and produces clones, some of which turn to the form of memory cells.

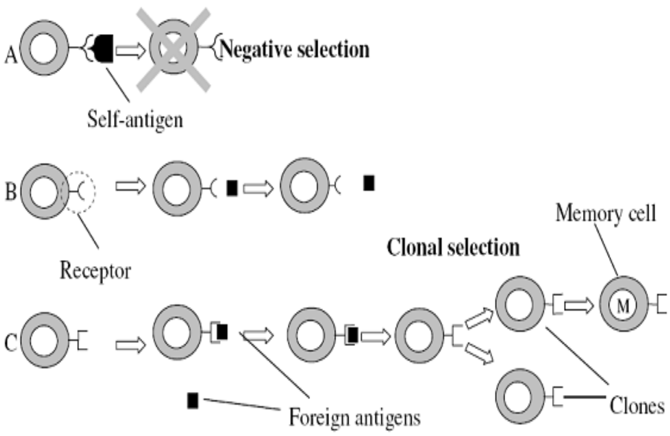

Fig. 2.
Reception Process

3. Suggested Methodology

3.1 Suggested Method

In order to solve vehicle scheduling of bus network, considering the designated lanes in the first stage and bus departure timetable in the second stage of the four mentioned stages in bus network designing, the novel algorithm of immune system inspired by checking human body issued. In this algorithm, considering the produced parameters in the first and second stages to achieve the objective function through changes which are done to respective objective function, we use the algorithm to optimize vehicle scheduling. The immune system algorithm performs in stages and with innate development and in each stage of development performance, optimizes the best vehicle scheduling of all the stages before until we achieve the expected limit in desired function.

3.1.1. Immune System Flowchart

As shown in Fig. 3 the basis of immune system algorithm is on repetition of anti-bodies generation which is shown in flowchart which indicates the number of repetitions in the algorithm. After each repetition, the final conditions of algorithm, which will be mentioned at the end of this section, are examined and if final conditions are correct, or objective function’s conditions are achieved, AIS algorithm is completed. In each repetition of AIS algorithm to produce a new generation of anti-bodies, the three main performances are used as follows: considering the number of anti-bodies in each generation, n, the first main performance is replacement. In this stage, we attempt to remove existing solutions in each generation possess the latest property and replace them with new accidentally produced solutions. It needs to be mentioned that each anti-body in generation is indicative of a solution for the problem.

Replacement performance is done with P_r possibility, whose amount is changeable for various performances. If during the repetition phase of AIS algorithm, replacement algorithm is not done, to produce remaining antibodies for completion of repetition, the other two performances (cloning and mutation) are used.

Replacement performance operates independently from the present generation, while production and mutation performances are done on the present generation and create the newer generation. As we shall see in the rest of the flowchart, if the amount of P_r is in a way that replacement performance is not done, we will move to antibody selection stage to produce or mutate antibodies. Anti-body selection is one of the major points of AIS algorithm. To perform this selection, affinity property is used. As noticed in the third section of the respective flowchart, if we can’t choose an anti-body from the present generation’s anti-bodies, we return again to the replacement stage. If an anti-body is chosen for production, in the fourth stage of the flowchart, we first compare the possibility of production with P_c . If the possibility condition is met, similar production performance is carried out. Otherwise, mutation will be performed with direct possibilities of P_m and $f_i N$.

After the completion of each of these stages of production and mutation, newly produced anti-bodies are transferred to the new generation. Repetition phase repeats itself until the number of new anti-bodies with the 3 main performers reaches n .

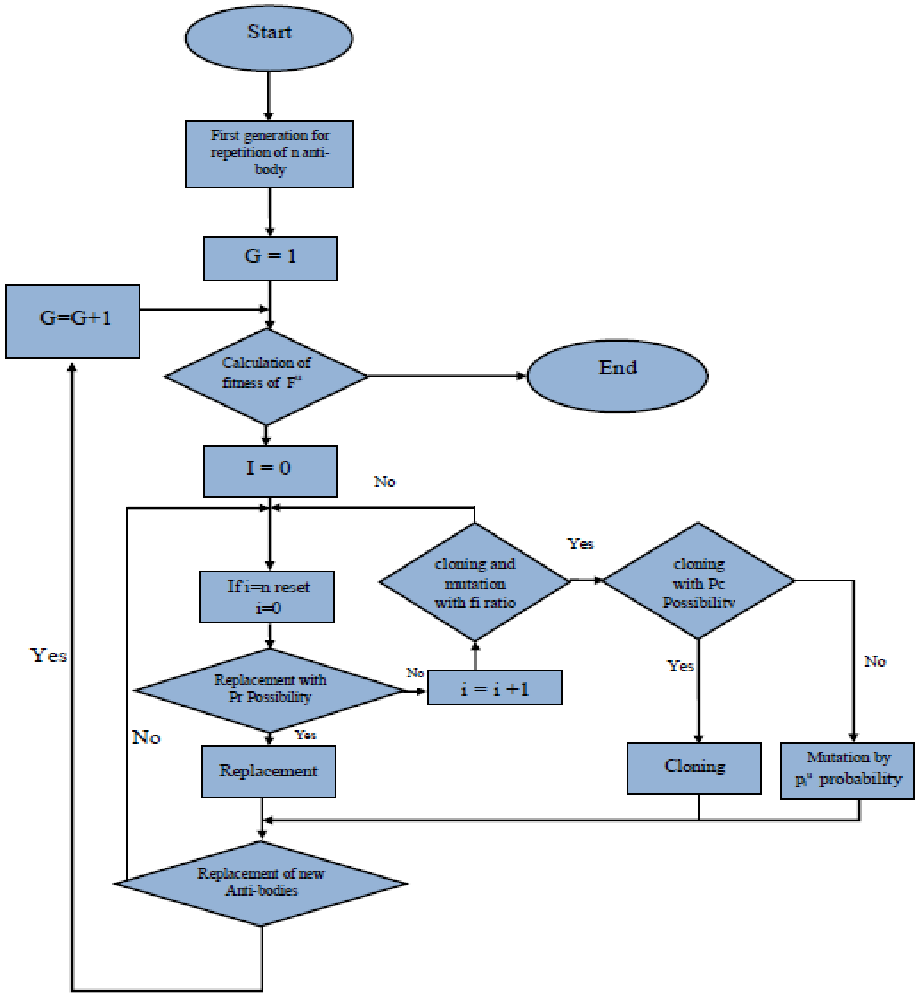

Fig. 3.
Immune System Flowchart

3.1.2. Algorithm

AIS algorithm which is presented here is expressed based on the two principles of anti-body production and replacement as follows:

1. Initialization: a primary set(population) AB, is made from n anti-bodies AB_i in which $i = 1...n$ and for the next generation $G = 1$
2. Evaluation: in the main philosophy, anti-gen, which shows the solution of the problem, is used to obtain the degree of propriety through comparing anti-gens and each of the anti-bodies. But, in this problem, through using a propriety which is inspired from input parameters of the problem, aim of the objective function and algorithm parameters, the amount of each anti-body is obtained. The best solution of the problem gets the lowest amount.
3. Replacement: with a certain P_r possibility, a new anti-body is produced and is placed in direction. This way, the anti-body with lower propriety is accidentally replaced. Parameter is the replacement possibility. P_r is the replacement possibility.
4. Cloning: if a new anti-body is not produced, an AB_i anti-body is chosen from the present from the present anti-body set with the possibility directly appropriate to its similarity. With a P_c possibility, anti-body is chosen, produced, and placed in the new generation. P_c is the parameter for cloning possibility.
5. Hyper Mutation: If an anti-body with high propriety is chosen but not produced in the last phase, it is used for hyper mutation, which is done in contrast with the anti-gen propriety. The possibility of mutation is calculated by P_m .

6. Iteration-repertories: stages 3 to 5 are repeated until a new population of AB' is produced to the number of n .
7. Iteration-algorithm: the number of the generation increases by one and the new generation is delivered to the second phase to be evaluated. This process continues repeatedly until it gets to the final condition.

3.1.2.1. Repetition of the Algorithm

After the new set is built, numerator increases by one here, the final condition to complete AIS algorithm expresses is expressed as follows:

1. Achieving the highest number of population
2. Achieving the expected degree of propriety
3. Achieving the lowest degree of difference in a certain number of last generation in terms of the best available solution.

4. Calculation Results of the Suggested Method

In this section, we will offer the results of the suggested model and compare it with the results of previous studies and models in the world on benchmark problems, in order to test the proposed model, the benchmark examples by Carpaneto et al. (1989) are used.

4.1. Benchmark Examples

Carpaneto et al. offered examples in multi-depot form that was produced randomly in 1989. These examples, as mentioned, are multi-depot to be used in vehicle scheduling. The examples in this article are 4-depot and 8-depot. For each of these problems, 3 forms -500 trips, 1000 trips, 1500 trips- are taken into consideration. For each of which 5 numerical examples are delivered. These examples are completely given by Dr. Huisman in his website (Huisman). Of course, the input of these problems is defined as a square matrix. It can be said to be a combination of trip length matrix in a wise manner.

4.2. Calculation Results of the Suggested Model

The suggested model was tested on 30 examples of Pepin et al. These examples are on the basis of the method of examples offered by Carpeneto et al. (1989). Pepin et al. (2006) used several methods to solve multi-depot vehicle scheduling problem and compared their results with benchmark data.

In this study, we have attempted to compare the resulting calculation findings from the suggested method with the best results obtained from the other mentioned methods. Some results of which are presented below in Tables 1 and 2:

Table 1

Conclusion for Benchmark Problems by 4-depot and 500 Trips

Benchmark problem	AIS Solution	Best Solution Of Other Methods	Other Method	Difference Percentage
S0	1287696	1289114	CPLEX	-0.11
S1	1240998	1241618	CPLEX	-0.04993
S2	1284838	1283811	CPLEX	0.08
S3	1258759	1258634	CPLEX	0.00993
S4	1317472	1317077	CPLEX	0.02999

Table 2

Conclusion for Benchmark Problems by 4-depot and 1000 Trips

Benchmark problem	AIS Solution	Best Solution Of Other Methods	Other Method	Difference Percentage
S0	2516699	2516247	Trancated branch-and-cut	0.01617
S1	2413152	2413393	Trancated column generation	-0.001
S2	2449717	2452905	Trancated branch-and-cut	-0.12997
S3	2488820	2490812	Trancated branch-and-cut	-0.7997
S4	2519442	2519191	CPLEX	-0.00996

5. Conclusion

In this study the third phase of the four-phase bus transit network design i.e. vehicle scheduling for lanes is done by using a new algorithm known as AIS which is inspired by human immune system, whose results on benchmark examples are compared with the results of the previous studies.

Results show that the above-mentioned algorithm has yielded acceptable, and in some cases the better answers. For future studies, more real world parameters such as vehicle using time restrictions regarding the need to refuel and return to work should be taken into consideration or the time needed for drivers' rest or lunch time can be added to the problem as new conditions to be dealt with. Another field for future studies is to use other methods and new algorithms like PSO for modeling. A combination of the above mentioned methods can even be used to solve vehicle scheduling problem. Another opportunity for more exact studies, is designing bus network dynamically in a large scale problem i.e. variable parameters should be considered with time like the matrix of passenger demands during the day and trip length matrix during the day should be considered as function of time.

References

Baita, F.; Pesenti, R.; Ukovich, W.; Favaretto, D. 2006. A Compartion of Different Solution Approaches to The Vehicle Scheduling Problem in a Practical Case, *Computers and Operations Research*, 172: 453-471.

Bertossi, A.A.; Carraresi, P.; Gallo, G. 1987. On Some Matching Problems Arising in Vehicle Scheduling Models, *Networks* 17(3): 271–281.

Bodin. L.; Golden, B.; Asad, A.; Ball, M. 1983. Routing and Scheduling of Vehicles and Crews the State of the Art, *Computer and Operation Research*, 10: 63-211.

Carpaneto, G., Dell'Amico, M., Fischetti, M., & Toth, P. (1989). A branch and bound algorithm for the multiple vehicle scheduling problem. *Networks*, *19*, 531–548.

Ceder, A. 2002. Urban Transit Scheduling: Framework, Review and Examples, *Journal of Urban Planning and Development* 128(4): 225–244.

Ceder, A. 2007. *Public Transit Design*.

Ceder, A.; Wilson, N.H.M. 1986. Bus Network Design, *Transportation Research-B*, 20(4): 331-334.

Daduna, J.; Paixao, J. 1995. Vehicle Scheduling for PublcTransit, an Overview, In Daduna J.,Branco I.,Paixao J.,editors , Computer Aided TransitScheduling, Springer, Berlin.

Dell Amico, M. UnaNuova. 1989. Proceduradi Assegnamento per il Vehicle Scheduling Problem, *Ricca Operativa*, 51: 3-21 (in Italian).

Eliiyi, D.T.; Ornek, A.; Karakutuk, S.S. 2008. A Vehicle Scheduling Problem with Fixed Trips and Time Limitations, *International Journal of Production Economics*, 42: 1251-1273.

Gavish, B.; Schweitzer, P.; Shlifer, E. 1987. Assigning Bus ses to Schedules in a Metropolitan Area, *Computer and Operational Research*, 5: 129-138.

Goldberg, D.E.; Deb, K.; Horn, J. 1992. *Massive Multimodality, Deception, and Genetic Algorithms*, Illigal Report No.92005, Published in R. Manner, B.Manderich (Ed.s), Amsterdam.

Haghani, A.; Banihashemi, M. 2002. Heuristic Approaches for Solving Large Scale Bus Transit Vehicle Scheduling Problem with Route Time Constrants, *Transportation Resaerch Part A*, 36: 309-333.

Haghani, A.; Banihashemi, M., Ching, K.H. 2003. A Comarative Analysis of Bus Transit Vehicle Scheduling Models, *Transportation Resaerch Part B*: 37: 301-322.

Hiusman, D. Homepage. Available from Internet: http://www.people.few.eur.nl/huisman.

Huisman, D.; Wagelmans, A.P.M. 2006. A Solution Approach for Dynamic Vehicle and Crew Scheduling, *European Journal of Operational Research*, 172: 453-471.

Israeli, Y.; Ceder, A. 1989. Designing Transit Routes at the Network Level, In Proceedings of the *First Vehicle Navigation and Information Systems Conference*, IEEE Vehicular Technology Society.

Odoni, A.R.; Rousseau, J.M.; Wilson, N.H.M. 1994. Models in Urban and Air Transportation, In Pollock S.M.; Rothkopt M.H.; Barne, H.A. editors, *Handbooks in Operations Research and Management Science*, 6: *Operations Research and the Public Sector*, Amsterdam: North Holland: 50-107.

Paixao, J.; Branco, I.M. 1988. *Bus Scheduling with a Fixed Number of Vehicles*, In Daduna J., Wern A.,editors, Computer-aided Transit Scheduling, Springer.

Sadeh, T. 1984. *Transit Network Design*, S.B. Technion, Master of Science Dissertation, Israel Institute of Technology.

Session 2: Sustainable Transport

MOBILITY MANAGEMENT – PROMOTION OF SUSTAINABLE TRANSPORTATION AND MANAGEMENT THE DEMAND FOR CAR USAGE

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Abstract: Nowadays cities are affected by the increasing number of cars. Car traffic leads to considerable problems related with congestion, parking, accidents as well as environmental pollution. Thus a very important issue is change of the people's mobility behaviours towards more sustainable transport means: public transport, bikes, walking trips or shared car usage – carpooling and carsharing systems. Travelers' attitudes and behaviours can be shaped by using the mobility management concept. Mobility management is an approach to the passenger transport, oriented on promotion of the sustainable mobility modes and on the management of the demand for car usage. Change of the mobility attitudes and behaviours is very long and not easy process, thus mobility management includes many instruments and strategies such as: legislative, infrastructure, financial, land use related instruments as well as strategies related to informational, educational and promotional activities. The paper presents the mobility management concept as well as gives examples of instruments and solutions applied in USA and Western Europe, but also in Central and Eastern Europe conditions, especially in Poland.

Keywords: sustainable transport, transportation management, mobility management, mobility behaviours.

1. Introduction

Contemporary cities are affected by increasing number of cars which results in problems particularly related with growing congestion. Car traffic causes decrease in travel speed, irregularity of public transport operation and, as a consequence for travelers – large time losses, included productive time as well as time for resting. Because of congestion, the accessibility to the destination points, especially those located in the city center is threatened. Others difficulties concern: road safety, increasing air pollution, traffic noise and global warming. Construction of new roads and transport facilities requires large financial resources, covers large areas and results in reductions in space which could be dedicated for others purposes (parks, playgrounds etc.). Parked vehicles form often obstacles for pedestrians, cyclists and people with disabilities. Transport contributes also to urban sprawl and to decentralization of cities.

Concerning these problems, cities have realized that the key issue for problems reduction is to change people's mobility behaviours towards less car usage and to encourage them to travel using public transport, bikes, walking trips. This approach does not aim on complete elimination of car journeys, but – on more rational usage of individual transport modes e.g. realization of car trips in case of lack of opportunity to choice of mobility means. Another possibility is shared usage of one vehicle by few people – travelling in carpooling or carsharing systems. Travelers' attitudes and behaviours can be shaped in presented way using the mobility management concept. Mobility management is an approach to the passenger transport, oriented on promotion of sustainable mobility modes and on management of demand for car usage. City residents are able to make a choice related with sustainable mobility means but at the same time some car restrictions and good conditions for pro-ecological transport need to be implemented. These solutions and strong promotion can make public and bike transport as well as walking trips more competitive than cars. Mobility management, widely applied in many European countries, Asia, Australia and North America - in Poland is innovative concept. Depending on approaches existing in individual country, Mobility Management is also called: Travel Demand Management (Garling, 2007), Transportation Control Measures (Pendyala at al., 1997) and Transportation Demand Management (Litman, 2003).

2. Purposes of Mobility Management Concept

Apart from encouragement travelers to the change of mobility attitudes and behaviours, realization of mobility management concept aimed also on (Portal, 2003) fulfillment of mobility needs through more effective and more integrated usage of existing transport and urban infrastructure,

- reduction of traffic flows through decrease in number and length of car trips and decrease in demand on private vehicle trips,
- reduction of alarming effects of noise and air pollution through usage of energy efficient vehicles and alternative fuels,
- good access to the transport modes and safety provision for all residents through improvements in vehicles and infrastructure for pedestrians, cyclists and public transport users,
- improvement in access to the journey destinations through provision of high quality public transport service and implementation of carpooling and car sharing systems,
- provision of different transport modes integration and improvement in connections in existing transportation network,

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- improvement in attractiveness of places (cities, regions, areas etc.) for residents, workers, shoppers and visitors,
- increase in economic efficiency of transport system.

3. Mobility Management Instruments

Change of the mobility attitudes and behaviours is very long and not easy process, thus mobility management includes many instruments, strategies and solutions which have different influence. A lot of them are related with offering the new transportation options, others provide incentives to decrease in number of trips, to change of mobility mode, trip destination, route or time of realization. Some of them can limit the need of physical movement thanks to the substitutes like telecommunication technology or more efficient land use planning techniques. Political or legislative reforms are also very important – a lot of them aimed on proofreading of existing land use planning process and taking into consideration the question of the mobility management in this process (Litman, 2002). Mobility management instruments are presented below.

3.1. Legislative Instruments

Legislative instruments concern a range of international, national, regional and local documents and regulations which analyze present transport situation, diagnose problems and indicate threats, but also opportunities for achievement of sustainable transport development. These acts put emphasis on need or necessity of application of mobility management instruments and others solutions and strategies aimed on implementation of effective and integrated urban transport system. One of the most important EU instruments is Green Paper "Towards a new culture for urban mobility". Document was adapted by European Commission and it defines a new role for urban transport within the European transport policy (European Commision. 2008). Essential paper for Polish transport system is "National Transport Policy, 2006 – 2025", which diagnoses trends and problems of national transport, formulates the aims, principles, priorities of transport policy, directions of transport development (also regarding urban transport) as well as determines appropriate instruments for implementation. Krakow, as a first city in Poland, passes „Krakow Transport Policy" (1993). Most important aspects defined in document concern: decrease in mobility needs, reduction of car traffic, increase in private vehicles occupancy, increase in safety and security of pedestrians and cyclists, provision priority for public transport in traffic and in future investments as well as incentives for usage of pro-ecological transport modes.

Examples of urban legislative instruments are regulations concerning parking policy or vehicle restrictions which help to discourage or prohibit car use (e.g. ban private cars from downtown on certain days or eliminate transit traffic across historical area). In the city centre of Krakow there are three different types of access zones: A – zone prohibits vehicle traffic and is designated only for pedestrians, B – absolute priority is given to pedestrians and maximum driving speed should not exceed 20km/h; parking is permitted only in designated areas, C – zone with limited and paid parking. In the future Krakow Authority is going to enlarge B zone and implement a new access regime based on research work done under CIVITAS CARAVEL project. So far, first access controlled areas extension in the project has been achieved only partly, but concerning parking policy – 300 parking places were removed and two public squares (Little Market Square and Plac Szczepanski) have been renewed and given back to the pedestrians (Fig.1).

Fig. 1.
Little Market Square – view before (L) and after (R) reduction of parking spaces
Source: Krakow Municipality

3.2. Land use Planning Related Instruments

Land use planning related instruments allow to control the car traffic level in urban areas and to manage of demand on alternative mobility modes. The United Kingdom is using land use management as a key strategy in reducing transportation carbon emissions and other environmental impacts (Litman, 1999).This kind of instruments can be related e.g. with traffic calming which includes various strategies to reduce traffic speeds and volumes on specific routes and make them more pedestrian – and bicycle – friendly. Also with techniques like: increased residential and employment densities, mixed land use, and jobs – housing balance, one is able to reduce total vehicle travel as a result of localization of common destinations (stores, services, jobs) closer together. Demand on pro-ecological transport modes can be stimulated through transit oriented design places, higher density development within reasonable walking distance and with high quality public transport service (Litman, 1999). Land use planning related instrument is also indicator of parking places, which limit beforehand the number of parking places and the same allowing controlling the level of congestion in separated city areas.

3. 3. Infrastructural Instruments

Infrastructural instruments are related with development of public transport, walking trips and bicycles friendly solutions: construction or reconstruction of infrastructure, vehicle fleet purchase, improvements in organization and quality of services, application of ITS, organization of Park & Ride, Bike & Ride systems, city bikes rental schemes etc. Especially in Polish conditions the key issue of mobility management process is provision to the residents high quality public transport service (Starowicz, 2008) dense, cohesive and safety bike path network but also well signed, safety pedestrian routes. These solutions will help to keep current public transport users and cyclists as well as encourage other people to travelling in sustainable way, particularly residents who used to travel by car till now.

Examples of infrastructural instruments were shown below – Fig. 2 presents “model” bus – tram stop at the Lubicz St. in Krakow. Stop was rebuilt by adjusting the height of platforms. Now stop is safe and comfortable enough for passengers especially for elders and disabled people. Fig. 3 presents one of the parking of Bike & Ride system implemented in suburban of Stuttgart – this solution help to encourage users to travel by bikes as well as public transport modes.

Fig. 2.
“Model” bus – tram stop at the Lubicz St. in Krakow
Source: Krakow Municipality

Fig. 3.
Bike & Ride parking in suburban of Stuttgart
Source: own resource.

3.4. Financial Instruments

Financial instruments usually aimed on making car travel more expensive and difficult and the same – less attractive for the drivers. Cordon pricing (area pricing) is the most common applied financial instrument (Banister, 2005). Some of pricing schemes are time – based and they take into account not only the transit through the area, but the effects of parking too. Others, based on distance driven by the car, are usually applied on the motorways.

Experience of cities implementing area pricing schemes (e.g. Stockholm, Oslo, London) show that financial instruments are effective solutions allowing significantly reduce the traffic congestion and increase the usage of sustainable transport modes (Bustrip). As an example – congestion charging scheme was introduced in London in 2003 for the area within the Inner Ring Road of Central London, covering 21 km² (1,3 % of the total area of London). The aims of this project concern: reducing congestion, improving bus service, improving journey time reliability, increasing the reliability and efficiency of freight distribution as well as raising funding for investment in transport. After six months of project realization following effects have obtained (February to August 2003) (Banister, 2005).

- Traffic congestion in charging area has reduced by 30%
- Bike trips in charging area have increased by 30%
- Number of accidents in charging area has decreased by 20%
- Number of public transport users has increased
- The reliability of public transport service has increased

Financial instrument is also implementation of 15 – minute public transport ticket binding in Krakow from the second half of 2010. The aim of this solution is to discourage drivers to car usage during travelling to the city center and encourage them to public transport journeys. In Krakow, public transport journeys are realized with usage of one – travel tickets (cost of ticket for adults is 2.50 zl or 1 – hour ticket (3.10 zl). The cost of 15 – minute ticket was established on the level of 1.50 zl.

3.5. “Soft” Instruments

Decision related with choice of particular transport mode concerns many sociological, cultural, psychological aspects, thus there is a necessity to take into consideration specific needs and expectations of different users. That is why the mobility management concept consists of range of “soft” instruments corresponded to individual clients’ needs that can be flexible adapted to various conditions and expectations of target groups.

The term: “soft” is popularly used in English version and it really means activities deal with human mobility behaviour through information, communication, organization and coordination, which have become increasingly important in today’s society (Portal, 2003). Besides, “soft” instruments are not obligatory to the users instead of “hard” instruments related with construction and regulations side of transport (e.g. infrastructure, laws, regulations, tax and pricing schemes). “Soft” measures usually enhance the effectiveness of the “hard” measures related with transport infrastructure development (e.g. new tram lines or new bike paths construction), do not require large financial investments and may have a high benefit – cost ratio.

Examples of “soft” instruments were presented below (MAX, 2007; Portal, 2003). Information and consulting – are related with provision to the travelers information about sustainable mobility modes, analysis of present transport situation, looking for the solutions, evaluation of the alternatives and recommendation of the best solution (e.g. comparison of travel time and costs of different transport modes). Information can be offer through leaflets, brochures, websites including travel planners and data about travelling but also by person called mobility consultant. The post of mobility consultant was established at Krakow University of Technology. This person gives employees and students advice and information about traveling and the same has an influence on their mobility behaviours (Fig. 4). Mobility consultant provides information concerning bus, tram, rail and air transport connections and tariffs, car usage costs, bike paths in city, carpooling system, development plans of city transport infrastructure etc.

Fig. 4.
Mobility consultant during discussion with the client
Source: own resource.

- Activities related with creation and sale of transport products – these activities include offering mobility products like: tickets, public transport maps, bike paths maps in specific locations e.g. in special mobility points placed in the city center or in points for tourists. Fig. 5 presents mobility point in the city center of Stuttgart –information, advisory, promotional place where the mobility products are available for the users. This category of activities includes also creation of innovative transport products e.g. loyalty programs or public transport tickets which provide entrance to the cultural or sports events.
- Activities related with transport services organization, reservation and coordination – this kind of instruments concerning organization and coordination of new ways of travelling (e.g. carpooling or car sharing systems), additional public transport services (e.g. organization of shuttle service between selected area and exchange point), coordination of mobility services for the handicaps, reservation of free places in vehicles for carpooling or car sharing users as well as coordination and improvements in existing services, like increase in frequency of selected lines.
- Activities related with usage of telecommunication technology – telecommunication technology is usually used in order to replace commuting. It typically means that employers allow certain employees to work at home or at a local workstation either part – or full – time. Communication between them is realized by telephone or Internet (Skype conversation, teleconferences). This technology can be applied also for shopping, social life and others services done by phone or Internet, without need of travelling.

- Educational activities – mean all measures focusing on users' travel awareness raising that present possibility of individual person to make a choice in travel planning process and indicate the more sustainable mobility options. The most popular educational event is "European Mobility Week". Others activities consist of distribution of leaflets, brochures, posters but also organization of workshops and training in kindergartens, schools, work places. Special workshops are also dedicated for people who are interested in working in the area of mobility management. In framework of CIVITAS CARAVEL project, the City of Krakow has organized a series of educational seminars in kindergartens, primary schools, high schools and universities. The aim of these meetings was to present problems resulting from car traffic increase and benefits from travelling by sustainable mobility modes for users, environment and quality of city life. These actions were focusing on young people who will take a decision about cities development in next decades (Niewitała and Ochyra, 2008).
- Promotional activities – include different marketing campaigns consisting of special events (e.g. bike happenings), leaflets, brochures, posters, gadgets which encourage people to travelling by tram, bus, bikes, by foot or in carpooling and car sharing systems. (Staszak, 2009; Staszak and Smirnow, 2009).
- Most popular promotional events are "Bike2work" or "Car Free days", which are organized in many cities of Europe, North America and Australia every year.

Fig. 5.
Mobility point in Stuttgart – information, advisory, promotional place where the mobility products are available for the users
Source: www.stuttgart.de.

4. The Area of Mobility Management Application

The idea of mobility management concept concerns especially urban transport system, but instruments presented above can be applied also to the area of region or country e.g. legislative instruments. In many foreign sites mobility management is usually perceived as an activity focused on particular area or place which generate and attract large traffic flows like: distinguished city areas (city center, housing estate, industrial area), big institutions and companies (municipality, school, university, hospital, shopping center etc.).

Beside "soft" instruments are appropriate to temporary events – trade fairs, concerts, sports matches – the organization of these events has a significant influence on urban transport system and results often in paralysis of the city. Mobility management helps to reduce the negative effects of temporary events organization (Nosal, 2008).

The choice of suitable instruments and solutions implemented in frameworks of mobility management depends on political, economic and demographic situation of the city, region, country, as well as travel awareness motivating mobility behaviours. The best results are generated through simultaneously application of many different instruments.

5. Conclusions

Paper presents the mobility management approach, innovative in Poland, but very popular in west and north EU countries, North America and Australia. Foreign examples of concept realization show many positive results, e.g. reduction of traffic congestion, improvement in air quality, improvement in public transport service and safety, citizens' satisfaction from urban transport operation.

Because of progress in science and technology and appearance of new transport, communication and information solutions, mobility management also develops and its definition is variously understood and adapted to require and conditions of individual countries. In many European sites, where the quality of public transport is very high, exist dense and cohesive bike network, P&R infrastructure and legislative and land use planning instruments are widely known and applied, mobility management are understood as set of activities only related with “soft” instruments (MAX, 2007).

Taking into consideration differences concern economical and political situation, available sources and mobility awareness, some of instruments implemented in UE or USA are not placed in Polish conditions till now e.g. congestion charging schemes, HOV lane – high occupancy vehicle lane (dedicated traffic lanes for vehicles with 2+, 3+ or 4+ passengers) or Guaranteed Ride Home (in many American companies, employees who travel to work by bike or in carpooling system, in case of lack of possibility to use these transport modes, can back home by taxi at employer’s expense).

References

Banister, D. 2005. *Unsustainable transport. City transport in the new century*, Routledge. 305 p.

BUSTRIP Project report. Przemieszczanie zrównoważone – przewodnik po planach zrównoważonego transport miejskiego. Available from Internet: <www.movingsustainably.net>.

European Commision. 2008. Green Paper. Towards a new culture for urban mobility. Brussels. Available from internet : < http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_0551en01.pdf>.
European Commission. 1999. Proceedings of the *Mobility management. Research for sustainable mobility*.

Faron, A.; Rudnicki, A. 2010. Idea i narzędzia unijnego projektu MAX mającego na celu podniesienie świadomości potrzeby zarządzania mobilnością, *Transport Miejski i Regionalny*, 1/2010.

Garling, T.; Steg, L. 2007. *Threats from car traffic to the quality of urban life: problems, causes and solutions.* ELSEVIER, Amsterdam.

Garling, T.2007. *Effectiveness, public acceptance and political feasibility of coercive measures for reducing car traffic*. ELSEVIER, Amsterdam.

Gronau, W.; Kagermeier, A. 2004. Mobility management outside metropolitan areas: case study from north Rhine Westphalia, *Journal of transport geography*, 12(4): 315-322.

Litman, T. 1999. Potential Transportation Demand Management Strategies. Available from internet: <www.vtpi.org/tdm>.

Litman, T. 2002. *Mobility management. Sustainable transport. A sourcebook for policy-makers in developing cities*. GTZ.

Litman, T. 2003. A Sourcebook for Policy-makers in Developing Cities Module 2b: Mobility Management. Available from interent: <http://www.vtpi.org/gtz_module.pdf>.

MAX project report. 2007. Definition and Categorization of Mobility Management Measures. Available from internet: <www.epomm.org/docs/MAX_Defn_catgsn_MM_measures_Final.doc>.

MOMENTUM project final report. 2000. *Mobility management for the urban environment, Deliverable 1 – State of the Art and Deliverable 2 – Blueprint for Mobility Centers*.

Niewitała, D.; Ochyra, M. 2008. Innowacyjne działania w zakresie popularyzowania i promowania idei zrównoważonej mobilności, *Transport Miejski i Regionalny*, 7-8/2008.

Nosal, K. 2008. Zintegrowany plan mobilności dla Politechniki Krakowskiej jako przykład zaspakajania potrzeb komunikacyjnych pracowników i studentów oraz zarządzania ich mobilnością, *Transport Miejski i Regionalny*, 7-8/2008.

Nosal, K., 2009. *Wpływ* planów mobilności na zmianę zachowań komunikacyjnych. In proceedings of *XIV Konferencja naukowo- techniczna, Problemy komunikacyjne miast w warunkach zatłoczenia komunikacyjnego*, SITK. Poznań.

Pendyala, R.M.; Kitamura, R.; Chen, C.; Pas E.I. 1997. An activity-based micro-simulation analysis of transportation control measures, *Transport Policy*, 4(3): 183-192.

Portal – transport teaching material. 2003. Mobility management and travel awareness. Available from internet: <http://www.eu-portal.net/material/downloadarea/kt7_wm_en.pdf>.

Raeva, D. 2007. Mobility Management: Sustainability Option for Sofia's Urban Transport Policy? Available from internet: <http://www.lund.se/upload/130748/Mobility%20Management%20Sustainability%20Option%20for.pdf>.

Rudnicki, A. 2009. Polityka rozwoju przestrzennego a zatłoczenie komunikacyjne. In proceedings of the *XIV Konferencja naukowo- techniczna, Problemy komunikacyjne miast w warunkach zatłoczenia komunikacyjnego*, SITK. Poznań.

Starowicz, W. 2008. *Jakość usług w miejskim transporcie publiczny.* Wydawnictwo Politechniki Krakowskiej. Kraków.

Staszak, J. 2009. Promocja usług miejskiego transportu zbiorowego jako element strategii zrównoważonego rozwoju ze szczególnym uwzględnieniem Gdyni. *Transport Miejski i Regionalny*, 7-8/2009.

Staszak, J.; Smirnow, R. 2009. Udział Gdyni w projekcie edukacyjnym dla dzieci i młodzieży - YOUTH - promującym transport miejski. *Transport Miejski i Regionalny*, 3/2009.

Suchorzewski, W. 2009. Opłaty za wjazd do obszarów śródmiejskich – sukcesy i porażki. In proceedings of the *XIV Konferencja naukowo- techniczna, Problemy komunikacyjne miast w warunkach zatłoczenia komunikacyjnego*, SITK. Poznań.

Vigar, G. 2002. *The politics of mobility: transport, the environment, and public policy*, London, Spon Press.

VEHICLE CONVERSIONS TO ALTERNATIVE FUELS ON AN UNPREPARED MARKET OF A DEVELOPING COUNTRY: A CERTAIN WAY TO FAILURE

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Abstract: After a substantial success of LPG vehicles in Serbia and an extensive shift toward bi-fuelled LPG gasoline passenger cars, the market, and especially corporate users were eager to welcome all the other alternative and renewable fuels, as CNG and Biodiesel. The main prerequisite was that they could be implemented shortly, as soon as possible with as lower technical interventions and implementation investments as possible with really high expectations of considerable short-term savings. It is now certain that enthusiastic but inexperienced users as well as an immature vehicle market and refueling infrastructure in a developing country recovering from a decade-long crisis as Republic of Serbia, expected a miracle, which unfortunately did not happen. In the paper, the authors present some of the problems arisen especially from insufficient fuel availability and poor quality of conversion since the majority of car owners expected important incentives and subventions for conversions due to the stringent cost limitations (i.e. lower incomes). Unfortunately, national policy never backed up this isolated effort. From such an implementation experience important lessons were learnt and highlighted in the paper, as well as some of the applicable best practices to overcome it from similar/comparable countries. Eventually, several crucial recommendations were delivered for all the subsequent trials, promotions and presently lacking but in the near future necessary national supportive policy for alternative fuels in transportation in order not to disappoint anymore the users and though make a stable path for their wider, easier and effective implementation.

Keywords: conventional vehicle conversions, alternative fuels, CNG, biofuels, Biodiesel, implementation issues.

1. Introduction

Numerous researches have shown that biofuels (i.e. fuels obtained from the biomass) are the most promising alternative fuels worldwide since they can be effectively used in the existing internal combustion (IC) engines. In addition, these fuels have much more favorable environmental impact than petrol and diesel. Presently, two most widely spread types of biofuels worldwide are biodiesel (denoted by B followed by the percentage of biodiesel in the blend) and bioethanol blends (denoted by letter E - for ethanol - followed by the percentage of bioethanol in the blend). Closely following the latter, leading alternative fuels (but still dominantly fossil by origin) are the liquefied petroleum gas (LPG) and the compressed (CNG) or the liquefied natural gas (LNG).

Republic of Serbia has initiated in the 1990s the first steps in the implementation of LPG, which was ultimately a success story regarding the number of users and converted vehicles to the day. On the other hand, biodiesel and compressed natural gas, although recently started to be implemented, both suffered an important draw back and will need important incentives to get back on the road. The success of the LPG was primarily due to the equipment for conversion, which was rather cheap compared to other fuels, and to the fact that practically every workshop could mount it since, at the time, this procedure did not require a type-approval (therefore no additional costs) as the state was looking the other way in order not to additionally burden the citizens in an already difficult situation regarding fuel supply in the times of the national crisis and foreign embargo. Many passenger vehicles’ owners, including taxi vehicles, independently and individually converted to LPG ruled by considerable short-term savings. This was quite understandable, as citizens, owners of passenger cars, in general, were not interested in wider environmental problems or lack of fossil fuel reserves worldwide, but rather on direct (personal) financial savings. Such explanation was logical since LPG was much cheaper than the conventional fuels (especially petrol, whose alternative it represents) because of low production costs and no initial taxes/excise duty. In 2009, when already an important vehicle fleet (as said, predominantly passenger cars) was converted to this fuel the state decided to induce order in this field (which is a consistent condition in many countries) and required from all users to acquire the type-approval for their LPG equipment and converted vehicles, which induced some additional costs for all previous and subsequent conversions. Nevertheless, an important number of vehicles have already spread the word on short- and long-term benefits and this vertiginous trend could not be stopped easily.

Regarding compressed natural gas (CNG) as a vehicle fuel, it started in Serbia in 1995, with the promotion of a Study on natural gas use prospects within the Serbian transport sector, which was presented at the Chamber of Commerce of Yugoslavia.

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As a result, a pilot project was initiated in 1998, with a locally manufactured prototype of a public transportation bus IK104 CNG, whose mass production, despite the good results never came to life, as well as a small CNG refueling station - FuelMaker FM4. The results of the initial tests in operation were better than theoretically expected. However, adverse economic and political situation in the country at the time significantly hindered and slowed the research and wider implementation. From 2000 onwards, the research in actual public transport operations continued, and the results fully confirmed the favorable assumptions regarding CNG application in vehicles. However, despite such satisfactory results of the pilot project, the wider use of compressed natural gas as a vehicle fuel in Serbia did not succeed. In general, in Serbia, CNG is still under-utilized as a motor vehicle fuel. The fact that large transport companies, especially urban and interurban public transport companies, as well as other major public fleets (police, ambulance, utilities, etc.) still do not use alternative fuels is discouraging for the individuals. There are several reasons for this situation, and the key ones are: inadequate role of the state, i.e. unsatisfactory regulations and fiscal policy, inadequate logistics support for the use of CNG (public refueling stations), public opinion/awareness and many more. But still, based on the data from Natural & bio Gas Vehicle Association, updated in December 2011, in Serbia there are currently 789 compressed natural gas vehicles, of which 36 buses, which is quite a figure in view of present lack of serious involvement of the state in the matter.

As for the national CNG bus market, after the first prototype, only nine years later (in 2005) Ikarbus launched a new bus prototype IK-103 CNG. Afterwards another Serbian manufacturer - FAP from Priboj in cooperation with the Centre for engines of the Institute for Nuclear Sciences from Vinča initiated the development of CNG buses in 2006, whose final product was the bus FAP A 537.4 CNG released on the Fair of commercial vehicles in Belgrade in 2008. As third manufacturer on our market of CNG vehicles in 2009 appeared the company “Vulović transport” from Kragujevac. At the time they released their first low-floor natural gas powered bus in Serbia - MAZ BIK 203CNG-S. This vehicle was developed in cooperation with the Belarus factory MAZ, which complied with the Euro IV emission standard. In 2010 the same company initiates the manufacturing of the bus model MAZ-BIK 203CNG with advanced technical features compared to their first model. Cummins engine was mounted to MAZ-BIK 203CNG, but with much better features in view of emission of pollutants since it complies with the EURO VI emission standard. Such sudden interest in local production was incited by the state subsidies for buying locally manufactured vehicles started in 2009, which will be discussed further ahead.

As for biodiesel, its production and distribution first started unregulated in the 1990s in Vojvodina (northern Serbian region), which soon ended as an unsuccessful experiment. Since the regulated (and standardized) biodiesel production started in 2007, some framework was set for 2006 with about 1.4 million tons of consumed diesel, meanwhile there was no biodiesel production or consumption in Serbia. It was therefore estimated by Tesic et al. (2010) that the consumption of biodiesel made less than 1% of diesel consumption in Serbia in 2007. Refueling station named “Vjestica” in Novi Sad in November 2007 was selling pure biodiesel (B100) for cars at the price of 72.6 RSD per liter (0.91 €/l). In Germany the price of biodiesel at the time was 1.025 €/liter and for diesel 1.144 €/liter. Unfortunately, already in 2008 there was no production, nor use of biodiesel in Serbia (Tešić et al, 2008), since VictoriaOil was the only biodiesel production company in 2007, with a 1st-generation biodiesel factory in Šid (the first and the only in Serbia) with an annual production capacity of 100,000 t of biodiesel. At the time, there was also an initiative in NIS (Petrol industry of Serbia) to initiate a sector for 1st-generation biodiesel production based also in the region of Vojvodina (close to Novi Sad) since it was estimated as a good opportunity on a “fresh” market (although this initiative was actually abandoned soon after).

2. Alternative fuels in early implementation in Serbia

In this section, the alternative fuels, whose implementation has already started and are in the early stage, will be considered. Nevertheless, their further development is for several years under serious doubt, mainly due to reckless high-level (political) strategic decisions. As during the two previous decades LPG experienced substantial expansion due to a much cheaper vehicle operation, several attempts for the introduction of other alternative fuels have been initiated in Serbia. Those alternative fuels consist of compressed natural gas and biodiesel, and they will be further analyzed hereafter.

Natural gas is a blend of different gases, predominantly methane, and to a lesser degree propane, butane, carbon dioxide, hydrogen, etc. Methane content may range from 82 to 98%, which is the reason for this fuel to be often referred to as “methane”. Besides oil deposits, where it can be found separately or dissolved in oil, it can be also found at landfill sites as biomethane (i.e. biofuel).

Methane being the most stable saturated hydrocarbon, slightly soluble in water and almost two times lighter than air, when it comes to a leakage it ascends and rapidly decomposes in the atmosphere (opposite to LPG).

As it is obtained by a relatively simple technological process, with rather small financial investment, its price is importantly lower than the price of conventional liquid fuels, even LPG, and especially all other alternative fuels. Despite natural gas reserves in many countries worldwide are very large, there are recent research and implementation projects regarding the development of methane production from biomass. As for natural gas as vehicle fuel, it is an environmentally and economically efficient fuel that can be found in two forms - as compressed natural gas (CNG) or as liquefied natural gas (LNG). In the first case, the natural gas is stored in tanks at high pressures (200-250 MPa), while in the second case the natural gas must be refrigerated to very low temperatures in the tanks (at approx. -162 °C). Due to a number of technical advantages, natural gas is by far the most commonly used in vehicles in a compressed state and very rarely as liquefied.

The experiences of an urban public transport operator JGSP "Novi Sad" with CNG powered buses and CNG station, and a company Vulović Transport from Kragujevac will be addressed. JGSP "Novi Sad" purchased six CNG powered buses Solaris Urbino 12 CNG and 5 Urby Iveco minibuses in 2011. They also possess a bus Ikarbus IK-103 CNG. Another five Iveco Citelis buses were purchased and their delivery is expected in October this year. Consumption of compressed natural gas of Solaris buses varies from 40 to 42 kg/100 km. This bus has 6 CNG containers (cylinders) of 200 L capacity i.e. 200 to 250 kg of gas, which allows the fuel range from 400 to 450 km before the next refueling. The consumption is (among others) strongly influenced by the quality of the natural gas, which is variable. The methane content in the fuel is typically around 98%. However, sometimes the methane content falls to 83%. CNG refueling lasts for 15 to 20 minutes per vehicle, for the container pressure of 200 bar. For minibuses the container (cylinder) pressure is 230 bar. According to the plans of JGSP "Novi Sad" vehicles are refueled from midnight until the next morning (4 a.m.), because the vehicle daily driving cycle is from 4 a.m. until 12 a.m. Motor oil change interval for these buses is 30,000 km.

CNG station (owned by DP Novi Sad Gas) at the JGSP "Novi Sad" parking/maintenance facility site is connected to the gas network with a pressure of 8 bar. By type, this is a fast filling station, containing several CNG storage containers (cylinders) equipped with four dispensers. An issue regarding the compressor at this CNG station is that it turns off when the gas pressure falls below 5 bar (which is not a negligible event), which paralyzes the operation of these vehicles and discourages the operator to seriously consider switching exclusively to this fuel, but needs a backup in form of modern diesel powered buses.

According to the classification, the public CNG refueling station of the company Vulović Transport in Kragujevac is a fast filling station. The gas storage containers capacity is 2,800 Nm^3 and the cascade containers have the following pressures: low pressure (80 bar), medium (80 to 180 bar) and high pressure over 180 bar. This station is connected to the gas pipeline system with a pressure of 6 bar, with a capacity of 1,500 Nm^3 / h. If the pressure drops below 6 bar, the gas flow drops and amounts 1,300 Nm^3 / h. The pressure in the vehicle container (cylinder) is 220 bar, and a 190 bar pressure is reached for the bus refueling in seven minutes and approximately the same amount of time is required to reach the maximum pressure. Thus, the vehicle refueling takes about 15 minutes per vehicle.

Unlike refueling infrastructure for conventional liquid fuels (gasoline, diesel) and LPG, in Serbia such infrastructure for compressed natural gas is practically negligible. The first CNG refueling station (internal/for own-account) was built in 1998 for testing purposes within the mentioned Study on natural gas use prospects within the Serbian transport sector. The first public CNG refueling station was built and opened in Novi Sad in 2004. Presently in Serbia there are seven public CNG stations in five cities: two stations in Belgrade and Pančevo, and one CNG station in Čačak, Kragujevac and Kruševac.

Besides public stations there are equally three internal CNG stations. Two of them are located in Novi Sad from which one was already mentioned (in ownership of NIS Gas), while the second was built as cooperation of public transport operator JGSP "Novi Sad" and DP "Novi Sad Gas". The third internal station is based in Belgrade on the site of Ikarbus factory.

Therefore, the available CNG fuel supply infrastructure (stations network) is absolutely inadequate and even very discouraging for potential users.
Moreover, the entire Serbian initiative to popularize and logistically support the CNG distribution system is limited to two private companies Kryogas and BRC from Belgrade and one association organizing yearly conferences in order to raise the public awareness.

Besides, there is a limited number of workshops for the CNG conversions and maintenance of such CNG powered vehicles (primarily in Belgrade and Novi Sad) and the cost of vehicle conversion (retrofitting) is still very high for our conditions (800 EUR for carburetor engine to 2500 EUR for direct injection engines).

Consequently, inadequate logistical support represents one of the basic problems of wider implementation of CNG as a motor vehicle fuel in Serbia.

Biodiesel, as defined by the European standard EN 14214 (European Parliament, 2003) was stipulated in Serbia in 2006 by SRPS (ISO) standard EN 14214 “Fuels for motor vehicles. Fatty acid methyl esters (MEFA) for diesel engines, the requirements and test methods” (identical to the aforementioned European standard). In addition, at the level of Serbia and Montenegro, in May 2006, the Regulation regarding biofuels (The Parliament of the Republic of Serbia, 2006) was adopted specifying technical and other requirements that such fuels must fulfill. It can entirely replace the fossil diesel in compression ignition IC engines. This fuel’s cetane number is between 46 and 70; it has extremely low sulfur content (less than 0.01%) and oxygen content of approx. 11%. Biodiesel has higher self-ignition point (150 °C) compared to the conventional diesel (77 °C). Biodiesel can be used as pure fuel in compression-ignition IC engines, but is usually used blended with conventional diesel to reduce emissions of particulate matter, carbon monoxide, hydrocarbons and other pollutants. Blend of 20% of biodiesel (B20) with fossil diesel can be used in most modern diesel engines without any engine modifications. However, transport and storage of such fuels require certain special measures. Large number of today’s commercial vehicles’ manufacturers enables use of biodiesel or its blend with diesel in their vehicles. For certain vehicle models and engine technologies (regardless of age) use of varied biodiesel blends is allowed, even recommended. In the following Table 1 are given the recommendations of commercial vehicles’ manufacturers in terms of using biodiesel and fossil diesel blends.

Table 1
Commercial vehicles manufacturer's recommendations regarding the allowed use of biodiesel and diesel blends

Commercial vehicle manufacturer	Recommended Biodiesel blends
CATERPILLAR	B100, B20, B5
IVECO	B100
MERCEDES-BENZ	B100
DAF	B100, B20, B7
MAN	B100
RENAULT	B30
DEUTZ	B100, B30
SCANIA	B100
VOLVO	B30, B5
SETRA	B100

As shown in the table above, an important number of Caterpillar engine types can be powered by biodiesel blends in any proportion, even by pure biodiesel (B100). Certain C type engines can use up to B20 biodiesel blends, while in other engines can be used up to B5. Iveco vehicle manufacturer allows the use of biodiesel blends and even pure biodiesel (B100) in engines with nozzles and high-pressure pumps. For vehicles with common rail engines there is no official information about the possibility of biodiesel blends use. A large number of existing engine types of the manufacturer Mercedes-Benz can use any biodiesel and diesel blend, provided that they comply with the European standard EN 14214. Several engine types in DAF vehicles can be powered by pure biodiesel (B100). BE and CE types of engines can use blends up to B20 while FR and GR types of engines may run on biodiesel B7. MAN allows the use of biodiesel B100.

On Renault trucks and buses the use of pure biodiesel is not allowed, but mostly up to a share of 30% biodiesel in the blend. This recommendation applies to all the company's vehicles whose engines meet Euro 3, Euro 4 and Euro 5 standards. Scania allows most of its engines to be powered by biodiesel B100, meeting the EN 14214 standard. However, the manufacturer does not recommend the use of biodiesel for fire trucks, as well as in vehicles that stand still for a long time. Volvo allows the use of biodiesel blends up to the share of 30% (B30). However, in order to comply with guarantee conditions, only 5% biodiesel blends (B5) may be used. Setra allows the use of 100% biodiesel in a large number of engine types and models of buses.

2.1. Barriers to wider implementation of CNG and biodiesel

The most important questions related to the use of CNG-powered vehicles in Serbia are the legislative and fiscal policies. These acts and measures should define the necessary pre-conditions and encourage the use of CNG as a fuel powering commercial and passenger vehicles. Such regulations, as well as fiscal policy in Serbia are practically non-existent. Some of the regulations regarding gaseous fuels are older than twenty years; therefore they do not comply with today’s ISO standards.

The effective ISO standards in the EU since 2002 are divided into three main areas: the regulations related to the formation of a refueling stations' network, next the quality of natural gas used as fuel and finally regulations with respect to the CNG powered vehicles.

Among the most important obstacles to the substantial increase of CNG share in Serbia may be the complex administrative procedures, lack of certain specific standards, procedures and equipment for CNG operation; insufficient regulations regarding the design, development, control and installation of CNG equipment. Without a proactive participation of the state, primarily through subsidies, it is unlikely that the situation will be significantly improved. Since in Serbia, there is no legislation that deals with a network of CNG refueling stations (by the way, in Serbia there is no serious stations' network). Although there are standards regarding the guaranteed fuel quality (CNG), its quality control is performed presently only at main gas metering-regulation stations by operators directly dealing with natural gas import and distribution, which represents a clear conflict of interest and seriously endangers such fragile market. Many refueling station owners actually mostly complain regarding the quality of CNG, especially its methane share (the lower CH_4 share decreases the calorific power of this fuel).

The aim of international standard SRPS ISO 15403 is to provide manufacturers, vehicle operators, refueling station operators and others involved in the CNG vehicle industry with information on the fuel quality for natural gas vehicles (NGVs) required to develop and operate CNG vehicle equipment successfully. Fuel complying with the requirements of this international standard should:

a) provide for the safe operation of the vehicle and associated equipment needed for its refueling and maintenance,
b) protect the fuel system from the detrimental effects of corrosion, poisoning, and liquid or solid deposition, and
c) provide satisfactory vehicle performance under any and all conditions of climate and driving demands.

One of the important prerequisites for the construction of refueling stations for compressed natural gas vehicles is to provide a pressure as close as possible to the pressure in the master pipeline (high pressure, up to 50 bar). Gas pipeline type (master or distribution pipeline) and distance from the refueling station location requires the fulfilment of the specified condition. In our country, connection to the pipeline system requires the implementation of the procedure prescribed by PC "Srbijagas". The mentioned procedure is passed by an internal rulebook of the company based on the following laws and regulations:

a) Law on Planning and Construction (Official Gazette RS No. 72/2009, 81/2009 and 24/2011);
b) Energy Law (Official Gazette RS No. 57/2011 and 80/2011);
c) Ordinance on the criteria for issuing energy permits, content of application and manner of issuing energy permits (Official Gazette RS No. 23/2006, 113/2008 and 50/2011);
d) Regulation on conditions for the delivery of natural gas (Official Gazette RS No. 47/2006, 3/2010 and 48/2010);
e) Decision on establishing the methodology for the criteria and determining the cost of connections to the natural gas transport and distribution system (Official Gazette RS No. 48/2008 and 54/2008).

Concerning the fiscal policy, the situation is well illustrated on the example of the ecological tax to be paid upon motor vehicle registration. The fee is determined depending on the engine capacity (displacement) and its power without taking into account the type of fuel used to power the vehicle. So, the same fee should be paid by owners of vehicles powered by conventional fuels and similar CNG or biodiesel powered vehicle, which are significantly more environmentally friendly. Also, there is no tax, or any benefits or subsidies for the purchase of new CNG vehicles from foreign manufacturers (imported) or if a vehicle owner retrofits his conventionally fuelled vehicle to alternative fuel. Anyhow, public transport fleets in Belgrade and Novi Sad in the recent couple of years have been systematically renewed in significant number with CNG vehicles, which represents their greatest prospects for wider implementation.

Of particular importance is the decision of the Serbian government to subsidize domestic production of buses (-20% of the retail price) with additional subsidies (-10%) for the purchase of CNG powered buses (The Parliament of the Republic of Serbia, 2012), which lays down the conditions and means of encouraging the production, sale and implementation of the subsidized purchase of buses manufactured in the Republic of Serbia. Direct beneficiaries of the incentive are bus manufacturers while indirect beneficiaries are the end users. In 2012 funds for this purpose were dedicated in the amount of 175 million RSD. Therefore, the only additional benefit is for the buyers of locally manufactured CNG buses.

Practically, for now, the only advantage of using quality CNG powered vehicles in Serbia is the savings on the difference in fuel prices (CNG 0.88 €/kg, LPG 0.69 €/kg, while diesel costs 1.38 €/liter and petrol 1.47 €/liter).

CNG has the advantage over diesel and petrol in terms of prices, since its cost does not involve the excise duty. However, since CNG is not from renewable energy sources, the structure of prices will be changed at one point.

Thus, there is a tendency to introduce excise duty on CNG as soon as the share of CNG powered vehicles state-wide increase until becoming a serious competition with diesel and petrol vehicles. Accordingly, e.g. Australia is moving with a gradual introduction of the excise duty of different amounts (from 5.22 cents per kg in 2011 to 26.13 cents per kg in 2015). A similar trend is observed in the Czech Republic where it is planned to introduce excise duty on CNG so by 2023 the excise duty will amount to 13.38 cents per kg. In the UK, there is also an excise duty on CNG and from £ 0.247 per kg at the beginning of 2012 was raised on August 1st 2012 to £ 0.277 per kg.

Regarding CNG vehicles maintenance interventions that are not directly related to the fuel supply technology (i.e. alternative fuel storage and lines) neither to the specifics of vehicle operation, they are identical as in all other similar vehicles. While realising interventions on the vehicle, it is necessary to implement adequate safety and protection measures. Another specific issue is when it comes to interventions directly related to the CNG technology, qualified staff as well as appropriate tools and equipment are required which call for significant investments. Specifics of CNG vehicles' maintenance involve: a gas blending system which requires more frequent maintenance than a diesel fuel injection system, and spark plugs replacement every 50,000-60,000 kilometers. Gas containers on the vehicle should be inspected every three years according to current regulations regarding mobile and closed vessels for compressed gases (Federal Parliament of the SFRY, 1980). Within the Law on Road Traffic Safety (Official Gazette RS, no. 41/2009, 53/2010 and 101/2011) a mandatory periodic inspection of gas powering devices built into motor vehicles is prescribed, where these periods shall not exceed 5 years. Regulation UN ECE 110R prescribes the periodical visual inspection of CNG containers at least every 4 years after the date of its entry into service on the vehicle. The visual inspection consists of seeing if there are any flaws or mechanical, abrasive or chemical damage, as well as a gas leak.

1st-generation biodiesel production and generation is constantly increasing worldwide. Since 2006 new production facilities are persistently opened, especially in Western Europe, with Germany as a leading worldwide producer. Global biodiesel production in 2007 reached a level of 0.2% of total global needs for diesel fuel. In Europe, where about 70% of road transport consumed fuel is diesel, the production of biodiesel in 2007 amounted to about 5.8 billion gallons, or about 2% of the total demand for fossil diesel (Sims & Taylor, 2008). As for Serbia in 2007, VictoriaOil actually produced just 27,000 tons of 1st-generation biodiesel (while its production capacity was around 100,000 tons). Due to a significant increase in the price of raw materials for biodiesel, a lack of state incentives (and without real prospects for them in the near future) and a marginal rise in the price of conventional diesel in 2008 and 2009 the production of biodiesel was finally abandoned indefinitely (producing it only for its own fleet) in 2009, and the producers opted to switch to the production of edible oil, which in contrast was profitable at the time and ever since.

Serbia has a significant land potential to produce raw materials for 1st generation biodiesel production, which is estimated at about 10% of the total arable land with about 350,000 hectares. This area only is sufficient to ensure resources for an annual production of about 250,000 tons of 1st generation biodiesel, which is estimated to be enough to replace between 13 and 16% diesel in Serbia. Of course, this is only a theoretical potential for biodiesel production in Serbia, while the actual potential is much lower. Regarding Vojvodina it could not be realistically expected to achieve an increase in the area under oilseeds, but it sure can improve the yield. As for the European Union, one hectare of rapeseed provides a sufficient amount of grain to produce 1090 liters of biodiesel (Enguídanos et al, 2002). However, in Vojvodina, rapeseed, sunflower and soybeans have lower yields than the European average. On average seed yield and oil content in the seed, one hectare of land in Serbia provides about 690 liters of biodiesel from rapeseed, 816 liters of biodiesel from sunflower and 460 liters of biodiesel from soybean seeds (Tešić et al, 2008).

On the other hand, most of the potential available areas (about 90%) for the cultivation of raw materials for biodiesel are located in central Serbia. However, the most significant barrier for biodiesel production in Central Serbia is the fragmentation of plantations and their great mutual distance. This is not only a logistic problem of production and collection of raw materials, but also high cost of investment in new detention centers (silos) and increasing transportation costs (Tešić et al, 2010).

When taking into account the existing capacity of factories for oil production and current needs for edible oil, it can be concluded that the production capacity of the Serbian oil production factories is oversized and that one part can be used to produce biodiesel (Tešić et al, 2008). However, over 90% of oil production capacity is located in Vojvodina, while the greatest part of areas which could potentially be used to produce oilseeds for biodiesel are located in central Serbia.

The relative importance of biodiesel to replace certain amount of fossil diesel in Serbia depends on the yield of oilseeds, crop rotation (frequency of growing the same crop), consumption of edible oil, diesel consumption, EU accession process of Serbia and unexploited arable areas (Tešić et al, 2008).

From an economic point of view, significant use of biodiesel will be possible if the price of biodiesel becomes competitive to the price of diesel. The price of biodiesel should be for 5-8% lower than the price of diesel due to biodiesel's lower energy potential and higher consumption. Competitiveness of biodiesel is determined primarily by two factors: the retail price of Euro-diesel and biodiesel cost, which in turn largely depends on the price of raw materials i.e. oilseeds prices (Tešić et al, 2010). Based on the analysis performed, the production of biodiesel in the future could be competitive to diesel only under the assumption of full or partial exemption from excise duty for biodiesel. This, however, would cause a decrease in public revenues from the collection of excise duty on fossil fuels, which in present crisis is inacceptable for the government of a developing country like Serbia.

2.1. Public opinion regarding mentioned alternative (bio-) fuels

One of the reasons for non-acceptance of certain alternative fuels by the users, mainly passenger car owners, is linked to their fears towards all gaseous fuels stored under pressure (CNG, LPG, and hydrogen) as being dangerous or threatening safety of drivers, passengers and other road users. Although there is certain justification in this point of view, the fears are unfounded and unjustified. This is by far confirmed by the long-term experience of these fuels' use, and previously well-developed standards regarding protection and security in operating and storing such gases. There is also a certain amount of unfamiliarity among the population, including some part of experts, about certain new aspects of alternative fuels implementation, their favorable characteristics, both from an environmental point of view, and from the financial point of view of the users, then also regarding the location of the refueling stations and equipment installation and maintenance workshops, possibilities to purchase or convert conventional vehicles, the type-approval process, registration and so on.

Another serious problem is the worldwide growing debate about the use of food products for the production of fuel, as is the case with biodiesel. Especially in the years of natural disasters and poor yields of oilseeds (such as this year due to drought), leading to a serious shortage, such a discussion could and certainly will induce a growing, but unjustified fear among the general public and therefore even more reserved attitude towards this biofuel.

3. Conclusion and recommendations in view of potential success in alternative fuels implementation in Serbia

Since The Republic of Serbia ratified the Treaty on establishing the European Energy Community in 2006, thereby, inter alia, adopting the obligation to, within one year from the effective date of the contract, submit to the European Commission an implementation plan of Directive 2003/30/EC of the European Parliament and the Council on promoting use of biofuels or other fuels produced from renewable energy sources in the transport sector (Enguidanos et al, 2002). The directive defines biofuels and imposes obligations on States to put on market an amount of biofuel (2% of the total amount of fuels used in transport sector to the end of 2005, i.e. 5.75% by the end of 2010).

Regardless of the international obligations of the Republic of Serbia, the need for increased using renewable resources is in accordance with the practices of developed countries and their aiming at reducing emissions and encouraging sustainable development.

Except direct effects (reduction of consumption of imported energy and endangering the environment), increased production and use of biodiesel in the transport sector would engage domestic investment capital, encourage domestic production and development of small and medium-sized companies. At the same time this would help local industry to participate in offerings of foreign companies to invest in the production of energy from renewable sources in order to acquire the so-called Green certificate.

The authors as well as numerous experts consider that CNG has a great potential especially regarding urban public transport bus fleets, because of their operation, which is technologically dependent on refueling stations for own-account. Cities of Belgrade and Novi Sad have already implemented certain number of CNG powered buses in their everyday public transport operations, which are showing important savings, although both operators are experiencing certain problems with refueling infrastructure and/or supply.

As a result, and learning from the experiences from both mentioned examples, at the beginning of 2012 the city of Pančevo, concerned by an important level of air pollution (mainly heavy industry related), has decided to finance the Project of technological options, economic and environmental effects of the implementation of CNG vehicles into the public transport in the city of Pančevo, that was realized by the team from the Faculty of transport and traffic engineering of the University of Belgrade. The most important findings in this project were that with the acquisition of new CNG buses the operation costs of the bus fleet, especially the fuel cost, will be significantly reduced. This would induce, to a certain extent, a reduction in required subsidies for the public transport operation by the city as the founder of the public transport operator, although such investments in vehicles procurement and CNG station construction are substantial, especially in present economic situation in Serbia.

Internal (company owned) CNG refueling station is the cheapest option of fuel supply. In the case of complete vehicle fleet renewal (of 86 vehicles) in a short-term period (i.e. in 3-5 years) and timely construction of the CNG station, significant reduction of fuel costs can be achieved in regard to the existing fleet, of over 9 million euros in ten years period. The return of investment for the construction of a CNG station would be already achieved in the second year of its operation. Potentially significant reduction in fuel costs, funding the vehicle fleet renewal with state subsidies for the purchase of domestic production buses, and increase of income caused by the use of new vehicles and a CNG station by the external users, can almost fully compensate the cost even of such urban bus fleet renewal.

Since the city of Belgrade is currently acquiring a significant number of new buses (several hundreds of standard and articulated buses) it is important to raise the awareness of local governments in this respect and opt for as many alternatively fueled vehicles as possible. The cities and national government should act more proactively than they do presently in favoring and to a certain extent subsidizing biofuels implementation in public, especially utility fleets.

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References

Enguidanos, M.; Soria A.; Kavalov, B.; Jensen, P. 2002. *Technoeconomic analysis of Biodiesel production in the EU: a short summary for decision makers*, European Commission, Report EUR 20279 EN. 27 p.

European Parliament, 2003, Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport, *Official Journal of the European Union* L 123: 42-46.

Federal Parliament of the SFRY.1980. Regulation on technical standards for mobile and closed vessels for compressed, liquid and pressurized dissolved gases, *Official Gazette SFRY, No. 25/80 and 9/86, Official Gazette FRY, No. 21/94, 56/95 and 1/2003 and Official Gazette RS, No. 21/2010.*

Sims, R.; Taylor, M. 2008, *From 1st- to 2nd- generation biofuel technologies*, International Energy Agency, France

Tešić, M.; Kiss, F.; Janković, V. 2010. *Possibility of production and use of Biodiesel in Serbia*. Jefferson Institute, USA. 24 p. Available from internet: <http://www.jeffersoninst.org/sites/default/files/Biodiesel.pdf>

Tešić M.; Kish, F.; Janković, V. 2008. *Possibility of production and use of biodiesel in the AP Vojvodina*, Monograph, Vojvodina Academy of Sciences and Arts, Novi Sad. 193 p.

The Parliament of the Republic of Serbia. 2006. Regulations on technical and other requirements for liquid fuel with bio origin, *Official gazette SCG, No. 23/2006*.

The Parliament of the Republic of Serbia. 2012. Regulation on conditions and ways to support production, sale and implementation of subsidized purchase of buses manufactured in the Republic of Serbia in 2012, *Official Gazette of the RS, No. 2/2012 and 35/2012*

HOW TO TRANSFORM CAR-DEPENDENT CITY INTO PEDESTRIAN CITY?

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Abstract: The case study of this research is New Belgrade, planned and designed as a Modern city capital for new Yugoslav state and society. Today, it is a part of Belgrade that is trying to use its competitive advantages and redefine its position as a new business and commercial centre. Once empty streets of New Belgrade are today subject of traffic jams and lack of parking. If the sustainable imperative is put as the general and most important goal, then the possibilities of walking in Modern cities must be reconsidered not only as a type of recreation, but as sustainable mode of transport as well. This paper focuses on pedestrian network development in cities of Modern movement. The basics lie in a study of the main artery Boulevard Zoran Djindjic in New Belgrade and its corresponding blocks. The aim is to reassess open spaces of the street and make proposals for improvement in accordance with 5km/h principles. In addition, the research investigates possibilities of creating and transforming car-dependent city into more pedestrian-friendly environment, thus networking with open spaces inside these blocks. The analysis refers to contents of the ground floors and its treatment as potential pedestrian destinations. The second part of analysis is related to mapping the values of these open spaces in order to define urban ambient inside the block, as well as to create secondary destinations and achieve balanced use of space by pedestrians. It will be conducted using the Space Syntax methodology. The aim is to determine the flows of natural movement, conditioned by the spatial configuration of the study area. According to the results, paper will present the proposal of new space configuration. In the final instance, tendency is to increase the intensity of pedestrian movement and improvement of open spaces' quality.

Keywords: Pedestrian city, Pedestrian network, Open public spaces, Natural movement, Space configuration, New Belgrade

1. Introduction

Existing theories related to the matrix of pedestrian and motor traffic in urban form are focused on the problem concerning flows to and from land use *attractors*. Without taking into account the impact of space configuration, these studies have shown the relation between the level of movement and the presence of attractors. Unlike the normative theories, Hillier indicates that the configuration space determines the level of movement and the presence of attractors, suggesting that it is the main generator of movement patterns. Studies have shown that the relation between these elements (A-attractors, C-configuration and M-movement) can be established, as illustrated in Fig. 1. Attractors and movement can influence each other, but the other two relations are asymmetrical. Configuration can affect the distribution of attractors, but the attractors' location can't influence the configuration. Similarly, the configuration can affect the movement, but the movement can not affect the configuration. By determining mutual relations between movement, configuration and attractors, the only possible logic is based on the impact of configuration on the movement and distribution of the attractor, while movement and attractors can only affect each other. Furthermore, by establishing relations between these elements, Hillier determines the logic of connection between them, where priority is given to the configuration (Hillier et al., 1993).

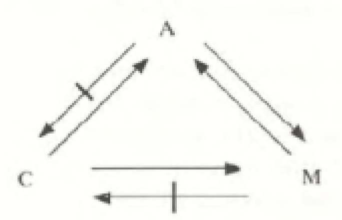

Fig. 4.
The relation between space configuration, movement and attractor
Source: Hillier et al., 1993.

The basic generator of the theory is in observing the structure of the urban matrix as spatial configuration and strong determinant of both pedestrian and motor urban movement (Hillier, 2007).

Since this relation is fundamental and defining, it represent a powerful force in shaping the historically created cities and has an effect on: a) the patterns of land use, b) the built density, c) a combination of activities and functions and d) establishing a relation between parts and the whole in the city structure.

Results of conducted studies suggest that socio-economic forces shape the city on the basis of an established relations between the movement and the structure of the urban matrix (network), so the cities that are functioning adequately can be understood as a "movement economies" (Hillier, 2007).

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Perceived / established connection between the structure of urban matrix and density of movement along the lines Hillier calls the principle of *natural movement*. Natural movement is the level of movement (observed on each line) which is determined by the structure of the urban matrix, rather than the presence of a specific attractors or magnets. In large and well-built urban networks, people are moving linearly, but the beginning and end of the line can be anywhere. Although not always quantitatively the most frequent type of movement in urban areas, natural movement is still the most pervasive and without it the majority of space would be empty for a long time. In addition, this movement is most consistent to the extent that it is difficult to avoid the conclusion that the natural movement is the raison d'être of the urban network. On this basis, it is considered that the urban network is structured in order to create (by generating and channeling movement) some kind of assumed field of meeting and avoidance.

Having in mind that the natural movement is culturally varying phenomenon, it takes different forms in different cultures, while reflecting different spatial logic of urban networks. Thus, the urban network is cultural product, because it creates a meeting field with different structures through natural movement (Hillier et al., 1993). This is mainly related to the establishment of different levels and types of possible boundaries between different categories of people: residents and foreigners, men and women, older and younger, social groups, classes, etc. Unlike the cultural differences, the logic that links the spatial configuration and movement is considered as constant element of natural movement. A key element of the above relation is the natural movement as global property of configuration. In this context, it corresponds to the configuration parameters that are related to the links between every element of the system, even if they are hundreds of miles away from each other.

By observing evident concentration of high density and major transportation nodes, the starting points and destinations can be found anywhere within city structure. If this is taken into account, the movement can be seen widely, from any point to any point (Hillier, 2007). It means that the network itself is associated with generation of urban planning and its functional logic. The analysis of natural movement leads to the conclusion that the movement is basically the morphological outcome of urbanism, and the functional product is inner nature of the matrix, not its specialized aspect. Seen in this way, the question of movement and use of space in general cannot be separated from the question of the form (Hillier et al., 1993). Studies have shown that the distribution of pedestrian movement in urban network is determined by the spatial configuration, which is strongly influenced by density of built areas, while the vehicle traffic operates under the strong influence of spatial integration in relation to the width of the street network and lane itself.

The reasons for analyzing the potential of Boulevard Zoran Djindjic to become pedestrian-friendly space lies in the results of survey conducted on two (end) parts of the street during 2011 and 2012 (Milakovic and Vukmirovic, 2011a). One part of the street included the newly built physical structure that belongs to block 21, and the other was spontaneous/informal physical structure built in block 1 (Fig. 2). The aim of mentioned research was to determine the characteristics of the existing physical structure that emerged according to the 5km/h ideology - spaces on human scale. The focus was on monitoring the activities and physical characteristics of ground floors, with special reference to Gehl's criteria of function and scale (Gehl et al., 2006).

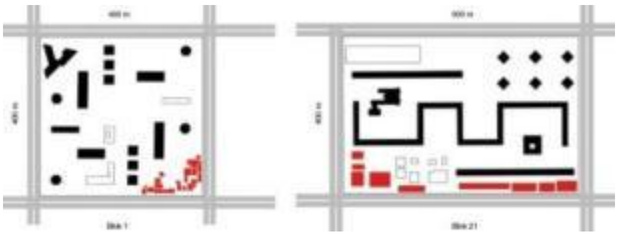

Fig. 5.
Diagram of new built structures (red marked parts) in blocks 1 (L) and 21 (R).
Source: Mira Milakovic.

Although at first sight the path' characteristics fits the pedestrian environment, research has shown that new built part of block 1 is unsuitable in terms of pedestrian movement. The reasons are inadequate rhythm of content units on the ground and their monofunctional character. This means that it attracts fewer users (mainly restaurants and office visitors). In addition, this type of construction has the character of land usurpation in open public spaces by private investors.

Having in mind that there is a new actual *Detailed regulation plan* for this part of the block (which propose a housing and office building), a recommendation would be more content units in ground floors (15-20 units / 100m), with open windows to the street and variety of functions. Despite all other (dis)advantages of new-built structures in block 21, analyzed path and its characteristics fit in the category A, the pedestrian environment by Gehl. However, more attention should be paid to details and enhancement of the area. The above study has shown that a newly constructed physical structure in one part of the Boulevard is corresponding to pedestrian measures, and thus can be characterized as a zone with potential to become a qualitative urban public space.

2. Methodology

The second type of testing the space potential of New Belgrade central area along the Boulevard Zoran Djindjic to become a pedestrian-friendly is carried out by taking into account its space configuration. Using the comparative analysis method, the research results were compared with the characteristics of Belgrade historical center, which is perceived as adequate pedestrian environment.

2.1. Scope of the underlying polygons

Scope of the underlying polygons of New Belgrade center and the center of the historical Belgrade were obtained using the optimal distance of pedestrian movement. Optimal walking distance is considered to be the distance of 500m, which coincides with the acceptable length of the walk. It is most noticeable in the center of the city, which is confirmed by the size of urban centers of 1km2 (i.e. an area of 1x1km, or a radius of 500m). The above length indicates that the walking distance of 1000m leads people to the majority of functions in the city (Fig. 3).

Gehl's studies have shown that cities like London and New York correspond to these patterns, as they include several centers in which mentioned area of 1km2 is recognizable (Gehl, 2010). In this way, it has been determined that the pedestrian distance does not change in relation to the size of cities.

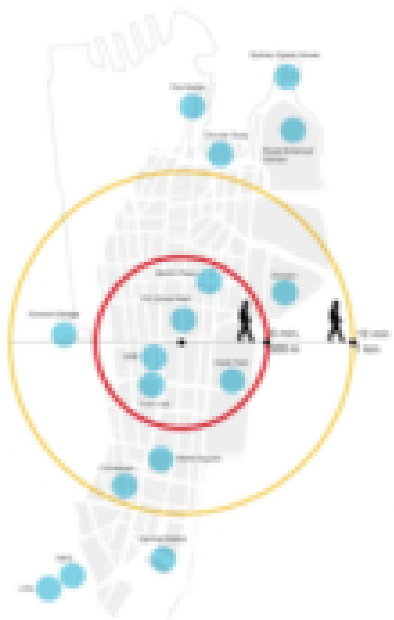

Fig. 6.
Center of Sydney and a radius of 500m and 1000m.
Source: http://sustahood.com/

Accordingly, the distance of 500m is the distance that most pedestrians consider acceptable, but need not be taken as absolute truth. Acceptable distance also depends on a combination of distance and path quality. If comfort is at a lower level, walking will be shorter. Contrary to that is the situation in which the path is interesting, rich with experience and enjoyable, where pedestrians forget the distance and enjoy the experiences that happen to them. In order to include both factors for this research, the scope of underlying polygons is determined by radius of 1000m. In this way, larger surface is covered, thus satisfying the criterion that at some paths the acceptable walking length is higher, given that it is an interesting, rich and enjoyable experience.

Based on this input data, the maps are made both for the New Belgrade central area and historical city center. The center of a 1000m radius in New Belgrade was placed on the Belgrade Sports Arena, while in the historical city it is in the center of the Republic Square. Buildings are kept on both maps (buildings ground floor layout), as the relevant structure for the study.

The historical city center is characterized by traditional / closed block in which buildings are facades of the streets, while New Belgrade is dominated by free standing buildings and modern / open block.

Large green open areas that are mostly not in use for movement were seen as obstacles. It means that they have been neglected in terms of their use for recreation. The highway was treated as an obstacle as well.

2.2. Software used

For research purposes, the software Depthmap 10 is used. Depthmap is open application that analyzes the visibility of architectural and urban systems. Specifically, through this software the following analysis are conducted: (1) topologically based measures (integration, which is a measure of topological accessibility) - correlates significantly with pedestrian and vehicular movement patterns, (2) isovist properties of an area - correlate with spatial behaviour, and (3) the representations of layouts (as convex, axial or visibility graphs) and the topological and angular analysis, which seem to have a correspondence to the way humans cognise space, maybe because they reflect embodiment (Pinelo & Turner, 2010).

Furthermore, Depthmap is used to derive an 'axial map' of a layout. That is, derive a reduced straight-line network of the open space in an environment. The axial map[1] has been the staple of space syntax research for many years, but the mathematical derivation of it is novel. The automatic derivation allows an objective map for research into city form and function. Once the map has been generated, it may be analyzed using graph measures, and the measures may be transferred to gate layers in order to compare with indicators of pedestrian or social behavior (VR Centre for the Built Environment, 2006).

Analysis of the underlying polygons is done on two levels: global, in relation to the wider area, and at the local level. A parameter radius 3 is entered for the purpose of integration analysis at the local level, while the analysis of the integration value in the global (wider) level it was radius n. The obtained analysis' results showed density of pedestrians (i.e. pedestrian movement) along the lines of the covered area. This density is best calculated with integration for a system that includes up to three lines distant from each other (radius-3 integration). Unlike pedestrian movement, car traffic intensity is observed on a larger scale, and paths will depend on the greater radius of integration. The difference in approach is reflected in the fact that travel by car is longer and thus drivers read a matrix of possible trajectories based on the logic of a greater scale, as opposed to pedestrians which movement is limited to narrower (local) territory, i.e. on a smaller scale.

The results used in the research are related to graphics performance - connectivity diagrams, line length of possible movement paths, integration at the local level (R3, for the purposes of pedestrian movement in relation to the findings that Hillier and Hanson [HH] established) and total connectivity (R3 total connectivity related to pedestrian movement). By default, Depthmap displays attributes with a color scale which runs from a blue tinged magenta for the very lowest value, to blue (through cyan) to green (through yellow) to red, and up to a red tinged magenta, for the very highest value (Turner, 2004). The scale is approximately continuous rather than discrete, that is, every value has a different color assigned to it.[2]

3. Results

The first phase of the research, treated as a kind of input data and verification, included the territory of the three Belgrade municipalities: Stari Grad, New Belgrade and Zemun. Formed axial map was made on the base that included axis of the street paths. The results showed that the minimum value of the connectivity is 0, the maximum 7, and the average is 3.53. Values related to the integration with the radius n=3 (which show the frequency of pedestrian movement) are: minimum 0.33, maximum 2.30 and 1.49 averages.

Lines length, i.e. direct lines between points range from a minimum of 1.23 m to a maximum of 851.84 m. The average value of the lines length within the allocated municipalities' territories is 90.65 m. The total connectivity ranges from 0 to 10422, with an average value of 10351.6.

[1] The basic premise of "natural movement" is that the movement in the urban network is determined by configuration quantity labeled as "integration" in the basic chart of axial network map (Hillier & Hanson, 1984). "Axial Map" of an urban network consists of long and short straight lines that are drawn so as to cover the whole web. "Coverage" refers to the fact that all the traffic circles are complete and all convex elements are running through it (Hillier, et al. 1993).

[2] In fact, this is not quite true; Depthmap uses a scale of 192 colors where available on the computer you are using, so values will be grouped together into one of these 192 colors (Turner, 2004).

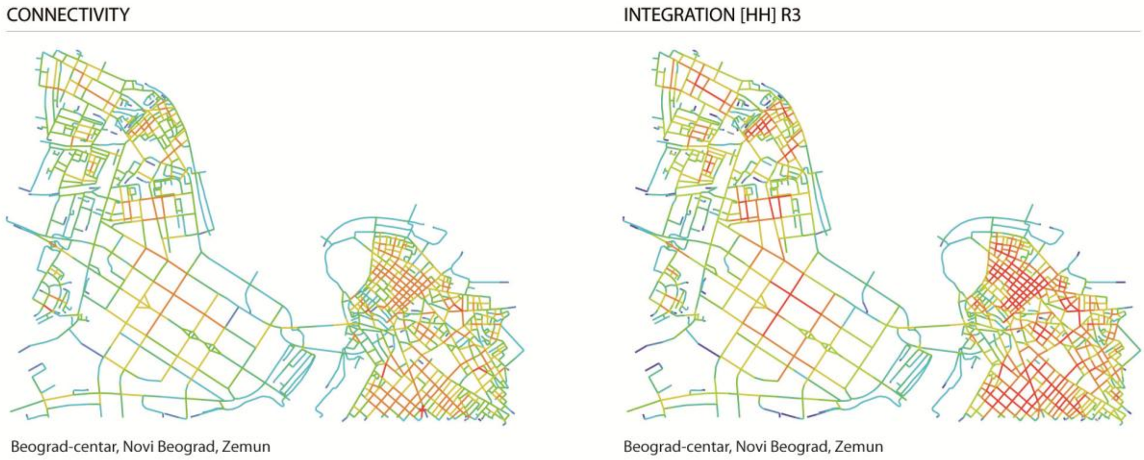

Fig. 7.
Axial maps of three Belgrade municipalities Stari Grad, Novi Beograd i Zemun: a) connectivity and b) integration [HH] R3.
Source: Milena Vukmirovic

Connectivity diagram (Fig. 4a) shows that Slavia Square and part of the Balkan street are area with the highest value. Slightly lower connection value, represented in orange, has a much larger number of paths, so some areas can be separated as the wholes. In the area of the Stari Grad Municipality, these areas are formed by a network of the street paths in Dorćol and surrounding of Parliament building (Majke Jevrosime, Vlajkoviceva and Svetogorska streets); in the area of New Belgrade these paths are Zoran Djindjic Boulevard, Boulevard of Art, part of Mihajlo Pupin Boulevard and Omladinskih Brigada street, as well as their intersections; in the area of Zemun Municipality these are few street paths that form a network in the historic center.

Integration diagram with the radius n=3 shows slightly different results (Fig. 4b). Contrary to the connectivity, whole areas correspond to the highest values, represented here in red - these are the areas that have the greatest potential for frequency of pedestrian movement. In Stari Grad Municipality, these are the areas of the upper Dorćol, lower Dorćol close to Kalemegdan, surrounding of the church (Saborna crkva) and the area around Parliament; in New Belgrade area, these are paths of Zoran Djindjic Boulevard and the Boulevard of Art; in Zemun - street paths network in historic core.

Presented results of the wider research polygon served as the input data, basis and the framework of the second phase of the study, related to the specific (central) area of New Belgrade and Belgrade historic centre. The surfaces covered in this phase were in a radius of 1000m. For research purposes, following values were analyzed in details: connectivity, the length of possible movement lines (line length), integration with a radius n=3 (integration [HH] R3) and the overall connection with the radius n=3 (R3 total connectivity). The basic map used for this analysis included only barriers in the movement (objects, large traffic corridors such as the highway, rivers Sava and the Danube, and large green areas, where the movement is forbidden or they are used for recreation). In accordance, the axial diagrams of New Belgrade and historic center of Belgrade represent all possible lines of (natural) movement between these barriers.

3.1. Connectivity

Connectivity is the characteristic which has being observed in relation to the wider area. It represent the total number of elements with which one path creates a connection. In the area of New Belgrade, the highest value is 6885, recorded along the Boulevard Zoran Djindjic. The minimum value of the connectivity is 3, and the average 1044.24. By observing derived diagram in details, one can see that values of this parameter decreases going from Boulevard Zoran Djindjic towards the border covered by a radius of 1000 m (Fig. 5a).

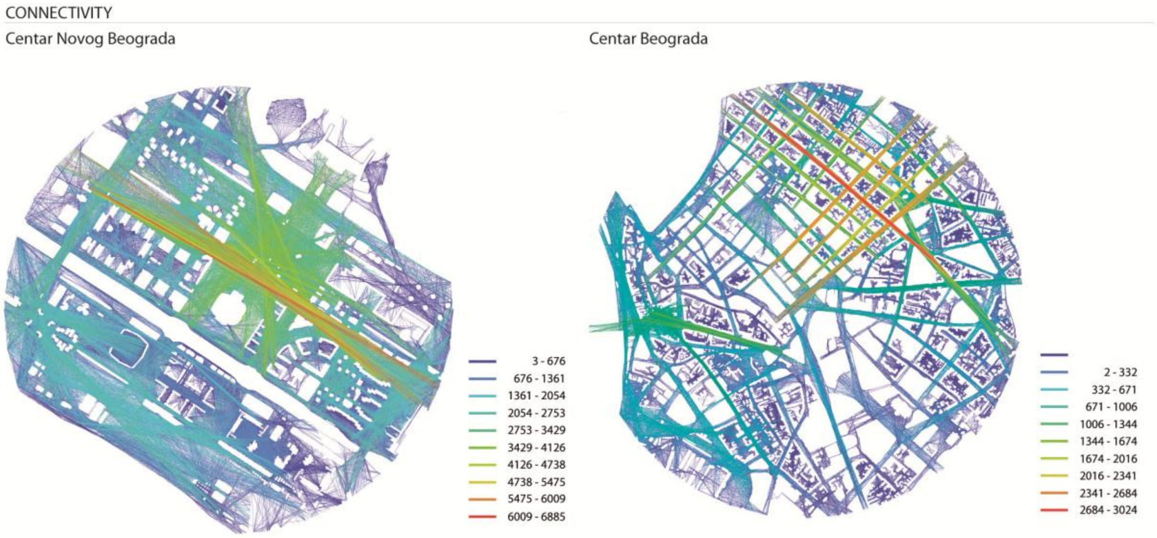

Fig. 8.
Axial map_Connectivity: a) New Belgrade and b) Belgrade Center.
Source: Milena Vukmirovic

In the area of the historic city center one street path is allocated that has the highest connectivity value (3024) - Strahinjica Bana Street. However, unlike the polygons in New Belgrade, here are noted few street paths that have high values represented in orange (2341-2684). These are the Francuska Street, Dobračina, Kneginje Ljubice and Skender Begova Street (Fig. 5b). The lowest connectivity value is 2, and the average 367.397.

Comparing the connectivity values obtained in the polygons, it can be seen that the connectivity in New Belgrade is nearly double then those in historic city. In addition, analysis of graphs shows that the highest values of this parameter in New Belgrade are widespread on its surface (open block spaces) - around the Sports Arena (if the maximum along the route is ignored), while the highest values in the historic city are those which include the network of street paths (Dorćol).

3.2. Line length

Line length is a parameter that indicates the shortest distance between two points on the observed polygon. In the area of New Belgrade longest line of natural movement (1968.76m) is mapped along the Boulevard Zoran Djindjic path. Among the other paths exceeding 1358m (yellow shade), there are also noted Mihajlo Pupin Boulevard, Milutina Milankovića (paths parallel with Blv. Zoran Djindjic) and Boulevard of Art (Fig. 6a). The minimum line length of natural movement is 3.89 m and the average is 317.25 m.

The maximum line length of the natural movement in the historic city polygon is identified along the path of Strahinjića bana Street (1246.47m). Analyzed graph (Fig. 6b) showed that the length of 994.82 m (orange shade) have paths of Francuska Street, Kralja Petra Street and path Zmaj Jovina - Kneginje Ljubice Street. The lowest values up to 122.80 m (dark blue) were recorded in the spaces within the blocks.

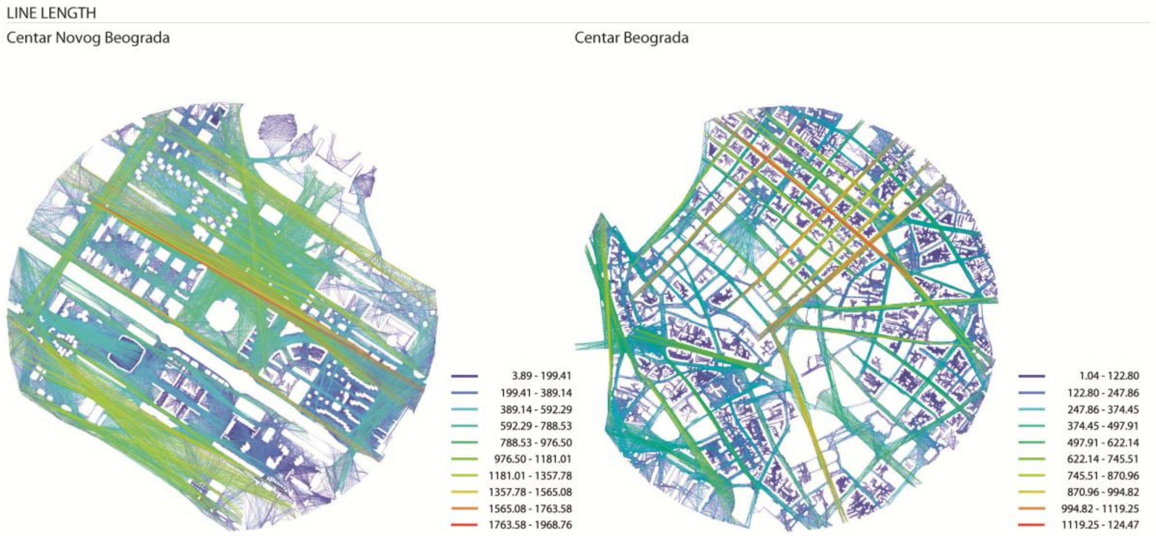

Fig. 9.
Axial map_Line length: a) New Belgrade and b) Belgrade Center
Source: Milena Vukmirovic

Comparing diagrams and values derived from these polygons, it can be concluded that the majority of the natural movement lines in New Belgrade exceed a length of 592m, while in the historic city this value appear only along the main street paths. However, their length is still less than 622m.

3.3. Integration [HH] R3

Based on the theory of space syntax, the key parameter which determines the potential frequency of pedestrian movement is a parameter of integration with the radius n=3. Using the above parameter, the number of direction changes (turns) is measured. These turns are necessary to provide in relation to the whole area, in order to gain access to other streets of the network system, while using the shortest path. Segments of street paths with minimum number of turns are called the most integrative. In the theory of integration, it shows cognitive complexity of the streets' accessibility, which can be provided by the way pedestrians use it.

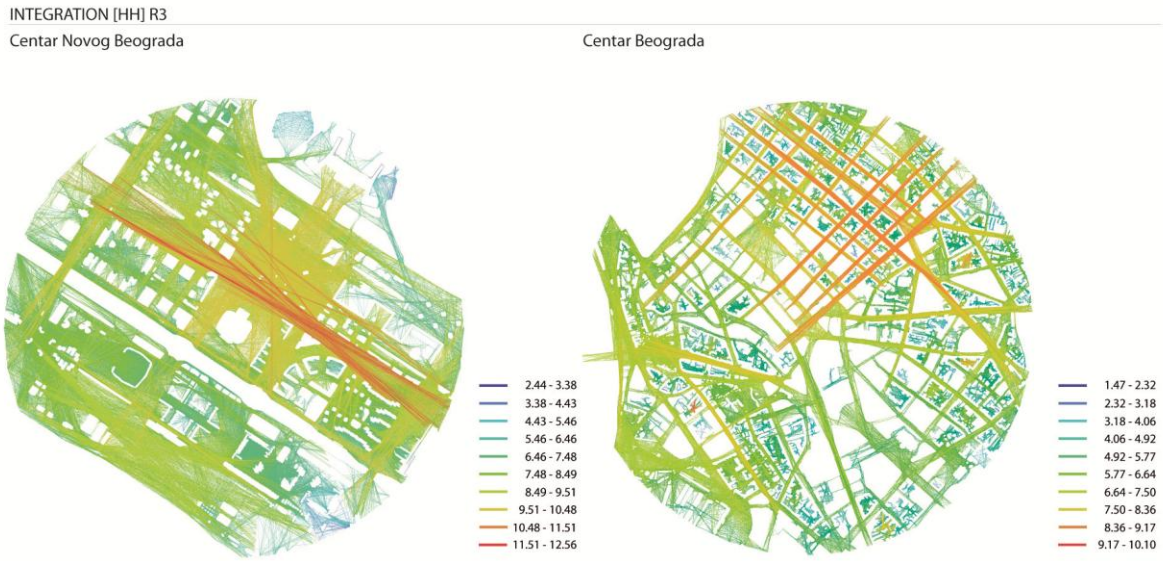

Fig. 10.
Axial map_Integration [HH] R3: a) New Belgrade and b) Belgrade center
Source: Milena Vukmirovic

Bearing in mind that the radius of both polygon diagrams is 1000m, it is not surprising that the warmer shades dominate, thus indicating higher values of the parameter. Accordingly, subjects of interest are the paths with the highest values (lines in orange and red). The New Belgrade polygon has the highest parameter value of 12.56, identified in the area that corresponds to the path Boulevard Zoran Djindjic. If looking at the lines that are over 10.48, it can be seen that the most of them are along Blv. Zoran Djindjic, but also connecting open public spaces in 21, 26 and 30 block. The only line with this value, which intersects these paths diagonally, is a line that connects Mihajlo Pupin and Arsenija Čarnojevića Boulevard (Fig. 7a). The minimum integration value in New Belgrade is 2.44 and the average 7.566, which suggests the conclusion that this area has a high potential for frequent pedestrian traffic.

Contrary to the one dominant path with high integration values in New Belgrade, the network appears in the historic Belgrade center. Its values range from 8.36 to 9.17 (orange) and 9.17 to 10.10 (red). The maximum integration value of 10.10 is measured along Starhinjića bana Street path. Together with Francuska, Dositejeva, Dobracina, Zmaj Jovina, Kneginje Ljubice, Kapetan Misina and Kralja Petra Street in sothwest-northeast and Skender Begova, Cara Dusana, Gospodar Jovanova i Jevremova in northwest-southeast, it forms the network (Fig. 7b). The minimum integration value is 1.47 and the average 5.917, suggesting that this area (not one path, like in New Belgrade) has a high potential for frequent pedestrian traffic. The lower integration value in historic center is measured inside the blocks' space, which resulted in a decrease of the average value.

3.4. Total connectivity R3

Total connectivity is a parameter related to the local level, which shows the connection of the underlying polygons when the radius value is n=3. Unlike the connectivity at a global level, the diagrams of New Belgrade and historic Belgrade center are dominated with warmer colors, thus general conclusion is that these areas are well connected from the aspect of pedestrians. The New Belgrade polygon has maximum parameter value of 3.43 e +007 measured. Analyzing the graph, the highest values (from 3.07e+007 to 3.43e+007) are mapped along the Boulevard of Art, Zoran Djindjic and Mihajlo Pupin (Fig. 8a). Another characteristic of this area is a good connection of open spaces inside the blocks, which are parallel to Blv. Zoran Djindjic. The minimum value is 1075, and the average 2.01e+007.

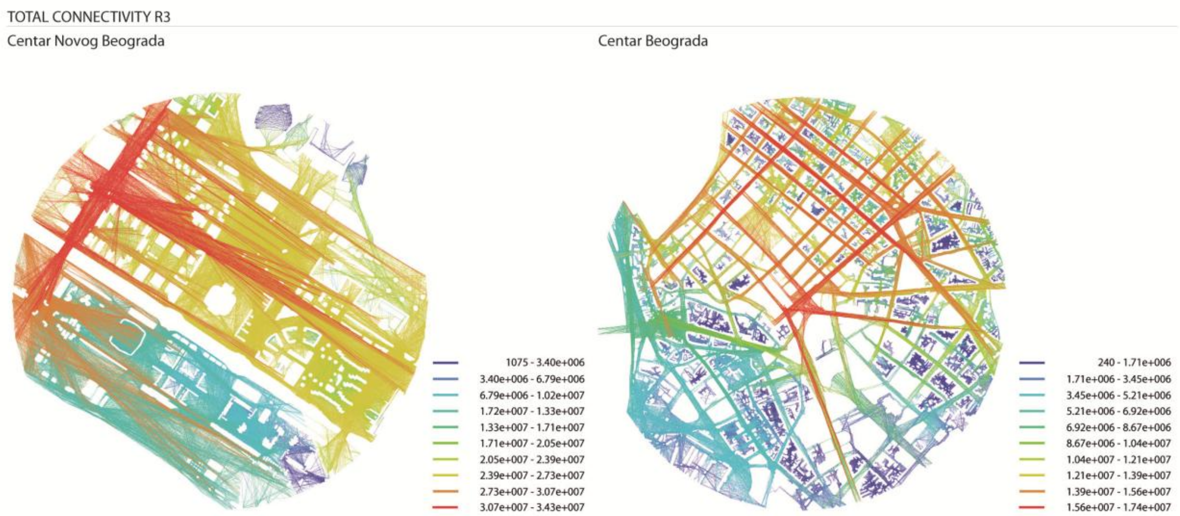

Fig. 11.
Axial map_Total connectivity R3: a) New Belgrade and b) Belgrade center
Source: Milena Vukmirovic

Total local level connectivity of open space network in the historic Belgrade center ranges from 240 to 1.74e+007. With a focus on a value over 1.56e+007 (red), analysis of the polygon diagram showed that the best connected spaces create an area which has the form of a network. These spaces are streets Strahinjića bana, Kralja Petra, Francuska street together with Republic Square and Terazije square (Fig. 8b). The lowest value of total connectivity has directions that are formed inside the block spaces.

The comparative analysis of total connectivity diagram of these two polygons showed that both areas have great potential in relation to pedestrian movement.

The difference is seen in the most intense connectivity of spaces - although specific street paths are followed in New Belgrade, the form is more suitable to irregularly shaped surface, as opposed to the historic part of the city where the street network dominates.

4. Conclusion

New Belgrade has been built according to the ideas of Modern movement and their principle of automobile as the main traffic element. However, the results obtained using contemporary methodology based on the space syntax theory, showed that this area has the potential for developing pedestrian movement. Using the parameters of connectivity, integration, and total connectivity, it has been found that Boulevard Zoran Djindjic has the most potential, because the maximum values appear along this path. In addition, the potential is also marked in the open public spaces inside the contact blocks.

However, in order to establish a more equal distribution of pedestrian movement on the polygon, it is necessary to use some of the advantages that have been noticed in the historic Belgrade city. In the first place, it is development of the network of pedestrian paths. This could be achieved by establishing and verifying the possible space configuration, for example introducing new elements (barriers, structures, urban furniture, diversified activities, ambient, etc.). Modeling and design verification of this space (Blv. Zoran Djindjic with contact blocks) could result in better spatial solutions, that would be in line with the best possible logic of natural, pedestrian movement.

Furthermore, by using these types of spatial research, it is possible to preserve the ambient and environmental values specific for this area as well as the logic of its design, which refers to the recognizable period of our social history and heritage.

Acknowledgements

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References

Gehl, J., 2010. *Cities for People.* Washington: Island Press.

Gehl, J.; Johansen, L.; Reigstad, S. 2006. Close encounters between buildings. *Urban Design International,* 11: 29-47.

Hillier, B. 2007. *Space is the machine: A configurational theory of architecture.* London: Space Syntax.

Hillier, B.; Hanson, J. 1984. *The Social Logic of Space*. New York: Cambridge University Press.

Hillier, B.; Penn, A.; Hanson, J.; Grajewski, T.; Xu, J. 1993. Natural movement - or, configuration and attraction in urban pedestrian movement. *Environment and Planning B: Planning and Design,* 20: 29-66.

Milakovic, M.; Vukmirovic, M. 2011. *New Life of Modern Cities: Transformation and Renewal of Public Spaces in New Belgrade.* Essen, CEIT ALANOVA - Department of Urbanism, Transport, Environment & Information Society: 655-665.

Pinelo, J. & Turner, A., 2010. Introduction to UCL Depthmap 10. Available from Internet: <http://www.vr.ucl.ac.uk/depthmap>

Turner, A. 2004. *Depthmap 4_A Researcher's Handbook.* London: Bartlett School of Graduate Studies, UCL.

VR Centre for the Built Environment, 2006. UCL Depthmap: Spatial Network Analysis Software. Available from internet: <http://www.vr.ucl.ac.uk/depthmap/>

BENEFITS AND FIRST EFFECTS OF NOVI SAD BIKE-SHARING SYSTEM

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Abstract: The first part of the paper provides a general overview of existing bike-sharing (BS) systems in European cities that have longer tradition in promoting cycling and implementing such systems. The paper examines existing capacities, findings of user satisfaction surveys, impacts of bike-sharing introduction on modal split and on the emissions of pollutants. The second part of the paper presents the effects of introducing the first phase of BS system to Novi Sad which is a part of a broader scheme termed "Let's return Novi Sad back to cyclists." It also presents basic features of Novi Sad traffic system development over the past thirty years, with particular attention to bicycle traffic development. The goal of these analyses was to highlight the importance of introducing new traffic policy measures to reduce car use and expand the use of environmentally friendly modes of transport. BS scheme is one of the measures to address Novi Sad's traffic issues and it requires continuous follow-up: monitoring usage, implementing corrective measures and improving the system.

Key words: transport planning, urban transport, sustainable mobility, bike-sharing.

1. Introduction

Public bicycle systems have drawn a lot of attention recently, primarily due to the initiative to expand cycling as a transport option and to reduce traffic's detrimental effects on the environment. The concept emerged in 1960s but has developed slowly until the most sophisticated tracking technologies were introduced, which initiated a rapid expansion of bike-sharing throughout Europe and the rest of the world (DeMaio, 2009). Today there are an estimated 375 bike-sharing systems operating in 33 countries around the world using about 236,000 bicycles (Midgley, 2011). Since 2008 the rate of growth in bike-sharing systems has been very rapid and has probably outstripped growth in every other form of urban transport (Midgley, 2011).

The first generation of these systems appeared in 1968 in Amsterdam (the Netherlands). It was termed "White Bikes" because regular bicycles were painted in white and were available to the general public. The second generation was introduced in Copenhagen in 1995 (DeMaio, 2009). It was not until the third generation appeared that the systems' major problem of frequent bicycle theft was solved. Various technological innovations were introduced, such as electronic locking mechanisms, telecommunications, smartcards, access via mobile phones and computers etc. The number of new systems has continuously grown in the ensuing years, the most important and the largest ones being "Call a Bike" (Munich, Germany) "Velo'v" (Lyon, France), "Vélib'" (Paris, France), "Bicing" (Barcelona, Spain), "SmartBike" (Washington, USA) etc.

Technological advances and improvements of the earlier and existing bike-sharing models ushered in the fourth-generation systems whose major features will be flexible stations, bicycle redistribution innovations, integration with other modes of transport, the use of GPS (Global Positioning System) to track bicycles, introduction of more electric bicycles etc. (Shaheen et al. 2010).

The first part of the paper provides a general overview of existing bike-sharing (BS) systems in European cities that have longer tradition in promoting cycling and implementing such systems. It examines existing capacities, findings of user satisfaction surveys, benefits and impacts of bike-sharing introduction on modal split and on the emissions of pollutants.

The second part of the paper presents basic features of Novi Sad traffic system development over the past thirty years and bicycle traffic development in particular.

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The main goal of these analyses was to highlight the importance of introducing new traffic policy measures to reduce car dependence and increase access to specific city zones. Bicycle sharing is one of Novi Sad's policy measures to promote cycling that has been largely neglected as a transport option in Novi Sad, and to achieve sustainable mobility. European experiences and effects of the first phase of Novi Sad BS system implementation provided guidelines for improving and expanding the system in order to achieve the defined goal - to return Novi Sad to bicyclists.

2. Impacts of Bike-sharing

Bicycle sharing systems in Paris, Barcelona and Lyon are mostly cited as best practice examples.

Paris has the largest and the most famous bike-sharing system. It was termed "Vélib" and was launched in July 2007 with 10,000 bicycles in 750 automated docking stations, each station having the minimum fleet of 15 bicycles. Within a few years "Vélib" has become a self-service system with around 20,600 bicycles in 1,451 stations spaced 300 m apart. About 370 km of bicycle lanes were built throughout the city. Within the first year of operation "Vélib" generated 27.5 millions of trips, with an average of 8 to 10 users per bicycle per day and 75,000 trips per day (Midgley, 2009). Unfortunately, Paris had the highest bicycle theft rate of all bike-sharing systems. Within the first two years of operation nearly all of 20,600 bicycles had to be replaced at the cost of €400 per bicycle. Around 7,800 bicycles were stolen and 11,600 were destroyed beyond repair (Midgley, 2011; Vélib: Mairie de Paris, 2009).

Barcelona launched its bike-sharing system "Bicing" in March 2007 with 6,000 bicycles in 400 stations that were spaced 300 to 400 m apart. The stations have the capacity of 15 to 30 bicycles. Each bicycle is used 10 to15 times per day by different users, whereas the whole system has an average of around 40,000 loans per day (Bicing Barcelona, 2011).

Perhaps the most interesting best practice example in terms of relevance to the Novi Sad context is a mid-sized city of Lyon in France. Within a few months after the launch of Lyon's "Vélo'v" bike-sharing system, thousands of people were encouraged to use bicycle for transport. The system opened in May 2005. Each of 2,000 bicycles was used 16 times per day on average. Within the first six months of operation about 2 millions of trips were made. Today the system is using 4,000 bicycles distributed across more than 350 stations throughout the city, spaced about 300 m apart. Within five years of operation, the system had 27.7 millions of bike loans, 58 millions of kilometers travelled by shared bicycles and about 42,000 active subscriptions. Today it generates about 17,000 trips per day (Vélo'v Lyion, 2011).

The development of bike-sharing systems over the last ten years has been accompanied by continuous researches of technology improvement options, service quality, influences on urban mobility and the choice of cycling as the most convenient transport option. In Paris, 89% of "Velib" users said that bike-sharing considerably increased their mobility. Nearly 79% of "SmartBike" users in Washington DC assessed bike-sharing to be faster or more convenient than other available options (Shaheen et al. 2010). In Barcelona, 45% of users use the "Bicing" bike-sharing system 5 or more times per week (NYC Dept. City Planning, 2009).

Such data gathered from user satisfaction surveys generally suggest that in most cities bike-sharing encouraged people to accept cycling as a mode of transport. Unfortunately there is limited data available on modal shift from cars to bicycles and on reducing car dependence for periods before and after the introduction of bike-sharing, so explicit conclusions are hard to draw. Data from Barcelona, Lyon and Paris suggest that it has affected reduced car use to a certain extent. The percentage of car or motorcycle trips replaced for bicycles in these cities ranges from 2 to 10. In fact, the shift is mainly from public transport to bike-sharing. In a 2008 survey of "Vélib'" users in Paris, 20% said that they used car less (Midgley, 2011). This percentage increased to 46% in 2009 (DeMaio 2009).

A survey of "SmartBike" users (Washington DC, USA) found that the system drew nearly 16% of individuals who would otherwise have used cars (Shaheen et al. 2010).

A survey conducted for the purpose of doctorate thesis preparation (Fernández, 2011) found that only in three European cities bike-sharing trips made for 0.4% of all trips: in Barcelona (0.43%), in Paris (0.76%) and in Lyon (0.92%), which is one of the reasons why these cities are cited as best practice examples.
However, the most desirable benefit from bike-sharing is primarily the increased mode share of cycling in urban transport.

Numerous surveys conducted over the past years in many European cities found that investing in overall cycling infrastructure, and bicycle sharing is only a part of it, results in greater bicycle popularity and attractiveness for making trips on a daily basis (Oulu, Oxford, the Hague, Copenhagen) (TTR, 2006). It has been noticed that more developed and richer cities have stronger cycling infrastructure as well. The construction of safe infrastructure as the principal step to promote cycling resulted in the significant bicycle share in overall mode split. Twenty five cities and regions throughout Europe took part in preparing Urban Transport Benchmarking Initiative project, which revealed that average mode share of cycling was 9% in selected cities. The average spatial footprint of cycling network in overall traffic infrastructure was 15 %.

Unlike the cities that participated in the Benchmarking project, Paris, Barcelona and Lyon had considerably small cycling mode share. Bike-sharing was introduced with the aim to promote cycling and reduce the number of motorized trips. Lyon saw a 44% increase in bicycle use within the first year of the "Velo'v" system (Bührmann, 2007); Paris saw a 70% increase after the launch of "Vélib'", cycling participating with 2.5% in the city's overall traffic volume (Shaheen et al. 2010; Pioneer Valley Planning Commission, 2008). In Barcelona, cycling accounted for 0.75% of overall traffic volume in 2005, whereas in 2007 (the year of bike-sharing system opening) it increased to 1.76%. Similar situation was in Paris, where cycling mode share was 1% in 2001 and it increased to 2.5% in 2007. Drawing from existing surveys, it can be concluded that cities with bike-sharing systems saw an increase from 1 to 1.5% in cycling mode share (DeMaio 2009).

Given that major problems of urban traffic occur during peak hours, information on bike-sharing usage for trips to workplace or school is significant for determining potential benefits of introducing bike-sharing. These trips are known to account for the largest share of peak hours, for which reason traffic policy measures are mostly oriented towards this user group. The surveys (NYC Dept. City Planning, 2009) showed that 61% of "Velib'" users in Paris and 67% of "Bicing" users in Barcelona used bicycle to travel to their workplace or school, and in Lyon as many as 80% of bicycle sharing trips were used for commuting trips.

Another noticeable benefit of bike-sharing is that it provides a transport option without emissions of noxious pollutants. With an average of 78,000 trips per day and about 20 minutes per trip, the "Velib" users in Paris travel an average of 312,000 km per day. The same distance travelled by car would have resulted in 57,720 kg of CO_2 emissions on average. In Hangzhou in China, bike-sharing system's fleet of around 60,000 bicycles generates about 172,000 trips per day. With an average duration of trips of around 30 minutes, about 1,032,000 kilometers are travelled daily. The same distance travelled by car would have resulted in around 190,920 kg of CO_2 emissions (Shaheen et al. 2010).

The OBIS project results (OBIS Project, 2012) published in 2012 provided additional information on how to assess local demand for shared bicycles and whether bike-sharing would be viable in cities in Serbia, in terms of city size, climate or other factors. The project was aimed at optimizing bike-sharing in Europe and it analyzed the features of such systems in more than 50 cities classified by their population as small, mid-sized and large. 75% of BS systems in large cities (population above 500,000) offer a 24-hour service as opposed to 38% in small cities (up to 100,000 residents). 93% of BS systems in cities with warm climate (average annual temperature above 11˚C) operate during the whole year, as opposed to 45% in cities with cooler climate (average annual temperature below 11˚C), in which the peak usage is reached only in summer months. Cities with warm climate show regular use patterns during the whole year. Studies showed that in selected cities there are from 14 to 16 loans per 10,000 residents, and the number of stations is from 1.3 to 1.8 per 10,000 citizens. BS systems generate an average of 463 loans per bicycle in large cities, 378 in mid-sized cities and 235 in small cities.

3. Cycling in Novi Sad

Novi Sad (129.4 km^2 and 280 000 inhabitants) is one of the cities of the Danube region. Due to its favorable geographic position and good transport links, it has become a dominant socioeconomic centre of Vojvodina, in many ways specific macro-regional and administrative part of the Republic of Serbia. It is the second largest city in Serbia, home to significant scientific, research and development and professional organizations, as well as numerous medical, cultural and educational institutions.

Based on the NOSTRAM transport model data (JP Urbanizam 2009), within the total scope of the road transport using the city's road and street network car trips dominate (with 80% share) compared to the bus and truck transport. The same 2009 research found that approximately 80,000 motor vehicles were registered in the city area. Compared to 1971, when previous extensive research had been conducted, the number of registered passenger cars increased by nearly 60%.

A set of social and economic changes led to the increase in total number of trips—more than 30% from 1976 to 2009, which is proportional to population increase. Total number of trips made during one day in Novi Sad in 1976 was about 500,000, and in 2009 about 745,000. The modal split changed in the same period as well: it was marked by significant increase in the number of car trips (car mode share increased from 19% to 26%) and was accompanied by the corresponding decrease in public transport use from 28% to 22%. The share of walking remained at the same level of 48% whereas the percentage of bicycle trips has been on the decrease for many years. In 1960s bicycle trips accounted for almost 10% of all trips, in the 70s about 5%, and 2009 data showed that cycling accounted for only 2.5% of total daily trips. The use of bicycle for everyday trips such as travelling to workplace, school and faculty accounted for only 19 %, whereas other bicycle trips had other purposes such as private visits, recreation etc. (JP Urbanizam 2009).

Novi Sad's mobility level (as an indicator of the city's and its traffic system's development) was 2.75 trips per resident per day in 2009. Bicycle travel mobility was only 0.068 trips per resident (or 2.5% share in all journeys), which indicated low bicycle use in urban trips when compared to the data from developed European countries (Fig. 1).

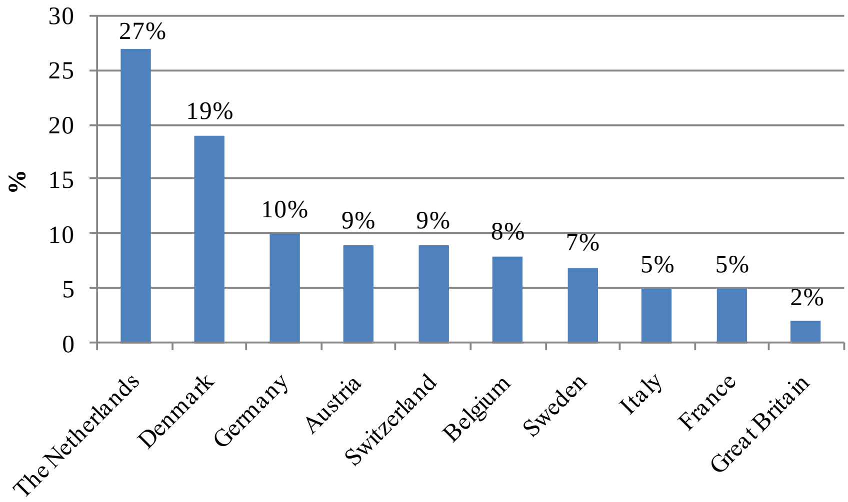

Fig. 1.
Bicycle share in all journeys in some other European countries (Ministerie van Verkeer en Waterstaat 2009)

Although the amount of bicycle facilities has increased (21 km in 1990; 63 km in 2009), existing bicycle network is marked by no interconnection of bicycle lanes (no connection between trips' origin and destination), poor condition of surface coarse and small extent of bicycle facilities in the city center, which is perhaps the most important drawback as Novi Sad is a city with distinct monocentric structure and radial street network.

Even though the number of registered passenger cars has significantly increased over the last 30 years, motorization level in Novi Sad is relatively low when compared to European cities of similar size. Based on traffic demand projections made in 2009 for the purpose of Petrovaradin Ring Road Detailed Design (2011), 133,000 registered cars are expected for 2029 (450 PC/1,000 inhabitants). When compared to the current situation, it is an increase of 64%, with an average annual increase of 2.5%. The increase in the number of trips made by one inhabitant during one day is also expected; towards the end of the planned period the number will be 3.0 trips per day in all modes including walking. Should the projected employment growth be realized, between 118,000 and 120,000 trips that have working as purpose should be expected at the end of the planned period (2029).

4. NS BIKE Project

NS Bike project was launched on July 11 in 2011 within a broader scheme termed "***Let's return Novi Sad back to cyclists***", a joint venture between the City of Novi Sad and Novi Sad Parking Services. The bike-sharing system is planned to comprise 60 stations spaced 400 to 500 m apart with a fleet of around 600 bicycles. The stations' distribution and capacity were established based on the distribution of main activity centres and spatial distribution of trips that was determined by a research conducted for Novi Sad Transport Model (NOSTRAM) purposes (Fig. 2).

The system is being introduced through several phases. In terms of its technological features, the goal is to have a fully automated system until the end of the system's introduction: users pick up and return bicycles using smartcards which enables the system to track bicycles at any moment.

There are basically two types of bike-sharing systems: manual and automated. A manual system is one where transactions related to picking up and returning bicycles are supervised by staff. Such systems may involve information technology for keeping track of the bicycle use and are mostly introduced in small to mid-size cities. In an automated bike-sharing system, transactions related to picking up and returning bicycles rely on self-service and are not supervised. Bicycles are placed on special racks that are equipped with electronic locking mechanism. The locks were initially coin-, credit card-, or electronic key card-operated, whereas recently a mobile phone has been mostly used to make a call or send a text message to the operator who sends back an entry code as a combination to unlock the bicycle. Such systems rely heavily on information technology for user interface, system control and monitoring. Users are identified via their credit card, key card or mobile phone and can be held responsible in case of damage to bicycle (Midgley, 2011).

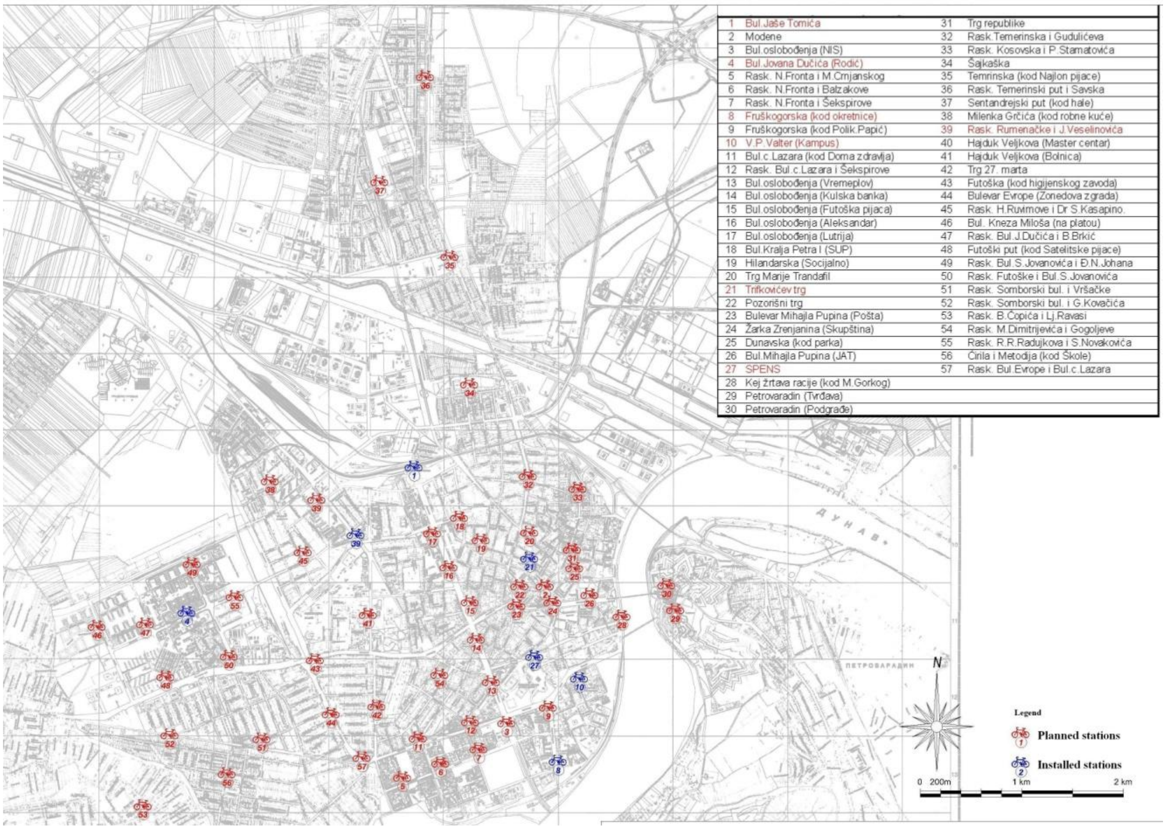

Fig. 2.
Distribution of all and installed stations

The first phase of Novi Sad bike-sharing introduction was completed during the first half of 2012. Five semi-automated stations (staff required) were installed, each having the fleet of 14 bicycles.

The first stations were distributed at main activity centres such as bus and railway stations terminals, the Štrand beach, Spens sports and recreation centre, the inner city centre and the University campus (Fig. 3).

The second phase commenced in early August 2012 when two fully automated stations were opened. In July 2012 registration fee (card issuance fee) was charged 500 dinars. Usage fee was charged 20 din/h or 100 din/day.

Fig. 3.
A station

4.1. Effects of the First Phase of Bike-sharing Introduction

A research was conducted at five existing bike-sharing stations in late June in 2012 with the aim to analyze the effects of the first phase of the system's implementation. Until then there were 1450 registered users in Novi Sad. Within the seven days of research there were 320 bicycle loans. Based on existing capacities, it was determined that one bicycle generated an average of 4.57 loans per week, that is, 0.653 loans per day. The loan duration was within a range of 5 minutes to 24 hours, the average being around 2.5 h (Fig. 4).

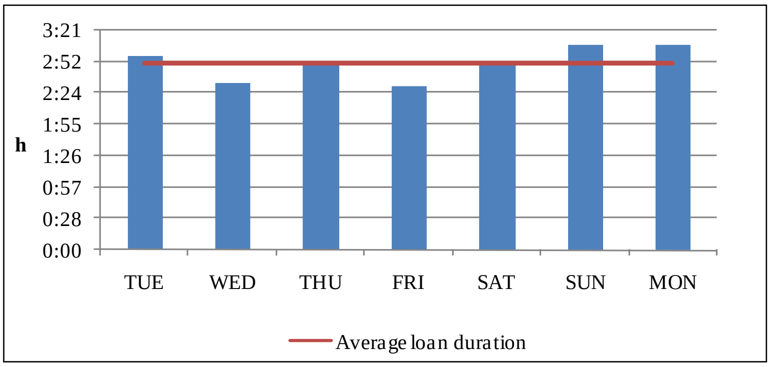

Fig. 4.
Loan duration

A majority of loans were registered on workdays (Fig. 5). Even though a user survey has not been conducted yet, drawing from trip distribution per time of departure from stations during one day (Fig. 6), it can be concluded that so far most users had not used bicycles every day and the loans had mostly been made for recreational trips.

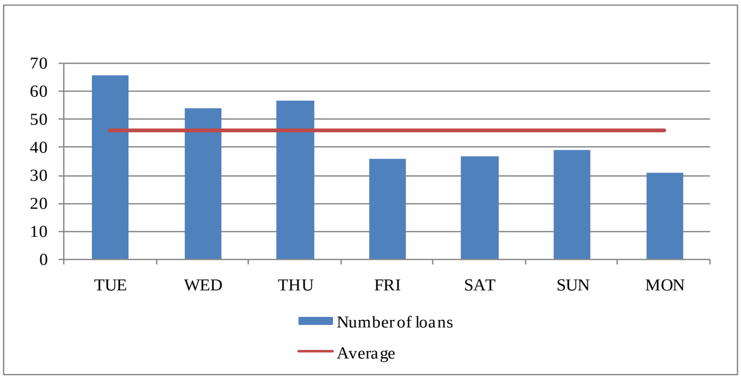

Fig. 5.
System usage during the research week

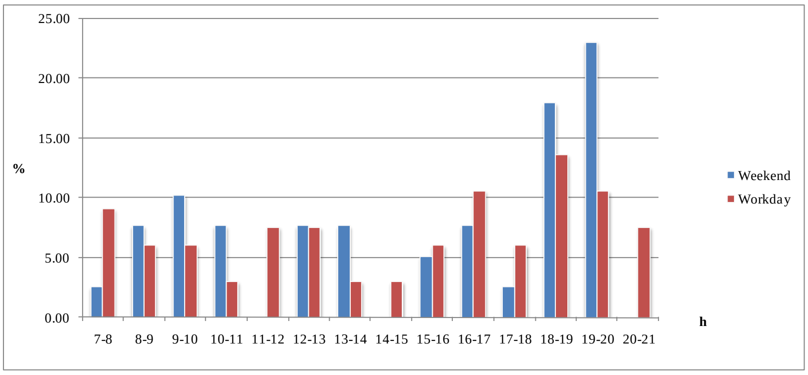

Fig. 6.
Distribution per departure time for workday and weekend

Prior to the system launch, the investor feared vandalism, damage and bicycle theft. It is a positive fact that so far there has been no serious bicycle or station damage or acts of vandalism. Concerning the issue of bicycle theft, there were four registered thefts: one theft was stopped at attempt, one bicycle was found later and two bicycles have not been found yet.

5. Conclusions and Recommendations

The rationale for introducing bike-sharing is primarily to promote cycling as an alternative to more extensive car use. Increased sustainability resulting from increased bicycle use reflects in reduced traffic congestion, reduced noise and air pollution, increased access to specific zones etc.

The experiences of European cities with a long history of bike-sharing are sources of useful information on positive effects of these systems. NS Bike project, which is a pioneering bike-sharing system not only in Serbia but in the whole region as well, may be deemed too ambitious or unrealistic given the conditions in the country. However, if we examine cycling development conditions in Novi Sad, existing levels of bicycle use and increasing problems of the city's traffic system, it can freely be said that over the past few decades nearly nothing has been done to enhance or at least sustain this system. If we also consider traffic development projections for the next twenty years, it is evident that Novi Sad is in dire need of such or similar endeavors.

Existing European experiences from cities like Lyon must set a benchmark for both benefits and drawbacks of certain solutions. There are numerous system improvement options in terms of technology, fees etc. In European cities a vast number of bike-sharing trips are in fact multimodal trips to access public transport facilities. The integration of these two modes of transport is vital for sustainable urban mobility, since bike-sharing is often seen as a means of promoting public transport sustainability, because if the distances between home and public transport and/or public transport and workplace are too long to walk, bike-sharing system is an option (Midgley, 2011).

This system is a missing link between existing public transport facilities and destinations, which offers a new form of mobility to complement existing public transport. 37% of Barcelona's bike-sharing trips are multimodal (Midgley, 2009). A 2008 survey of "Velib" users (Paris) found that 21% of them used bicycles to access subway station, train or bus facilities, and 25% used bike-sharing for return trips to complement other modes of transport (DeMaio 2008).

Pricing structure is another specific measure to promote cycling and bike-sharing. In many cities the first hour of loan is free. In terms of single trips, bike-sharing system usage fee in Novi Sad is twice lower than public transport fee and parking fee per hour. However, future pricing solutions have to be oriented towards attracting trips in which purpose of travel is work and increasing cycling during peak hours. The implementation of such solutions requires the integration of urban subsystems and their joint operation with the aim to address the main issue: How to achieve the city's greater transport system sustainability? **In Barcelona, 100% of revenue gathered from parking tariff goes to operate Bicing, the city's bike-sharing system**. There are numerous European examples where parking revenues are used to support other **mobility needs**. **Several boroughs in London use parking revenue to subsidize transport passes for seniors and the disabled, who ride public transport for free.**

The implementation of the first phase of Novi Sad bike-sharing revealed certain technological drawbacks and corrective measures need to be undertaken within the second phase. The first five stations were located at main activity centres with a promotional role as well. Significant effects are expected after the implementation of the second phase – distribution of stations at high density areas, within the usual range of cycling distances (3.5-5km).

Acknowledgments

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References

Beroud, B. 2007. *Vélo'v: a mobility service to transfer?* Master Thesis, University Lumière Lyon, France.

Bicing Barcelona, Official Web Site, 2011, Available from Internet: < https://www.bicing.cat/>.

Bührmann, S. 2007. *New Seamless Mobility Services: Public Bicycles (NICHES Policy Note 4)*. Rupprecht Consult Forschung and Beratung GmbH. Cologne, Germany.

DeMaio, P. 2009. Bike-sharing: History, Impacts, Models of Provision, and Future, *Journal of Public Transportation*, 12(4): 41-56

Fernández, A.C. 2011. *The contribution of bike-sharing to sustainable mobility in Europe*. Doctoral Thesis, Technical University of Vienna. 235 p.

JP Urbanizam - Zavod za urbanizam Novi Sad. 2009. Saobraćajna studija grada Novog Sada sa dinamikom uređenja saobraćaja – NOSTRAM (Traffic Study of Novi Sad with the traffic management dynamics). Available from Internet: <http://www.nsurbanizam.rs/sites/default/files/1770%20Saobracajna%20studija-NOSTRAM-.pdf>

Midgley, P. 2011. *Bike-sharing schemes: Enhancing sustainable mobility in urban areas, Background Paper No. 8*, Nine teenth Session, Commission on Sustainable Development, UN. 24 p.

Midgley, P. 2009. The Role of Smart Bike-sharing Systems in Urban Mobility, *Journeys*, 2: 23-31

Ministerie van Verkeer en Waterstaat 2009. Cycling in the Netherlands, Available from Internet: <http://www.fietsberaad.nl/library/repository/bestanden/CyclingintheNetherlands2009.pdf.>

New York City Dept. City Planning. 2009. Report: *Bike-share opportunities in New York City.* 135 p

OBIS Project, 2012. *Optimising Bike Sharing in European Cities*, The Intelligent Energy – Europe Programme. 89 p.

Pioneer Valley Planning Commission, 2008. *Bike Share Program Report.* 18 p.

Shaheen, S.; Guzman, S.; Zhang, H. 2010. Bike-sharing in Europe, the Americas, and Asia: Past, Present, and Future. *Transportation Research Record: Journal of the Transportation Research Board*, 2143/2010: 159–167

TTR (Transport and Travel Research). 2006. *The Urban Transport Benchmarking Initiative,* Final Report (Prepared for European Commission Directorate General for Energy and Transport). 52 p.

Vélib: Mairie de Paris, Official Web Site. 2009. Available from Internet: <http://www.velib.paris.fr/>

Vélo'v Lyion, Official Web Site. 2011. Available from Internet: <http://www.velov.grandlyon.com/>

ECOLOGICAL ORIENTATION IN MEASUREMENT OF TRANSPORT INTENSITY IN ECONOMY

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Abstract: The paper presents the problem of transport intensity measure in the new conditions, in terms of sustainable development. Shows the traditional way of measuring the transport intensity of the economy and the formulas of the new approach which is based on ecological thinking. Shows the output of authors such as Tapio, Stead, Banister. It was noted that Poland is still published, in which the formula would be used to measure transport intensity of the economy.

Keywords: transport, transport intensity, ecology

1. Introduction

Analysis of the place and the role of the transport in economy function, including the stimulation and the reaction into changes occurring in it, are obliging to look at the economy through the prism of the intricate and dynamic structure. It is possible in this case to consider the complexity of the economy above all from a point of view of two structures: sector and spatial, remaining with each other in the arrangement which indeed influence the transport. However dynamics of the economy are space-time expressing its state and structure, according to the assumption that the economy is in a sustained development, since its components are undergoing constant changes.

The problem of transport intensity in economy already has its place in the area of theoretical deliberations about the transport. There is, therefore, some new field of research. However, changes in the environment have forced transport intensified in recent years, an attempt to reinterpret the concept. The aim is to develop recall some of the discussions about a new approach to the scope of the concept of semantic transport intensity in economy against the background of its current understanding.

2. Transport and economy: power and scope of the interdependence

It is undisputed that transport plays a vital role in the economy. It is an integral part. Fully complementary role in relation to other sectors of the economy, but transport can also be seen further as a carrier system for the economy, highlighting the role of its conditioning to any other activity. This statement gives a clear to understand, first, that the functioning of the economy without transport is not possible, and secondly - the operation of transport without the economy would not be justified.

The economy isn't a monolith. Its branches form a structure that exhibit relevant differences generated transport needs in terms of their distribution in space and time and qualitative characteristics. It isn't impossible to exchange all differences in detail, nonetheless it is possible to point for most important, as:

- material or immaterial character of the production,
- type of produced goods (semi-finished products, consumer, industrial final goods etc.),
- transport, manual and stock susceptibility of goods,
- relation (and the relation degree) from raw material of the production,
- specificity of supply bases, production and markets,
- production cycle,
- cooperation degree of production,
- specificity of delivery channels,
- specificity of factors marking supply policy in the sphere of delivery, production and distribution,
- size and specificity of the demand's spatial structure,
- disintegration of the demand in time (continuity, seasonal character, susceptibility to hesitations etc.),
- participation in the international exchange,
- degrees and areas dependent on the use of personal transport, namely the possibility that the market for transport services.

Transportation needs can vary in size and structure within the various sectors of the economy. It is therefore necessary to analyze the behavior of those making up the sector in a dynamic, bearing in mind that this behavior is determined by the structure of the market. The size and structure of the transport needs can therefore be seen as a function of market structure and behavior of transport users.

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An important role in shaping the particular size of the transport needs of the life cycle of the sector to play the national economy. Rate of growth for individual sectors is, in fact diverse. It can be assumed that the growth sectors will report increased demand for transport, in the case of declining industries will need to gradually decrease. Furthermore, changes in transportation needs caused by changes in the sector structure of the economy and changes in the activity of the individual sectors have an effect on:

- directions of the quantitative transformation of the industrial structure of the transport system,
- directions of qualitative changes in the level of services provided by various modes of transport.

This means that the sector structure of the economy and activity of various sectors of the economy determines the suitability of each of the branch in meeting transportation needs.

Transport is both an element and the subject of economic development. Economic development usually associated with an increase in transport activity. Occurs, therefore, not only in the role of pacemaker, but the directions of economic development have also been a guideline for the development directions of transport. On the other hand, the transport may affect the development of stimulating the economy when its growth and potential is fully harmonized with the needs of the economy, and constraining, when its development and potential do not correspond to some extent needs to notify the economy.

3. Transport intensity in economy: “old” interpretation of a problem

According to this, as stated previously, the functioning of the economy, and more precisely, its various departments, is possible due to transport activities. The economy is therefore characterized by certain degree of transport intensity. In the literature, the subject of transport intensity (transport intensity of national economy) mainly as the state of involving the transport activity in the operations of other departments of economy (Ciesielski, 1996; Szempliński and Zaborska, 1978; Kuziemkowski, 1981; Rydzkowski and Wojewódzka-Król, 1997) are being defined what it is possible differently to express the business activity as the ratio of the demand for transports to the scale and to write in the following manner (Eq. (1)) (Liberadzki, 1998):

$$WT_{gosp} = \frac{V}{A_{gosp}} \tag{1}$$

where:

WT_{gosp} - ratio of transport intensity in economy
V - demand on transport
A_{gosp} - scale of economic activity

One should here understand the state of employing the transport activity as employing the work and objectified at the transport service of all departments of the economy, inclusive with the service of individual needs of the population.

It is clear that each of the sectors of the economy is characterized by only the appropriate level of transport intensity. And if so, the relationship described above will take the form (Eq. (2)) (Liberadzki, 1998):

$$\begin{pmatrix} WT_1 \\ WT_2 \\ . \\ . \\ WT_n \end{pmatrix} = \frac{\begin{pmatrix} V_1 \\ V_2 \\ . \\ . \\ V_n \end{pmatrix}}{\begin{pmatrix} A_1 \\ A_2 \\ . \\ . \\ A_n \end{pmatrix}} \tag{2}$$

where:

$WT_{1,2\ldots n}$ - ratio of transport intensity in economy branches
$V_{1,2\ldots n}$ - demand on transport reported by individual economy branches
$A_{1,2\ldots n}$ - scale of economic activity in individual economy branches
n - economy branches.

Partition and the industrial structure of the national economy are characterized by certain level of transport intensity, as it implicates:

- balance between the production of means of production and consumption,
- balance between the extraction of raw materials and industrial processing,
- balance between industries representing low and high degree of processing,
- spatial distance between the centers of demand-and supply centers,
- share of international trade in aggregate economic activity.

As noted, the structure is an overriding factor in determining transport intensity in economy. However, the significant role it should also be attributed to the historically shaped the organization of the economic sphere, more precisely the factors that determine it. They have been presented in previous discussions, the opportunity to discuss sources of transport needs (level of specialization in production, the level of cooperation, the degree of concentration of production, location of production facilities and logistics, organization and distribution of supplies, etc.).

Both the structure and the organization of economic activities in different sectors change over time. This process is continuous and inevitable. These changes, their content and strength, are directly reflected in their level of transport intensity (Table 1). The level of conscious transport intensity can also be adjusted. This is possible through the deliberate impact on the various factors determine the economic structure and organization of economic life.

Table 1
Models of macroeconomic situation and its impact on the level of transport intensity

Macroeconomic situation	Consequences	Character of economy
Assumptions: A – economic activity, WT – level of transport intensity, V – demand on transport, i – set of economic branches		
$\Delta A_i \geq 0$, $\Delta V \geq 0$ i depends on the growth of production in *i*	$\Delta WT \geq 0$	Transport intensity in economy
$\Delta A_i \geq 0$, $\Delta V > 0$	$\Delta WT > 0$	Transport intensity in economy
$\Delta A_i < 0$, ΔV depends on the proportion of changes in the economy	$\Delta WT \geq 0$ or $\Delta WT \leq 0$	Transport intensity in economy or Transport saving economy
$\Delta A_i > 0$, $\Delta V < 0$	$\Delta WT < 0$	Transport saving economy
$\Delta A_i < 0$, $\Delta V \leq 0$	$\Delta WT \leq 0$	Neutral economy or transport saving economy

Source: own studies

Its reasoning finds precision calculations and analysis by setting transport intensity for the various modes of transport. In the case of freight carried by road transport, for example, Brunel (Brunel, 2005), founded in their study that the narrow definition of industry involvement in the service economy can be measured as follows (Eq. (3)):

$$RFI_i = \frac{road\_TK_i}{GDP_i} \tag{3}$$

where:

road_TK$_i$ - “tkm” quantity made by motor transport in “i” country,
GDP$_i$ - PKB of “i” country.

In broader terms, the indicator is presented as follows (Eq. (4)):

$$RFI_i = \frac{road\_TK_i}{TK_i} \times \frac{TK_i}{T_i} \times \frac{T_i}{IND_i} \times \frac{IND_i}{GDP_i}, \tag{4}$$

where:

TK_i - “tkm” quantity made by all transport branches in “i” country,
T_i - number of tons of cargo transported,
IND_i - industrial production in “I” country

This means that considering the cargo, the involvement of motor transport in the service economy is the product: the participation of freight transportation by road in total freight transport (implemented by all branches), the average distance journeys, and the average weight of industrial production value of 1 $, the share of industrial production GDP. Of course this is just an example; the methodology can be, depending on the needs to modify.

The main premises of transport intensity analysis for the various modes of transport are characterized by diversity of these outlays and the diversity of involvement in various service sectors. Moreover, the trend for aggregate transport intensity is not appropriate for transport intensity designated for each branch. This study showed for the German economy, which showed decrease aggregate transport intensity, whiles the increase of road transport (Baum, 2000; Baum and Kurte, 2002).

Transport intensity can also be recognized as the sum, material-, energy- and labor- intensive, while specifying it as the ratio of expenditures incurred on the transport activity to the effects achieved in the economy, in its various branches, supported by transport, namely (Eq. (5)):

$$WT_{gosp} = \sum_{i=1}^{n} \frac{M_T + E_T + P_T}{Ef_G} = \left(\frac{M_{T_1} + E_{T_1} + P_{T_1}}{Ef_1} \right) + \left(\frac{M_{T_2} + E_{T_2} + P_{T_2}}{Ef_2} \right) + \ldots + \left(\frac{M_{T_n} + E_{T_n} + P_{T_n}}{Ef_n} \right) \tag{5}$$

where:

WT_{gosp} - ratio of transport intensity in economy,
M_T - material intensity of transport,
M_{Tn} - material intensity of transport serving n-branch of economy,
E_T - energy intensity of transport,
E_{Tn} - energy intensity of transport serving n-branch of economy,
P_T - labor intensity of transport,
P_{Tn} - labor intensity of transport serving n-branch of economy,
E_{fc} - effects gained in economy,
E_{fn} - effects gained in n-branch of economy,
i - amount of economic branches.

Therefore, the expenditures incurred in the transport activity can be expressed in three ways, firstly by the volume of traffic in tones, and secondly by the size of transport performance in tone-kilometers, and finally by the value of transportation in gold. In the first two cases are used in meters, natural, and more recently - a measure of value. National income and product are the effects of global economic activity. It should be noted that the use of only natural metrics, which is fairly standard practice, research, leads to obtain information about the transport intensity in an indirect and imprecise, and sometimes even incorrect. Increase in transport performance does not have to testify because of the increased transportation costs, and thus - as measured by the increased consumption of material resources, energy and labor. In addition, a special cognitive value, especially from the perspective of sustainable development is to calculate and analyze the transport of intensity in terms of material-, energy -and labor-intensive for its various sectors of the economy separately, because each of them characterized by different levels of expenditures incurred on transport activity, shaped by specific factors.

The aim of transport intensity measurement as Rydzkowski and Wojewódzka-Król (1997) noticed, determine sizes of the transport activity per unit of reference, but - like stress - there is no official statistical records, which would allow for precise, detailed measures of transport intensity particularly of subject character. Meters are the exception relating to the economy when the following options can be used:

- tons of transported charges taken back to the individual of the value of the national income and of the national product,
- tons and kilometers of the transit work taken back to the individual of the value of the national income and of the national product,
- value of transports and other core activities of the transport values taken back to the individual of national income and national product.

4. Transport intensity in economy: “new” interpretation of a problem

Relations between the structure and functioning of the economy are the current and important subject of the research invariably for many authors. Of course climbs and motives for these examinations are changing. In foreign literature from two last decades clearly two directions of analyses related to this are became scratched:

- examinations of developing the relation between the rise in the economy and transport intensity in a long stretch, in it particularly with respect to power and the scope of the effect of the factor of the fluctuation,
- or examinations, what strength of the influence of the rise in the economy on the rise in transports is (coupling), which means that what step the rise in the economy and the rise in transports are dependent on oneself in, as well as whether the disappearance of this influence is possible, it is dividing the rise in the economy and the rise in transports (decoupling).

In macroeconomic analysis can be clearly demarcated areas of interactions in long and short term. The modeling of the general demand for transport of long-term use is now entered into the current so-called "new econometrics, co integration theory, which allows examining relationships of variables over long periods and seeking their long-term sustainability. Co integration because, simply speaking, the existence of dynamic relationships between variables. 70-80 to the end of the twentieth century assumed stationary time series[1]. The fundamental discovery was made by Granger (1981), who noted that the time series properties are not generally met, and that economic processes are characterized by non-stationary. According to this, Granger and Engel (1987) formulated property of co integration time series that can be inferred from the growth of the economy by transport intensity; needs to know the property that say about their distribution during the past time. However, it is assumed that the time series describing the growth of the economy and transport intensity move in a non-stationary manner, but similar to it, and more - share similar growing trends. And if so, relationship, what unites them is respect for stationary signs. Recognizing, however, the transition from assumptions of linearity and symmetry depending on long-term adaptation to long-term equilibrium position toward the non-linearity, in studies of the effect of the economy on the demand for transport use is now co integration nonlinear analysis, often using the model correction through error. In addition, the use of models allows the determination of co integration more reliable predictions of the general level of transport intensity in the long run, because they may reflect the importance of cyclical fluctuations, which may manifest itself in greater or lesser degree, but are an important determinant. Can be seen here:

- cyclical fluctuations observed in the economy and their impact on the level of transport intensity,
- cyclical fluctuations observed in the transport and their impact on the economy,
- relationship between cyclical fluctuations in the economy and the cyclical fluctuations in transport.

Generally, therefore it can be concluded that there is the need to develop research and improve methods of forecasting long-term transport due to its significant role to other areas of the national economy. It is also the implication of the extended time horizon for planning its development as set out by:

- high capital-, material-, time-, effort-, and land intensity of transport investments,
- the need to synchronize the development of transport systems with the overall land development, while respecting the environmental conditions,
- making the development of transport systems from long-term trends of their development,
- changes in transport's technical and organizational structures.

The second stream of research and analysis of the relationship between the economy and transport, focusing on the strength depending on transport growth from growth in the economy, and more precisely - on the possibility of separation of economic growth from growth in transport, i.e. to achieve decoupling, is a response to the growing importance to sustainable development. Can be observed in this case, the emphasis of the following problems:

- What are the levels of the relation between the economy rise and the rise in transports (coupling levels)?
- How to measure levels of dividing the relation between the economy growth and the growth in the transport (decoupling levels)?
- How the energy consumption of the transport looks in the context of the economy service and how to measure it up?
- How the carbon dioxide emission looks through the transport in the context of the economy service and how to measure it up?
- How to measure transport intensity of economy in the aspect of the dematerialization and transmaterialization (immaterialization) of transport?

Tapio (2003) suggests that the separation of transport growth from economy growth, so called decoupling, put in the category of flexibility in the growth of GDP measured in terms of freight volume measured in tkm for freight or pkm passenger transport to value below 1. Because it reflects on the carriage of cargo, the pattern of this dependence, based on a Tapio’s proposal, is as follows (Eq. (6)):

$$e_{PKB/tkm} = \frac{\%\Delta PKB}{\%\Delta tkm} \tag{6}$$

where:

$e_{PKB/tkm}$ - flexibility in terms of economy growth in terms of increase in cargo transportation,
$\%\Delta PKB$ - percentage change in economy growth measured by GDP,
$\%\Delta tkm$ - percentage change in growth of cargo transport measured in tkm.

[1] Stationery time series means that the parameters such as average and variance do not change over time.

Tapio points out that in this way the level of decoupling can be measured, not only for transport in terms of aggregate, but also for each branch separately. Also indicate that in addition to the average distance transport of 1 ton of cargo in km, changing freight growth, depending on the context analysis can be expressed as the number of kilometers driven by a single vehicle.

Tapio suggests that measuring levels of decoupling economic growth and increase in freight to make, respecting the fact that transport is a significant contributor to CO_2 emissions. Hence suggests that the measure decoupling of CO_2 emissions from the transport of freight volume in the following manner (Eq. (7)):

$$e_{tkm/T_{CO_2}} = \frac{\%\Delta tkm}{\%\Delta T_{CO_2}} \tag{7}$$

where:

$e_{tkm/Tco2}$ - elasticity of growth in CO_2 emission caused by transport in terms of growth in transports of cargoes,
$\%\Delta tkm$ - percentage change of growth in transports of cargoes measured in tkm,
$\%\Delta T_{CO2}$ - percentage change of CO_2 emission caused by transport.

Continuing the deliberation line of Tapio, taking into account the elasticity of growth in CO_2 emission caused by transport in terms of growth in transports of cargoes let us measure the level of the decoupling expressed with elasticity of growth in economy on the account of CO_2 emission caused by transport, which can be written down as (Eq. (8)):

$$e_{PKB/T_{CO_2}} = \frac{\%\Delta PKB}{\%\Delta T_{CO_2}} \tag{8}$$

where:

$e_{PKB/Tco2}$ - elasticity of growth in economy in terms of growth in CO_2 emission caused by transport,
$\%\Delta PKB$ - percentage change in the growth in economy measured by GDP,
$\%\Delta T_{CO2}$ - percentage change of CO_2 emission caused by transport.

Indicator of economic growth in terms of elasticity of growth in CO_2 emissions caused by transport therefore indicates to what extent the economy service by transport, dependent on the growth of the economy, entails CO_2 emissions. Tapio believes that if this indicator shows decoupling achievement, it is possible to speak of the entrance to the levels of dematerialization of transport. Examining in turn the rate of growth elasticity of growth of cargo transportation, reaching decoupling in this case would be tantamount to the entry levels transport immaterialization. Dematerialization of transport is, therefore, a manifestation of reducing CO_2 emissions in transport, e.g. through technical innovations in transport, organic fuels, substitution by more environmentally friendly modes of transport (Jänicke, 1988; Kaivo-oja and Luukkanen, 2004), and immaterialization is a reduction of the level of transport intensity in economy, for example, through changes in the structure of the economy.

In addition to dematerialization and immaterialization, Tapio lists another form of decoupling that can be related to the engagement of transportation into economy service. He indicates decarbonization, which measures changes in the level of CO_2 emissions caused by transport with respect to CO_2 emissions throughout the economy (Tapio et al., 2007; Nakićenović, 1996), that is, by all other departments / sectors of the economy (Table 2). He adds that all these three forms of decoupling can take two options (Vehmas et al., 2003; Wernick et al., 1996), either the relative separation, however, when the involvement of transport is increasing, but it is not proportional to the growth of the economy, only smaller, or absolute separation, when economic growth occurs when successive reduction of its transport intensity.

Table 2
Decoupling forms of economic growth and transport growth (of cargos)

Decoupling forms	Measure
Immaterialization	tkm/GDP_{PPS}*
Dematerialization	Transport CO_2/tkm
Decarbonization	Transport CO_2/GDP_{PPS}

* PPS (Purchasing Power Standard) - applied in the EU conventional monetary unit by which economic units are compared in each country, taking into account the purchasing power of their currencies. In this way eliminates the influence of price differences on the size of these aggregates.

Source: own studies

To be valuable in this matter the reflections of Stead should be considered, which presents different approaches to measuring transport intensity that are currently used in research, analysis and statistics by EUROSTAT, the World Bank and OECD, demonstrating the growing importance of sustainable development. Thus shows that look at transportation-management relationship have been extended. He looks up, not only the tasks and duties of transportation to the economy, but also that it brings with it consequences for the environment of their implementation.

When considering a new approach to transport intensity in economy, two issues emerge. Firstly, it should be noted that this new approach is based, in essence, two shots - the measurement of efficiency for the transport of energy, or energy intensity of transport, and for measuring the efficiency of handling the economy (Table 3). It is also important that both approaches used the concept of net mass transport (NMM - net mass movement) and the gross weight of the carriage (GMM - gross mass movement), which moved from the energy sector in the area of transport S. Peake, believing that it is possible, by analogy, As with the analysis of energy efficiency in production and consumption (efficiency of energy intensity of production and consumption), to analyze the effectiveness of transport intensity in economy. Both the NMM and GMM capture the total passenger and cargo, where the rate of NMM is imputed as the sum of the ratio of total passenger carried and 11.11 (assuming that people and their luggage, they weigh on average 90 kg) and total tone-kilometers. As regards the rate of the GMM, it is imputed as NMM, in that it takes into account the additional weight means of transport used to transport people and cargo and empty driving modes, which relate to freight transport. There is, therefore, the conviction that operation of the economy by analyzing the transport efficiency of the prism is to show how the management of the environment necessary to support this could be done. Conforming or not to the standards imposing the principles of sustainable development, or the extent to which they correspond.

Table 3

Indicators of transport intensity area characteristics in modern statistics (for cargos)

Area of measurement	Measure of transport intensity
Energy intensity in transport	Energy consumption /tkm Energy consumption / cargo net mass
Effective service in economy	GDP_{PPS}/tkm GDP_{PPS}/cargo net mass GDP_{PPS}/ Energy consumption

Source: own studies

The second issue concerns the GDP, which is used in the traditional measurement approach of transport intensity in economy. This approach still has its analytical value, but it is too narrow, if considering that the functioning of the economy must conform to the objectives of sustainable development, creating conditions for sustainable prosperity. This means that the use of GDP in measuring transport intensity in economy with such a condition is insufficient.

Thus reveals the weakness of GDP as an indicator of economic activity. Hence, Stead takes the view that among the many new alternatives to measures of GDP, which appear in recent years, in studies on transport intensity in economy functioning by principles of sustainable development can use the rate of sustainable economic prosperity ISEW (Index of Sustainable Economic Welfare) developed by Daly and Cobb Jr. Simply speaking, the concept of ISEW is based on adoption as the basis for calculating public spending on final goods and, more specifically - the size of individual consumption that is being referred to as weighted by the increased or decreased, depending on whether additional consideration categories contribute to increasing the level of prosperity and may cause its decline.

Therefore, the contribution of transport will be analyzed in the creation and delivery of welfare, rather than in the growth of the economy, which does not necessarily mean well-being, something that was already under consideration. By analogy, therefore, as in the case of GDP transport intensity in economy can be measured as follows:

- ISEW / tkm
- ISEW / net mass of the transport
- ISEW / power consumption caused by the transport

Such attitude gives the possibility of more versatile measurement to the economy activity, as well as the wider look at the object of the transport service.

5. Conclusion

Summarizing the discussion above “old” and “new” interpretation of transport intensity in economy, transport intensity in economy, in the classic sense reflects the degree and strength of the relationship between transport and the economy. The new, broader interpretation shows how to shape the transport system that was tailored to the needs of the economy and have them meet without interference, while respecting the principle of rational management of the environment.

Acknowledgements

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References

Banister, D. et al. 2000. *European Transport Policy and Sustainable Mobility*. Spon Press, London-New York.

Banister, D. 2005. *Unsustainable Transport: The Transport Crisis*. Spon Press, London-New York. 304 p.

Baum, H.; Kurte, J. 2002. Transport and economic development. In the Proceedings of the *ECMT, Transport and economic development. 17th International Symposium on Theory and Practice in Transport Economics*. Paris. OECD.

Baum, H. 2000. Decoupling transport intensity form economic growth. In the Proceedings of the *ECMT, Key issues for transport beyond 2000. 15th International Symposium on Theory and Practice in Transport Economics*. Paris. OECD.

Brunel, J. 2005. *Freight transport and economic growth: an empirical explanation of the coupling in the EU using panel data*. Laboratoire d'économie des transports - CNRS: UMR5593, Université Lumière, Lyon II, Ecole Nationale des Travaux Publics de l'Etat, Lyon.

Charemza, W.W. ; Deadman, D. F. 1997. *Nowa ekonometria*. PWE, Warszawa.

Engle, R.F.; Granger, C.W.J. 1987. Co-integration and Error Correction. Representation, Estimation and Testing, *Econometrica*, 55(2): 251-276.

Granger, C.W.J. 1981. Some Properties of Time Series Data and their Use in Econometric Model Specification. Journal of *Econometrics*, 16(1): 121-130.

Jänicke, M. 1988. *Ökologische Modernisierung, Optionen und Restriktionen präventiver Umweltpolitik*. In: Simonis, U.E. (ed.), Präventive Umweltpolitik. Campus, Frankfurt am Main.

Kaivooja, J.; Luukkanen, J. 2004. The European Union balancing between CO_2 reduction commitments and growth policies: decomposition analyses. Energy Policy, 32(13): 1511-1530.

Lawn, P.A. 2003. A theoretical foundation to support the Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI), and other related indexes. *Ecological Economics*, 44(1): 105-118.

Liberadzki, B. 1998. *Transport: popyt, podaż, równowaga*. Wyższa Szkoła Ekonomiczno-Informatyczna w Warszawie, Warszawa.

Madeyski, M.; Lisowska, E. 1981. *Badania analityczne transportu samochodowego*. Wydawnictwo Komunikacji i Łączności, Warszawa.

Michaelis, L.; Davidson, O. 1996. GHG mitigation in transport sector. *Energy Policy,* 24(10-11): 969-984.

Nakićenović, N. 1996. Decarbonization: doing more with less. Technological Forecasting and Social Change, 51(1): 1-17.

Peake, S. 1994. *Transport in Transition*. Earthscan, London.

Rucińska, D. 1992. *Cykle gospodarcze w transporcie*. Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk.

Stead, D. 2001. Transport intensity in Europe – indicators and trends. Transport Policy, 8(1): 29-46.

Szempliński, T.; Zaborska, K. 1978. Transportochłonność gospodarki narodowej. *Przegląd Komunikacyjny*, Nº 2.

Tapio, P.; Banister, D.; Luukkanen, J.; Vehmas, J.; Willamo, R. 2007. Energy and transport in comparison: Immaterialisation, dematerialisation and decarbonisation in the EU15 between 1970 and 2000. *Energy Policy*, 35(

Tapio, P. 2003. Decoupling has begun in Finland. Economic growth, traffic volume growth and the CO2 policy of EU15 and Finland 1970-2001. TUTU Publication 5/2003, Turku School of Economics and Business Administration, Finland Futures Research Centre, Turku.

Transport w procesie integracji gospodarki, 1996. Ed. M. Ciesielski, Wydawnictwo Akademii Ekonomicznej w Poznaniu, Poznań.

Transport, 1997. Ed. W., Rydzkowski; K., Wojewódzka-Król. PWN, Warszawa.

Transportochłonność gospodarki narodowej, 1981. Eed. R. Kuziemkowski, Wydawnictwo Komunikacji i Łączności, Warszawa.

Vehmas, J.; Malaska, P.; Luukkanene, J.; Kaivooja, J.; Hietanen, O.; Vinnari, M.; Ilvonen, J. 2003. Europe in the global battle of sustainability: Rebound strikes back? Advanced Sustainability Analysis. Publications of the Turku School of Economics and Business Administration, Series Discussion and Working Papers 7, Turku.

Welfe, A. 2003. Ekonometria. PWE, Warszawa.

Wernick, I.K.; Herman, R.; Govind, S.; Ausubel, J. 1996. Materialization and dematerialization: measures and trends. Daedalus, Vol. 125, Nº 3.

SYSTEM COMPONENTS AND OPERATION CHARACTERISTICS OF ISTANBUL BRT

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Abstract: With a population over 13 million Istanbul is the largest city in Europe. Traffic congestion is by far the most important problem that lessens the quality of life of the residents. Currently 1.8 million automobiles choke its roads daily. The rapid increase in motor vehicles, more than eightfold since 1980, has coincided with a dramatic population and economic growth. As a result, Istanbul is now overwhelmed by a flood of people and vehicles, an inadequate road network and a public transport system that has been slow to develop. This paper presents an overall evaluation of the Bus Rapid Transit (BRT) System in Istanbul of which the first phase was opened in 2007 as a relatively high-speed, high-capacity public transport mode along one of the most congested traffic arterials in the city. Presently it carries about 600,000 passengers daily over a 44 km-long alignment with 33 stations. The paper focuses on system components and presents a comparison with some major BRT systems in the world. Moreover, operational characteristics of travel patterns and ridership are analyzed with the data collected from the surveys and operator of the system; Istanbul Electricity, Tramway and Tunnel General Management (IETT). This study concludes that although the Istanbul BRT System has some drawbacks regarding the running way, access to stations, fare structure and overloaded buses, it has resulted in considerable savings in commuters' travel time and CO_2 emissions. Finally, some suggestions for solving the important problems of the system are presented.

Keywords: Bus Rapid Transit, Sustainable Transport, Public Transportation, Urban Mobility

1. Introduction

Bus Rapid Transit (BRT) system is a rapidly spreading transportation system, which became popular among public transportation systems in the last 10 years. Aim of the system is to operate public transportation vehicles on a separated road allocated to them; so they are not affected by the usual traffic. Together with using high capacity and environmental friendly and vehicles, BRT systems offer fast and high capacity public transport alternative. Today, capacity of some BRT systems approach to the light rail systems' capacity (Yurdagül, 2012). Determining the components of the system is very important. Therefore, surveys and analyses that are made before deciding the BRT system are so important.

Istanbul is one of the most populated cities in the world with a population of over 13 million. Moreover, Istanbul has a very important role for Turkey's economy, because, the city is the largest center of social, cultural and touristic activities and also has the most developed industry in Turkey. The city's population has grown rapidly since 1950. In addition to the natural population growth, extraordinary migration from rural areas has been the major factor. Traffic congestion is a major problem in Istanbul. Today, over 23 million trips are made daily of which 50% are walk trips. The public transportation system has been unable to keep pace with the rapid growth and changing urban structure. Local authorities have been struggling under the pressure of urbanization without sufficient funds to accommodate growth. Buses and minibuses play a key role with the highest share (41% of motorized trips). Together with company and school buses that are essential complementary modes to public transport system, the share of the trips made by public transport has remained at a stable level of 70% in the last two decades whilst the car travels have increased from 19.3% to 26.3%, resulting in severe traffic congestion, environmental pollution and external costs.

Istanbul Metropolitan Municipality has implemented a Bus Rapid Transit (BRT) system as a fast and low-cost alternative for public transport users. The system components are running way, stations, vehicles, operation plan, fare collection and intelligent transportation system.

2. Istanbul BRT system

Construction of the Istanbul BRT system was started in December 2005 on one of the most congested arterial roads, D100 highway.

The operation started in August 2007, between Topkapı and Küçükçekmece. The route was later extended to Avcılar to complete the first phase of 13.3 km. Travel time decreased nearly by 40 minutes with the introduction of first phase of the system.

In September 2008, the system was extended to Zincirlikuyu and Mecidiyeköy which are the most used stations today. The second phase of the system was 11.3 km long. The parallel bus lines were ceased. In the peak hours, travel time from Avcılar to Zincirlikuyu dropped from 100-120 minutes to 50 minutes.

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In the third phase, the BRT system was extended from Zincirlikuyu to Söğütlüçeşme with a 14-km long section partly using the Bosporus Bridge. The system runs in the mixed traffic along nearly a 3 km section including the bridge.

Today, the BRT system in Istanbul operates between Söğütlüçeşme and Avcılar stations over a route of 44.1 km with 33 stations (Fig. 1). The system is operated by Istanbul Electricity, Tramway and Tunnel General Management (IETT). Five lines are operated along this corridor:

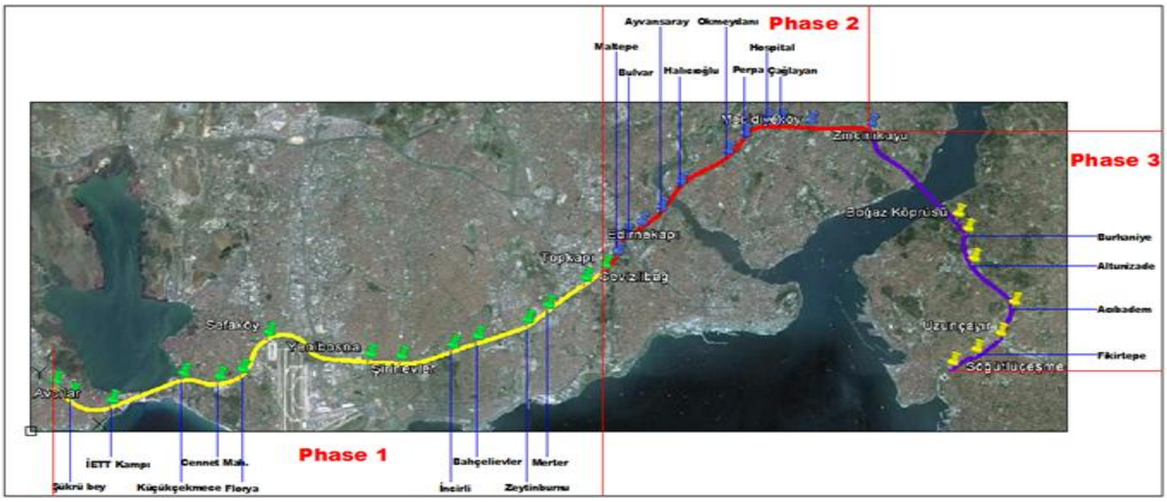

Fig. 1.
Phases of Istanbul BRT system

Line 34 between Avcılar and Zincirlikuyu, Line 34A between Edirnekapı and Söğütlüçeşme, Line 34G between Avcılar and Söğütlüçeşme, Line 34T between Avcılar and Topkapı and Line 34Z between Zincirlikuyu and Söğütlüçeşme. Avcılar, Edirnekapı, Zincirlikuyu and Söğütlüçeşme are the main interchange stations. The BRT system carried over 500,000 passengers daily in February 2012. The system operates at capacity in the peak hours.

Doors of buses are on the right side and stations are in the median of the highway. Therefore, buses operate in the middle of D100 highway in the opposite direction to regular traffic. The main components of the Istanbul BRT system are running way, stations, buses, operation plan and fare collection. The BRT system has no intelligent transportation system (ITS) except fare collection and station information system in the buses.

2.1. Running way

BRT running ways can be built next to highways, in the medians of arterial streets, in abandoned rail corridors, and in tunnels. Because it is the most important component that affects the system cost, decision about BRT system corridors is very critical. In addition, running way affects reliability of the system and speed of buses. Therefore, this is the most effective component on system image (Yurdagül, 2012).

The BRT running way can be separated physically from the usual traffic flow or can be separated by road marking. If it is important to increase system's speed, physical separation from normal traffic flow should be preferred BRT running ways have minimum intersections with other vehicles and ways, because of increasing speed and passenger comfort (Yurdagül, 2012).

Istanbul BRT system is 44.1 km long and it is the 12th longest BRT system in the world (Baker, 2003; ITDB, 2012). The BRT system has one lane in each direction separated from the vehicle traffic with bollards and steel cables.

There are 2 terminal stations: Avcılar in the European side of the city and Söğütlüçeşme in the Asian side. Additionally, the system has 3 turning areas at Topkapı, Edirnekapı and Zincirlikuyu stations.

The system has no passing lanes. Therefore, when a bus brakes down or an accident happens, the system suffers from long vehicle queues causing considerable delays.

Running ways of BRT systems in the world have different local characteristics. Operating over extensive BRT networks, TransJakarta in Jakarta, Indonesia, and Transmilenio in Bogotá, Colombia, are the longest BRT systems in the world (Baker, 2003; ITDB, 2012).

2.2. Stations

Stations are the most important component that connect BRT system with passengers and the other public transportation systems and also important for travel time. BRT systems generally run along the corridors with high passenger demand and BRT stations should serve the areas along the corridors. A good BRT station should be a convenient connection for the transit buses (Yurdagül, 2012).

Integration of the system with other public transportation systems, location of the station and distance to other stations affect the system performance. Conflicts between boarding and alighting passengers in and around the stations should be minimized. Therefore, facilities like overpasses, underpasses, etc. should be well-designed. Another important thing is that passengers should be able to access to the BRT stations on foot (Yurdagül, 2012).

Istanbul BRT system has 33 stations, mostly located on the median of the road. Zincirlikuyu and Söğütlüçeşme stations are on the right side of the system. There are 2 terminal stations: Avcılar and Söğütlüçeşme. Additionally the system has 3 turning areas at Topkapı, Edirnekapı and Zincirlikuyu stations. Avcılar, Mecidiyeköy, Söğütlüçeşme, Zincirlikuyu, Şirinevler, Edirnekapı and Sefaköy have the highest passenger demand.

Stations are 60 m long and 4 m width. Passengers have to use overpasses and underpasses to access the median stations. At the beginning of the operation, overpasses were mostly inadequate which affected the system's image negatively. Therefore, a number of re-designing and upgrading have been made to improve the service quality of overpasses. BRT stations do not have shelters to protect passengers from the weather conditions.

Average spacing of stations is 1,210 meter which is higher than world's 32 BRT systems' average of 881 m (Fig. 2) (Baker, 2003; ITDB, 2012).

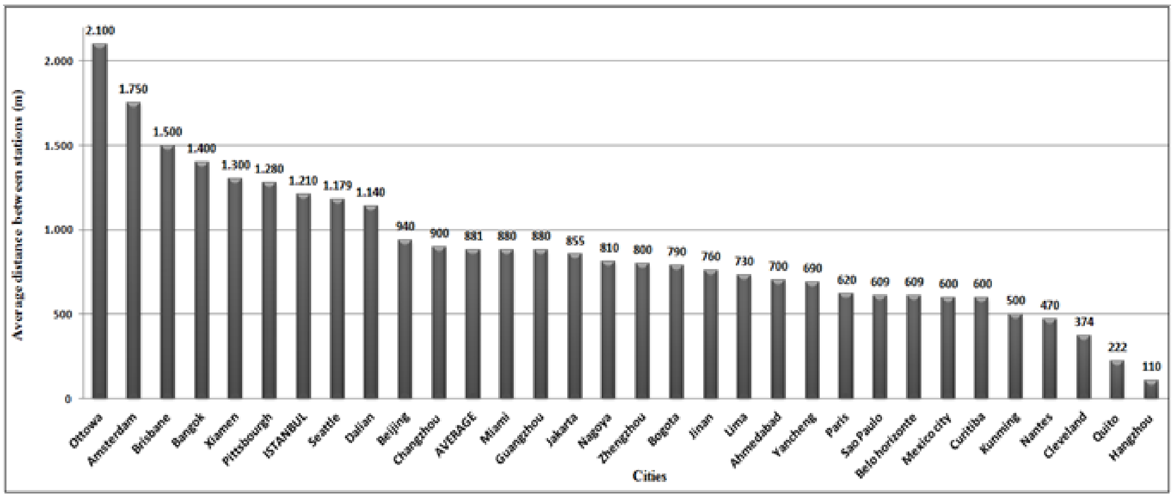

Fig. 2.
Average distance between stations
Source: Yurdagül, 2012

Both a passenger survey that was carried out by IETT in 2011, Istanbul BRT operator, and our P&R (park-and-ride) survey have shown that P&R use is very low (2%) in the system. Nearly 60% of BRT passengers access the system by public transport. Moreover, the surveys have also shown that 4% of the BRT passengers have switched from cars (IETT, 2011).

2.3. Buses

Buses in BRT systems have a direct impact on speed, capacity, environmental friendliness and passenger comfort. Also in BRT systems, passengers spend most of their times in vehicles. Therefore, passengers derive much of their impression of the BRT system from their experience with vehicles. Similarly, for passengers who do not use BRT systems, vehicles are the system elements that are most visible.

During the peak hours, traffic is highly congested and traffic speed is very low along the BRT corridor. Car users are impressed by the high average speed of the BRT buses and this has resulted in switch of some drivers to the BRT system.

Safety and comfort of the BRT buses are other parameters that affect the BRT users. Passenger circulation is an important problem in BRT systems; therefore, BRT system operators make some changes in BRT vehicles. These include the provision of additional or wider door channels or the provision of doors on the opposite (left) side of the vehicle. These changes increase the system cost.

Choosing the most appropriate bus types for the BRT system is very difficult for the operators. A careful analysis should be undertaken, otherwise, it will cause additional cost, and also systems' identity and reliability will decrease.

In Istanbul BRT system, 3 types of buses are operated: Citaro, CapaCity and Phileas. Operator of the BRT system, IETT, has a fleet of 400 buses of which 50 are Phileas, 250 are CapaCity and 100 are Citaro.

During the peak hour 315 buses are operated. Capacity and Phileas buses are operated only in the BRT system, Citaro is operated on the entire bus network in the city.

In the peak hours, buses run at capacity and they are mostly overloaded. Passengers generally complain about overloaded buses and this affects the image of the system negatively. Overloading also increases the wear and tear of the parts of the buses and the pavement.

As compared to regular buses operating in the city, CapaCity and Phileas buses have less sitting areas per meter of their length. Therefore, passenger circulation is better and vehicles dwell time is shorter at stations. Although buses are equipped with some intelligent transportation systems (ITS) such as lane assist and precision docking, since the running ways do not have necessary equipment these ITS technologies are not in use.

A comparison of procurement costs of CapaCity and Phileas buses show that the price of a Phileas bus is nearly three times higher than a CapaCity bus. However, a Phileas bus carries nearly 30 more passengers than a CapaCity bus). In other words, 75 Capacity buses would provide the same total capacity of 50 Phileas buses, at a total cost saving of €39 million.

With its 315 buses operating in the peak hours, Istanbul BRT has the 4th largest bus fleet in the world, after Bogota, Ottawa and Jakarta. Moreover, the BRT system in Istanbul ranks 3rd in the world in terms of buses per km of the BRT network (Fig. 3). BRT systems in Ottawa and Bogota have the highest rates in the world (Baker, 2003; ITDB, 2012; Buran, 2011).

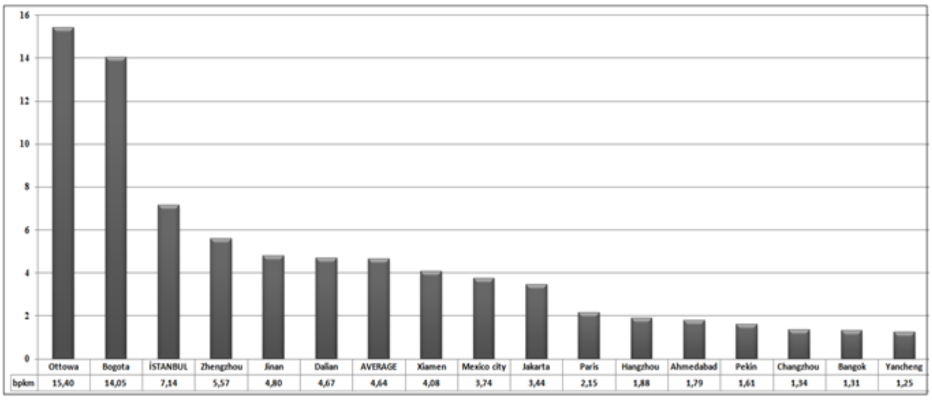

Fig. 3.
Number of buses per network kilometer
Source: Yurdagül, 2012

2.4. Operation Plan

Operation plans of BRT systems are flexible components that affect the performance and the image of the system. Operation plans can be changed according to the needs. Operation plans in BRT systems need to be frequent, direct, easy-to understand, comfortable, reliable, operationally efficient, and above all, rapid. As BRT system is a part of public transportation system, relations with other public transportation systems are very important part of operation plans of BRT (Yurdagül, 2012).

A BRT system should be fast, safe, reliable, comfortable and easy-to-understand. It should be easily integrated with the environmental and physical conditions in the area. Moreover, some land-use and environmental changes may occur along the BRT system corridor. Therefore, public transportation operators have to decide how to change the operation plan accordingly. Although BRT systems have often less line capacities than rail transit systems, BRT systems are more flexible.

Istanbul BRT system is operated 24-hour a day. Frequency of buses varies throughout the day. There are no passing lanes and buses stop at all stations. Average operating speed is nearly the same along the entire route. Since emergency vehicles cannot use running way of the system, especially during the peak hours, solving the problems such as vehicle failures or accidents takes a long time.

Two buses depart from a terminal station back to back during the peak hours, so as to prevent the delay overloaded terminal stations. The system operates at 30-second headway with 315 buses. The fleet is not enough for a seamless operation in the peak hours.

Long bus queues and long dwell times at overloaded stations in the peak hours reduce the travel time savings resulting from the high operating speed between the stations.

Mostly overloaded buses depart from terminal stations especially. Therefore, passengers have difficulties in getting on/off the buses at the other stations that causes long waiting times. For solving the problem, empty buses depart from terminal stations when dwell times affect operation of the system.

2.5. Ridership

Ridership determines the success of BRT systems. High ridership often shows that the system is very effective for the corridor. But operators should make no compromise between service quality and increasing ridership. The most important goal in BRT system operation is to transport a high volume of passengers in the fastest, safest and the most comfortable way.

Istanbul BRT system's ridership has increased significantly since it started operation. The pattern of annual ridership by months is shown in Fig. 4. Ridership increases from January to May, decreases from May to September followed with an increase thereafter. Nearly 54% of the BRT passengers use the system for work and school trips (IETT, 2011). Therefore, ridership of Istanbul BRT system is affected by school terms and holidays. The system carries over 500,000 passengers daily since the 2nd phase opened. In February 2012, ridership of the system was nearly 550,000 in workdays and 415,000 in weekends. The system is operated at capacity in the peak hours since October 2011.

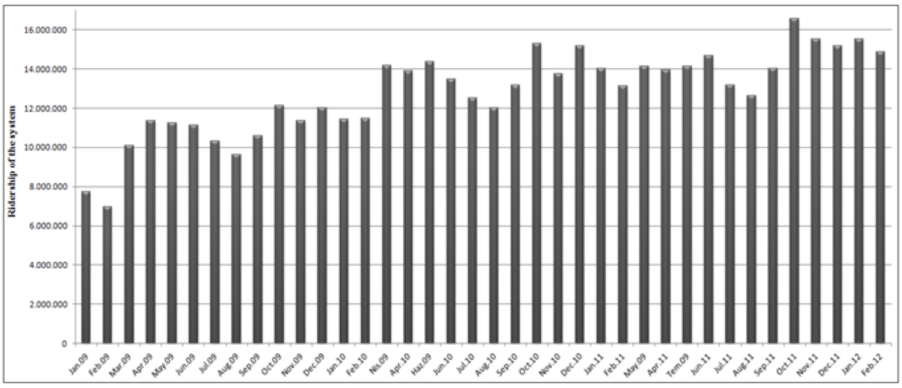

Fig. 4.
Monthly ridership of Istanbul BRT system
Source: Yurdagül, 2012

Fig. 5 presents a comparison of daily ridership per kilometer on some BRT systems in the world. The BRT system in Guangzhou, China, is 22.5 km long and with 35,778 passengers per km, it has the maximum ridership density in the world. The BRT system in Curitiba, Brazil, is 72 km long that is one of the longest BRT systems in the world. It has the second highest ridership density of 31,389 passengers per km. With a ridership density of 13,605 passengers per km, Istanbul BRT system is the 8th BRT system, despite the fact that the system's running way is the 12th longest BRT system in the world. Therefore, this comparison shows that ridership density per km depends on local characteristics, such as population, land-use, etc. (Baker, 2003; ITDB, 2012).

Average commercial speed of the BRT systems in the world is 25.5 km/h. Istanbul BRT system, with its 40 km/h commercial speed, is the 3rd fastest system in the world (Fig. 6) (Baker, 2003; ITDB, 2012).

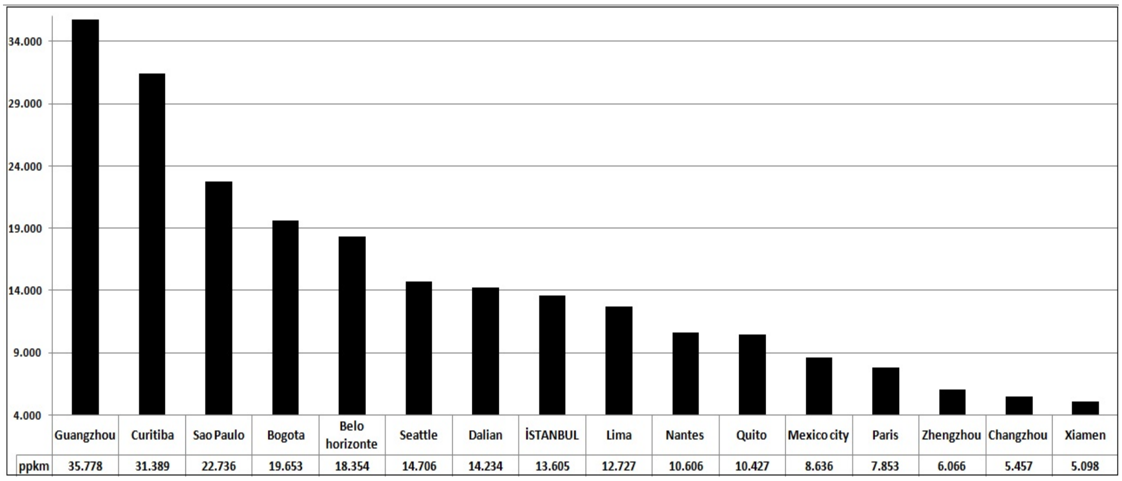

Fig. 5.
Ridership Density of World BRT Systems
Source: Yurdagül, 2012

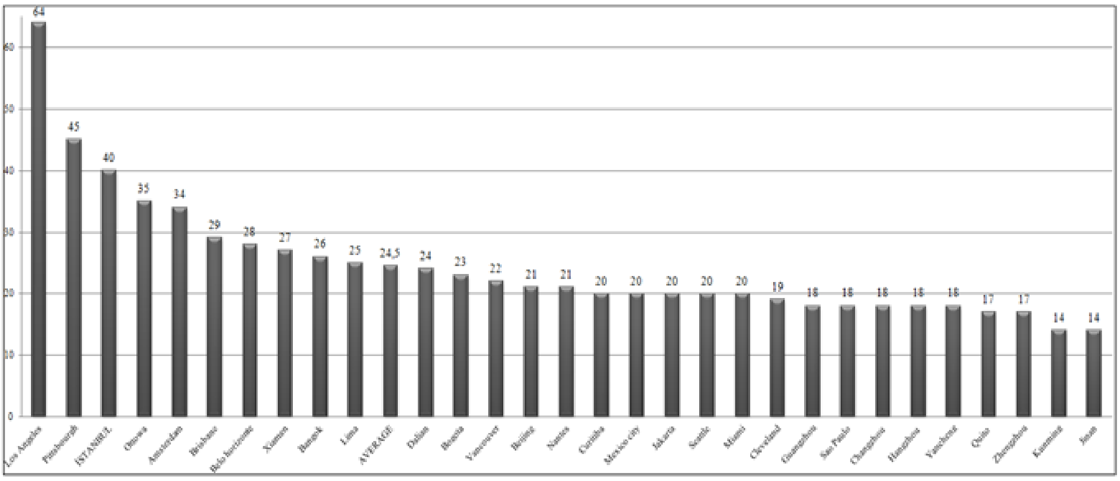

Fig. 6.
Average Commercial Speed of World BRT Systems
Source: Yurdagül, 2012

2.6. Fare collection systems

Success of fare collection systems is determined by fare collection methods, fare collection devices and tariff of fares. It is common to use magnetic fare collection devices, in order to minimize the time cost for passengers. If there are several public transportation operators in the city, integrated fare collection systems should be used for the integration of the public transportation systems (Yurdagül, 2012).

Closed fare system is used in Istanbul BRT system. All the stations are surrounded by the turnstiles and are kept under control. Passengers pay the fare before entering the station. After midnight, turnstiles are operated at terminal stations; at all other stations, passengers pay the fare in buses. Median running ways and stations make accessibility of the system difficult, but control of fare collection is easier.

Magnetic stripe cards and smart tickets are used for fare collection. Cash, tokens, and/or paper fare are not used since November 2010.

Tariff change by the number of stations travelled. Passengers travelling 3 or less stations pay less than the average of other public transportation systems whereas passengers travelling more than 3 stations pay more. This tariff structure makes the system more expensive than other regular bus routes, because only 7% of passengers travel 3 or less stations. Average number of stations (travel length) that passengers travel is 12 (IETT, 2011).

3. Conclusion

Performance of BRT systems depends on system components, integration with other public transportation systems and regional conditions. Public transportation systems have significant social, economic and environmental impacts in cities. Istanbul BRT system runs along one of the most important transportation corridors in the city and it is integrated with other bus and minibus lines and the subway system. Therefore, the system has played a very important role in the public transport system in Istanbul for about 4 years. Although the system has some drawbacks regarding the running way, access to stations, fare structure and overloaded buses, it has resulted in an average travel time saving of 26 minutes, and 86% reduction in CO_2 emission per trip (Yurdagül, 2012). Most importantly, the success of the system has partly changed the dominant views of decision makers regarding the allocation of road space for the benefit of car drivers.

Segregated running ways of Istanbul BRT system ensure a reliable travel time. There have been some pavement problems since the operation started. Although these problems have been fixed in time, drainage problems still continue and cause some safety issues on rainy days. Moreover, cancellation of road shoulders to introduce two BRT lanes on the D 100 highway has reduced the safety of other motor vehicle traffic.

More than one BRT bus can be accommodated at Istanbul BRT system stations. In the peak hours, buses run at capacity and they are mostly overloaded. Passengers generally complain about overloaded buses and this affects the image of the system negatively. Overloading also increases the wear and tear of the parts of the buses and the pavement.

Passengers have to use overpasses and underpasses to access the median stations. Overpasses were mostly inadequate which affected the system's image negatively when the system began to operate. A number of re-designing and upgrading have been made to improve the service quality of overpasses. BRT stations do not have shelters to protect passengers from the weather conditions.

References

Baker, B. 2003. *Bus Rapid Transit Volume 1: Case Studies in Bus Rapid Transit.* Transportation Research Board of the National Academies: 35-54.

Buran, B. 2011. *Metrobüs İşletme Modeli ve Simülasyon: Avcılar-Söğütlüçeşme Metrobüs Hattı*, Transist 2011, Istanbul.

IETT. 2011; Customer satisfaction questionnaire.

ITDB (The Institute for Transportation and Development Policy), 2012. Available from internet: <http://www.chinabrt.org/defaulten.aspx>.

Gerçek, H.; Demir O. 2007. *Topkapı – Avcılar Metrobüs Projesi ve Yeni Otobüs Alımı Ekonomik ve Mali Fizibilite Etüdü*, Istanbul.

Kumbaroğlu, G.; Arıkan, Y.; Karali, N. 2007. *Karbondioksit Salımları Araştırması*, Açık Toplum Enstitüsü, Istanbul.

Tann, H,M. Hinebaugh D. 2009. Characteristics of Bus Rapid Transit for Decision-Making,, In *Federal Transit Administration (FTA), Project No: FTA-FL-26-7109.2009.1*.

Yurdagül, E. 2012. *İstanbul Avcılar – Söğütlüçeşme Metrobüs Sisteminin Bileşenlerinin Değerlendirmesi ve Dünyadaki Metrobüs Sistemleri ile Karşılaştırılması;* Master Thesis; Istanbul Technical University.

VEHICLE DEPRECIATION CAUSED BY STOP-AND-GO SITUATION IN DHAKA CITY

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Abstract: With the present growth of vehicle, question rises for Dhaka Metropolitan City whether it is possible to have a desired travel speed due to stop-and-go situation. Weak infrastructure has led the heterogeneous mixing of vehicle along with non-lane based movement and no access control. Vehicles plying on the road are facing various problems. One major problem is the accelerated vehicle depreciation and increasing operational and maintenance cost. In this regard, a comprehensive study was undertaken to find out the problems associated with the frequent vehicle interruption. Observation methodology was used to count the number of interruptions of different types of vehicle, where it was found that at congested peak period on average the number of interruption of a particular vehicle is almost 3-10 times as compared to free flow condition. It was also appeared that the extent of peak period in Dhaka city is ever increasing and average vehicle travel speed is reduced to almost 8 kmph. In order to assess the extent of vehicle depreciation caused by the stop-and-go situation, a broad questionnaire survey was conducted among the vehicle owners as well as in various garages. Findings of this research along with appropriate remedial measures would be presented in the paper.

Keywords: Heterogeneous traffic, Interrupted traffic movement, Traffic stop-and-go situation, Vehicle depreciation, Bangladesh

1. Introduction

Dhaka, the capital of Bangladesh has been considered as the heart of the country. It is one of the fastest growing cities in the world experiencing an ever increasing influx of people from across the country, which has pushed for so many recent steps of modernization in transportation sector. But present situation is more complex here as compared to other countries. Traffic composition in Dhaka is far more complicated with heterogeneous mixing of motorized and non-motorized vehicles. Only 8% of the total area is occupied by road. Local roads are connected with main roads maintaining no hierarchy. With the present growth of vehicle (over 10%) (Uddin et al., 2008), roads in Dhaka city remain motionless for hours and vehicle faces interruptions frequently before reaching destination.

A number of factors contribute to the interruption on road in Dhaka city. Traffic congestion is predominant here, it is that saturated condition on road when the number of road user increases, and is characterized by slower speeds of vehicle and increased vehicular queue. Also sudden interruptions by roadway environment, non-motor activities, uncontrolled movements of non-lane based vehicles etc. are observed. As a result, movements of the vehicle cannot be smooth, resulting stop-and-go situation. Longer trip time amplifies the pressure on economy halting the increasing number of road users (mainly commuters and students). Also drivers have to perform frequent braking, which causes sudden stop of vehicle after every short distance and resulting impact often ends up with stopping causing serious vibration along the body of heavy vehicles, like buses. Eventually, this stop-and-go situation leads to frequent repair or alteration of vehicle parts, thus accelerates vehicle depreciation. An extensive study on this traffic stop-and-go situation will help to reveal the real situation with respect to trip time prevailing on road and find out the depreciation occurs in different types of vehicle in Dhaka city.

2. Effect of stop-and-go situation

In Dhaka, supply constraints contribute to major problem of smooth flow of vehicles. Though Dhaka metropolitan area is the area under the jurisdiction of the Dhaka Metropolitan Police, it is further defined by the Dhaka Metropolitan Development Plan (DMDP). According to DMDP, the road proportions in Dhaka are - primary road 6.7%, secondary road 3.7%, feeder 5.21% and other narrow roads 84.6% (Bhuiyan, 2007).This is very meager amount as compared to travel demand.

Factors like vehicle composition, lack of lane discipline, rampant violation of right-of-way, random pedestrian behaviors have led any type of solution of existing poor traffic situation to a great dilemma. Traffic stop-and-go situation is a direct consequence of these factors; which results in longer trip times, sudden serious vibration and discomfort to passengers, rear end and side-on collisions.

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Along with these short term effects, many long term effects are observed resulting in damage of vehicle performance. Vehicle safety is directly linked with vehicle brake system and tyre. It is to be noted that from a research on accidents on Jamuna Multi-purpose Bridge, it was found that 10% of the total number of accidents during the period of 01-01-99 to 30-04-04 occurred due to brake failure and 46% due to defective tyre (Hoque et al., 2007). Also according to research on safety consciousness toward buses by the Society of Automotive Engineers of China, among 12 factors, poor brakes (33.4%) were of one of greatest public concern (Lin, 2010). Vehicle brake must be maintained at all times to ensure the safety of the people in vehicle and everyone on the road. It is reported in a research paper (Choudhury, 2006) that if vehicle brake can be kept defect less, 60% improvement of road accidents will happen. Pneumatic tyre is also badly affected by the sudden interruption and heat generation by friction between pavement and tyre. It hinders durability of tyre and noticeable change in performance occurs.

3. Methodology

STP (Strategic Transport Plan, 2005) study showed that 22% trips in Dhaka are made by walking, 29% by rickshaw, 31% by transit (bus, rail) and 18% by non-transit modes (private cars). As city buses are one of the major means of transport, both counter based and non-counter based (local) buses were included in the research. Another two major types of vehicle (human hauler and private car) were chosen for the study. In Fig.1, chosen routes for undertaking survey are shown, while selected vehicle details are presented in Table 1.

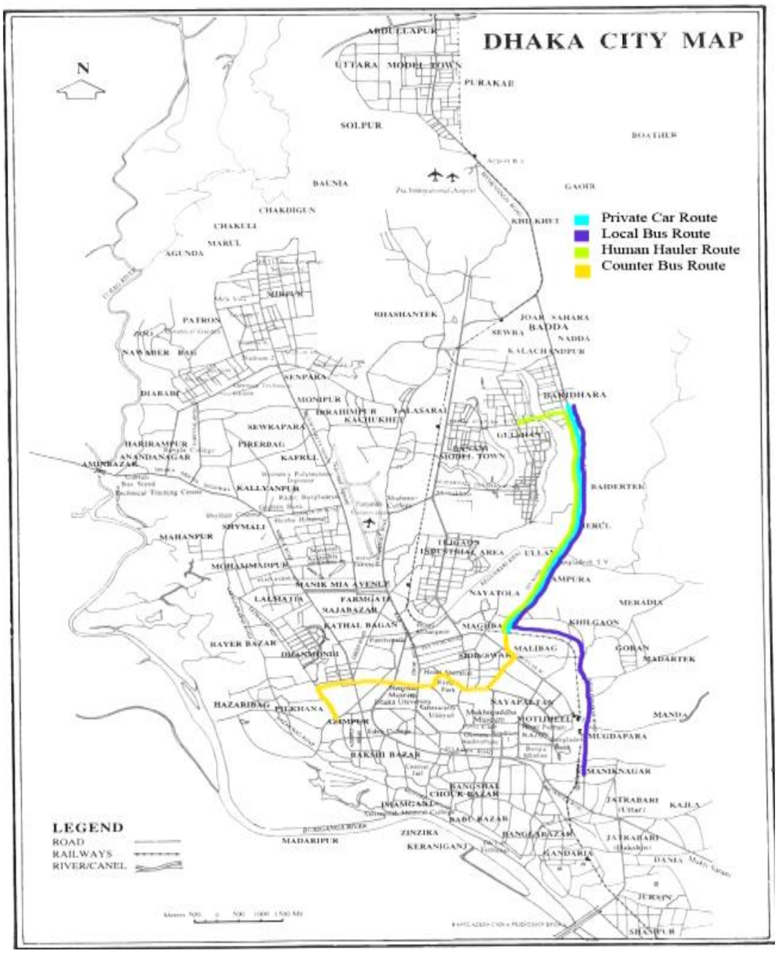

Fig. 1.
Routes chosen for survey

Table 1
Vehicle modes, types, name of company, study routes in Dhaka city

Vehicle modes	Vehicle types	Name of company	Routes
Counter bus	Large bus	Falgun Paribahan	Azimpur Bus Stand to Malibag Level Crossing
Non-counter bus (Local bus)	Mini bus	Turag Paribahan	Bashundhara Residential Zone Gate to Maniknagar
Non-counter human hauler	Human hauler	Bondhu Paribahan	Malibag Level Crossing to Gulshan 2 Junction
Passenger car	Motor car	-	Bashundhara Residential Zone Gate to Malibag Level Crossing

3.1 Delay Study

To find out the trip delayed under various flow conditions and by different types of vehicle category, a delay study survey was conducted by "Random Car Selection Method" for a week with digital stop watch (accuracy up to 0.01 second).

3.2 Determining Number of Interruptions

For comprehensive detailing of the number of interruptions for a particular distance, "Observation Methodology" was followed without interrupting vehicle flow. Any reduction in speed and change in movement was considered as the application of brake. Data had been taken for more than a week (including holidays). To observe interruption at uninterrupted flow condition, data was collected in the morning off-peak lean period.

3.3 Face-to-Face Interview

An extensive questionnaire survey was conducted on total 112 randomly selected drivers to enlist the factors of depreciation of vehicle. As an indicator of accelerated depreciation of vehicle parts, another prime concern was finding the observed life of brake parts (brake shoe, brake pad) and tyre. Drivers were questioned when vehicles were at rest.

3.4 Tyre Condition Survey

Detailed tyre condition survey of total 50 vehicles was conducted to find the tyre condition of urban vehicles. They were categorized as 'Good', 'Fair' and 'Poor' condition as per following qualitative terms:

Good – tyre is perfectly skid resistant, properly inflated and treads are deep and clear.
Fair – tyre is an almost good condition, skid resistant and treads are fair to perform satisfactory break.
Poor – tyre is repaired by poor local vulcanization with mixed rubber. Treads are almost worn out.

4. Data Collection and Analysis

4.1 Drivers' perception study

One of the major objectives of the research was to find out the ways of accelerated vehicle depreciation from the view point of both Dhaka intra-city and intercity heavy vehicle drivers. Accordingly a perception study was conducted among the 112 bus-truck drivers. The data and drivers' observations are summarized in Table 2.

Table 2:
Major causes of vehicle depreciation reported by drivers

Major causes	Dhaka city bus drivers		Inter district bus and truck drivers	
	No.	%	No.	%
Competitive behavior	7	14	6	9.7
Roadway environment (inconsistent or faulty roadway alignment and geometry)	5	10	17	27.4
Poor vehicle maintenance practice	3	6	8	12.9
Uneven road surface	13	26	18	29
Poor traffic condition or stop-and-go situation caused by excessive vehicular load, uncontrolled mix of NMVs & other slow moving vehicles, random pedestrian crossing, unrestricted use of road for non-motor activities etc.)	22	44	13	21
Total number of driver interviewed	50	100	62	100

From Table 2, it was clear that the majority (44%) of urban drivers considered that poor traffic stop-and-go situation is mainly responsible for the accelerated vehicle depreciation. While as per the long route vehicles' drivers, it was identified as the third contributing factor (21%); they think undulated road surface with random potholes and heaps were the most critical factors for rapid vehicle aging process. It appeared from this perception study that in urban area, traffic stop-and-go situation, where drivers are compelled to apply brakes, clutches, accelerator frequently and gets unwanted vehicular hit and side swiping type friction, is the most critical factors for accelerated wear and tear of vehicle parts.

4.2 Extent of Traffic Stop-and-go Situation

To understand the extent of stop-and-go situation and its adverse impact on vehicle, travel time survey and number of interruption along the study routes were observed simultaneously. For reliable estimates of interruptions of a particular vehicle during one week, studies were undertaken both at week-days and weak-ends. Numbers of vehicle interruptions data were used for assessing the average life expectancies of tyre and brake of vehicle. Average of both the travel times and number of interruptions data are collated for different vehicle categories and presented in Table 3. Same data is graphically depicted in Fig. 2.

Table 3
Average travel time and average number of interruptions

Vehicle category	Travel distance	Average travel time at			Average number of interruptions at		
		Free flow	Peak hour flow		Free flow	Peak hour flow	
			Typical week-days	Typical week-ends		Typical week-days	Typical week-ends
Counter bus	6.7 km	19 min 35 sec	49 min 42 sec	37 min 36 sec	20	128	65
Local bus	11.1 km	33 min 9 sec	53 min 9 sec	51 min 2 sec	39	143	79
Human hauler	6.6 km	18 min 35 sec	47 min 47 sec	31 min 59 sec	38	177	120
Passenger car	7.2 km	9 min 56 sec	33 min 12 sec	19 min 34 sec	10	96	41

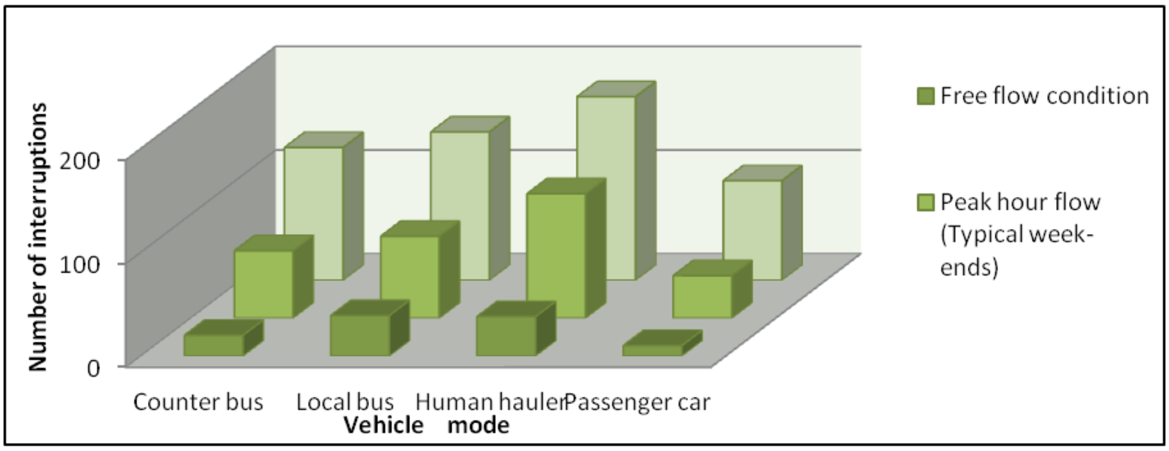

Fig. 2.
Comparison of number of interruptions

From the data presented in Table 3, it is evident that as far as travel time and number of interruptions are concerned, no direct linear correlation can be established between these two parameters. It is also observed that even during week-ends a good number of interruptions occurred in Dhaka city, particularly at peak hours. From illustrative diagram of Fig. 2, it is found that numbers of interruptions in week-days are almost 3-10 times higher than that of free flow condition. For week-ends, almost 2-4 times higher interruptions are recorded which is contrary to common belief that roads are almost frictionless in week-ends. Along with these frequent disruptions, number of hard braking incident increases which amplify the magnitude of vehicle depreciation.

Table 4 shows the calculated average journey speed in km/h unit from Table 3.

Table 4
Average journey speed (kmph unit)

<table>
<tr><th colspan="2" rowspan="2">Average journey speed at</th><th colspan="4">Vehicle types</th></tr>
<tr><th>Counter bus</th><th>Local bus</th><th>Human hauler</th><th>Passenger car</th></tr>
<tr><td colspan="2">Free flow</td><td>20.65</td><td>20.1</td><td>21.3</td><td>43.5</td></tr>
<tr><td rowspan="2">Peak hour flow</td><td>Typical week-day</td><td>8.1</td><td>12.5</td><td>8.3</td><td>13.0</td></tr>
<tr><td>Typical week-ends</td><td>10.8</td><td>13.1</td><td>12.4</td><td>22.1</td></tr>
</table>

For public buses, it was observed that average peak hour journey speed remains almost 8 kmph, except for local bus. Half of the survey route (Malibag level crossing to Maniknagar) was found with less friction increasing the average journey speed of local bus. Observed travel speed of first half route was around 7 kmph, which led to a belief that this speed range of 7-8 kmph is expected during peak hour for every public vehicle. These poor travel speeds of vehicles may be considered as one of the slowest while average speed in Bangalore, Bangkok, Beijing and Singapore had been 12, 15, 18 and 34 kmph respectively (Azad, 2010). Thus prevailing interrupted flow condition in Dhaka hinders the efficiency of public transport leaving no significance difference in operating speeds between motorized vehicles and NMVs.

4.3 Vehicle Part-wise Analysis

4.3.1 Brake System Depreciation

Drivers confident depend mainly on brake system. Of the two main brake systems (disc and drum brake system), for passenger cars, the front axle is equipped with disc brake system, while rear axle has drum brake system. For heavy vehicles, drum brake system is fitted with both axles. Sudden friction causes metallic sounds from faulty braking system, which acts as an indicator of brake maintenance or replacement as brake system follows a gradual process of deterioration. Table 5 displays related findings from the field.

Table 5
Vehicles causing sounds while braking

Number of vehicles	Vehicle types							
	Counter bus		Local bus		Human hauler		Passenger car	
	No.	%	No.	%	No.	%	No.	%
Causing sound while braking	11	73.3	8	66.7	5	50	1	7.7
Causing no sound while braking	4	26.7	4	33.3	5	50	12	92.3
Total	15	100	12	100	10	100	13	100

To meet the ever growing travel demand, little time is found to repair a vehicle after returning to garage. Owners profit earning mentality worsens the situation. As a result, defective vehicles are very common on the roads of Dhaka. Table 5 reveals that number of counter buses was highest (73.3%) causing excessive noise while braking, whereas 66.7% of the local buses and half of the human haulers were producing sounds. This reveals that for counter buses, brake maintenance frequency is relatively poor. On the contrary, passenger car owners are more concerned about safety and comfort. Periodic checking and immediate replacement of faulty parts contribute to the longer performance of brake system for cars.

Field inspection revealed that, for drum brake system, standard life of a good brake shoe is around 2 years. Despite the fact that vehicle parts durability is related to mileage it ran, collected data was time based due to lack of time and reliable field sources. Table 6 clearly shows that due to excess deterioration of brake shoe, observed life is almost half of the expected life for public vehicles. Many owners expect to save budget by buying poor brake shoes. It was found from this investigation that poor durability of these shoes threatens the safety issues by deteriorating within a very limited time compared with the good quality brake shoes.

Table 6
Average lifetime of brake shoe (collected from brake workers)

Average lifetime of	Vehicle types			
	Counter bus	Local bus	Human hauler	Passenger car
Good quality brake shoe	6-8 month	6-8 month	6-8 month	2 year
Poor brake shoe	4 month	2-4 month	2 month	1 year

Field investigation revealed that human haulers caused maximum number of interruptions. Hence it was quite obvious that the life expectancy of brake shoe for human haulers would be the lowest of all, Table 6 reflects the same.

For disc brake, average lifetime of a genuine brake pad is considered to be 1 year. But for almost all vehicles in Dhaka, brake pads last for a minimum of 3-4 weeks for large buses to a maximum of 6-8 months for passenger cars.

4.3.2 Tyre Depreciation

Due to lack of periodic resurfacing of the flexible pavements, main roads in Dhaka are filled with enormous potholes, undulations etc. Shocks from this uneven road surfaces are absorbed by tyres, whose durability is inversely affected by frequent interruptions. Data of front tyre conditions of urban vehicles from tyre condition survey is organized in Table 7.

Table 7
Tyre condition survey: front tyre

Vehicle Category	Front tyre (left)								Front tyre (right)							
	Good		Fair		Poor		Total		Good		Fair		Poor		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Counter bus	8	53.3	2	13.3	5	33.3	15	100	8	53.3	2	13.3	5	33.3	15	100
Local bus	3	25	8	66.7	1	8.3	12	100	3	25	7	58.3	2	16.7	12	100
Human hauler	1	10	5	50	4	40	10	100	3	30	5	50	2	20	10	100
Passenger car	10	76.9	3	23.1	0	0	13	100	6	46.2	7	53.8	0	0	13	100

As rear wheels of large buses are dual wheel with single axle, condition survey result for rear wheel was different from front wheel, which is represented in Table 8.

Table 8
Tyre condition survey: rear tyre

Vehicle Category	Rear wheel type	Rear tyre (left)								Rear tyre (right)							
		One good and one fair		Both fair		One poor		Total		One good and one fair		Both fair		One poor		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Counter bus	Dual wheel single axle	1	6.7	10	66.7	4	26.7	15	100	1	6.7	7	46.7	7	46.7	15	100
Local bus		1	8.3	3	25	8	66.7	12	100	0	0	4	33.3	8	66.7	12	100
		Good		Fair		Poor		Total		Good		Fair		Poor		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Human hauler	Single wheel single axle	1	10	4	40	5	50	10	100	0	0	4	40	6	60	10	100
Passenger car		7	53.8	4	30.8	1	7.7	13	100	6	46.2	7	53.8	0	0	13	100

Due to motives of maximum profit earning, public vehicle owners are reluctant about the tyre durability, which depends on level of maintenance. Table 7 reveals that front tyres (both left and right) of maximum number of counter buses were good (53.3%). But maximum tyres were found in fair condition for local buses (66.7% of left and 58.3% of right) and human haulers (50%). For rear tyre also it is almost clearly seen from Table 8 that local buses and human haulers are neglected from regular maintenance and periodic checking. 66.7% of the rear tyres (both left and right) of local buses (dual wheel) were inspected with one poor tyre. While for human haulers, 60% of rear right tyres of were poor. This alarming situation can lead to serious fatal accidents anytime on a busy road as these vehicles move through both peak and off-peak hours in Dhaka. Tyre maintenance of counter buses are of better quality, so higher proportions of rear tyres were of ‘Both fair’ (77% of rear left and 54% of rear right) quality.

Another field investigation was conducted to find the observed average life expectancy of tyres. Standard life of a tyre is generally given in mileage, on the contrary collected field data of life expectancies were time based. Attempt was made to convert the time based life expectancies of a tyre to mileage by knowing the number of trips per day completed by that vehicle.

Total kilometer driven by a tyre =
(Observed lifetime of that tyre) X (number of trips within that time) X (route length in kilometer per trip)

Obtained value is presented in Table 9. Standard lifetime of tyre of passenger car which was selected for the survey was considered 60000 km. For larger vehicles’ tyres, more mileage was expected. But excess application of brake directly resulted in less durability of tyres.

Table 9
Average life expectancy of tyre

Average life expectancy of	Vehicle types			
	Counter bus	**Local bus**	**Human hauler**	**Passenger car**
Good quality tyre	Less than 47000 km	Less than 25000 km	-	Less than 45000 km
Relatively poor quality tyre	Less than 27000 km	Less than 15000 km	Less than 19000 km	Less than 30000 km

5. Conclusion and Recommendation

Traffic stop-and-go situation is a direct consequence of inequity between demand and supply. There is no doubt that with prevailing weak infrastructure and limited road spaces in Dhaka, hardly any solution can be provided to satisfy the conflicting needs of different road users. As demand is rising, appropriate solution in an overly populated city like Dhaka within shortest possible time is an uphill task. A possible solution may be considered to grow awareness among people about using public vehicle during peak hour to keep the vehicle number minimum on road. Recent trend of registered vehicle in Dhaka city shows a rapid increase in number of small cars and motor cycles. Future policy makers should give a restriction of number of small vehicles. Also time restriction of using private cars and motor cycles on road may impose a positive impression to solve present situation.

Side frictions like illegal parking, roadside non motor activities, non-station based boarding of vehicle of the roads contribute to the significant number of disruptions. It can be said from experience that more rigorous punishments of drivers and road users will not substantially reduce such friction. Sincerity and cooperative mentality raised by repetitive social awareness campaigns will reduce the stress on road.

Introduction of fitness checking at six months interval may help current situation as significant number of parts deteriorate within less than a year. Singapore, with its highly sophisticated test system, specifies inspections every six months for public service vehicles (PSVs), heavy goods vehicles (HGVs) and taxis (Hoque et al., 2007).

In Dhaka, scope of developing integrated transport system by introducing circular waterways connecting the surrounding rivers and increasing the mobility of the rail network with suburban areas prevails. The more passenger one can deviate from road in Dhaka, the easier it will be for the vehicles on road to move without interruption.

Awareness of the vehicle owners is seriously recommended to ensure the in-time replacement of defective parts. Availability of good quality spare parts is to be ensured for smooth maintenance practice. Effective control on local market to ensure the availability of good quality parts is to be emphasized for sustainable development.

Finally, effect of defective vehicles is not financially viable, socially equitable or environmentally friendly. Import of foreign supply of vehicle parts increases with the growth of maintenance frequency. The rising number of defective vehicles contributes to the rapid aging of relatively newer vehicles which acts like a vicious circle. Huge economic losses are incurring which need to be quantified. Thus with all these recommended steps there come great challenges for the upcoming years for the government of Bangladesh. Only strong determination and long term planning of the government as well as participation of local road users can ensure smooth flow of vehicles on road and longer durability of vehicles parts, which will reflect through better economy of the country and less fatalities on road in future.

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References

Azad, M.A.S. 2010. The Traffic System of Dhaka City and Effective Utilization of Road Space. Available from internet: <http://www.asfiazad.wordpress.com/4/>.

Bhuiyan, A.A. 2007. *Study on Bus Operation in Dhaka City, Report for Air Quality Management Project*, Department of Environment (DOE), Government of the People's Republic of Bangladesh. 9 p.

Choudhury, S.K. 2006. Road Accidents Caused due to Defective Motor Vehicles and Their Remedial Measure. In Proceedings of the *International Conference on Road Safety in Developing Countries*: 384-386.

Hoque, M.S.; Hasan, M.R. 2007. Involvement of vehicle factors in road accidents, *Journal of Civil Engineering (JCE)*, The Institute of Engineers Bangladesh (IEB), Vol. 35(1): 17-27.

Lin, S. 2010. Automobile Traffic-Related Problems and Vehicle Technology Policies in China. *Working paper of Institute for Technology*, Enterprise and Competitiveness, Doshisha University. Working Paper Series 10-05: 24 p.

Uddin, A.N.; Chowdhury, T.I.; Shahjahan, M. 2008. 3rd-EST-Forum Bangladesh Country Paper Presentation. Available from internet: <http://www.uncrd.or.jp/env/3rd-regional-est-forum/doc/13_Bangladesh.pdf>.

Session 3: Transport Safety and Security

COMMON STANDARDS FOR TRAINING OF EXPERTS ON ROAD SAFETY - RELEVANCE FOR SECONDARY ROADS

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Abstract: European Union's legislative mandate on road infrastructure safety is limited to the cross-border network. In this framework was issued the Directive 2008/96/CE on road infrastructure safety management. The implementation of the Directive's guidelines is mandatory only for the major European cross boarder highways (TEN-T), while it is well known that the highest number of fatalities occurs on the "secondary roads" not only in Europe but worldwide. To encourage Member States to apply the same guidelines also on national and regional road networks, the European Commission co-financed a study with the aim to extend the Directive's approach through a common training and education of road safety auditors and inspectors, entitled to practice at national and international level. This approach is a model in every situation where there is a need to train and educate a new generation of road safety professionals. The shared procedure will lead to a common standard of infrastructure safety management, with the appropriate flexibility to be adapted to specific local situations. The high replicability of the study's results and recommendations will allow a number of European and non-European central and local Authorities to set up their own training and certification system. The basic training documentation resulting from the project can be adapted to be used wherever requested and needed, where urgent upgrade and maintenance of the infrastructure asset is badly needed.

Keywords: Road Safety; Safety Inspectors and Auditors; Infrastructure design and maintenance.

1. Introduction

Road infrastructure can contribute deeply to the safety of transport users. Its contribution can be enhanced and increased by a responsible process of design, construction and maintenance of the roads, in order to keep their safety level up-to-date at all times.

To this end the European Union has published guidelines on the kind of audits and inspections necessary to ensure the right level of construction and maintenance of European roads.

European Union's legislative mandate on road infrastructure safety is limited by the TFEU[2] to the cross-border network (so-called TEN-T, Trans European Network in Transport), consisting of major multimodal cross-border corridors, whose road components are mainly motorways and highways.

The European Directive 2008/96/EC issued on 19 November 2008 introduces a comprehensive system of road infrastructure safety management. It addresses projects for the construction of new road infrastructure or substantial modifications to the existing network which affects the traffic flow within the trans-European road network.

The Directive focuses on the following:

1. Road safety **impact assessment**: a strategic comparative analysis of the impact on the safety performance of the road network of a new road or a substantial modification to the existing network. The assessment is to be performed at the initial planning stage before approval of the project.
2. Road safety **audit**: an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation) as to identify, in a detailed way, unsafe features of a road infrastructure project.
3. **Ranking of sections** with high accident concentration: a method to identify, analyse and rank sections of the road network which have been in operation for more than three years and where a large number of fatal accidents have occurred. **Network safety ranking**: a method for identifying, analysing and classifying parts of the existing road network according to their potential of safety enhancement; the purpose is to target investments to the road sections with the highest accident concentration and/or the highest accident reduction potential.
4. **Safety inspections**: an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety as a preventive tool.

Safety must be integrated in all phases of planning, design and operation of the road infrastructure.

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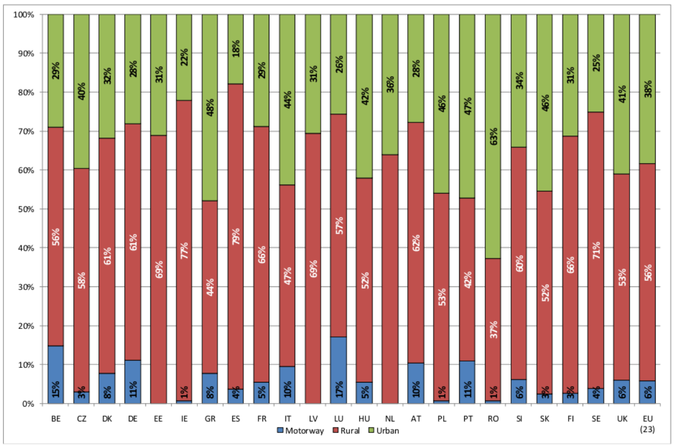
[2]Treaty Founding the European Union art. 9 to 100 under Title VI,

Several Member States already use well experimented road infrastructure safety management systems. These countries should continue using their existing methods, in so far as they are consistent with the aims of the Directive.
Member States wishing to create their own safety management system could use the tools provided by the research project “Ripcord-Iserest”[1].
The recently terminated project ‘Pilot4Safety’ provides the needed material for education and training of road safety experts, based on a commonly acknowledged international curriculum.

Member States had to:

- ensure that, if they do not already exist, training curricula for road safety auditors are adopted by 19 December 2011;
- bring into force the laws, regulations and administrative provisions necessary to comply with the Directive by 19 December 2010;
- ensure that guidelines (measures which lay down the steps to be followed and the elements to be considered in applying the safety procedures), if they do not already exist, are adopted by 19 December 2011.

Member States’ guidelines will be made available on a public website.
When adopted by the Member States, the Directive applies only to the part of the TEN-T road network under the responsibility of the Member State.
In the European Union, only 6% of road accident fatalities in 2008 occurred on motorways, and 56% in accidents on rural roads [2][CARE, 2010] (Fig. 1).



Countries included: BE, CZ, DK, DE, EE, IE, GR, ES, FR, IT, LV, LU, HU, NL, AT, PL, PT, RO, SI, SK, FI, SE, UK

Source: CARE Database
Date of Query: October 2010

Fig. 1.
Fatalities by road characteristics
Source: CARE Database, October 2010

To improve road safety and road infrastructure safety management, the pilot study PILOT4SAFETY, co-financed by the European Commission – DG MOVE, is applying the Directive’s approach on selected rural roads in 5 EU regions, to share good practices and define common agreed training curricula and tools for qualification of road safety personnel.

2. Methodology

The project is focused on Road Safety Audits (RSA) and Inspections (RSI) out of the 4 measures indicated by the Directive, as these two procedures greatly influence the infrastructure road safety factors. These preventive tools for projects of new infrastructure and maintenance of existing roads can be applied in the short term without any network analysis, but need an adequate training of the auditors and inspectors.

FEHRL (Forum of European National Highway Research Laboratories) was the project coordinator and the training supplier via its member Institutes.

Generalitat Catalunya (Spain), Randers Municipality (Denmark), Astral Lazio (Italy), Region of Central Macedonia (Greece), and CDV (Czech Republic) participate directly with their road safety experts in the training and the subsequent RSA and RSI pilot applications. Prefecture of Pieria Greece), the Walloon region and the Brussels-Capital region (Belgium) also joined the initiative by participating in the training.

[1] http://www.transport-research.info/web/projects/project_details.cfm?ID=35434
[2] 2 lanes paved roads, outside the urban area

Further European regions have expressed their interest to join the initiative and an exchange of experiences has been established with another EU funded project (BALTRIS) focused on road safety in the Baltic regions.

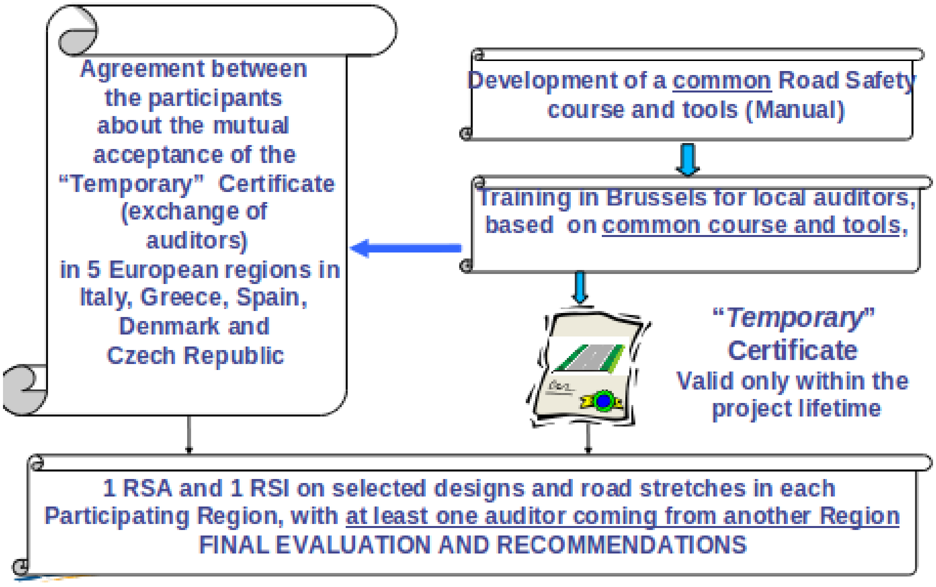


Fig. 2.
Scheme of the Pilot4Safety Approach

The training was designed with a modular concept: a preliminary part presented the road safety basics; 2 modules progressively detailed the RSA or RSI procedures, and a final practical part aimed at checking and consolidating the acquired knowledge.

PILOT4SAFETY
Task 5: RSA training Plan

Pilot4Safety

RSA training Plan

Preliminary part - Topics
• Accident analysis and statistics, Accident causation and risk assessment • Principles of road safety engineering • Characteristics and requirements of different (secondary) road users • Characteristics of different secondary road types • Characteristics of different intersection types • Road Safety Engineering Measures and design standards • Fundamental Safety Elements • Typical safety deficiencies + safety treatments
Basics about RSA
• What is a road safety audit? • Why do we need a road safety audit? • Sharing participants past experiences in audits • Benefits and costs of RSA • Legal aspects (Directive 2008/96/EC) • Participants and responsibilities in RSA • Data requirements
The audit process
• RSA procedures and stages • Checklist: reason - choice - structure - use • Tools and methods (e.g. RSA software, simulation)
Practical part
• Exercise: "Different audit stages" • Site visits / Checking Plans • Findings + Reporting • Evaluation and discussion on the exercises • Final discussion and evaluation (feedback questionnaire)

Fig. 3.
The four modules of the RSA training plan (source: Pilot4SAFETY project)

3. Results

'Pilot4Safety' (Fig. 2 and Fig. 3) aimed to apply the Directive's approaches related to training and certification of Road Safety Experts for the application of Road safety Audit and Road Safety Inspection procedures to selected secondary roads in the EU regions represented in the project. The idea was to share good practices and define common agreed training curricula and tools for qualification of road safety personnel. Verification in field studies took place to check if such qualifications could be reciprocally recognized in five different European Regions, with two field trials for each Region**.**

The **project objectives** were:

- to develop curricula and specific tools for the auditing and inspections of rural roads in EU Regions adaptable to the needs of regional/local road authorities,
- to reach an agreement between the involved Regions about the acceptance of a common training curricula and the exchange of safety experts,

to carry out one Road Safety Audit and one Road Safety Inspection respectively on a design and on an existing road in each participating Region: each safety team includes at least one safety expert from another Region.

Thanks to the project results' high transferability, the general objective was to have a number of Regions applying the same approaches of the directive 2008/96/CE to secondary roads with a consequent reduction in the number of road fatalities, in accordance with the EU specific objectives. The project contributes to the implementation of coherent safety procedures on the whole road network, at Member State level, as well as at EU level.

The expected impact of the Pilot4Safety project was the promotion and further propagation of the tools of the EU Directive 2008/96/CE on road infrastructure safety management on regional roads which are not covered by the Directive.

The final report contains a template for an international certification, developed taking into account the project's results.

Using the Directive as a reference for safety application will allow the road managers to easily extend the application field of the Directive to a larger part of their network, including rural roads.

This will lead to more homogeneous national and EU road safety practices and an extended safety approach to the overall national road network.

The replicable modules of the curricula will allow a more extended use of the training material in both Member States and Neighbouring Countries.

3.1. The Common Curricula

A common standardised approach has been adopted in each project phase: the first draft of the Curricula was prepared by FEHRL. It contained a structured list of items related to basics of road infrastructure safety, RSA, and RSI with details about the number of training hours for each item for a total of 160 hours. After an internal discussion and a specific survey, an updated version of the curriculum was issued taking into account the needs of the different regional road authorities expressed during this consultation process.

It is to be underlined that both the RSA and RSI Curricula foresaw the possibility for the trainees to give feedbacks on the course plan, as well as some specific minor changes in the topics. As the expectations of each single Road Authority have been taken into consideration, the curriculum plan remained as flexible as possible, maintaining the same common approach. More than 16 hours of training has been dedicated to a presentation given by the trainees dealing with the road safety procedures in their regions.

3.2. The "Safety prevention manual for secondary roads"

The aim of the manual is to support the training of road safety auditors and road safety inspectors in the future. It is intended to be used in all upcoming courses, building on the extensive experience gained in the Pilot4Safety project. This manual, already available on the Pilot4Safety website in English, Bulgarian and Slovakian, is composed of the introduction, a general road safety part from several EU research projects, Principles of Road Safety Engineering, a special session on Vulnerable Road Users, as well as two specific Road Safety Audits (RSA) and Road Safety Inspections (RSI) sections. Many useful templates and checklists are annexed at the end.

The pilot project focused on RSA and RSI, but the Directive 2008/96/CE considers as well the following road safety procedures:

- Road safety impact assessment (RSIA or RIA) (strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network),
- Road safety audit for the design stages of roads (RSA) (independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages starting from planning to early operation),
- Safety ranking and management of the road network in operation (incl. management of high risks road sections)
- Road safety inspections for existing roads (RSI) (an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety).

As a basis for training of international safety personnel coming from several EU countries, a clear definition of the relevant procedures and a clear understanding of how these procedures complement each other to achieve an overall road infrastructure safety management has been considered necessary and therefore included in the Manual.

The analyses made and reported during the project activities have shown that the practices are not really standardised and that there are various interpretations on how to conduct them.

There is also no standardised definition, even though there is a kind of common understanding of what a Road Safety Inspection and Road Safety Audit should be.

A comprehensive definition of RSI has therefore been drafted (based on the different elements underlined in the two previous chapters) by the partners and adopted for the project (Table 1).

Table 1
Consolidated definition of RSI as adopted by PILOT4SAFETY

Road Safety Inspection is a preventive safety management tool implemented by road authorities/operators as part of a global Road Safety Management. It is a systematic field study organized sufficiently frequently on all existing roads or sections of roads to safeguard adequate safety levels. It is carried out by trained road safety experts to identify hazardous conditions, deficiencies that may lead to serious accidents. RSI results in a formal report on detected road hazards and safety issues

This definition is the result of the analysis of some relevant references and reflects the common understanding of the RSI procedure. However, the definition also leaves unanswered some very important questions, like the inspection frequency, the use or not of accident data, the independence of the inspection team, the report layout and content. The project activities (RSI on the field) faced these problems which are addressed in the Evaluation Report issued at the end of the project.

While the directive (art. 2) defines RSA as “an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation”, the Pilot4Safety partners have harmonised the concept and adopted the following definition (Table 2).

Table 2
Consolidated definition of RSA as adopted by PILOT4SAFETY

The R**oad Safety Audit** describes a systematic and independent examination of a project designed to highlight potential security issues at the earliest possible stage of planning and construction, to reduce or eliminate these problems and limit the risk to which could be submitted different types of users.

Highlighting problems at the earliest possible stage is an important issue, because it is commonly recognized that the earlier the identification, the higher the number of the audit recommendations that are accepted by the road managers.

The different types of users are mentioned to underline that the audit should take into consideration also the vulnerable road users (VRU) like pedestrians, cyclists and disabled people.

Specific measures for the safety of these user groups are under analysis by ongoing EU funded projects, e.g. uncluttered roads for a shared space between pedestrians, cyclists and motorized users, elder-friendly cities, motorcyclist’s friendly road restraint barriers.

4. Conclusion

A Common European standardized training and certification methodology is achievable, the different local needs are taken into consideration and the methodology is divided in a general part and a specific one related to the local road safety issues.

The discussion related to the international curricula did not raise any particular problem between the international partners, due to a good common understanding of the RSA and RSI basic concepts; the amendments to the final version were only related to minor issues.

The large numbers of existing road safety handbooks, manuals and guidelines have obliged the partners to make a choice during the preparation of the training tool: the approach was towards an easy and practical manual, mainly related to the rural roads, summarizing the main findings of the previous European projects and some selected parts from other road infrastructure safety guidelines. The resulting final handbook responds to all the needs expressed at the beginning of the pilot project.

The training course carried out in English implies an additional pre-selection of the technicians coming from different countries, based on their linguistic skills. This is a problem referring to all situations where the participants to the training schemes come from regions where different languages are spoken. This should be a road authority's concern; however the recent experience has shown that the language barrier, in case of specific technical issues, can be overcome if addressed in advance.

The common training in Brussels has been evaluated as a fruitful experience by the majority of the trainees, particularly for the exchange of experience between road safety personnel coming from different countries. However, once a European common standardized certification methodology is achieved, courses can be carried out locally in the regional language and there will be translated versions of the training handbook and other material.

This pilot initiative should set the basis for a larger one, involving more European regions, to ensure a fine tuning of the main findings and to launch the common European procedure.

Reactions from some Member States on the effectiveness of the action, and the importance of extending the EU Directive to national/regional road networks have been very positive. In the time a significant increase of rural road safety level is expected by the focused training of road safety professionals.

References

CARE European Road Accident Database. Available from Internet:
<http://ec.europa.eu/transport/road_safety/specialist/statistics/care_reports_graphics/index_en.htm>

Cocu, X.,;Adesiyun, A.; Lemke, K.; Polidori, C.; Saleh, P.; Volckaert, A. 2011. *Report on the training in Brussels. Project PILOT4SAFETY, Deliverable D4*

Cocu, X.; Volckaert, A. 2010. Praktische regels voor geslaagde verkeersveiligheidinspecties, Verkeersspecialist nr. 170 (beursspecial), Kluwer.
Directive 2008/96/EC of the European Parliament and of the Council of 19 November 2008 on road infrastructure safety management. 2008. *Official Journal of the European Union*, L 319: 59-67

European Commission - *Towards a European road safety area: policy orientations on road safety 2011-2020* COM (2010) 389 final

Pilot4SAFETY: Pilot project for common EU Curriculum for Road Safety experts: training and application on Secondary Roads. Available from Internet: <http://pilot4safety.fehrl.org/>

Polidori, C.; Cocu, X.; Volckaert, A.; Lemke, K.; Teichner, T. 2011. *Safety prevention manual for secondary roads. Project PILOT4SAFETY, Deliverable D2*

Saleh, P.; Yannis, G.; Vlahogianni, E.; Golias, J. 2010. Road Infrastructure and Safety of Powered Two-Wheelers. In Proceedings of the *Vortrag: World Conference on Transport Research*. Lissabon, Portugal.

Matena, S.; Weber, R.; Ary Huber, C.; Gaitanidou, E.; Vaneerdewegh, P.; Strnad, B.; Cardoso, J.; Schermers, G.; Elvik, R. 2008. Road Safety Audit Best Practice Guidelines, Qualification for Auditors and Programming. Ripcord-Iserest, D4. Available from Internet: <http://ripcord.bast.de/>

RESULTS IN INCREASING SAFETY OF NAUTICAL TOURISM AND TOURISTIC CAPACITES OF THE CROSS BORDER AREA REPUBLIC OF CROATIA AND MONTENEGRO WITHIN IPA PROJECT EU

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Abstract: In the paper are presented results of the IPA project, component II "Joint promotion and increased level of safety of nautical tourism in Dubrovnik-Neretva County and Montenegrin Coast - NauTour". Project in the cross border area Dubrovnik – Neretva County and Montenegrin coast is implemented from Croatian side by Hydrographic Institute of the Republic Institute, as a leading partner of the whole project with the participation of its partner the University of Dubrovnik (Maritime department). On the Montenegrin part, the leading Montenegrin partner is the Hydrological and Meteorological Institute of Montenegro with the participation of its partner the National Tourist Organisation of Montenegro. The most important results related to safety are: establishment of the hydrographic and oceanographic activity in Montenegro and measurement of marinas, production of some charts and plans. Results related to touristic capacity are: issue of the two guides, booklet with cross border nautical routes and web site for boaters.

Key words: EU, IPA, cross-border cooperation, safety of navigation, nautical tourism.

1. Introduction

Through its funds and programs, the European Union (EU) provides assistance to different types of projects and activities. The Instrument for Pre-Accession Assistance (IPA) is one of the programs intended for either EU accession candidate countries or potential candidates in the period from 2007–2013. IPA consists of five components and IPA component II refers to cross-border cooperation. The overall objective of the IPA II Cross-Border Programme Croatia - Montenegro is to improve the quality of life in border regions (Agency for Regional Development of the Republic of Croatia).

One of the first five approved project proposals for Croatia - Montenegro cross-border cooperation is the IPA project "Joint promotion and increased level of safety of nautical tourism in Dubrovnik – Neretva County and Montenegrin coast". Project started in January 2011. The project is planned to be completed in 23 months (by the end of 2012). The total value of the project for both sides is 451,928.36 €.

Overall Objective of the project was to further improve the tourist and nautical potential of Dubrovnik – Neretva County and Montenegrin Coast through their joint promotion as integrated tourist destinations. The Specific Objective was to improve the quality of services and level of safety in nautical tourism in the cross-border area of Dubrovnik – Neretva County and Montenegrin Coast through cooperation of hydrographic institutions, nautical tourism service providers and harbormasters' offices.

1.1 Partnership in the project

On the Croatian part, the leading partner of the entire project was the Hydrographic Institute of the Republic of Croatia (HHI), with the participation of its partner the University of Dubrovnik (Maritime department). On the Montenegrin part, the leading Montenegrin partner was the Hydrological and Meteorological Institute of Montenegro with the participation of its partner the National Tourist Organisation of Montenegro.

Associate partners in the project were the Ministry of Maritime Affairs, Transport and Infrastructure from the Croatian side and the Maritime safety department of Montenegro, Harbour Master's Office Kotor and Marina Porto Montenegro from the Montenegrin part who supported the project through information provision and dissemination and participation in project activities. (Fig. 1)

HHI was the Functional Lead Partner who was managing the project within the whole project area and was coordinating all activities and other partners in project. HM-I was responsible for part of the maritime-safety activities and was the beneficiary of the capacity building activities under result 3.

National Tourist Organisation in MNE provided expertise on the tourism and promotion-related aspects of the project and run the activities connected with promotion. Dubrovnik University provided expertise on nautical tourism and it was responsible for setting up and managing the Web-page and related contents.

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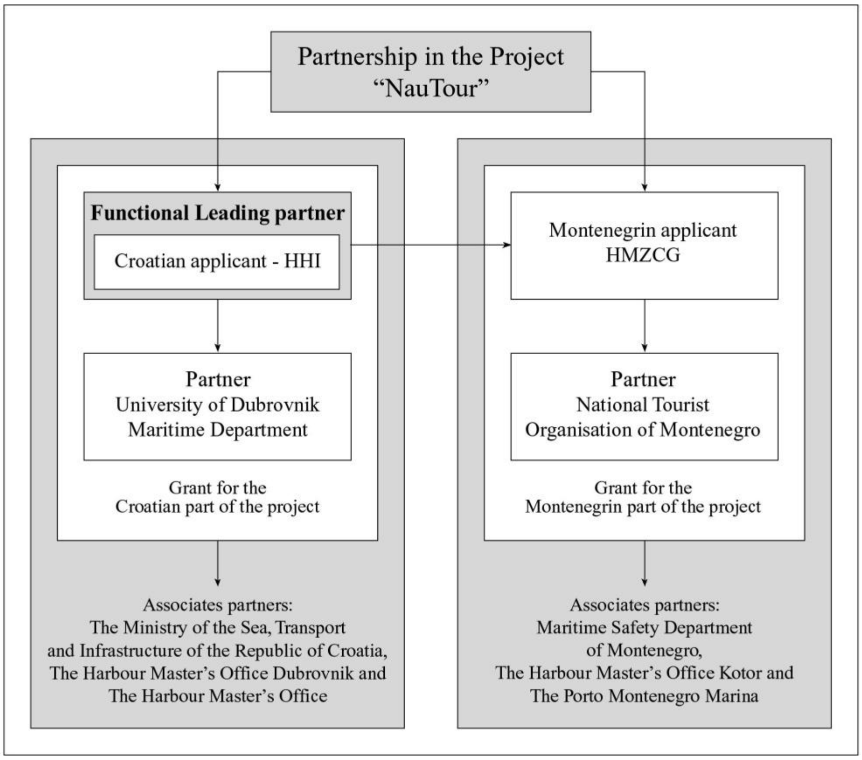

Fig. 1.
Partnership in the project

2. Background and problem analysis

Both Croatia and Montenegro are countries generating large proportions of their incomes through tourism. Nautical tourism is very important part of tourist offer in both countries.

The border areas, Dubrovnik-Neretva County (DNC) and Montenegrin Coast, are interlinked by geographical closeness, historical connections and similarities. However, little (almost nothing) has been done in terms of joint promotion and the two parts of the Adriatic Coast currently function on a rather competitive level, so tourists wishing to travel from one country to another are rarely receiving relevant information about the other side of the border. Both parts of the project area have a tremendous potential for the development of nautical tourism, which is yet to be exploited.

Expectations of nautical tourists are high when it comes to the services and safety of sailing and boating, access to information on tourist attractions and services in the area they are visiting and general quality of service. Study on "Attitudes and Consumer Habbits of Tourists in Croatia" (Tomas. Nautika 2007) has shown that one of the key concerns of the nautical tourists is personal safety and safety of navigation. The research has also shown that nautical tourists are not satisfied with the offer of cultural events, entertainment and sports events in the areas they visit. Moreover, they judge the information on tourist events available in Croatian marinas insufficient. Croatia in general does not have a complete "nautical-tourism product" who would meet the expectations of consumers. Same can be said for Montenegro.

In Croatia, while the basic infrastructural and safety requirements for nautical tourism are met, so far, the comprehensive promotion of the destinations, combining the practical information on navigation with tourist offer in terms of culture, entertainment, traditional products is still in an early stage. In Montenegro, the situation is somewhat worse.

Namely, even in the segment of the basic requirements for maritime safety, Montenegro is still at an early stage of establishing the regular information provision.

Official nautical charts and other nautical publications are not regularly updated and the stocks of the old printed versions are short. The safety of navigation is therefore at risk.

The hydrographic service is institutionally situated in Hydrological and Meteorological Service of Montenegro (HI-M), whose Department for Hydrography and Oceanography has been established in 2008 and currently has neither all the required staff and expertise, nor all the necessary equipment for the hydrographic measurements and preparation of official publications.

While both countries are aiming to develop nautical tourism, cooperation in this area does not exist. The tourists coming to Dubrovnik Coast cannot collect any information on the nearby Montenegrin marinas and services for nautical tourism or on the tourist offer, and vice versa. With this project, stakeholders from both countries will use the opportunity and create joint nautical tourist offer and start regarding the border as an opportunity for tourism, rather than as a threat.

The typical nautical tourist is a highly educated and economically stable person, with high consumer potential and high demands and expectations. Their key concerns during their stay are with the personal safety and safety of their vessel and navigation. They are currently not satisfied with the levels of tourist offer in marinas and with information provision on cultural and other tourist events in the destination. Currently, the nautical tourists coming to the project area lack the following:

1) In Montenegro, they do not have all the needed maritime safety data (nautical charts and publications);
2) In either DNC or Montenegro, they to not have a comprehensive overview of tourism and safety-related information;
3) If they wish to travel across the border, they can not obtain the information material and nautical publications from Montenegro in Croatia and vice versa.

The key problem that this project aims to approach is the lack of joint promotion of nautical tourism and information provision on maritime safety and tourist offer for nautical tourists in the cross-border area of Montenegro and DNC.

This is due to the following 3 groups of issues:

1) There is no comprehensive overview and source of information which would provide easy access to both types of information (safety and tourist information) to the nautical tourists across the border and encourage their interest into the overall cross-border area. In Montenegro, they do not have all the needed maritime safety data (nautical charts and publications).
2) No cross-border nautical routes are designed and promoted. If they wish to travel across the border, they can not obtain the information material and nautical publications from Montenegro in Croatia and vice versa.
There is no cooperation between the relevant stakeholders in the two countries. Service providers such as marinas and charter agencies rarely cooperate even nationally, while no cross-border cooperation exists. They mainly do not see the opportunity that joint promotion represents and are not used to seek common solutions for the similar problems their encounter on a daily basis. Harbormasters' offices are part of national mechanisms and are not focused on cross-border issues, while cooperation between the hydrographic institutions was on hold during the institutional reorganization in the Montenegrin hydrographic services.
3) The capacities for maritime safety related hydrographic services in Montenegro are currently very low due to the lack of qualified staff and equipment.

3. Results of the project

The overall objective of the project was to further improve the tourist potentials of Dubrovnik - Neretva County and Montenegrin Coast through their joint promotion as integrated tourist destinations rich in cultural and natural assets. The project aimed to support the socio-economic development of the whole area through supporting its most propulsive industry: tourism. The project also aimed to generally increase the levels of maritime safety, through improving the safety of navigation of nautical tourists and all other persons navigating in the area.

In order to realise the planned objectives it was necessary to perform a series of activities, like: collect and systematise data on all major natural and cultural sites and tourist services in cross-border area, collect and systematise information important for the safety of navigation in cross-border area.

From the collected data it was necessary to design a web page for leisure mariners that visit the said area, write and publish tourist guide-books of the area for yachts (sailing ships and motor boats) and guide-books for mega yachts, work out cross-border nautical and tourist navigation routes for yachts (sailing ships and motor yachts) and nautical and tourist navigation routes for mega yachts, organise round tables, presentations and promotions of the programme for all activity subjects in tourist and safety segment of nautical tourism and for leisure mariners, organize institutional development and support founding Hydrographic and Oceanographic department within the Hydrological and Meteorological Institute of Montenegro (training for hydrographic survey, hydrographic survey of two marinas on the Montenegrin coast, prepare and publish plans for 3 Montenegrin marinas), etc.

Major results of the project achieved are:

1. Sustainable access to tourist information for nautical tourists on the cross-border area (services, safety, tourist attractions) established

One of the aims of the project was to improve the quality of service of the cross-border area in terms of nautical and tourist services.

Within the project, the safety level in nautical tourism is increased, through the cooperation of hydrographic institutions, institutions that provide various tourist services (marinas and other tourist ports, charter companies), institutions for maritime safety and safety in general (harbour master's offices, port administrations, cross-border maritime police).

The project established a set of comprehensive information sources for nautical tourists, which will give them overview of 4 key groups of issues crucial for their travel through the cross-border area: general overview of the geography, history, culture and tradition of the area; information on tourist offer in relation to nautical tourism; information on maritime safety in the area and suggested cross-border routes.

Publications issued:

a) Tourist Guide for Nautical Tourists to DNC and Montenegro (for smaller and medium-sized boats), Tourist Guide for Mega-Yachts (over 30 m) DNC and Montenegro. Tourist Guides give to domestic and foreign sailors a lot of useful information: an overview of areas - geography, history, culture, tradition and nature, pictures of attractive and typical locations and places, informative map of the area with annotated key locations, chapter for specific tourist harbor and marina with pictures, plans to useful links for boaters etc.
b) Booklet with useful information for navigators, info maps of cross-border area and sailing and boating routes, interactive (5 cross-border routes for sailboats, 4 cross-border routes for motorboats and 4 cross-border routes for Mega-Yachts (over 30 m)). (NauTour)
c) Web-page for nautical tourists is active **(www.nautour.info).** It is designated for boaters (and anyone interested) who visited the project area. Web forum is also active as a place where individuals can get expert answers, and as a place for the exchange of information, ideas and experiences among sailors. (NauTour).

The publications prepared will serve the tourism service providers (staff of the marinas/harbours, charter boat agencies and other tourist agencies) in two essential ways, which are currently missing: 1) it will give them a promotion tool which works to their advantage in a wider area and 2) it will improve their quality of service by enabling them to inform their visitors of all the issues of interest for nautical tourist.

2. Basis for coordination of tourism services providers in nautical tourism (marines, charter agencies) and maritime safety authorities from the cross-border area established

The project set the framework for communication and interaction of the stakeholders in nautical tourism. The project brought them together in the same events and introduces them with the opportunities and models of cross-border cooperation in both nautical tourism and maritime safety. Communication between the two types of institutions (private and public, tourism and safety oriented) is established in order to encourage the potential policy improvements that would benefit the development of cross-border nautical tourism initiatives. They were involved in preparation of project publications so that not only participation, but their ownership of the project results is secured.

3. Capacities of HI-M for conducting the hydrographical measurements and preparing official hydrographical publications enhanced through cooperation with HHI

Institutional strengthening of HI-M, was accomplished through education, practical training, procurement of equipment and conducting of hydrographic survey and production of nautical charts.

Project was designed to support HI-M staff in the Department for Hydrography and Oceanography (DHO) based in Lepetane (Tivat Municipality) in their role as the official hydrographical service of Montenegro. This was achieved through institutional cooperation with HHI, which is a very well established institution with high institutional and professional capacities, by providing a sort of institutional twinning on a cross-border level. HHI supported the HMNMNE staff on 2 levels: supporting their internal institutional organization and development through familiarization with HHI's internal organization and procedures and joint planning of institutional development of HI-M DHO and raising their capacities to perform hydrographical measurements at the level of quality required by the International Hydrographical Organization through provision of equipment, training and practical exercise of measuring 2 marinas in Montenegrin coast (Kotor and Zelenika). Also, as an added value to the project hydrographical measurement of the Kumbor area was made.

During hydrographic measurements (18.09.-02.10.2012.) with the research vessel “Hydra”, common CRO/MNE team has found maximum depth so far measured in the Kotor Bay. Depth was measured near Perast (in waters southwest of Drazin Vrt).

So far max. known depth was measured in 2009 and was 64 m, and a new maximum depth measured during the project research is 68m (The Hydrological and Meteorological Institute of Montenegro).

4. As a result of cross-border cooperation between the institutions involved in the project NAUTOUR, collaboration between CRO/MNE institutions has continued through new EU IPA project application.

Within the Public Second Call for submitting project proposals within the IPA cross-border Programme Croatia - Montenegro, 2007 – 2013 which was opened in December 2011. until March 2012., HHI and MNE partners prepared and submitted project application for measure 1.1. which supports sustainable cross - border networks for joint environmental, nature and cultural protection. Project was applied under name “Jassper”- “Joint Actions for Sea Pollution Prevention“. It’s in the evaluation process. (Cross Border Programme Croatia – Montenegro).

4. Conclusion

As a major result of the project “NauTour” nautical tourist visiting the project area will have an improved level of information they receive on tourist and cultural offer and maritime safety by streamlining all the relevant information into the same sources. The project enabled them to discover the whole cross-border area as a destination interlinked with culture and traditions, by creating recommended cross-border nautical routes, including the tourist and cultural attractions of the area.

Finally, the project improved the level of quality of the maps and publications they receive in the Montenegrin part of the coast by preparing the hydrographic maps of 3 marinas. Staff of the marinas and other harbors of nautical tourism, as well as the charter agencies in the area will be provided with a tool for joint promotion.

The project will improved the quality of information they provide to visitors on culture, tradition and tourist offer, as well as on the safety and service information. 3 marinas will through this project receive new, up-dated hydrographic maps of their area. The ground will be set for them to liaise and share the experiences, problems they encounter in every-day work and ides for cooperation. They will get an opportunity to generate ideas and initiate joint projects in order to improve their offers.

The project results will be sustainable without much financial follow-up. The Web-page will require the continued allocation of personnel to run it. The cooperation between HHI and HI-M will be further defined in their joint participation in other projects from EU and other funds.

References

Agency for Regional Development of the Republic of Croatia. Available from Internet: <http://www.arr.hr/hrvatska-crna-gora-g40.aspx#rptPag(1)>

Study on Attitudes and Consumer Habits of Tourists in Croatia. 2007. Tomas, Nautika.

“NauTour” project web page, Available from Internet: <http://www.nautour.info/results.php >

“NauTour” project web page, Available from Internet: <http://www.nautour.info>

The Hydrological and Meteorological Institute of Montenegro, (press release), New maximum depth measured in Kotor Bay, Available from Internet: <http://www.meteo.co.me/index.php?id=144>

Cross Border Programme Croatia – Montenegro, Available from Internet: <www.cbccro-mne.org>

INTEGRATING GIS AND SPATIAL ANALYTICAL TECHNIQUES IN ANALYSIS OF ROAD TRAFFIC ACCIDENTS IN SERBIA

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Abstract: Road Safety issue is taking the major attention to local authorities of the country itself in the context of decreasing the number of Road Traffic Accidents. A top down view of the problem is illustrated starting from presenting the situation in European Union member countries and then passing in the Western Balkan (WB) countries; Albania, Bosnia and Herzegovina, Croatia, Montenegro, the Former Yugoslav Republic of Macedonia, Kosovo and Serbia. Through SANET tool in ArcGIS Desktop, is made possible to employ network K-function and Network Kernel Density methods. In contrast with planar methods, the network methods are not biased as they are applied in the case when accidents occur in a network road. Network K- function results in finding whether the clusters exist and for determining of the cluster locations is applied Network Kernel Density method. Multiple linear regression analysis method is used to find the most significant variables related to the road conditions, time and main cause that affect high rates of accidents. To sum up, this study is applied in City of Belgrade with implication for further researches. The results and outputs of this research can be used in deepening the studies of finding the most significant cause that impact road accidents for the given area and it could be extended and applied in other countries of the region as well.

Keywords: GIS, Road Traffic Accidents, Network analysis

1. Introduction

Road Safety issues are taking the wide world attention as are becoming the main concern in life deaths. Preventing Road Traffic Accidents (RTA) means good methods developed in identifying, analyzing and treating the exposed areas. In the 1990 according to the statistics of World Health Organization (WHO) results that RTA was sorted as the 9th most important cause of life lost annually in the world and the forecast for 2020 can make that road accidents deaths to be the second leading cause and to reach third place in the industrialized world. Thus, figures and facts are making RTA as one of the main concern in public world health and referring it as global 'epidemic'.

Development in the industry that followed after World War II brought the need of increasing the motorization in the developed countries. Jacobs, (Jacobs et. al., 2000) made a reference to developing vs. developed countries, high vs. low income, highly motorized vs. low motorized etc. The study estimated that even though the developed countries are highly motorized, 70% of the RTA is occurring in developing countries. *Global Status Report* (2004) on Road Safety, report which is based in data on 174 countries in the world, presents that over 90% of RTA occurs in middle and low income countries which have just 48% of the world's vehicle.

The aim of this study is to show the trend and to increase awareness of RTA issues in developing countries, here WB, also carrying statistical and GIS visual analysis in a short term period.

2. Background

2.1. Road accidents and GIS in developed countries (Europe)

On 30 November 1993, the creation of a community database on RTA was decided by the Council of Europe (Council Decision 93/704/EC, Oj No L329 of 30.12.1993, pp. 63-65). **C**ommunity database on **A**ccidents on the **R**oads in **E**urope (CARE) comprise data just about fatalities and injured with the main purpose to identify, quantify the road safety issues and to measure the efficiency in road safety measures. In 2010, the number of fatalities results to be close to the half of the number of fatalities for 2000 year (Fig. 3), figure that would accomplish one of the most ambitious objectives of EU for the last decade. The graph shows obviously the progress done over last 10 years but still a lot of job needs to be done. Having said that, government, international agencies and organizations of civil societies from more than 100 countries the next 10 years are launching the Decade of Action for Road Safety 2011-2020 which intend to save 5 million lives in this time period.

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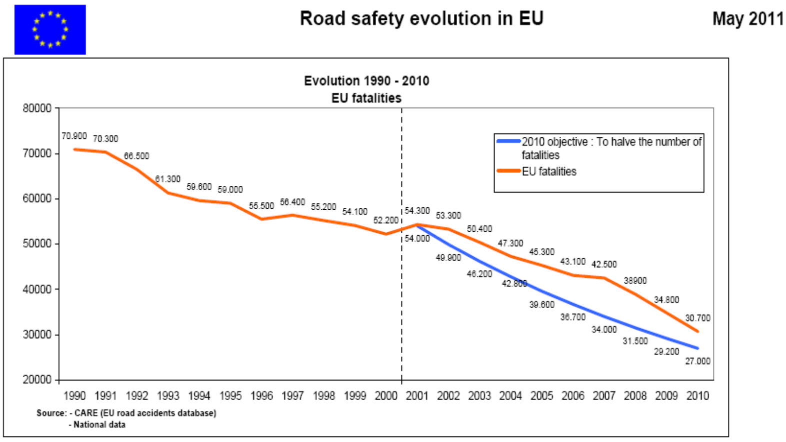

Fig.1.
Evolution of EU fatalities 1991 – 2010

2.2. Road Safety and GIS in Western Balkan

Countries of WB as countries in development are trying to reach and satisfy the rules and regulation of the EU in transport field as well. In WB Road Safety is under Ministry of Interior, and the police is responsible for collecting information in the spot. It is part of the national strategy integration of Ministry of Interior, Ministry of Transport and Ministry of Health to improve road safety.

The situation of Road Safety in WB presenting major indicators, trends and swat analysis are reflected yearly in the Multi Annual Plan (MAP) of South East Europe Transport Observatory (SEETO) which is collecting in yearly bases data through questionnaires in all countries.

From the figures in Table 1 a decrease of road fatalities in Bosnia and Herzegovina, Croatia and Serbia is noticed which is dedicated to stronger law enforcement, better institutional framework and the identification of the road safety problems. Even though there are some improvements overall risk indicators are above the EU average which are not showing a decreasing trend. As the level of motorization is rising the reasons that caused decrease trends which just started to be present last year it needs to be proved in the next coming years.

Table 1
Population, Total Number of Accidents, Injuries and Fatalities

Participant	Population (thousands)		Number of Vehicles (thousands)		Number of Accidents		Fatalities		Injured	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Albania	3,170	3,186	378	400	1,208	1,465	303	378	936	1,138
Bosnia and Herzegovina	4,346	4,346	882	905	40,859	40,237	434	382	11,884	11,052
Croatia	4,436	4,436	2,021	2,021	53,496	50,388	664	548	22,395	21,923
the FYRM	2,023	2,067	279	320	16,106	14,941	162	160	6,724	6,891
Montenegro	625	625	199	199	10,170	10,112	112	100	2,473	2,478
Serbia	7,350	7,335	1,751	1,822	67,708	64,897	897	808	22,275	21,512
Kosovo (under UNSCR 1244/99)	2,350	2,350	355	400	11,313	13,346	117	152	6,247	7,984
Total	**24,300**	**24,346**	**5,856**	**6,067**	**200,860**	**197,016**	**2,689**	**2,528**	**72,934**	**72,978**

Source:SEETO MAP 2011

Current situation is that data collected in the spot exist in spreadsheets of Excel from which are produced statistical analysis that are used by road safety engineers for further decisions. The location of the accident is defined per kilometer, every country is using mileages for their own road network.

It exist the idea that a harmonized database and investing in GIS techniques it will complete and give a better solution to the road safety issues but still this belongs to the future. In every country public institutions are publishing statistical data regarding road safety issues in national level and just in cumulative way.

2.3. Road Traffic Accidents in Serbia

Serbia lies in the North-East of WB countries and has the highest number of inhabitants in the region, 7,335,000 people. As such, it is expected to have a higher number of motor vehicles aftermath a higher number of traffic accidents as well. From data collected by SEETO result that the expectation is real and for the period 2004-2009 Serbia is in the first place in WB with an exception of the year 2003 where Croatia (92,102 cases) had the highest number of RTA.

However, to the road safety issue it is given a high importance and it is managed in a better way related to the other countries in the region. Based on the assumption that identifying patterns of road accidents in national road network of Serbia and drawing up the possibilities that GIS analysis can provide localization of the exposure places which will help the policy makers, this study aims to answer the following research questions:

- What types of factors are affecting road accidents and how they are related with accident rates?
- How much these factors are affecting the City of Belgrade? (Case study)
- Does GIS can be useful in road safety issues in WB?

3. Study area and road traffic accident data

In this paper are used just accidents events that have happened in the major road network of Serbia, excluding so accident events that have happened in the rural zones. Attribute fields provide information about time (hour, day, month) when the accident occurred, road characteristics, state of roads, road surface and main cause (Why the accident happened?). The location of the accident is provided by attribute fields that define in which kilometer/meter of the road section event occurred (e.g. the accident occurred in the 500km and 675m of the M-1 road).

About counties boundaries in Serbia, as it had to be chosen a smaller scale of work are used just boundaries of the municipalities of the capital city of Serbia, Belgrade. Also for the features of the road network, which are given in sections associated with attributes start node, end node, length is not done any data cleansing but there are added some more fields as Start Kilometer and End Kilometer.

RTA data provided by Criminology Police Academy (CPA) are about 8,045 records for 2007 and detailed as regards the attributes collected. Some of the attributes like the police station that has collected the data, persons that were guilty, stopped traffic and time how long it was stopped, damage material are deleted as are not part of the variables of this study. Accidents that have happened in the rural and urban area are not taken into account as the aim of this paper is to consider RTA events just in major roads.

Accident Type is one of the attribute's fields which is classified:

1. Fatal
2. Heavy injured
3. Slight injured or just with material damage

Part of this study paper is taken all categories resulting so in a sample with 2527 cases.

A join relationship is created between feature shape-file of the major roads with the respective section Road ID with the table where the AADT attribute is provided. No data cleansing is done about other indicators.

3.1. Data limitation

A significant number of RTA results that is not reported to the police. Studies of the hospital and medical data are a case which demonstrates under reporting and this case is more present in low-income countries (Aeron- Thomas 2000).

As underreporting is a case of serious injuries, fatality cases are suffering from the definition of death. Some countries define it "death in spot" and some others define it according to the recommendation standard "dead within 30 days". The field accident type in the accident data is the one that is affected from the above mentioned reasons which can results in a greater number of RTA than actually is. Another level of uncertainty is the definition of the locations of the RTA as it is defined in which kilometer has happened due to an approximation calculation and not with GPS devices.

4. Analysis of Traffic Accidents in Serbia

4.1 Methodology

4.1.1 Investigating relationship between accidents and causal factors

A number of analysis are undertaken to see possible relationships between accident rates and other attributes (Dai 2012). As road safety issues are complex it is seen as most efficient the method of multiple regression analysis which tests the significance of multiple independent variable. Accidents as a complex problem are a result of severity of causes each of which is playing a role that the event happens. In this study it will be discussed the relationship between the dependent variable 'accident rates' and other independent variables as 'state of road', road surface', 'road characteristics', 'main cause' and 'hour'/ time of the day when accident happened.

Content of variables include:

Hour - is keeping records about the time when the accident happened and is taking values from 1- 24.

Road Characteristics - has information about the road design whether is straight, curved, saddle or have junctions and is taking the values from 1-15.

State of Road - is containing values about the current state of road in the time of the accident occurred. Values refer to the categories whether the road is dry, wet, glazy or snow.

Surface Characteristics - the values in this category are keeping records about the surface of the road if it is asphalt, concrete, paved or unpaved.

Main Cause - is keeping explanation about the main cause of accident. Overall there are 110 causes.

All above variables are categorical with more than two levels and including them in multiple regression analysis as independent variables needs to recode them in a number of dummy variables. Before dummy coding, the categories used for each of independent variables are grouped in levels which are done to the similarity cases: e.g. State of Road values DRY-CLEAN, DRY-COAT OF DUST and SAND ETC are grouped as DRY and is given the value of 1. The same process is undertaken for all independent variables whereas 110 main causes' values are grouped in 4 level categories:

1- Alcohol/ Drugs
2- Equipment Failure/Road Design
3- Not obeying the rules
4- Speed.

As regard to the 'Hour' variable, can be grouped into four categories relating to the daytime as follows:

1-	Morning	4 –10	(>= 4 and < 10)
2-	Day	10 –16	(>=10 and < 16)
3-	Afternoon	16 –22	(>=16 and < 22)
4-	Night	22 – 4	(>=22 and < 4)

After all variables are grouped in categories are ready to dummy coded. The general rule is that a categorical variable with k levels can be transformed into k-1 variables and the last one, reference variable is the observation of all 0 values. In this case the dummy variable is coded with two levels, 0 and 1.

Thus, independent variables that will be included in the multiple regression formula are all dummies defined in the Fig. 2.

dummy Road State variables

Group_SR	dRS1	dRS2	dRS3
DRY	1	0	0
WET	0	1	0
GLAZE	0	0	1
SNOW	0	0	0

dummy Surface Characteristics variables

Group_SC	dSC1	dSC2	dSC3
ASPHALT	1	0	0
CONCRETE	0	1	0
STONE/MACADAM	0	0	1
UNPAVED	0	0	0

dummy Hour variables

Group_HOUR	dH1	dH2	dH3
4-10	1	0	0
10-16	0	1	0
16-22	0	0	1
22-4	0	0	0

dummy Road Characteristics variables

Group_SC	dRC1	dRC2	dRC3
STRAIGHT	1	0	0
CURVE/SADDLE	0	1	0
JUNCTION	0	0	1
LEVEL CROSSING	0	0	0

dummy Main Cause variables

Group_HOUR	dMC1	dMC2	dMC3
ALCOHOL/DRUGS	1	0	0
NOT OBEYING THE RULES	0	1	0
SPEED	0	0	1
EQ. FAILURE/ ROAD DESIGN	0	0	0

Fig. 2.
Dummy variables defined from Hour, Road state, Surface Characteristics, Road Characteristics and the Main Cause variables.

As dummy variables can be used same as the other variables then predicted value Y for calculating the dependent variable with multiple linear regression method it can be written as:

$y = B_0 + B_1dH1 + B_2dH2 + B_3dH3 + B_4dRC1 + B_5dRC2 + B_6dRC3 + B_7dRS1 + B_8dRS2 + B_9dRS3 + B_{10}dSC1 + B_{11}Dsc2 + B_{12}Dsc3 + B_{13}dMC1 + B_{14}dMC2 + B_{15}dMC3$.

Accident rate value is defined as (Eq. (1)):

$$accident\ rate\ for\ accident\ location\ i = \frac{counted\ number\ of\ accidents\ within\ a\ fixed\ distance\ d\ from\ i}{AADT\ for\ i} \quad (1)$$

where the *'counted number of accidents within a fixed distance d from i'* is calculated in ArcGIS by using 'Point Density' tool. It is chosen a smaller scale of study, municipalities of the capital city of Serbia, Belgrade, for better performance and visualization. The radius to search neighboring points is chosen d=1000 m according to the content of data and the way how is measured AADT. The output raster contains information about density in each cell. Based in the formula (Eq. (2)):

$$density = \frac{counted\ number\ of\ accidents\ within\ a\ fixed\ distance\ d\ from\ i}{\pi r^2} \quad (2)$$

where *r - radius*, is calculated the value of *'counted number of accidents within a fixed distance d from i'* and is added as a new attribute AADT, collected by section roads that derives from 100 m (just a small number of them) to 30 km. Nodes of section roads are defined mostly in base of populated areas (cities, towns, villages).

4.1.2 Identifying cluster patterns

One of the methods to analyze spatial pattern of incident data which consist of the locations of the event is Replay's K function. Event locations usually are available in planar (2 dimensions) although there are cases that are recorded in space (3 dimensions) or along a line. Even though the Ripley's K is one of the most effective methods for analyzing cluster patters it is based in a continuous planar space with Euclidian distance. Yamada (Yamada and Thill 2004) used two types of K function, planar and network, and analyzed road traffic accidents on a road network in Buffalo, New York State. It results that that using planar method in a network could mislead in outputs especially in the case of a constrained transport network, including traffic accidents. In this case when the events are located on network links, Network K-function method is proposed. Thus the distance between points is measured through shortest path on the network, firstly formulated by Okabe (Okabe et. al.1995) in contrary with planar method that measures it in space. Formula used for calculation of Kernel

Network function is: (Eq. (3)):

$$K(d) = \frac{r}{n} \sum_i \sum_j \frac{l(dij)}{n} \quad i \# j \quad (3)$$

r – radius
n – number of observations

where l (d_{ij})=1 for d_{ij}, otherwise I(d_{ij})=0

A parallel way of explanation was followed with calculating the density of events in a network. An extension of the Kernel density estimation method, applied to point distribution on plane, is Network Kernel Method that calculates the density in a linear unit, (Okabe et. al 2009) that estimates the density points on a network based on the formula (Eq. (4)):

$$\lambda(s) = \sum_{i=1}^{n} \frac{1}{r} k\left(\frac{d_{is}}{r}\right) \quad (4)$$

*Λ (s) – density in the location s; **r** – bandwidth; **k** – weight of point i at the distance d_{is} at the location s*

Related to the above mentioned for this case study is applied Network K function to identify whether or not is tendency towards clustering in the entire accident distribution. It is with high interest not just finding patterns but where they are located too. Network Kernel function is applied to see where the concentrations are.

4.2. Analysis and Results

4.2.1. Density distribution of accidents in Serbia

4,761.7 km, major road network length is laid in an 88,361 square kilometer area and the RTA locations are part of most of the network sections. In Fig. 3 are illustrated 8056 accidents that had happened in the year 2007 in the republic of Serbia. As it can be seen cluster patterns are present but hard to define where they are mostly located.

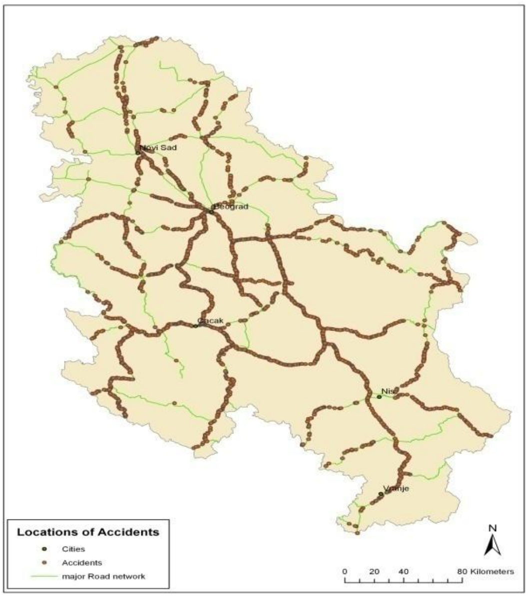

Fig. 3.
Locations of Road Traffic Accidents in Major Road Network of Serbia – Year 2007

For a better view and to facilitate working with a high number of records it is chosen to work in a smaller scale. City of Belgrade is chosen to be the study area in a smaller scale as a capital city with a high concentration of vehicle traffic and high number of inhabitants, 1,213,000 result registered in 2009.

The most congested section roads are sections part of the highway M-1 (Fig. 4) especially the sections that are part of New Belgrade municipality where the AADT vary from 100,000 to 148,000 vehicles per year. Even though these sections are part of major road network they lie in an urban area. Another fact that indicates the high traffic data is that New Belgrade in the last ten years is preferred as location for business institutions.

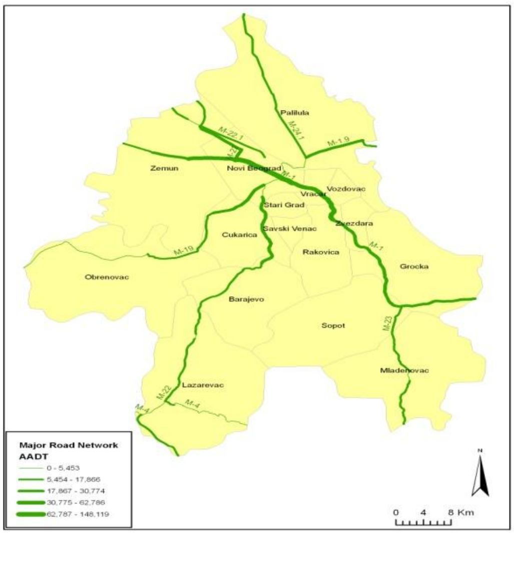

Fig. 4.
AADT 2007

Using Point Density in Spatial Analyst Tools with a bandwidth 1km and cell size 500m is found that M-1 and M-22 are most likely and exposed to have the higher number of accidents (Fig. 5).

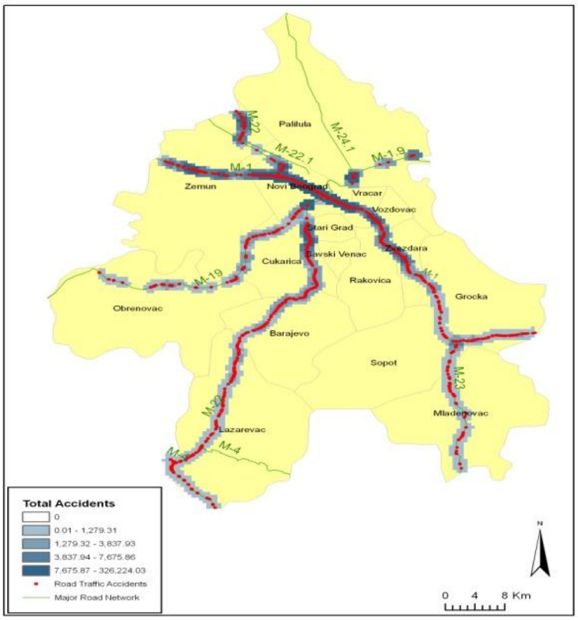

Fig. 5.
Density map of total accidents in City of Belgrade

4.2.2 Network K- function

Running the SANET tool, Network K- function makes possible to see whether or not the accident locations are clustered or dispersed in a road network. Fig. 6 shows the result of application of the network K-function to the major road network of Belgrade city with 1000 iterations and a class interval of 100m. The result reveals a statistically significant cluster pattern of road traffic accidents with each other as the observed curve is to the left of EXP upper 5%.

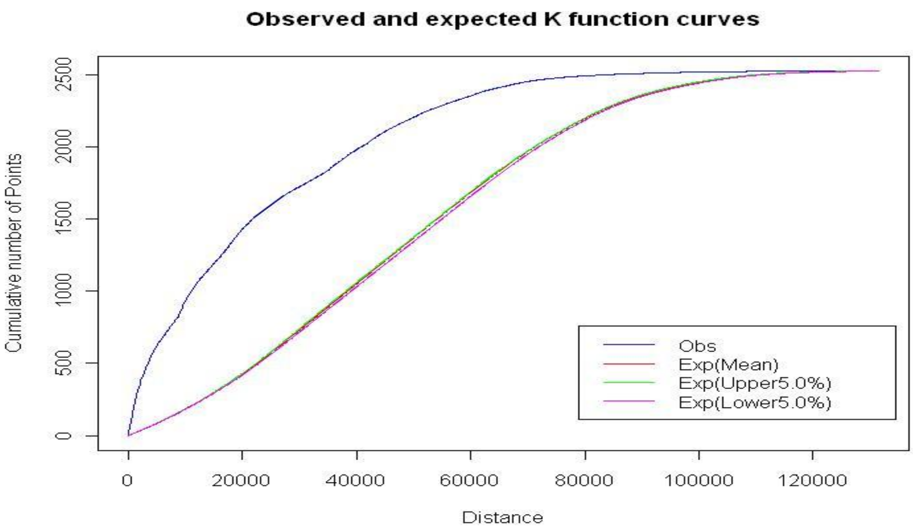

Fig. 6.
The result of network K- function method

4.2.3 Network Kernel Density Estimation

As network K function defined that clusters are present in the given network, the next step is finding where are located the accidents. Fig. 7 illustrates the density points on the road network calculated by Network Kernel method that gives more accurate account of events distribution in road/street level especially in micro-scale. Network Kernel method reveals that section roads part of M-1 (that are passing through municipalities in New Belgrade, Vracar, Vozdovac and Zvezdara) and some sections of M-22 in the south are most clustered.

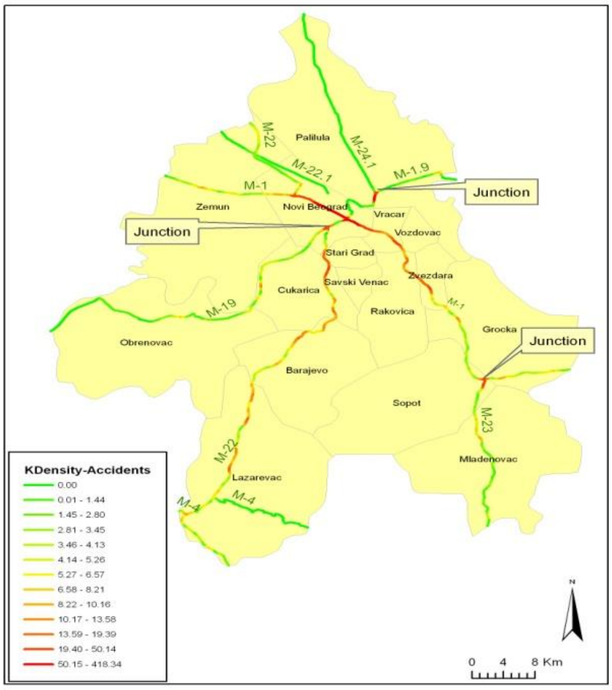

Fig. 7.
Network Kernel Density estimation with a radius 1km and cell size 500m

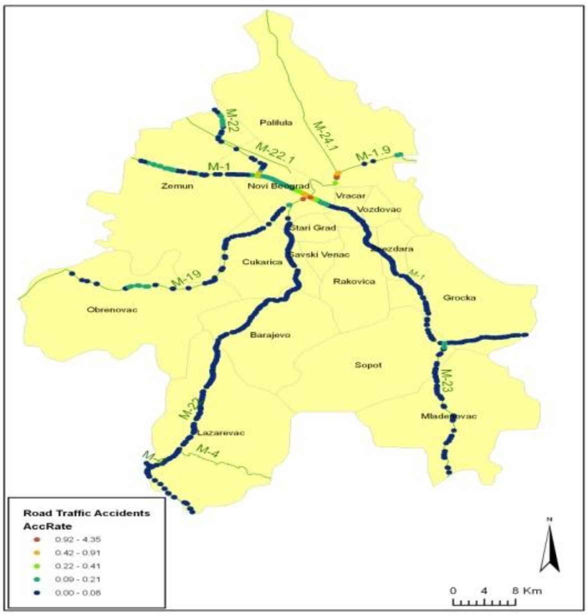

Fig. 8.
Distribution of accident rates

The accident rate on the magisterial roads in the congested areas as Novi Beograd and Zemun seems to be higher than other parts of the city of Belgrade.

4.2.4 Multiple Regression Analysis

Looking in the Pearson Correlation Matrix just a couple of dummy variables are significant. Stepwise method is employed to see the variables that are significant ($p < .05$) and entered in the model. The most significant variable that has the strongest impact results to be dMC3 - speed with a correlation coefficient .155 followed by dRC1- straight roads with a correlation coefficient .135. Speed factor is found to have a high influence (Elvik et.al. 2004) in the accident rates. In straight - dRC1 and paved - dSC1 roads is more likely that vehicles have a higher speed rather than unpaved or curved. This is explaining the second strongest variable dRC1 that is following the dMC3. Curved and Saddle - dRC2 variable which is sorted the 5th in the model is less significant firstly for the fact that this case study is in major roads (section 1.2- curved roads affect accident rates more in district level) and mostly of them are highways and not much curved with relate to geographical view of Serbia.

It is fact that in overall Balkan region it needs much to improve the driver behavior and it is not just drivers but motorcycles and pedestrians are most part of accidents.

Low level of fines and manual operating of police patrols just in a few places result that in most of the cases either drivers or pedestrians do not obey the rules. The presence of cameras, radars, a good system of reporting the cases in police and a connection with address system that can post the fines at the living/working place of individuals has showed a better result in the developed countries. dRS3 - glazy roads is explaining itself. It is listed as less significant as a psychological effect to take more care and reducing the speed is more likely in bad road conditions affected by weather or other environment factors than in dry roads. dH2 - variable shows that time interval from 10-16 is the time when more accidents happen. This time interval is the institutions' working time for public like (ministries, embassies etc). This case cannot be connected with rushing hours as it is different time interval in Belgrade. Institutions and private businesses working time is from 8-17 or 9-18 thus rushing hours are part of either Morning or Afternoon group. For more, the category of rushing hours would be more meaningful if are considered accidents in the urban streets rather in major roads.

R values for each of the variables are $0<R<1$ indicating a positive relationship even though weak. The results show that number of accidents is predicted by independent variables and they explain 5.1% of the variance of the number of accidents in this sample.

Based on the Table 2 the following multiple linear regression model is produced with a statistically significant F value of 19.538 ($p<0.1$):

$$\mathbf{Y = -.076 + .093\,dMC3 + .066\,dRC1 + .028\,dH2 + .045\,dMC2 - .068\,dRC2 + .133dSC1 - .149\,dRS3}$$

Table 2
Regression coefficients

Model	Unstandardized Coefficients		Standard Coefficients	t	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
(Constant)	-.076	.068		-1.118	.264			
dMC3	.093	.014	.229	6.802	.000	.155	.134	.132
dRC1	.066	.017	.091	3.887	.000	.135	.077	.075
dH2	.028	.008	.068	3.502	.000	.072	.070	.068
dMC2	.045	.015	.105	3.106	.002	-.097	.062	.060
dRC2	-.068	.030	-.053	-2.276	.023	-.104	-.045	-.044
dSC1	.133	.065	.040	2.043	.041	.044	.041	.040
dRS3	-.149	.074	-.039	-2.014	.044	-.042	-.040	-.039
a. Dependent Variable: ACCIDENT_RATE								

The table of regression coefficients shows that dRC2 and dRS3 have negative value which means that:
- accident rates in road curved/ saddle are .068 less then level crossing (dRC4- reference variable)
- and
- accident rates in glazy roads -.149 less than in roads with snow (dRS4- reference variable)

All other coefficients are positive, indicating that accident rates are larger than the reference variable.

To sum up, the last results clearly show that the accident rates are affected from different significant independent variables.

Other independent variables that didn't resulted significant in this case it doesn't mean that the data collected for these parameters are not useful as in other study areas (e.g. urban area) they can result more significant than others.

5. Conclusions

Annual data collected by SEETO from 2003-2009 used in this study gives an overview of road safety figures in WB countries. From facts brought in this paper it results that if developing countries will go in the same historic trend steps it will take quite a long time to achieve the rates of RTA-s in high-income countries. A small decrease of road fatalities in the last year (2009) mean that these countries are working on the main issues of reducing RTA-s.

Figures brought from EUROSTAT, obviously are showing that developing countries are most affected but even within the region of WB, the poorest countries as Albania, Kosovo and Macedonia are persisting an increase for road accidents in contrast with other countries.

Network methods used in a street network give more accurate results in analysis than planar methods. Network K-function and Network Kernel density methods employed for a smaller scale, city of Belgrade, make sure firstly for existing of clusters and secondly determine their location. This fact motivates the need for further researches and start functional location analysis for the purpose of the cause that make the accidents to occur. The accident rates and analysis through network methods employed are calculated in a street network thus the distribution is linear and cannot produce bias.

It results that the most exposed sections are in the highway M-1and especially sections that are passing in the municipality of New Belgrade. Even though part of major road, this sections are passing through an urban area and referred to the AADT map there is a high congestions of vehicle traffic. Apart of this explanation the M-1 is connecting the city of Belgrade with other cities in the surrounding area, means that vehicles are using this section roads as main route to enter and reach the desirable destination in the city which is connected with the explanation about the impact of dH2 variable.

Multiple regression analysis employed using accident rate values as a dependent variable and hour, road characteristics, road states, road surface and main cause show that even though between them and the dependent variable exist a weak correlation they are significant.

From MLR method results that strongest effect in accident rates have the predictors dMC3 - speed, dRC1- straight roads and dH2 - time of the day while others dMC2, dRC2, dSC1 and dRS3 less. When they are added in the model one by one the impact in dependent variable is increased which is showed by R square value. Thus, it can be explained the fact while driving with e high speed - dMC3 in a straight road- dRC1 is more likely to occur an accident than driving with a low speed. The probability is increased more if in this case is added time factor especially the time interval (10-16) - dH2 variable time which is explaining the increase of accident rates.

The regression analysis undertaken in the chapter 4, conduct than time interval from 10-16 hour has more impact than other three intervals. Also, speed and not obeying the rules factor are two most significant causes that affect accident rates in this case study. Other variables related to the current condition of the roads as straight road, asphalt, glaze and curved it can be explained by many factors. One it can results and connects with the fact of not obeying the rules e.g. driving in straight asphalted road can stimulate the driver to increase the speed over the limit and can result in undesirable event.

For further researches it could be the continuation of the methodology that made possible findings of clusters. These areas can be filtered and show the high rates of accidents which is attracting the interest to the public authorities. Variables used for finding relationship are showing the effect of the road conditions, time of the day and driving behavior where researches can be extended. A case could be the analysis that can find which day of the week has higher rate of the accidents and where these are located.

Once this methodology is completed it could be used as a framework to examine traffic accident distribution for the entire country and can be used as an example for the other countries in the WB.

Coming in the stage of analyzing data by GIS a sustainable system database that stores the locations of accidents should be established. The actual data analyzed in this study, location of which is found by linear referencing is suffering of the limitation in accuracy. GPS devices are important to be used and integrated with the database defining so the correct location of the event and updating the database in time. The system should provide access to the local road safety people which can help improving and decreasing the RTA.

There is an advantage if countries are using or participating in regional systems like European International Road Traffic and Accident Database (IRTAD) or the Asia-Pacific Road Accident Database (APRAD) run by the UN-ESCAP. A regional system for WB still does not exist as firstly should exist in the national level.

Acknowledgement

Criminology Police Academy who provided me with Road Traffic Accidents data for 2007 in Serbia, my employer South East Europe Transport Observatory (SEETO) from which I used annual statistical data about road safety and polygon features of the Western Balkan countries. I am grateful to the Republic Geodetic Authority of Serbia as well for providing me with features about major road network of Serbia.

References

Aeron-Thomas, A. 2000, *Under-Reporting of Road Traffic Casualties in Low Income Countries.* Unpublished Transport Research Library (TRL) Report PR/INT/199/00.

Aeron-Thomas, A. 2000. *Under-reporting of road traffic casualties in low income countries.* TRL Report PR/INT/199/00. TRL Ltd, Crowthorne: CSIS Discussion.

CARE database – reports and graphics. Available from Internet:
<http://ec.europa.eu/transport/road_safety/specialist/statistics/care_reports_graphics/index_en.htm>

Dai, D. 2012 - Identifying clusters and risk factors of injuries in pedestrian–vehicle crashes in a GIS environment. *Journal of Transport Geography* 24(2012): 206-214.

Elvik, R.; Christensen, P.; Amundsen, A. 2004. *Speed and road accidents: an evaluation of the Power Model*. TOI report 740. Oslo: The Institute of Transport Economics.

European Transport Safety Council - Estimating Crash Cost. Available from Internet: <http://www.grsproadsafety.org/themes/default/pdfs/Estimating%20crash%20costs.pdf>

European Transport Safety Council – Social and economic consequences of road traffic injury. Available from Internet: <http://www.etsc.eu/documents/Social%20and%20economic%20consequences%20of%20road%20traffic%20injury%20in%20Europe.pdf>

Jacobs G.; Aeron-Thomas, A.; Astrop, A. 2000. *Estimating global road fatalities*, TLR Report 445, transport Research Laboratory.

Okabe, A.; Okunuki, K.I.; Shiode, S. 1995. New methods for Network Spatial Analysis. Available from Internet: http://geog.lit.nagoya-u.ac.jp/nuki/pdf/060415TGISsubmitted.pdf.

Okabe, A.; Satoh, T.; Sugihara, K. 2009. A kernel density estimation method for networks, its computational method and a GIS-based tool. *International Journal of Geographical Information Science*, 23(1): 7-32.

South East Europe Transport Observatory - MAP 2011. Available from Internet: <http://www.seetoint.org/index.php?option=com_content&view=article&id=372&Itemid=104 >

Yamada, I.; Thill, J.C. 2002. Empirical Comparisons of Planar and Network K-functions in Traffic Accident Analysis. Available from Internet: http://www.ltrc.lsu.edu/TRB_82/TRB2003-001408.pdf.

WAYS OF COUNTERACTING MANIPULATIONS OF DIGITAL RECORDERS COMPULSORILY TAKEN IN LIGHT AND HEAVY VEHICLES

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Abstract: A tachograph which belongs to the group of ORD devices is the oldest recorder (On Board Recording Devices), and the duty of taking it was led into the USA already in 1939. In order to solve these all problems, they led with Directive of Advice No. 2135/98 from 24 September 1998 of the August of 2004 from the beginning of in the area of the European Union, new type of registering setting up in the road transport - digital tachograph. In order to make it impossible to abuse, a complex system of keys was applied cryptological and of certificates, saved in grating and devices, letting for explicit determining entitlements of users and authenticities of data, cards and devices. In spite of using the most modern keys and securing systems, with respect to elements of the system of digital tachographs a lot of modus operandis were observed so that they registered wrong sizes. The European Union took right action in order to before to prevent, nevertheless they must be implemented into the everyday life. That paper includes information about level of manipulation of digital tachograph and their elements, ways of manipulations of digital tachograph and future ways of counteracting manipulations.

Keywords: the tachograph card, control, digital tachograph, manipulation, technical inspection.

1. Introduction

Tachograph (from Greek *tachos* – speed and *grapho*-writes) is a device combining the functions of speed indicator and clock. Tachograph records in the function of time the distance travelled by the vehicle, speed, as well as the driver's activity, i.e. periods of work or of availability, breaks from work and daily rest periods.

Due to the safety on the roads, many countries have introduced restrictions on working time for drivers of vehicles used in road transport of goods and passengers. Vehicles and sets of vehicles with a maximum permissible total mass above 3,5 t and vehicles which are constructed or permanently adapted for carrying more than nine persons including the driver, are covered by the monitoring of the driver activity by tachographs. The second aspect of the use of recording equipment in road transport was and is currently to ensure the safety of participants in road traffic as one of the main problems of present times. Number of vehicles involved in road traffic continuously increases. Despite the actions, aimed at designing and building increasingly safer means of transport, the scale of accidents is very high.

In the current situation of the functioning of digital tachograph system there are the following constituent elements: the inclusion in the TACHOnet system, the process of issuing of tachograph cards, approving of workshop conducting inspection of digital recording equipment, preparedness of States which will introduce the system of digital tachographs (Fig. 1 and Fig. 2) (Rychter, 2010).

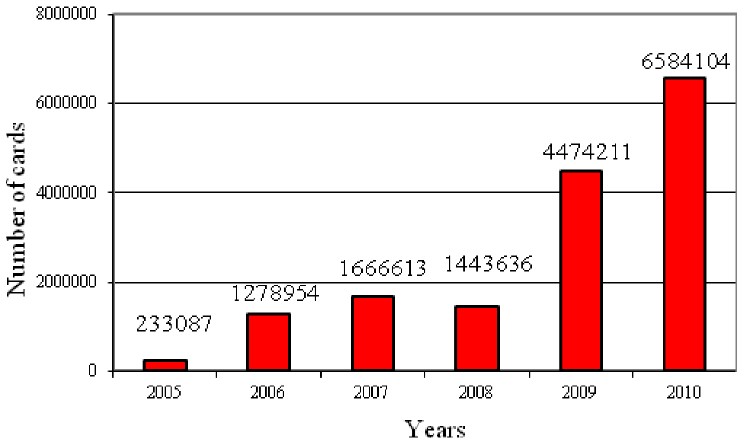

Fig. 1.
Number of Tachograph Cards Issued Over the Functioning of the Digital Tachograph System

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Digital recording devices use the same type of encryption protocol of signal as electronic tachographs, but with a greater degree of speed signal encryption transmitted between the motion sensor and the on-board unit. Such devices are much more safety than the equipment used previously, i.e. analogue tachographs, because of data once written in their memory cannot be changed or deleted. However, it was discovered the opportunity of very easy recording the forged information, which are stored in very safety way. Such proceedings totally change the concept of safety.

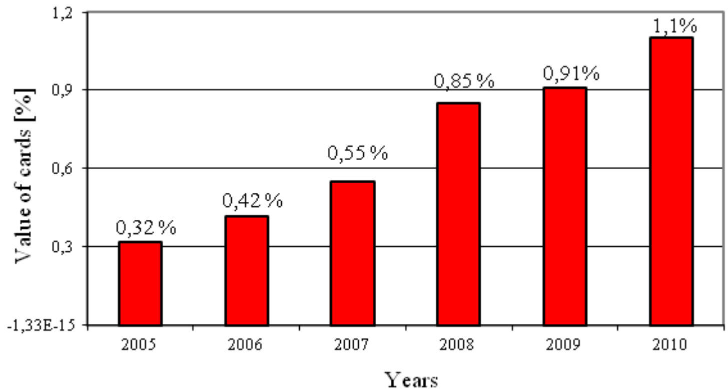

Fig. 2.
Part of Tachograph Cards Stolen and Lost During the Functioning of Digital Tachograph System

The loss of information about speed and distance, recorded in the memory of the digital tachograph, as well as the loss of data describing places of starting and finishing driver's work are quite difficult for the services authorised to inspection of digital recording equipment.

2. Control of Digital Recording Devices

Introduction of the digital tachograph in road transport had undeniably ensured:
- improving the efficiency and effectiveness of control of road haulage companies in road transport,
- the relevant standards in the field of social legislation and its harmonization in all the Member States of the European Union,
- strengthening the principles of fair competition,
- improving safety in road traffic.

The digital tachograph is a very important on-board device, used in road transport, due to control possibilities and enforcement of compliance with the legal provisions concerning the conditions of transport and social rules for drivers. Control of the road carriage (road transport and non-commercial carriage by road) it is the statutory task of the Road Transport Inspection (Article 50 of the Act of 6 September 2001 on road transport, Law Journal 2007, No 125, position 874, with changes). Additionally, police officers, Customs officers, border police inspectors and inspectors of the National Labour Inspection are also entitled to conduct the control of road haulage in area of the installation of tachographs in vehicles and the registration of the working time of drivers. The procedure of control in compliance with the provisions on periods of driving, minimum breaks and rest periods in road transport (both during roadside checks and checks in undertaking premises), as well as the required standard equipment of controllers and the list of basic elements which must be checked are determined by the regulation of Minister of Infrastructure of 2 September 2009 on the control of the carriage of goods by road (Law Journal No 145, position 1184). This regulation implements the directive 2006/22/EC of the European Parliament and of the Council of 15 March 2006 on minimum conditions for the implementation of Council Regulations (EEC) No 3820/85 and (EEC) No 3821/85 concerning social legislation relating to road transport activities and repealing Council Directive 88/599/EEC **(***Official Journal L 102, 11/04/2006, p. 0035 – 0044).*

According to these acts checks must be organized in such a way that:
- at least 3% of days worked by drivers of vehicles falling within the scope of Regulation (EEC) No 3821/85 and Regulation (EC) No 561/2006 are checked,
- not less than 30% of the total number of working days shall be checked at the roadside and not less than 50% of the total number of working days shall be checked at the premises of undertakings.

When performing inspection operations regarding compliance with the rules on periods of driving, minimum breaks and rest periods, the inspectors shall be equipped with the following devices able to:

- copy data from the digital tachograph installed in the vehicle and the driver card,
- read the downloaded data and its analysis or transmit the results of reading data to the office to make the analysis,
- make checks and detailed analysis of the confirmation of the digital signature attached to the data,
- analyze in order to determine the specific profile of the speed before the inspection of the registered equipment,
- check the sheets.

Optional equipment of the inspector includes especially devices able to make photocopies and photographic documentation.

The list of basic points which should be covered by roadside checks was defined in annex 5 to the mentioned above regulation of the Minister of Infrastructure on the control of road carriage and it includes the following elements:

- daily driving periods, breaks and daily rest periods,
- weekly driving periods and weekly rest periods,
- sheets from previous days, which should be in the vehicle in accordance with article 15, paragraph 7 of Council Regulation (EEC) No 3821/85 or data from the same period on the driver card, in memory of the digital tachograph or print with this device,
- cases exceeded the permitted speed of the vehicle,
- instantaneous speed reached by the vehicle, saved by the digital tachograph by not more than the previous 24 hours of use of the vehicle,
- correctness of operation and use of analogue equipment and digital recording equipment or record sheets or driver card.

In addition to elements during roadside check, at the premises of undertakings should be checked:

- weekly rest periods and driving times between these rest periods;
- observance of the two-weekly limitation of driving times;
- record sheets, vehicle unit and driver card data and printouts.

Nevertheless, to the control of vehicle unit, driver card data and printouts of the digital tachograph shall apply the provisions of § 10 of the regulation of the Minister of Internal Affairs and Administration of 18 July 2008 on the control of road traffic (Official Journal No 132, position 84, with changes). Inspector should check data in the memory of the digital tachograph and driver card through the insertion of the control card to the digital tachograph, and then display and viewing them, print or download using devices for copy the information. If the driver does not have a driver card or it is unable to use due to the damage, the inspector checks the data contained in the memory of the digital tachograph on the basis of the printout. The driver is required for writing on copy of printout, made by the inspector, his name and surname, driver card or driving license number and signature (Table 1).

Table 1
The Catalog of Infringements Dealt with Digital Tachograph According to Polish Act on Road Transport

Position	Infringement	Penalty [PLN]
6.1.1	Performing carriage by road using vehicle that does not have the digital recording equipment	3.000
6.1.2.	Performing carriage by road using vehicle with a digital recording device, which does not register all required elements	2.000
6.1.3.	Performing carriage by road using vehicle with digital recording device, which does not register, at the same time, data dealt with periods of activities of all drivers who drive the vehicle in checked period	1.000
6.1.4.	Performing carriage by road using vehicle with digital recording equipment without the required periodical check, control check or calibration	1.000
6.1.5.	Performing carriage by road vehicle with digital recording equipment, by the driver without his own, valid card	1.000
6.1.6.	Performing carriage by road by driver without the required printouts of the tachograph driver card in case of damage, failure or its lack-for each missing printouts	100
6.2.1.	The digital tachograph does not register on driver card speed of vehicle, activity of driver and distance of travel	5.000
6.3.4.	Using the same driver card by more than one driver	3.000
6.3.5	Using the same driver card by more than one driver in the same time	1.000
6.3.7.	Showing during check in premises of undertaking data from driver card, digital tachograph or document confirming the fact of not driving the vehicle – for each day	500
6.3.9.	Showing during check in premises of undertaking incomplete data on the periods of driver activity – for each day	300
6.3.11.	Not making a copy of data from driver card – for each driver	500
6.3.12.	Not making a copy of data from digital tachograph – for each vehicle	500
6.3.13	Not showing during check in premises of undertaking data copied from digital tachograph and driver card, stored in undertaking – for each day	300
6.3.14.	Interference with the data written in digital recording equipment, driver card and undertaking card	5.000

Transport undertaking is liable for infringement dealt with obligation of installation and usage of digital tachograph, found by inspections. The penalty is imposed on the transport undertaking by administrative decision. Amount of fines for such infringement are set out in the annex no 3 to the Act on road transport. Part 6 of annex no 3 specifies 15 infringements dealt with digital tachograph and assigned them a penalty ranging from 100 to 5.000 PLN. Below there is a modified extract from the annex no 3 to the Act on road transport for infringements of the provisions on the use of the digital tachograph.

It must be underlined that the driver is also liable for infringement dealt with improper usage of digital tachograph. The infringements and penalties are described in annex no 1 to the Act on road transport. For instance, for performing carriage by road using vehicle with digital recording equipment with illegal additional device influenced on incorrect function of digital tachograph the driver should be punished fine of 2000 PLN.
The ratio of issued decisions on the imposition of a penalty payment to the number of checked vehicles in the year 2010 equals 15.4% (14.4% according to inspections of vehicles registered in Poland and 17.6% - vehicles registered abroad). In view of the comparison of the results of the checks carried out by the Road Transport Inspection from the beginning of its existence, it should be underlined the systematic decline in the number of checks with the imposition of the penalty by administrative decision in proportion to the number of controlled vehicles. The following chart shows the increase in compliance with the provisions of the transport by carriers, which covers the period from the beginning of activity of the Road Transport Inspection by 2010 (Fig. 3).

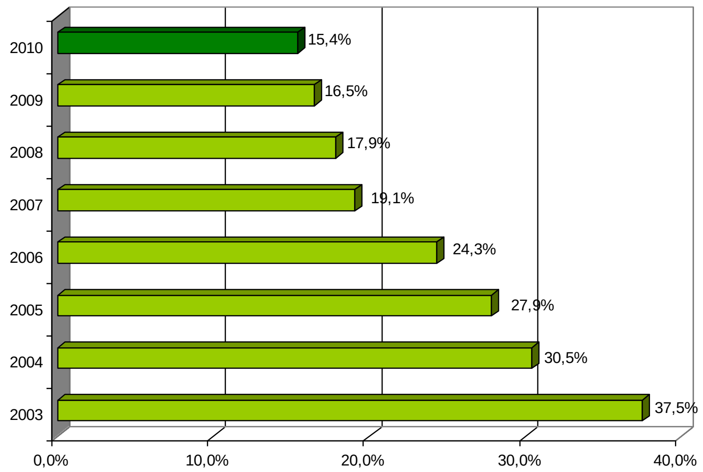

Fig. 3.
The Increase in Compliance with the Provisions of the Transport

The results of the roadside checks carried out by inspectors of the Road Transport Inspection indicate a statement of more than 172 000 infringements (in accordance with the annex to the Act on road transport). Approximately 70% of infringements were related to the provisions concerning driving and mandatory breaks and rest periods of drivers, over 15% of infringements were related to improper use of the recording equipment, while 10% constituted a violation of the requirements for the possession of the required licenses, certificates of accomplishment of the non-commercial, or documentation of drivers. Violations related to not paying by carriers the mandatory tolls on national roads is about 2% of the total number of infringements. The structure of infringements shows the Fig. 4.

Of the total number of approximately 65 000 of infringements related to the non-observance of rules on social legislation for drivers in road transport, the most common is not allowed reduction of daily rest periods and driving time without required break. A detailed list of the number of infringements noted in respect of the working time of drivers shows the Fig. 5.

According to infringements referred to compliance by the drivers and traders with the provisions concerning the use of recording equipment cases of incorrect use of the recording equipment or the incorrect use of recorded sheets are very common. A detailed list of the number of infringements noted in the use of the recording equipment shows the Fig. 6.

Violations of the standards of the working time of drivers will also rise to the liability of the driver in the form of fines levied by the criminal mandate. This responsibility is independent of the responsibility of transport undertaking and aims to more effective compliance with the provisions concerning the standards of driving and mandatory breaks (Fig. 7).

As a result of the checks carried out in enterprises engaged in road transport in 2010 it was issued 2077 administrative decisions on the imposition of fines of value: 25 000 000 PLN.

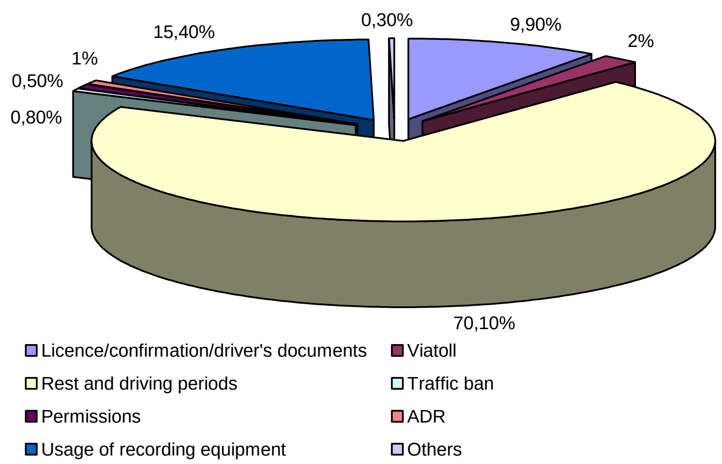

Fig. 4.
The Structure of Infringements in Road Transport

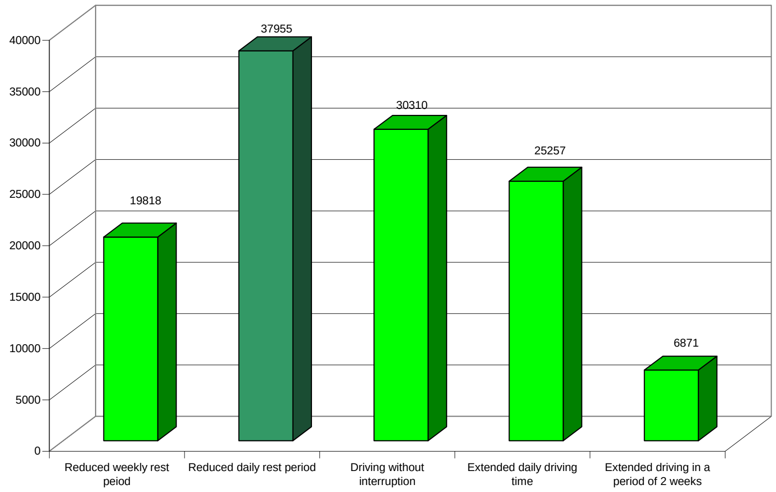

Fig. 5.
The Number of Infringements in Road Transport

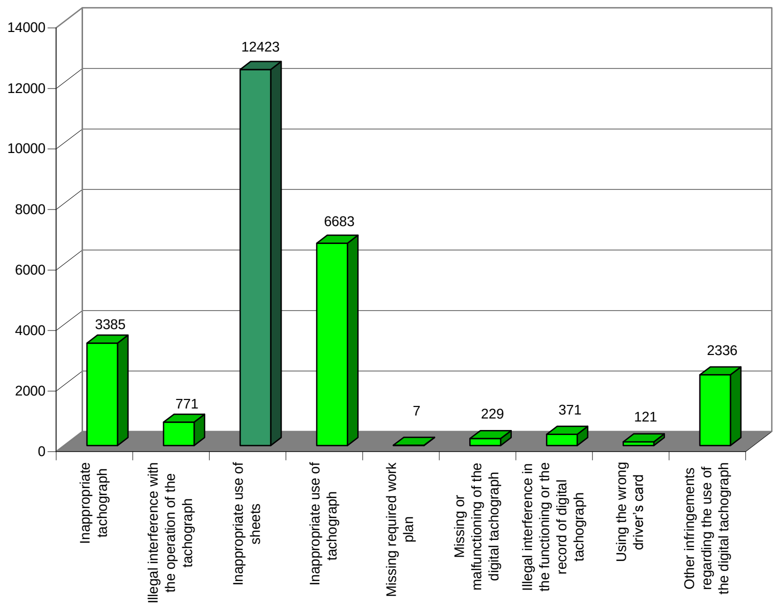

Fig. 6.
The Number of Infringements in Road Transport in Light of Using Recording Equipment

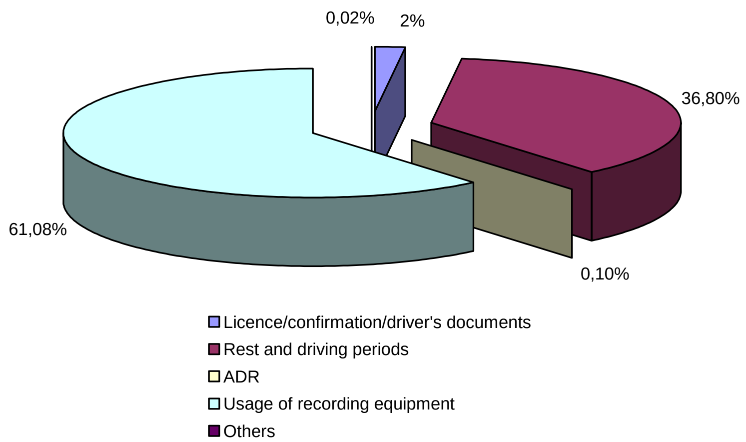

Fig. 7.
The Infringements Number of Standards of Driving and Mandatory Breaks

As a result of checks carried out at the premises of undertakings, inspectors of the Road Transport Inspection claimed more than 243 000 infringements. More than 62% of the infringements concerned the incorrect use of the recording equipment, 36% of infringements related to the non-observance by the drivers of the provisions concerning driving and mandatory breaks and rest periods, but approximately 1% were infringements referred to the violation of the requirements for the possession of the required licenses, certificates of accomplishment of the non-commercial, or documentation of drivers.

3. Guidelines for Prevention of Tampering with a Digital Recording Devices During Roadside Checks

One of the most important conditions of effective roadside checks is to ensure the proper training and full equipment for enforcement officers. “The digital tachograph is much like a burglar alarm in that the attacker only has to destroy confidence in it, by making it appear to be unreliable, in order to defeat it” (Desworte, 1998). For that reason the inspectors should have a control card, and the appropriate tools to copy data from a memory on-board unit and the memory of driver card and analysis of these data or printouts, in combination with record sheets and any other documents relating to working time for drivers. Officers should also be provided with the necessary software enable quick and easy analysis of such data.

Regardless of whether the checks are carried out on the roadside, or in the premises and whether that they are related to compliance with periods of rest and driving, the roadworthiness or other aspects, officers of the control services could also be able to test the proper functioning and proper use of the equipment to detect cases of manipulation of these devices.

The method of two check point, with the analysis of the actual speed or distance. Using this method of inspection, officers could measure actual speed of the vehicle at a specific point using portable or installed in some place cameras, before stopping the vehicle. Then, they could copy file containing details of speed over the last 24 hours from on-board memory unit and compare registered speed in a given point with the speed measured several kilometres before. At the checkpoint, this method requires only the comparison of two numbers after reading a file containing details of speed over the last 24 hours.

Using the method of distance in time control, it is important to remember to select the point of inspection, located in a known distance from the specific place where officers have other means (bills of collected tolls, camera records, the protocols of border inspections) that enable to specify the moment, when a vehicle stopped in this place or not. Then, officers could copy a file containing details of the speed of vehicle for the last 24 hours from memory of on-board unit, and compare these data with the average vehicle speed, based on the known distance and time needed to reach the checkpoint.

Significant differences between read data and measured or calculated speed it is possible that the manipulation of the tachograph has been made. In that situation the vehicle could be directly checked in the workshop, without the need for additional inspection in the checkpoint.

In case of data read from the memory of on-board unit, it should be underlined that data was included with a digital signature, originally generated by the digital recording equipment or driver card in order to verify the authenticity and integrity of the data.

Method of one checkpoint with a detailed analysis of the copied data. In order to confirm the suspicions as to the presence of a device to manipulate, officers should compare data on driver’s activity, copied from the memory of driver card and on-board unit with any documents in the vehicle and the driver’s statement. Inconsistencies between these data could form the basis for suspicion and further action. In the next stage, it should be analyzed information about events and faults, including attempting to breach security, interruptions in power outage, move or sensor fault, especially registered within the last 5 days.

In addition, it should be analyzed the information including technical data, with particular regard to data concerning time adjustment or calibration data. The last group of data can be predominantly useful in finding too many cases of calibration, what may indicate that they have been carried out using the workshop card, which has been stolen or lost. Control officers should check the status of identified workshop cards, including their validity in days, when they have been used for the calibration of digital recording equipment.

If control officers continue to suspect irregularities after analysis of all the data, they could perform the copying file from the memory on-board unit, containing detailed data on speed for the last 24 hours and using specialized software to check whether there were unrealistic increases or decreases the acceleration of the vehicle, and whether the profile order is consistent with other documents in the vehicle, together with the statements of the driver (the number of breaks, speed in mountainous region or in urban areas).

Method of one checkpoint based on the technical control of seals. If it would be possible, officers should inspect the seals. If there is no seal or it is destroyed (damaged), then the driver should explain this fact. If the driver does not have a credible explanation, this may constitute the infringement and it is recommended to make directly an inspection of the vehicle in an authorized workshop.

Vehicle or data inspection in premises of undertaking. It is recommended that the competent authorities of the Member States use the possibility of controlling vehicles and on-board units, drivers with the cards drivers in the premises of transport undertaking. Data managed by the entity, must be kept for at least one year and must be available for inspection, on every request of control officers. For that reason, it could be checked any vehicle, which is located in the premises of transport undertaking. Additionally, it could be done any appropriate tests and activities, limiting to a minimum any delay, which driver could be exposed. Such controls could also cover the possibility of preparing and equipping control officers with suitable devices to enable verification of the recording equipment, in conformity with UE regulations (EU 2009; EU 2002).

4. Guidelines for prevention of manipulation of digital recording equipment during technical examination

If, after roadside check using the procedures of technical inspection, there is suspicion that it has been installed the device used to manipulate the indications of digital recording equipment, control officers would direct the vehicle to an authorised workshop. National authorities of the Member States may authorise to instruct the authorised workshop to make specific research to detect devices for manipulation.

In most cases, detailed examinations would enable the detection of erroneous pairing of the motion sensor and on-board units, which may indicate the presence of a device or equipment for manipulation. Such studies should include the control of seals and tablets of installation, testing a reference and an analysis of the copied data from the memory on-board unit.

In the case of detection of such devices, regardless whether they were actually used by the driver or not, the recording equipment should be removed from the vehicle and used as evidence. In addition, authorised workshops should be authorized to carry out the technical inspection for correct operation, correct recording and storage of data, and whether the calibration parameters are correctly set.

After all technical inspection and lack of detection of equipment used to manipulation of the indications, the recording equipment shall be subjected to a complete calibration and should be endorsed with a new measurement table together with the new seals, under the supervision of the regulatory authorities.

Detection of cases of the use of devices for the manipulation of the digital tachograph system and the prevention of their use is a continuous process, which requires constant engagement. With technological progress the quantity of possible interference in the system and possible risks increase. Consequently, all entities involved in ensuring the safety of the digital tachograph system, including control officers, authorized workshop, drivers and transport undertakings are very important in process of preventing the manipulation of digital tachograph.

Summary

Appropriate functioning of all elements of the system of digital tachographs enables to achieve the intended purpose. In general, the guarantee of security of the whole digital tachograph system is the closest cooperation of all elements of this system and the most correct functioning of each element. However, it must be underlined that in order to prevent the manipulation of the digital tachograph, first of all it is very important to provide for:

- a requirement to ensure enforcement officers are appropriately trained, establishing the methodology for initial and continuing training,
- a range of technical measures – the tachograph to be connected to a Global Navigation Satellite System device to automate the recording of the daily journey start and end location, a remote (wireless) communications function to provide a signal, only on request, to allow an enforcement officer to assess whether to stop the vehicle for further checks and a harmonised interface to allow the use of Intelligent Transport Systems (ITS) with the tachograph.

References

Blecker, T.; Kersten, W.; Meyer, M. 2009. *High – Performance Logistics: Methods and Technologies*, Berlin.

Rychter, M. 2010. *Budowa i zastosowanie systemu tachografii cyfrowej*, Warsaw.

Furgel, I.; Lemke, K. 2006. *A review of the digital tachograph system (in:) K. Lemke, Ch. Paar, M. Wolf, Embedded Security in Cars: Security Current and Future Automotive it Applications*, Birkhäuser.

Desworte, Y.; Quiquater, J.J.; Gollmann, C.M. 1998. Computer Security In Proceedings of the *Lourain-la-Neuve, 5th European Symposium on Research in Computer Security,* Belgium.

Commission Regulation (EU) No 1266/2009 of 16 December 2009 adapting for the tenth time to technical progress Council Regulation (EEC) No 3821/85 on recording equipment in road transport. 2009. *Official Journal of the European Union,* L 339: 0003 – 0023.

Commission Regulation (EC) No 1360/2002 of 13 June 2002 adapting for the seventh time to technical progress Council Regulation (EEC) No 3821/85 on recording equipment in road transport. 2002. *Official Journal of the European Union,* L 207: 0001 – 0252.

Monitoring of Implementation of Digital Tachograh (MIDT) documentation.

ROAD SAFETY ANALYSIS USING ITALIAN GUIDELINES

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Abstract: Safe road design is about providing a road environment which ensures vehicle speeds will be within the human tolerances for serious injury and death wherever conflict points exist. International researchers have thus suggested a variety of approaches to analyze the road traffic safety level as some procedures based on the valuation of the accident rates and accident frequency. The research described in this paper aims to illustrate a network safety approach as suggested by Italian Guidelines in order to identify homogeneous roadway segments where the crash rate (crash frequency over traffic exposure) is higher or lower than on statistically significant thresholds referred to the whole analyzed road path. Three different road safety thresholds are suggested: a) low when the crash rate is of less than lower limit, b) moderate when the crash rate falls between upper and lower limits, c) severe when the crash rate is greater than the upper limit. It's suggested an additional careful study on the road segments with high crash rate making a comparison between existing and potential infrastructural-geometric-environmental failures to determine potential countermeasures. The study presented here involved a rural road in Southern Italy located on flat/rolling area with a vertical grade of less than 6%, without spiral transition curves between geometric tangent and circular elements, which is provided with controlled access or rather road interchanges and 11 km almost of slow lane for both travel directions. The data set used for this study includes crashes from 2003 through 2010; in particular 301 crashes were observed with 444 injuries and 41 deaths over the total length of the 71.92 km. Analysis showed that homogeneous road segments with high crash rates occurred in 16% of cases, while with medium crash rates in 38% of cases and low crash rates in 46% of cases.

Keywords: Crash Rates, Network Safety Approach, Driver speed behavior

1. Introduction

The road traffic safety has thence become a priority field worldwide and one of the major factors describing the transport system's state with its positive and negative changes.

Vehicle accidents are complex events involving the interaction of drivers, traffic, the road itself and the environment. It is believed that a significant proportion of variations in accident frequency are the result of differences in the major factors from site to site and time intervals and that a significant portion of accidents occur due to bad infrastructure and lack of alignment consistency (Mattar-Habib et al., 2008). Several researches computerized system has been developed to assist maintenance agencies in justifying safety improvement decisions. Two types of decisions were provided, for example maintenance priority setting according to accident characteristics, and proposals of likely countermeasures to specific safety hazards (Chassiakos et al., 2005).

International researchers (Lazda and Smirnovs, 2009) have thus suggested a variety of approaches to analyze the road traffic safety level as some procedures based on the valuation of the accident rates and accident frequency.

The responsibility for safety is shared between those who design and those who use the road transport system. Those who design the road transport system (e.g., road managers, vehicle manufacturers, road transport carriers, politicians, public employees, legislative authorities, and the police) bear the ultimate responsibility for safety. The responsibility of the road user is to abide by traffic regulations. Traffic regulations must fit in with the environment, and people must be educated about the logic and usefulness of the rules (Kanellaidis and Vardaki, 2011). The road safety has thence become a priority field worldwide and one of the major factors describing the transport system's state with its positive and negative changes (Ratkevičiūtė et al., 2007). The research described in this paper aims to study safety conditions of homogeneous road segments belonging to the two-lane rural road provided with 11 km almost of slow lane for both travel directions, located in the Southern Italy by using Italian Guidelines (2000) based on the assessment of crash rates thresholds. This study illustrates a "network" approach in order to identify the "black" roadway segments where the crash rate is higher than on the rest of the road studied path. This experimental analysis is only one component of a larger study, under way for several years now on a number of rural roads, with a view to improving performance and safety.

A user-friendly geographic information system (GIS) platform for environmental conditions, geometric and accident information on each analyzed homogeneous roadway segment has been used.

A GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows viewing, understanding, question, interpreting, and visualizing data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

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A GIS helps answer questions and solve problems by looking at data in a way that is quickly understood and easily shared. GIS technology can be integrated into any enterprise information system framework.

Italian Guidelines (2000) suggest an additional careful study for most critical homogeneous segment with high crash rate by comparing existing and potential infrastructural-geometric-environmental failures to determine potential countermeasures that can help to reduce the crash frequency.

By analyzing the crash rates, according to the Italian Guidelines (2000) we identified 32.04km of the analyzed highway with a low crash rate, 23.068km with a medium crash rate and 16.81km with a severe crash rate. Further investigations on driver speed behavior were carried out involving 56% of the road length with a severe crash rate. Speed data collection was carried by using a Light Detection and Ranging “KV Laser” located for 12 hours at the available lay-bys in connection with particular environmental and traffic conditions: dry roads, free flow conditions, and daylight hours.

The European Commission recently issued a directive (European Parliament, 2008) that requires the establishment and implementation of procedures relating to road-safety impact assessment, road-safety audits, management of road network safety, and safety inspection for roads to design, under construction, or in operation.

According to this European directive, procedure illustrated in this paper could be a simple and available tool which roadway engineers and practitioners should use to investigate and improve road safety.

2. Previous Studies

The design consistency evaluation is one of several promising tools that can be employed by roadway designers to improve roadway safety performance. A design inconsistency in a roadway segment can surprise drivers by violating their expectancies and increases the chance of delayed response times, speed errors, and unsafe driving maneuvers that may lead to higher collision risk. Possible factors that may affect safety conditions during travel can be directly linked to personal choices, vehicle conditions, the infrastructure and its environmental features and some experimental analyses were addressed to the relationships between vehicles, users and the environment. Many authors recommend ensuring the compatibility of the horizontal alignment elements. Compatibility of horizontal alignment elements is a traffic safety factor. If the horizontal alignment elements are compatible, the probability of driving errors is reduced. Incompatible elements of horizontal alignment can mislead the driver and cause him to choose an unsafe speed. Incompatibility of the horizontal alignment elements is increased if there is no successive transition between the elements. In practice, incompatible elements of horizontal alignment lead to unsafe driving because of potentially large speed variations. Investigations have shown that geometric compatibility of the horizontal alignment line is one of the attributes of traffic safety (Zˇilioniene and Vorobjovas, 2011). Many researchers have dealt with driver speed behavior on two-lane rural roads to identify all the possible factors that may affect safety conditions during travel. These factors can be directly linked to personal choices, vehicle conditions, the infrastructure and its environmental features. In the scientific literature there are many formulations of operating speed models on tangents and curves for two-lane rural roads and there are also several analyses of driver speed behavior entering and departing circular elements to measure deceleration and acceleration rates. Operating speed models set out in the literature generally predict a mean value of V_{85} (85^{th} percentile of speed distribution) at each geometric element, or a speed value for some roadway section. The number of operating speed prediction models on tangents set out in the literature generally is lower than on circular elements because driver speed behavior is more complex to analyze. In fact the users have more freedom driving on tangents segments than on circular elements, and therefore the variables that can correctly explain the phenomenon are outnumber.

Dell’Acqua and Russo (Dell’Acqua and Russo, 2011a) analyzed traffic-safety conditions for roadways in the Southern Italy located on flat/rolling land with a vertical grade of less than 6% and in the mountainous area with a vertical grade more than 6%. The study led to calibrate two injurious crash prediction models. Variables used in these models are: ADT, mean speed, the curvature change rate indicator, the vertical grade indicator, lanes plus shoulders width.

The same authors (Dell’Acqua and Russo, 2011b) developed four models to predict the operating speed on tangent and circular curve elements by using speed factors, geometric variables and the distress of road surface introduced in the equation by a four-point scale ranging from 0 to 3.

The results achieved are valuable for practitioners because they can use the difference between the operating speed obtained with the models and the standard design speed to determine the best solution that allows the standard design speed to be similar to the predicted operating speed by use of the explanatory variables introduced in the operating speed prediction models.

Torok (2011) describes the effect of road environment on chosen driving speed. Drivers in traffic flow, although guided by rules, make their own decisions when choosing speed. Decisions of drivers are influenced by environmental impacts and some of these impacts are planned, deliberate stimuli. Speed measurements were carried out on different urban and interurban road sections according to different design speeds or parameters.

The analysis of the weighting factors of the decision model shows that the drivers adjusted their speed in compliance with the actual environment of the roadway instead of respecting the maximum permissible speed in interurban, rural environment.

Lank and Steinauer (2011) presented the necessity of safety enhancements especially on low-volume rural roads. The basic causes of accidents described in this paper are inattentiveness or excessive speed. On the basis of the findings rumble strips can be recommended as an effective and above all cost effective measure for improving road safety. The results of this analysis showed how the rumble strips are cost-effective and quick to produce without weakening the road substance through milling work on the surface layer. Another advantage consisted in the additional visual warning of the road users through the retro-reflecting properties and the white coloring of the material.

Coutton-Jane et al. (2009) and Farah et al. (2009) show how a driving simulator can be an effective tool in research specially to investigate drivers' behavior. Detailed data that can be used to explain drivers' behavior is difficult to collect in the real world partly because human factor is variable, because it depends on a large number of parameters. So it should be useful to collect data with an interactive driving simulator and choose improvements to ensure safety.

3. Data Collection and Analysis

Italian Standard (2001) uses the design speed-profile to check the consistency of the horizontal alignment and to avoid dangerous changes in speed. However, the real speed used by the driver to travel can differ significantly from the design speed of the same element. Many researchers have verified that one of the parameters that most influence the safe driving is the speed variation and its correlation with the relative accident rates and accident frequency. Since 2003, the Department of Transportation Engineering at the University of Naples has been conducting a large research program based on speed and crash data collection on two-lane rural roads. The aim of this experimental analysis is to develop an accurate procedure to assess the safety conditions by a network approach reproducing real driver speed behavior at each roadway segments.

The accident data used in the research presented here involved almost 71.92 km of two-lane rural road in Southern Italy (S.P.430) located in the flat area with a vertical grade of less than 6%; Italian Guidelines (2000) were used attempting to identify the crash rate of the studied homogeneous road segments comparing the number of crashes per year per km per 10^6 vehicles (crash frequency over traffic exposure) with statistically thresholds. The analyzed highway with controlled access or rather road interchanges connects Capaccio (Paestum) and Sapri-Bussentino; 31 road segments (see Tab.1) with the same curvature change rate were adopted. In particular, these segments have a mean length of 2.32 km, mean ADT equal to5,392 vehicles per day over a period of eight years (2003-2010), speed limit of 90 km/h with possible local changes of 80km/h or 60km/h, road width (travel lanes equal to 3.75m plus shoulders equal to 1.50m) of 10.50 m. The studied road is characterized by 77 tangent segments ($length_{max}$ = 1,575m) and 99 circular curves (250m<radius<3000m) including 17 tunnels (40 m<L<1368 m) and 48 viaducts (32 m<L<717 m); it can be observed 11 km almost of slow lane for both travel directions with roadway width equal to 3.75m.

Crash data was made available to the Department of Transportation Engineering at the University of Naples by the Administration of the Province of Salerno. Over the total length of the network analyzed, 301 crashes can be observed from 2003 to 2010 with 444 injuries and 41 deaths. We identified two main crash types: single-vehicle crashes (vehicle exits the roadway and either strikes a fixed object or overturns) and tail crashes.

A careful analysis of the database has shown that a wide variety of crashes appear from 2009 to 2010 in connection with dry roads and good weather conditions; we have found that many deaths have occurred in the autumn (November) in 2004 while many injuries in the summer. It was observed that the maximum number for injurious crashes during relevant period is recorded for circular curves and of the vehicles involved in accidents, cars made up the highest proportion, at 85 %.

Italian Guidelines (2000) suggest a safety study to estimate the hazard conditions for each road segment by comparing the number of crashes over a specific roadway over a specific time period with the statistically thresholds referred to the whole analyzed road path.

In particular, when the homogeneous road segment is associated with severe crash rate, Italian Guidelines propose an evaluation between existing and potential infrastructural-geometric-environmental failures to determine potential countermeasures.

The suggested procedure can be summarized as follows:

- Determine the homogeneous road segments (*i*) into the road path can be divided and associate for the study period (*t*) the relative total number of crashes (N_i), length (l_i), number of vehicles per day over the period ($ADT_{i,t}$)
- Determine the *crash rate* "T_i" for each homogeneous segment defined as the number of crashes per year per km per 10^6 vehicles (crash frequency over traffic exposure) as follows (Eq. (1)):

$$T_i = \frac{10^6 \cdot N_i}{365 \cdot l_i \cdot \sum_t TGM_{i,t}} \tag{1}$$

- Determine the *mean crash rate* "T_m" on the analyzed road path as follows (Eq. (2)):

$$T_m = \frac{10^6 \cdot \sum N_i}{365 \cdot \sum_i \sum_t l \cdot TGM_{it}} \tag{2}$$

- Determine the lower control value "T^*_{inf}" (see Equ.3) and upper control value "T^*_{sup}" (see Equ.4) of the crash rate for the road segment *i-th* as follows (Eq. (3) and Eq. (4)):

$$T^*_{\inf} = T_m - K \cdot \sqrt{\frac{T_m}{M_i}} - \frac{1}{2 \cdot M_i} \tag{3}$$

$$T^*_{\sup} = T_m + K \cdot \sqrt{\frac{T_m}{M_i}} + \frac{1}{2 \cdot M_i} \tag{4}$$

Where:

K is the constant of the Poisson probability distribution equal to 1.645 with error margin never exceeded 10%;

M_i is estimated as follows (Eq. (5)):

$$M_i = 365 \cdot 10^{-6} \cdot l_i \cdot \sum_t TGM_{i,t} \tag{5}$$

- Crash level assignment for each *i-th* homogeneous road segment as follows (Eq. (6)):

$$T_i \le T^*_{\inf} \;\; Low\ crash\ rate \qquad T^*_{\inf} \le T_i \le T^*_{\sup} \;\; Moderate\ crash\ rate \qquad T_i \ge T^*_{\sup} \;\; Severe\ crash\ rate \tag{6}$$

Table 1 shows in detail the summary of the main features for the studied homogeneous road segments (ID) with crash counts from 2003 to 2010, with the relative crash rate (T_i), lower control line (T^*_{inf}) and upper control line (T^*_{inf}) and crash level assignment according to the Equation 6.

Analysis showed that homogeneous road segments with high crash rates occurred in 16% of cases (6 segments) while with moderate crash rates in 38% of cases (15 segments) and low crash rates in 46% of cases (10 segments).

Further investigations on driver speed behavior were carried out involving only homogeneous road segments with severe crash rate investigating 9.471km (ID 28 and ID 29). Speed data collection was carried by using a Light Detection and Ranging "KV Laser" located for 12 hours at the lay-bys available on this road homogeneous segment in connection with particular environmental and traffic conditions: dry roads, free flow conditions, and daylight hours.

Table 1
Safety Thresholds for the Analyzed Road Segments

ID	*Lenght [km]*	*ADT [vehicle/day]*	*Number of crashes*	T_i	T^*_{inf}	T^*_{sup}	*Crash Rate*
1	1.612	10925	11	0.214	0.263	0.580	Low
2	1.939	8920	14	0.277	0.261	0.582	Moderate
3	4.055	8920	30	0.284	0.313	0.530	Low
4	3.8	8920	28	0.283	0.309	0.534	Low
5	1.493	7057	8	0.260	0.213	0.631	Moderate
6	4.624	7057	24	0.252	0.307	0.536	Low
7	1.975	6701	0	0.000	-	-	Low
8	0.294	6727	1	0.173	-0.109	0.953	Moderate
9	0.316	6727	4	0.644	-0.088	0.931	Moderate
10	0.866	6756	9	0.527	0.134	0.709	Moderate
11	0.622	6755	1	0.082	0.076	0.767	Moderate
12	1.855	6755	2	0.055	0.231	0.612	Low
13	0.996	6755	1	0.051	0.155	0.688	Low
14	2.287	6755	0	0.000	0.252	0.592	Low
15	1.59	6554	5	0.262	0.151	0.692	Moderate
16	0.523	6554	2	0.200	0.034	0.809	Moderate
17	4.635	6146	30	0.361	0.299	0.545	Moderate
18	2.901	6016	33	0.648	0.262	0.581	Severe
19	2.555	6016	29	0.646	0.251	0.592	Severe
20	2.72	6016	31	0.649	0.257	0.587	Severe
21	1.276	4663	6	0.345	0.137	0.707	Moderate
22	2.837	4663	13	0.337	0.237	0.607	Moderate
23	2.908	3569	5	0.165	0.211	0.632	Low
24	1.683	3569	2	0.114	0.138	0.705	Low
25	1.415	1671	4	1.072	-0.265	1.109	Moderate
26	1.598	1336	2	0.609	-0.320	1.163	Moderate
27	4.842	1167	2	0.222	0.010	0.833	Moderate
28	6.485	877	13	1.025	0.082	0.761	Severe
29	2.986	742	9	1.686	-0.134	0.978	Severe
30	3.016	1417	6	0.481	0.079	0.764	Moderate
31	1.214	443	7	4.458	-0.749	1.593	Severe

One of the parameters that most influence the safe driving is the speed variable. In the scientific literature some research works have dealt with speed prediction models to analyse real driver behaviour. Operating speed profiles are used to assess the design consistency by identifying locations with a great speed variability between following road elements. The aim of an additional careful analysis on the road segments with severe crash rate was to find a relationship involving crash rate and difference between operating and design speed. Drivers often prefer to feel a certain degree of discomfort in exchange for obtaining greater speeds. For some geometric conditions, drivers adopt a speed that sacrifices not only comfort but also safety.

4. Case Study

Investigations on driver speed behavior were carried out on two homogeneous road segments with a severe crash rate (ID 28 and ID 29) involving a total length of 9.471km.

Speed data collection was carried in 2012 by using a Light Detection and Ranging “KV Laser” located for 12 hours at the lay-bys available along the selected elements length by using a tripod hidden from the view of roadway users, who might have altered their speed once they had seen the device.

Motorcycles and also trucks were eliminated from the database to estimate at each section the 85th percentile of speed distribution according to some procedures in the scientific literature (Dell’Acqua and Russo, 2011a). Two road sections were selected for the speed data collection: one section located on a tangent segment and another located on a circular curve (see Table 2).

Fig.1 gives some examples of the road cross-sections type for the selected road segments.

Fig. 1.
Road Cross Sections Type

Table 2 shows some synthetic features measured on selected elements where speed data collection were carried out: one tangent segment belonging to 28th homogeneous road segment and one circular curve belonging to 29th homogeneous road segment as shown in Tab.1. In particular, we have associated, with each element, the position of speed device, the direction of travel (0, according to the increase of kilometers from Paestum to Policastro and 1, according to the decrease of kilometers from Policastro to Paestum), the length, the curvature, and for two directions of travel for selected highway we have related the sample size for calculating speed values, design speed value (V_d), observed mean speed value (V_{mean}), observed operating speed value (V_{85}), std. dev. of speed distribution (σ), coefficient of variation (CV) that is an indicator of measurement dispersion to compare different samples on the basis of the mean operating speed and standard deviations. It can be seen that all defined sections, in both direction, have a C.V. of less than 1 and this means that no section has a dispersion of speed data higher than another section.

Table 2
Descriptive statistics of features on studied elements

ID	*Element*	*Device position along the road* **[km]**	*Dir*	*Lenght* **[m]**	*1/R* **[m^{-1}]**	*Size* **[n]**	V_d **[km/h]**	V_{mean} **[km/h]**	V_{85} **[km/h]**	σ **[km/h]**	*CV*
28	Tangent	162+400	0	1278	0	850	100	94	116	24.231	0.19
			1			771	100	91	111	20.385	0.20
29	Curve	163+000	0	558.72	0.002	889	100	90	107	16.572	0.18
			1			277	100	82	102	18.888	0.22

5. Conclusions and Next Steps

The research presented here aims to assess the level of the crash rate at each homogeneous road segment by a comparison with standard Italian thresholds. We used 71.98 km of a two-lane rural road for this study with 11 km almost of slow lane for both travel directions in Southern Italy.

8 years of the accident database (2003 to 2010) were involved, with 444 injuries and 41 deaths; single-vehicle crashes and tail crashes were main crash types.

We have also observed that the maximum number for injurious crashes during relevant period is recorded for circular curves and of the vehicles involved in accidents, cars made up the highest proportion, at 85%. Analysis showed that homogeneous road segments with high crash rate occurred in 16% of cases; thus, 9.471km with severe crash rate were further investigated by speed data collection in connection with dry roads, free flow conditions, and daylight hours to analyze slightly driver speed behavior and crash rate relationship.

In this way, by knowing critical road segments, we can define a consistent combination of interventions according also to the difference between design and operating speed value reducing crash frequency, its severity and social cost for the more frequently expected and dangerous crash scenario.

Future development of research addresses a) the investigation of driver speed behavior on larger sample of homogeneous road segments associated with severe crash rates, b) the improvement of the crash information, c) before-after analysis compared the results of a simulated setting with real implementation solution to check the reliability of the proposed alternatives improving the safety conditions.

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References

Chassiakos A. P.; Panagolia C.; Theodorakopoulos D.D. 2005. Development of Decision-Support System for Managing Highway Safety, *Journal of Transportation Engineering of ASCE*: 364-373.

Coutton-Jean C.; Mestre D.R.; Goulon C.; Bootsma R.J. 2009. The role of edge lines in curve driving. *Elsevier Trasportation Research Part F: Traffic Psychology and Behaviour*, 12: 483-493.

Dell'Acqua, G.; Russo, F. 2011a. Road Performance Evaluation Using Geometric Consistency and Pavement Distress Data. *Transportation Research Record*: *Journal of the Transportations Research Board,* 2203: 194–202.

Dell'Acqua, G.; Russo, F. 2011b. Safety Performance Functions for Low-Volume Roads. *The Baltic Journal of Road and Bridge Engineering*, 6(4): 225-234.

European Parliament and the Council on Road Infrastructure Safety Management. 2008. Directive 2008/96/EC, *Official Journal of the European Union* L319: 59–67.

Farah, H.; Bekhor, S.; Polus, A.; 2009. Risk evaluation by modelling of passing behaviour on two –lane rural highways. *Elsevier Trasportation Research*: *Accident Analysis and Prevention,* 41: 887-894.

Kanellaidis, G.; Vardaki, S. 2011. Highway Geometric Design from the Perspective of Recent Safety Developments, *Journal of Transportation Engineering of ASCE:* 841-844.

Lank, C.; Steinauer, B. 2011. Increasing Road Safety by Influencing Drivers' Speed Choice with Sound and Vibration. *Transportation Research Record*: *Journal of the Transportations Research Board*, 2248: 45–52.

Lazda, Z.; Smirnovs, J. 2009. Evaluation of Road Traffic Safety Level in the State Main Road Network of Latvi*a, The Baltic Journal of Road and Bridge Engineering* 4(4): 156-160.

Mattar-Habib, C.; Polus, A.; Farah, H. 2008. Further Evaluation of the Relationship between Enhanced Consistency Model and Crash-Rates of Two-Lane Rural Roads in Israel and Germany, *European Journal of Transport and Infrastructure Research* – EJTIR 8(4): 320–332.

Ministero delle Infrastrutture e dei Trasporti - Ispettorato Generale per la Circolazione e la Sicurezza Stradale. 2000. *Linee guida per le analisi di sicurezza delle strade*. Rapporto CNR 5/05/2000, Italy.

Ministero delle Infrastrutture e dei Trasporti. 2001. *Norme funzionali e geometriche per la costruzione delle strade*. D.M. 05/11/2001, Italy.

Ratkevičiūtė, K.; Čygas, D.; Laurinavičius, A.; Mačiulis, A. 2007. Analysis and Evaluation of the Efficiency of Road Safety Measures Applied to Lithuanian Roads, *The Baltic Journal of Road and Bridge Engineering* 2(2): 81-87.

Török, A. 2011. Investigation of road environment effects on choice of urban and interurban driving speed. *International Journal for Traffic and Transport Engineering,* 1(1): 1–9.

Zˇilioniene, D. and Vorobjovas, V. 2011. Correspondence of Horizontal and Vertical Alignment with Safe Driving Conditions on Low-Volume Roads, *Transportation Research Record: Journal of the Transportation Research Board,* 2203: 49–56.

ANALYSIS OF ROAD SAFETY: THREE LEVELS OF INVESTIGATION

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Abstract: A survey for road safety must draw on a wide range of data, for the technician or researcher it is important to be able to access the databases organized and up to date. These data concern sure the incidents, the study area demographics, the current infrastructure data, traffic flows, but other data relate to different study problems. Without well organized bases the collection and analysis of data becomes an expensive phase that can and should be carried out, depending on the available resources, to a different levels of detail. Various levels of detail require the acquisition of different kinds of data. Their treatment may provide different indexes and accidents ratio that can bring different interpretations of the road accident phenomena: the interpretations are related to the consistency of the used data. The survey over a wide area can be carried out by three different levels of analysis. The first is a macroscopic level by aggregated data and with a minimal detail. A second level deepens the investigations that can cover those sub-areas for which has been possible to detect presence of some accident phenomena. This more detailed investigation (meso-level) needs for focus gather further careful data, analysis and formulation of specific actions only for those safety situations that the second level has highlighted. For these situations, at end, it can upgrade to a more detailed level and therefore more expensive. This level (micro level) can require a study of every single accident report in the area. The procedure is general and can be applied to the analysis of traffic safety on rural roads or on urban roads. In the work an example of safety analysis sequence for a town of small / medium size will be considered, with the analysis and processing of technical steps that were valued necessary.

Keywords: Road safety, Safety Analysis, Level of Analysis, Urban road, Rural road.

1. Introduction

The aim of safety analyses is the reduction in the number of accidents and their consequences. This objective is pursued through the study of accidents that occurred under certain environmental and traffic conditions. Accident studies allow the technician or the researchers to formulate instructions on possible actions to solve the technical failure of the traffic flows observed and to realize improvements to achieve a quantifiable reduction in crash frequency or severity.

The study of road safety in urban or rural area has shown that the number of accidents and their severity depends on:
- the characteristics of the road environment,
- the traffic conditions,
- the behavior of road users.

The characteristics of the road environment both in urban and rural area affect the safety conditions, so the characteristics to be observed can be mainly of geometrical character (width of the road section, number of lanes in each direction, presence or absence of specialized lanes, presence or absence of sight distances). Other conditions that relate to the road environment and can affect the safety of traffic flow are relative to the type and conditions of the pavement, the presence or absence of lighting at night, etc.

Also traffic conditions may affect road safety (Martin 2002): low traffic flows encourage high speed driving and accidents with more serious consequences, high flows tend to increase accidents due to driver impatience (dangerous or incorrect maneuvers).

The driver behavior is ultimately the main factor influencing the traffic safety. The reactions of a driver's road environment and traffic conditions occur through the velocity vector (magnitude and direction) associated with it. The measures of the velocity vector may be a valuation of the behavioral reactions of the driver subjected to the external factors already shown.

The way to analyze accidents can, therefore, be different depending on the level of detail and data available for the study area. In many cases, safety studies are commissioned to limited budget and it is with such limited resources that the technician has to work.

On the other hand, if the safety study should not be able to providing direct application proposals for solutions defined, it can also be limited to a survey of some special situations in order to provide general solutions (strategic solutions).

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This study using three different levels and allows results from the first level of approximation using aggregated data of accidents, but if necessary it is possible to deepen the results obtained with examining the broken down data to the higher study level. This paper proposes and deepens the study of traffic safety with three different levels of approximation: it start from an initial level that can be used for more general studies in the area with the use of accident data available from official statistics up to third and deeper level of study of smallest areas directly with use of data taken from accident reports drawn by police officers, for every single accident and of data on traffic flows on the sections affected. For each level are different objectives, the necessary data to the study, descriptive models of the phenomenon and, of course, results.

2. Description of the method of analysis on different levels

As well as land use planning approaches are realized at different levels, similarly the study of traffic safety can be conducted at various levels of approximation: the three proposed levels can be defined in terms of study area or simply how to degree of approximation required (Fig. 1 and Fig. 2):

- Macro-level: level with the highest degree of approximation and based on the use of aggregate data accidents, the characteristics of the vehicle fleet and road users; it is suitable for surveys of large areas or large conurbations;
- Meso-level: level with a relatively higher degree of detail of the previous still based on aggregated data, but with more information on infrastructure (geometry, traffic conditions, weather). It is a level indicated for surveys about smaller areas and allows the construction of accident maps;
- Micro-level: the level with the best degree of approximation possible based on the use of disaggregated data such as those that can be drawn from reports of single incidents; with this new information, joined to those of previous levels, it is possible to analyze every single crash to try to suggest the most probable causes that caused it.

The first two levels of investigation provide numerical results which indexes and ratios to be evaluated for comparison. One of the methods of comparison could be to consider the values, among all those calculated, which exceeds the average value of the determinations. More selective might be to consider as the threshold the average value increased by a some amount of the standard error or standard deviation value. In the latter case, the assumption of distribution like that normal (Gaussian), if the average is added once the value of standard deviation then it considers all the measurements that exceed the 84^{th} percentile of the distribution of values.

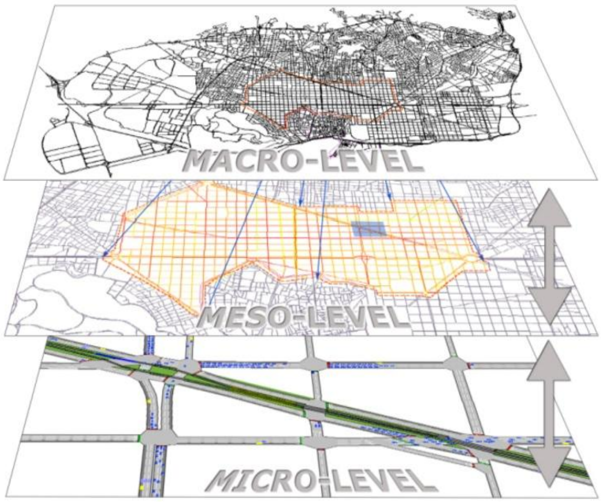

Fig. 1.
Different levels of approximation

Levels	Data	Results
Macro	Accident number, injury, deaths Type of accidents, vehicles involved, etc. Territorial characteristics as surface area, population and transportation systems, employees and students, mobility systems, fleet vehicles, etc.	Localized aggregate and generalised aggregated statistics as Mortality ratio; Ratio to cause injury, Hazard ratio (injured / accidents), Hazard ratio (involved / circulating), Hazard ratio (involved / outstanding by the distance), Risk of death (deaths / passengers as function of traffic), etc.
Meso	*Like the earlier and more* Location of road accidents, Geometric characteristics of the infrastructure, Weather information, Characteristics of traffic flows, etc.	*Like the earlier and more* Accident indices (accidents / km), Accident indices (accidents / km depending by flows), Mapping of sections as function of the accident indices, Thematic maps, etc.
Micro	*Like the earlier and more* Access and registration of accident reports, Detailed geometric characteristics of the infrastructure, Characteristics of the road pavements, Detailed traffic flows, etc.	*Like the earlier and more* Thematic maps based on the type of accidents, as function of frequency of accidents, depending on the severity of accidents, Road safety audits, Accident scenarios, etc.

Fig. 2.
Different levels of approximation, data, results

2.1. Macro-level analysis

The macroscopic level of analysis requires data that can be obtained from official statistics published annually (in Italy that provided by ACI-ISTAT on vehicles and accidents) or decennial (ISTAT census of the population):

- Statistics showing the number of accidents, the type, number of injuries, injury severity and type of vehicles involved;
- Territorial general characteristics of the study area such as, for example, the total area, the number of people (employees, students etc.), the reasons of displacement, the present mode of transport, the vehicle fleet assets.

With these data it is possible to the construction of indexes and descriptive statistical reports such as, for example, those shown in Table 1.

Some indexes and relationships given in Table 1 should be taken with caution because are very sensitive (R_m, for example, could provides very high number of accidents down) or too rough. This level of analysis is applicable over broad areas. The results that can be drawn from the indices and ratios indicated in Table 1 may only be used as comparisons between areas.

Table 1
Some indexes and descriptive ratios related to the Macro-level investigation

Index/Ratios	Expression	Variables
Mortality index	$R_m = (M/I)*100$	*I = Total number of accidents* *M = Number of deaths* *F = Number of injuries* *P = Population of area* *V = vehicle (i, damaged; c, in circulation)*
Severity index	$R_f = (F/I)*100$	
Severity rates	$T_f = (F/P)*10^3$	
Hazard Ratio	$R_p = (M/(M+F))*100$	
Flow ratio	$R_c = V_i/V_c$	

Table 2
Some indexes and descriptive reports related to the Meso-level investigation

Index/Ratios	Expression	Variables
Accident rate	$T_i = (I/\text{km})$	*I = Total number of accidents* *AADT = Annual Average Daily Traffic* *Ic, If, Im = Accidents with property damage, with injuries, deaths* *a, b, c = coefficients (weights)*
Accident rate	$T_i = (I/(\text{AADT}*365*\text{km}))*10^8$	
Severity Index	$S_i = \frac{a*I_c + b*I_f + c*I_m}{I}$	

2.2. Meso-level analysis

Also for analysis to the upper level of detail (meso-analysis) uses the values taken by the indices of Table 1. A higher level of definition also requires information about the characteristics of the relevant infrastructure such as layouts, traffic flows and if available, the weather. Know the characteristics of the infrastructure may allow the segmentation of a road in homogeneous sections (uniform geometry or traffic flows). This additional information (AADT, annual average daily traffic, in TRAIL 2012) allow coming up with further indexes useful to provide additional information that was not possible to discriminate the previous level of analysis. In particular, it is possible to define accident indexes for homogeneous sections based on geometric characteristics and concerning the conditions of circulation, as shown in Table 2.

The index values shown in Table 2 are used both for comparisons between homogeneous sections the same infrastructure between both of different infrastructures. The first index provides an indication about the risks of the section compared only to the length of the section considered.

The second one considers the number of accidents compared to traffic flows and it is a more explanatory index for road safety phenomena. In fact, it indicates how many times an accident occurs as a function of all the events «transits» that are recorded on the section. The low value of the index is usually multiplied by 10^8. The severity index (S_i) provides overall information on the consequences (in terms of damage) accidents in the area. Its value is, of course, affected by the value chosen for the coefficients (a, b and c): a current practice puts them respectively equal to 1, 2 and 5. The best degree of accuracy and knowledge of homogeneous sections network of the study area also allows to prepare thematic maps that facilitate the understanding of the road safety phenomena in the area. It may be interesting to recall that the application of this level of investigation of traffic safety may be sufficient for use with PMS (Pavement Management Systems).

2.3. Micro-level analysis

The micro level is the one with the highest degree of accuracy and with as much detail as possible about the data. When the level of the previous study for some situations shows indices higher than that chosen as reference, it is necessary to deepen the study in greater detail and with different methods. If it use the technique of Road Safety Audits should obtain precise data on which to assess formally the rightness of the design of the section / intersection that must be analyzed. These data allow to identify potential hazards existing in the section / intersection both from the point of view of the layout that from the point of view of functionality. Must detect the presence of safety issues that may affect any user category, investigating how the road space is perceived, interpreted and used. Finally suggest some countermeasures with the best benefit-cost ratio. The Road Safety Audits, however, will not be discussed in this note.

In this work the approach to the study of sections / intersections that have shown higher risk rates will be played with the definition and analysis of accident scenarios. These start from the definition or identification (a priori or a posteriori) of a number of scenarios for the accident events known (rank), accidents cluster for similarity. The risk of a single scenario may be assessed by indices of accidents that are in some way, directly proportional to the probability of occurrence of the accident event. The sequence of steps for the analysis of the scenarios, for a defined area of study, is the following:

- Acquisition of detailed information on individual claims on the basis of incident reports prepared by agents;
- Study of any claim for the correct definition of the 4 typical situations (driving, failure, shock, and emergency);
- Allocation of individual accidents analyzed for individual scenarios defined;
- Evaluation of the hazard scenarios more populated;
- Proposal of a series of measures of road traffic safety.

In a previous work has been able to define a large number of accident scenarios that have found application mainly for urban traffic safety (Brenac, 1997; Capaldo, 2003). Some of them will be illustrated in the following.

To better describe the various phases of analysis proposed they will be applied to a real case study.

3. Application to a real case

The case study chosen is a town of about 37,000 inhabitants in an area of approximately 73.5 km^2. The town of Formia is located in the province of Latina, in the Lazio region (IT). It facing the Tyrrhenian Sea and has a strong tourist vocation. The orthographic characteristics of the territory define areas with different main destination: a town center and a residential area with some zones for agricultural and a decentralized industrial zone. The fleet of vehicles registered in the municipality is about 34,000 units in the same year of the census of the population: 68% of the total is constituted by the cars and the motorcycles by about 22%.

3.1. Macro Level Analysis

The macro level analysis of the territory from the collection of essential data about demographics, the surface and the vehicle fleet assets, are described in the previous paragraph. Later they were collected and examined the data of traffic accidents. The municipality is chosen small and medium sized so these data are immediately and freely available along with other annual statistics. They may be purchased or it may contact the local police command to obtain aggregate information on accidents. With these data it was possible to construct diagrams that allow the comparison of the percentage of total accidents recorded in the municipality of Formia than those recorded in Italy, for months and hours of the day (Fig. 3 and Fig. 4).

The first of these diagrams shows how to during the summer months of July and August there is a considerable increase in the percentage of accidents due primarily to the increase the traffic flows.

During the daytime there are still accident peaks around the range of time from 8.00 am to 9.00 am and from 6.00 pm to 7:00 pm. In addition there was a minor peak between 3.00 pm to 4.00 pm. Essentially peaks accidents recorded can be associated with increased traffic flows concentrated in the morning hours (went to work) and the evening (returned from work) for different user groups (two peaks).

The comparison between the accident rates and cause injury (first and second row of Table 3) indicates how the municipality of Formia has index higher than those national and an index of accidents (third row of Table 3) higher than region Lazio and the province of Latina and, so, requires some more detailed surveys.

3.2. Meso-level Analysis

The aggregate data accidents were found through the offices of the state police and local police in the year 2011. It has reported a total of 124 accidents and allow to quantify those that occurred at junctions and intersections (60 on 124 that corresponding to about 48%). The accidents on road trunks are the almost equal to this percentage. Further processing of the data leads to Table 4, which considers all the roads that have recorded at least three accidents. For these roads have been calculated relations between Injured / Accidents and Severity Index (see Table 2). Were also calculated average and standard deviation for the data in Table 4 and the sum of the average with the standard deviation (see point 2). The calculation was carried out only on the values presented in Table 4 that the partial data chosen from the beginning of the study showed that the highest number of accidents. The average is therefore higher than the average that applies to all accidents recorded in 2011 in the municipal area. For this reason it is considered sufficient to use the mean as the threshold hazard for the identified infrastructure.

In this way have been identified, according to a decreasing order of the index of severity and related to the ratio between injured and accidents, at least three locations that need a special attention (1, 2 and 4). In this case it seems to also add the location 5.

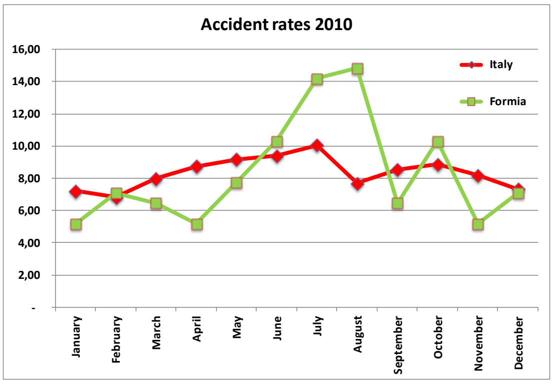

Fig. 3.
Accident rates during the months for Italy and Formia

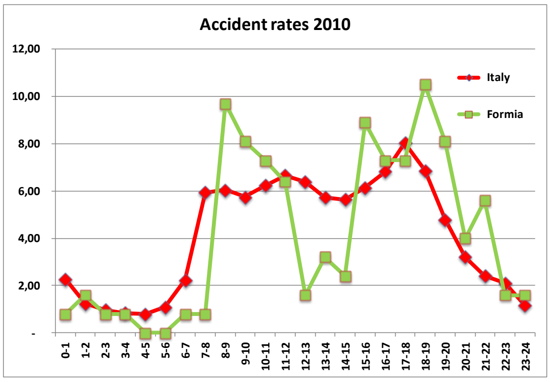

Fig. 4.
Accident rates during the daily hours for Italy and Formia

3.3. Micro-level analysis

The analysis at the highest level of definition (micro-level) was conducted with the accident scenarios (Brenac, Megherb, 1996, Brenac et al., 1996, Brenac, 1997, Capaldo, 2002, 2003, Capaldo, Biggiero 2006). In this work, for concision, are showed only those scenarios that were more frequent in the safety study of the town of Formia. It should be noted that the technique of accident scenarios is a tool for the classification of incidents based on their overall similarity but not on the exact identity of the accidents themselves. In particular, the technique is carried out through the similarity of the timeline that leads from the driving situation to shock situation. The classification of a number of accidents that have the same sequence of occurrence allows defining a series of remedies that tend to disrupt the sequence in one of its phases and, ultimately, lead to the accident.

In this phase of work were analyzed individual reports of 124 incidents in the municipality of Formia for the year 2011, have also been localized intersections identified in Table 4 and they were taken into consideration only the scenarios with greater frequency occurrences, they are reported in the following Table 5.

The 124 road accidents are all they those agents have recorded for the year 2011 in the municipal area. Accident reports are related to damage to the property, the people and, if these are, the fatalities. They, therefore, are not only road accidents that follow the standard definition (only accidents that have caused at least an injury to person).

Table 3
Index and ratios for the study area for year 2010

Index/Ratio	Variables	Italy	Lazio	Latina	Formia
$T_i=(I/P)*10^3$	*I = Total number of accidents*	3,49	4,82	3,80	4,13
$T_f=(F/P)*10^3$	*F = Number of injuries* *P = Population in the area*	4,99	6,74	6,11	5,70
$I_c=(I/V_c)*10^3$	*Vc = vehicles on the road*	4,34	5,56	4,52	4,57

In Table 6 are considered accident scenarios that adapt to the situations observed in locations with severity index greater than the threshold.

Table 4
Indexes and descriptive reports related to different locations for the meso-level survey

	Roads	N. of Accidents.	Accidents with Injury	N. of Injury	Injury/ Accidents	S_i
1	SS 7 Appia side to NA	28	25	34	1,21	1,89
2	SS 7 Variante Appia	17	15	28	1,65	1,88
3	Via Vitruvio	15	10	17	1,13	1,67
4	Via Emanuele Filiberto	8	7	9	1,13	1,88
5	Viale dell’Unità d’Italia	7	4	8	1,14	1,57
6	Via Giacomo Matteotti	6	4	7	1,17	1,67
7	Lungomare della Repubblica	5	3	6	1,20	1,60
8	Via Rotabile	4	2	4	1,00	1,50
9	SS 7 Appia side to RM	3	2	2	0,67	1,67
10	Via Ferrucci	3	1	1	0,33	1,33
11	SS 630	3	2	2	0,67	1,67
	Average				***1,02***	***1,63***
	Std. Dev.				***0,35***	***0,16***
	Average + Std. Dev.				***1,37***	***1,79***

Table 5
Accident scenarios chosen for the locations highlighted in Table 4

Ref.	Driving situation	Breaking situation	Emergency	Choc
1a	A vehicle moving along a main road and have to turn left	The vehicle is about to turn, but came from behind a high speed vehicle	no reaction	The vehicle is buffered
1b		The vehicle is about to turn but comes from the opposite lane a vehicle at high speed	no reaction	The vehicle is overcome
2c	A vehicle is on the secondary road with the obligation of the above or the stop sign and must take the main left	The vehicle failed to meet the requirement of the above or the STOP signal	no reaction	The vehicle is overcome on the main road
2d			no reaction	The vehicle overcomes another vehicle on the highway

Source: (Capaldo (2003))

Almost all locations in Table 4 are in peri urban, except that relating to the n. 4 which is in the city center of the town. The scenarios with greater number of events are those 1a, 1b and 2c. These are all situations arising from operations, regular and not, for intersections with traffic at high speeds (speed as high as not to allow reactions by drivers of vehicles). All the locations are on the main roads with high volumes flows caused by attraction poles (for urban intersection) or transit flows.

All scenarios showed in Table 5 are descriptive of accidents that occur at intersections affected by high traffic flows and speeds. Drivers of the main road do not pay too much attention to vehicles of the same current also wishing to change direction (turn left). On the other hand the high flows into the mainstream «force» the drivers of the secondary stream to doing something illegal to enter. But in any case there is no time to attempt any reaction (fast flows, confined spaces, small gaps). A first set of remedies regards the design of the intersections. For scenarios 1a and 1b can improve the situation if the intersection had a middle lane in order to accumulation of the flows for a left turn: in this way the vehicle going not to turn on the median centerline but it waiting on its turn lane, more «secure». To avoid situations that realize the scenarios 2c and 2d it can proceed with some traffic lights intersections.

Table 6
Indexes and descriptive reports related to different locations for meso-level analysis

Roads		Scenarios	N. of Accidents	Accidents with injury	N. of injury	N. injury/ N. accidents	S_i
1	SS 7 Appia	1b	5	4	7	1,40	1,80
2	SS 7 Variante Appia	1a	3	3	5	1,67	2,00
4	Via E. Filiberto	1a	2	1	2	1,00	1,50
		1b	1	1	1	1,00	2,00
		2d	1	1	1	1,00	2,00
5	Viale dell'Unità d'Italia	2c	2	1	4	2,00	1,50
		2d	1	1	1	1,00	2,00
		1b	1	1	1	1,00	2,00

3.4. Proposals for action and economic evaluations

For all scenarios and for all locations considered it is necessary try to obtain a reduction of the running speeds of vehicle flows. Systems to try and get the results are: putting the new road vertical signs, and also new horizontal lines (paint, plastic, elastic polymeric materials etc.) for the redesign of the intersections and any specialized turn lanes. Where possible it is recommended the adoption of transverse rumble strips, transverse grooves up to the speed bumps. To obtain slowdowns gains may be utilized also recorders / viewers speed of transit (without registration of the plate of the vehicle for an automatic fine).

The costs of measures must be proportionate to the benefits obtained in the time in which expects to amortize the realized works. The economic benefits can be valued according to the damage and injuries that such measures to are able to prevent. For example, a light injured has a cost to the community of about 25,000 Euros, a seriously injured has a cost to more than 75,000 Euros and a dead can reach a cost around 1.200.000/1.500.000 Euros.

4. Conclusion

In this work it has applied in sequence a series of methodologies for analysis of road accidents, with different levels of detail, to arrive at proposals for measures targeted on the actual needs recorded on the survey sites. The analysis was conducted on the real territory starting with an overview of the theoretical approach to a more detailed definition that has considered the single road accident that occurred at the intersections or trunks of the municipal area. These different levels have allowed focusing the attention (and limited resources) only on those incidental situations with higher indices of risk or injuries.

The work finally demonstrated the need to operate on different data bases: these must be as complete as possible, easily and constantly upgradeable, as well as interactive. From this point of view it must encourage the establishment of monitoring centers on wide areas in order to road safety studies, centers that may facilitate the coordination, the maintenance and the filling of all different databases.

References

Brenac T.; Delcamp J.; Pelat S.; Teisseire G.; 1996. *Scenarios types d'accidents de la circulation dans le department des Bouches du Rhone*. Rapport MA 9611-2-73.

Brenac, T. 1997. *L'analyse séquentielle de l'accident de la route (méthode INRETS) comment la mettre en pratique dans les diagnostics de sécurité routière?* Rapport INRETS, Outils et Méthodes: 3 - 79.

Brenac, T.; Megherb, B. 1996. Diagnostic de sécurité routière sur une ville: intéret de l'analyse fine de procédures d'accidents tirées aléatoirement. *Recherche Transports Sécurité*, 52: 59 - 71.

Capaldo F. S. 2002. Analisi di incidenti in ambito urbano medio-piccolo. In Proceedings of the *XII Convegno Internazionale SIIV,* Parma, Italy.

Capaldo, F. S. 2003. Sicurezza stradale urbana: definizione di scenari di incidente ad elevata sinistrosità. In Proceedings of the *XIII Convegno Nazionale SIIV, Padova*, 2003.

Capaldo, F. S.; Biggiero L. 2006. Una misura della sinistrosità degli scenari di incidente in ambito urbano. In Proceedings of the *XVI Convegno Nazionale SIIV - Campus di Arcavacata di Rende (CS).*

Greibe, P. 2003. Accident prediction models for urban roads, *Accident Analysis and Prevention* 35(2): 273-285.

Martin, J. L. 2002. Relationship between crash rate and hourly traffic flow on interurban motorways, *Accident Analysis and Prevention* 34(5): 619-629.

TRAIL, 2012. Portale nazionale delle infrastrutture di trasporto e logistica del sistema camerale. Available from Internet: <http://www.trail.unioncamere.it/ricerca_infrastrutture.asp?idtipo=infrastrutture&idcategoria=1>

Session 4: Transport Infrastructure and Intelligent Transport Systems

ITS SUPPORTED PARKING LOT MANAGEMENT

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Abstract: In recent decades the number of vehicles in urban areas has rapidly increased causing problems such as traffic congestion and prolonged parking space search time. To overcome the problem of parking place search, large ground/underground parking lots have been built in city centres and other areas with high demand for parking space like office buildings, shopping malls, airports, etc. Driver information systems based on technologies developed within the intelligent transportation systems (ITS) have been implemented to inform the drivers about the number of free parking spaces and their distribution between different parking lots or between different levels in a particular parking lot. Such ITS based information systems use different sensors to detect car presence on a parking space like magnetic, infrared or ultrasonic sensors and belong to classical parking lot management systems. These sensors must be mounted on every single parking space and require significant installation and maintenance effort. Many parking lots also have installed cameras that cover most or all parking places used for surveillance purpose. To reduce parking lot management cost, installed cameras are being more and more used for parking lot management tasks like incoming and outgoing car counting, parking place occupancy detection, incident detection, parking lot security, and parking payment via license plate recognition. Such camera based systems have several advantages: high reliability (comparable to infrared sensors), one camera can cover a relatively large parking lot area, relatively small numbers of cameras are needed to cover the entire parking lot (number of classical sensors is equal to number of parking spaces), intelligent cameras with integrated embedded computer vision systems perform vehicle detection locally thus enabling easy integration into existing parking lot management systems, video footage can be used for additional purposes like person counting and recognition, surveillance, security, etc. This paper gives a review of existing computer vision based parking lot management systems. Implementation possibilities of additional ITS functionality (driver informing, driver navigation to a free parking space, parking lot usage statistics) are being analyzed. Problems of such systems are being investigated and possible solutions are evaluated. Comparison of vision system complexity to classical management systems is also given.

Keywords: ITS, parking lot management, computer vision, driver navigation system.

1. Introduction

Rapid economic and technical development enabled people all over the globe private ownership of a vehicle. While enabling people more freedom, shorter travel times and better utilization of their working and leisure time, mass ownership of vehicles is also constantly producing challenges for urban, traffic and road planers. Demand for wider and higher quality roads rises, crossroads have to be controlled, traffic rules have to be augmented, etc. One of the challenging demands, that today has still room for improvement, are places where vehicles can be left when not used or parking lots. They have to be placed in areas with high parking space demand and offer appropriate capacity (Maršanić et al. 2010).

Parking lots can be owned by several persons (every vehicle owner has its own parking place in the parking lot) or by only one person or company. When a large parking lot is owned by only one person or company, economic revenue of that parking lot is crucial. Therefore they are built in areas with high vehicle and people circulation like shopping malls, airports, business centres, tourist resorts, intermodal traffic junctions, etc. Parking lot owner and user share the same goal, i.e. to provide/find free parking space at the most convenient place. Both have a need for a parking lot control system that monitors and informs about the quantity of free parking spaces, ensures safe usage, navigates individual users to reserved parking space or parking lot nearest to the final goal, and ensures accurate payment according to time the vehicle spent on the parking place.

Such parking lot control systems have to work individually and as part of a wider urban parking system. They are usually built under the measure->process->react control framework to bring the whole system into desired reference state. In this case, the desired reference state is a road traffic area with satisfied traffic users (drivers and pedestrians), traffic without congestion at parking lot entry or exit area and minimal traffic induced by vehicles searching for a free parking space. It is necessary to mention here that traffic induced by vehicles searching for free parking space can present a significant amount in dense urban areas - up to 30% or more in extreme situations. Poor management of large parking lots can also cause traffic congestion and significant vehicle queues in parking entrance or exit area. In closed, underground parking lots this can lead to potentially dangerous situations for drivers' health due to vehicle exhaust gases.

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Integration of individual parking lots in an urban wide traffic control system is crucial in applying the intelligent transport system (ITS) framework in traffic control (Shaheen et al. 2005). The idea is to control the traffic in such a way as to reduce the build-up of significant traffic congestion or queuing areas or prevent it completely. For this functionality, measurement of driver behaviour, creating models for forecasting problematic situations and archiving traffic measurements for future examination is very important. Desired result is urban traffic with less congestion and fewer incident situations, less environment pollution, satisfied traffic users, etc. Drawback is that large areas have to be monitored in order to obtain data about traffic speed, traffic flow density, vehicle types, duration of peak traffic hours, including interval start and end time, significant number of various sensors, archiving large amount of data, etc.

To overcome mentioned drawbacks, starting in the last decade, vision systems are being more and more used for mentioned traffic parameters measuring tasks (ARH Inc., 2012). Statistical and artificial intelligence based methods are also being applied for reduction of representative data set archive size. Vision based traffic monitoring system have the advantage that one sensor can be used for various tasks like vehicle detection, traffic density measurement, traffic speed measurement, vehicle (license plate recognition) or pedestrian (face recognition) identification, detection of incident situations, origin-destination matrix generation in crossroads, and road condition measurement. Additional benefit is that such a system can also cover a larger area. This advantage is significant when relatively slow traffic, like the one in parking lots, has to be monitored. Cameras equipped with pan-tilt units and a night-vision system can be utilized to their maximum which will be commented in continuation of this paper.

This paper is organized as follows. Second chapter describes parking lot management problems followed by the third chapter that gives an overview of existing parking lot management systems. Fourth chapter describes possibilities of computer vision based parking lot management systems and the fifth chapter presents ITS functionality that can be applied with computer vision based parking lot control systems. Paper ends with a conclusion and authors' ideas for future work.

2. Parking lot management problem

The parking lot management problem can be viewed from several angles. Parking lot owners want to ensure appropriate economic revenue and protect their investment; drivers want to have a secure guarded place to leave their vehicle at a reasonable price; and authorities want the surrounding road traffic to be without congestion, moderate density and with minimal incident situations caused by the parking lot. Drivers are mostly interested in finding of a parking lot with free parking spaces near to their travel goal. Owners and authorities are much more interested in the influence of the parking lot on surrounding road area traffic, users' safety, and ensuring optimal usage of the parking lot (enough available parking places in peak traffic hours and profitable parking lot occupancy in off-peak traffic hours).

To achieve this goal, each parking lot has to be equipped with a control system that enables monitoring of the number of free and occupied parking places and informing potential parking lot users about the parking lot status (open with/without free available parking spaces or closed) locally and in a wider area. Additionally, it is preferable that the systems contains driver navigation to a parking lot with free parking spaces in an urban area and driver navigation to a free parking space in a parking lot, tracking of parking lot occupancy during parking lot working hours for further analysis, parking service payment according to parking time duration, and security monitoring of the parking lot to prevent damage from fire, air pollution or criminals. It has to be also ensured that the parking lot area is in a state suitable for safe usage by their users. There is also the feature of universality that has to be fulfilled so parts like RFID tags or radio transponders that require their placement on every vehicle that is using the parking lot, have to be avoided if possible. The term universality denotes here the possibility that every vehicle can use the parking lot without making any specific changes on it. Special cases are parking lots related to high security areas (government, financial, research and military facilities) where only certified users can access a certain part of the parking lot.

Such parking lot control system consist of a sensor module, measurement data processing module, control module, driver and authorities informing module, parking lot data archiving module, security module, and actuator module as given in Fig. 1. All modules are connected by a local communication network. Sensor module consists of various sensors that can measure needed parking lot management parameters. Measurement data processing module collects data from the sensor module and extracts crucial parking lot status data (number of free parking places, CO_2 concentration, temperature, lighting conditions, etc.). Control module processes measured data and makes decision about parking lot management (information signs data, data archiving, payment status, etc.). Driver informing module forwards relevant data to authorities and parking lot users.

Data archiving module saves relevant parking lot management data for further analysis regarding authority's investigations or parking lot owner optimization procedures. Security module is connected to prevention and processing of criminal acts in one part and in ensuring safety in the parking lot area in the other part. Actuator module consists of elements that can influence parking lot parameters like entrance and exit ramps, ventilation system, lighting, and fire extinguisher system.

Regarding mentioned demands on a parking lot management system, a system with several sensor, actuator and informing categories has to be used always.

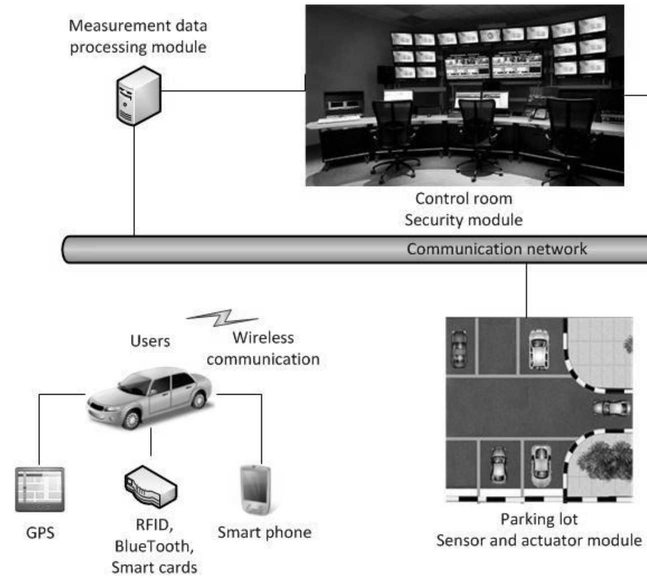

Fig. 1.
Parking lot management system modules

3. Existing Parking Systems

Parking systems can be divided into five major categories: Parking Guidance and Information Systems (PGIS), Transit Based Information Systems (TBIS), smart payment systems, E-parking and automatic parking systems (Shaheen et al. 2005). Every category uses various sensors regarding vehicle detection for parking lot status monitoring, driver informing and parking usage payment related tasks.

3.1. Parking Guidance and Information System

PGIS use variable message signs (VMS) to provide drivers with information on the location and the availability of parking spaces in parking lots (Sakai et al. 1995). Every PGIS consists of four mayor components: information gathering module, information disseminating module, control centre, and telecommunication network. The implementation of PGIS can include an entire city area or only a particular car park facility. Both implementations provide information which aids the decision making process of drivers in reaching their destination location and in locating a vacant parking space within a parking lot. The city wide PGIS is indeed helpful in assisting drivers navigating to a parking lot with vacant parking spaces via the information occupancy status for various parking lots around the city. PGIS implemented within a parking lot provides guidance in locating a vacant parking space within the parking lot (Shaheen et al. 2005). Vehicle and parking space detectors used in booth PGIS implementations include loop detectors, machine vision, ultrasonic, infrared, microwave and laser detectors (Idris et al. 2010).

3.2. Transit Based Information System

TBIS provides parking space information and public transport schedules in Park and Ride facilities. The systems main purpose is to encourage commuters to park their vehicles and use other public transport modes for their transit. This in turn reduces traffic congestion, pollution, and fuel consumption. Transit Based Information System is very similar to PGIS regarding used vehicle detectors. It also uses VMS to provide information. The difference exists in the fact that the TBIS concentrates on guiding drivers to park-and-ride facilities (Idris et al. 2010).

3.3. Smart payment system

The smart payment system presents an advanced payment system to replace conventional parking meters and payment systems. Conventional parking lot usage payment methods cause delays and inconveniences for the users and personnel as they have to deal with cash. So the usage of a smart payment system reduces maintenance and staffing requirement for payment handling purposes as well as for parking lot management (Chinrungrueng et al. 2007). The smart payment system can be based on contact or contactless methods. Contact methods involve using smart, debit or credit cards. Contactless methods involve using smart cards, RFID technologies, automated vehicle identification technology, and mobile communication devices. Contactless methods are much faster but require appropriate infrastructure by both, parking lot management system and users.

When this payment system is used, conventional vehicle detectors are not necessary. These systems have security issues regarding the fact that some of used technologies like RFID are vulnerable to exploits, malwares and worms attacks (Idris et al. 2010). Additional data encryption can minimize this drawback. Smart payment systems are usually used as a module integrated as part of an existing parking lot management system.

3.4. E-parking

E-parking systems provide information about car parking space availability and allow parking space reservation at a desired parking lot. A driver can ensure the availability of a vacant car park space when he arrives at the desired parking lot. Accessing the system can be done using a smart phone, personal digital assistant, short message service or through Internet. The system must be able to identify the customer that made the reservation or its vehicle and allow them access to reserved parking space (Chinrungrueng et al. 2007). There are many different implementations of the user identification process. Some examples are a confirmation code access received on the customer cell phone, printed receipts, smart cards, magnetic cards and Bluetooth based identification. E-parking has additional benefits like simpler payment mechanism of aforementioned smart payment system whereby payments by the parking lot users are made hassle free using e-payment technologies discussed previously (Idris et al. 2010).

3.5. Automatic parking system

Automatic parking systems use computer controlled mechanisms which allow users to drive up to the entrance bay, place their car in a specially designed cradle, lock their car and let the system automatically place the vehicle in allocated parking space. To retrieve their car, users only have to insert a code and password. The mechanical system retrieves their vehicle automatically. Goal of an automatic parking system is the efficient use of expensive and limited parking lots in dense populated urban areas. Because vehicles are moved and placed in an assigned container-like parking place by manipulators, the whole parking lot needs a relative small building area. Needed area used in conventional parking lots for car driving can be mostly used for additional parking places. Automatic parking systems are very popular in developed countries such as Japan, United States and Canada (Shaheen et al. 2005). As the car park facility is designed with conveyer belts, rotatable lifts and shuttles, whole system has to be coordinated to ensure successful and safe placement and retrieval of the vehicles (Idris et al. 2010). Such systems use a variety of vehicle detectors ranging from infrared, ultrasonic, microwave to laser detectors. Since vehicle cradles are made of metal, inductive and magnetic sensors are inappropriate due to significant magnetic interference. Vision sensors are mostly used for surveillance purposes.

3.6. Analysis of existing parking systems

The parameters used in the comparative analysis of existing parking systems are sensors, efficient use of parking space, financial investments, driver informing and customer satisfaction.

Initial implementations of PGIS in the early 1970s provided only information about free parking zones around the city using an inductive loop for tracking available parking spaces. In recent implementations, PGIS provide more specific information such as directions to empty parking lots and precise location of available parking places for city zones, parking facilities, and on-street parking. Infrared, ultrasonic, microwave and laser detectors are used for the detection of available parking places. Some PIGS implementations have also the ability to learn from historical data to forecast parking demand by time of day. The characteristics of this parking lot management category are reduced parking queues; relatively high understanding of driver information signs; and visitors to a city are more likely use PGIS than regular commuters. Drawback of such systems is that travel time and corresponding economic benefits are relatively small for such a complex system.

Transit Based Information System are designed and implemented to increase the benefits of PGIS, including increased use and revenues of transit systems, and reduced vehicle travel and air pollution. Small number of parking space at suburban rail stations may be a significant constraint to transit ridership. For that reason en-route information on parking space availability at transit stations may have a significant effect on transit ridership. Except information about number of available empty parking spaces, this system provides information about next public transportation departure time. Additionally, suggestion information type, whether it is better to use transit when alternate roadway routes are congested can also be provided. Such suggestions help drivers to decide in advance if they should leave their car and complete their journey by public transportation or continue all the way by car. For the detection of available parking spaces such systems uses sensors like PGIS systems and can also forecast parking demand by time of day using historical data. Apart from providing information to drivers, these systems also enable the reservation of parking space via Internet or phone.

Traditional parking payment methods typically have high operational and maintenance costs. The smart payment system has the advantage of available technology as to reduce operation, maintenance and enforcement costs as well as to improve customer convenience and make parking payment simpler. It also efficiently uses existing parking spaces to facilitate fast, convenient and reliable reservations and parking payment.

E-parking is an innovative business platform, which allows drivers to acquire parking availability information for a given destination, reserve an available parking space and pay for parking upon departure, without ever leaving their cars.

An automated parking system has a high initial cost but price is competitive considering the provided quality of service. The savings in required building space are about 50% compared to conventional parking lots in areas where parking space is scarce and expensive. This kind of parking lot management does not require special ventilation systems for vehicle emissions, because the vehicles are transported with the car engines turned off and the parking area is without human presence. The highest advantage of this system is security. Users avoid walking through empty parking lots or unsafe streets at night, crashes caused by improperly parking and car thefts are avoided. Furthermore, this kind of parking lot is also suitable for persons with disabilities without extra cost. The parking lot is equipped with vision sensors for surveillance purposes, and if any unusual motion is detected like a child or pet that was forgotten in the back seat, the parking systems will warn the user and refuse to operate until the unsafe situation is resolved.

4. Computer vision based systems

Computer vision based systems for parking lot management are currently active areas of research. As mentioned above, existing parking management implementations use such systems to a certain extent and in combination with other sensors. Computer vision based systems became particularly important in parking lot management systems mainly due to their fast response, easy installation, operation, maintenance, and their ability to monitor wide areas when information gathered at one camera location can be linked to another camera (Bong et al. 2008). In early systems, video cameras were used only for basic video surveillance of the parking lot which is today a standard part of nearly every parking lot. Today’s parking lot management systems use video image processing to automatically analyze the scene of interest and extract information regarding parking lot occupancy, license plates and other traffic data of interest. A video image processor (VIP) system usually consists of one or more cameras, a microprocessor-based computer for digitizing and processing of the imagery, and software for image interpretation. Addition of a VIP provides additionally management and information functionality to parking lots with basic vision surveillance systems (Idris et al. 2010).

A vision based parking system enables the surveillance of a whole parking lot and can additionally count occupied and empty parking spaces. Furthermore, it also has the possibility to monitor the status of each individual parking space and to guide a car to a vacant parking space in an intelligent way. Thus it increases the efficiency of parking lot management systems and enables drivers to quickly park their vehicles without too much effort. Second thing which this technology can enable is tracking of time spent at a parking lot for every individual vehicle. Consequently it is necessary to recognize license plates for unique identification of every vehicle, saving arrival time and time of departure. It allows integration of smart payment systems into an existing parking lot.

To ensure high profitability of video surveillance, every video camera should cover as many parking spaces within its field of view as possible. However, the problems with indoor parking lots are numerous barriers which can reduce the camera’s field of view. For that reason, the number of necessary cameras is usually increased.

Video surveillance is more useful at outdoor parking where cameras are placed at higher mounting locations ensuring a wider field of view over the parking lot. Major problem of outdoor surveillances are variable weather conditions which influence performances of such a system. Other problems are shadow effects, occlusion effects, change of lighting conditions and perspective distortion. Variable light intensity is one of the major challenges in a vision based detection system (Fleyeh, 2010).

4.1. The complexity of the system

Vision based parking system faces the challenges of multi scale information gathering, contextual event detection and the deployment of large systems (Hampapur et al. 2005). System complexity is related to the hardware and software part. Hardware part consist of several camera sensors, network and server infrastructure. Several servers are needed for image processing, data archiving and information dissemination. The majority of computational power is used for image processing and high level data extraction (vehicle and incident situations recognition, parking lot occupancy computation, license plate recognition, etc.). This presents a drawback of such a system which can be overcome by the usage of parallel and distributed computing. Unlike classical parking lot management systems, computer vision system generates large amounts of various data. Such data are in the form of raw video footage or extracted high level data. Cloud based data storage presents a very efficient solution for storing significant amount of video data.

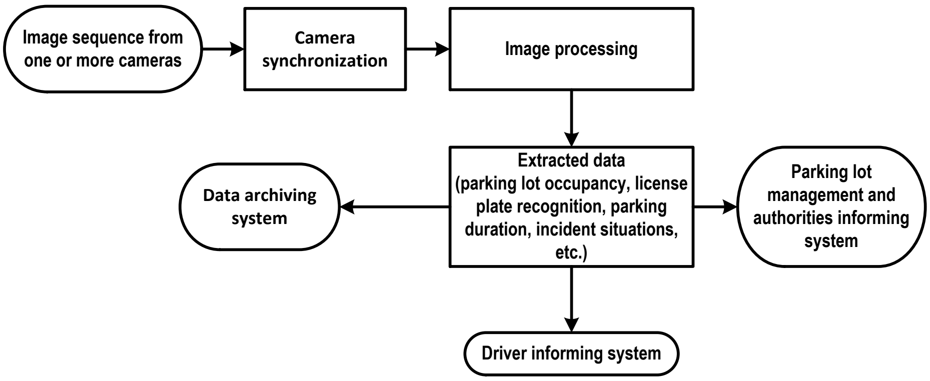

Fig. 2.
Flowchart of a vision based parking lot management system

Basic flowchart of a vision based parking lot management system is shown in Fig. 2. Due to the limited field of view, a camera synchronization algorithm is used to integrate visual cues from multiple cameras to make a panoramic scene construction of the whole parking lot. Such an approach is needed if more than one camera is used. After that, software for image processing and data extraction computes variables of interest using the parking lot panoramic scene. For possible further analysis, extracted data are stored in an archiving system. Last step consists of information dissemination to parking lot management, authorities and to the driver information system.

4.2. Existing systems based on computer vision

Basis for every computer based parking lot management system is the occupancy parking lots recognition, also known as the Car Park Occupancy Information System (COINS). After processing the information about parking lot occupancy and collected archiving data on a central computer system, extracted information is forwarded to a driver information system. Most popular driver information systems are display panels that are located at strategic locations in the parking lot but nowadays they can be provided by using smart phones, web technology, etc. COINS can be based on four different categories of technology: counter-based, wired sensor-based, wireless sensor-based and computer vision-based (Bong et al. 2006). In contrast to other technology, computer vision-based system have the possibility to provide exact information about location of a vacant parking place without installing a sensor at each individual parking space.

4.3. License plate recognition

Unique identification of every single vehicle can be made universally available by using license plate recognition (LPR) systems. LPR plays an important role in numerous applications such as unattended autonomous parking lot surveillance, security control of restricted areas, traffic safety enforcement, statistical analysis, etc.

A typical system for LPR consists of four parts: vehicle image acquisition, license plate localization and segmentation, character segmentation and standardization, and license plate characters identification (Anagnostopoulos et al. 2008, Romić et al. 2012). The license plates localization processing step is crucial for the entire system because it directly influences the accuracy and efficiency of all subsequent recognition steps. Researchers have proposed many methods for license plates localization in order to extract the license plate areas. Some of them are: edge detection methods, line sensitive filters, the window method and the mathematics morphology method. For the license characters identification also a large number of techniques, such as Bayes' classifiers, artificial neural networks, support vector machines, and K-nearest neighbour classification are used (Wen et al. 2011). These algorithms can also process the license plate segmentation part and recognize license plate characters.

First LPR systems were problematic due to low resolution analog video signal, small available computational power and license plate configurations not suitable for computer based vision recognition. With technology advancement of computational power, usage of intelligent cameras that include built in basic image processing functions and adaptation of license plate configuration these problem are now overcome. Current LPR systems are suitable for real-time application with vehicle speeds up to 250 km/h (ARH Inc., 2012).

5. ITS functionality

There exists an interconnection of standard ITS and parking lot management functional modules. Both systems share the functional modules related to traffic state measurement, measured data processing and archiving, payment system, and traffic user information. From this interconnection arises the need for integration of both systems. Most significant importance regarding ITS based integration of parking lots into a wider urban traffic area is related to driver information and navigation systems. Such driver information systems have two modes: (i) mode related to informing and navigating drivers searching for a parking lot, and (ii) mode related to informing and navigating in a parking lot to a free parking space. For both purposes variable message signs presenting number of free parking spaces and distance to particular parking lot/space are used. These systems are today common in larger cities or larger parking lots.

Today's increased traffic density and time efficiency demands additional functionality regarding general traffic control and parking lot control. One such driver assistant functionality is automatic assignment of a free parking place to a vehicle when it enters a parking lot. Camera vision sensor combined with vehicle license plate recognition present a good combination for such a task. Each vehicle has a unique license plate which can be recognized using a computer vision based license plate recognition system. Each vehicle can then be tracked when driving to assigned parking space and informed on crucial turns to stay on the optimal route to prevent unnecessary time and fuel waste in searching for assigned parking space. Also, control system can easily detect driver error and change the variable message signs display to help the driver to correct its error without violating traffic rules or to guide him to a different assigned parking place. Additionally, such a control system can recognize frequent users or users with special needs like disabled persons, woman drivers or families with children. After recognition, control system can assign appropriate parking place near elevators, guarded areas, shopping or entertainment areas.

Authorities and parking lot owners have the need to include functionalities related to traffic incident detection and monitoring of the parking lot. This functionalities are also part of ITS because today's vehicles are still driven by humans and incident situations due to driver error can occur. Such situations are related to speeding, illegal turns, illegal parking, driving in wrong direction, minor accidents and abuse of parking lot purpose. Vision system combined with data archiving module and license plate detection systems is a significant help to authorities and drivers in prevention or solving incident situations and damage compensation related to minor accidents, especially regarding the fact that in a parking lot vehicles are parked closely together and the probability for finding a witness for incident reconstruction is very low. Another important issue is helping parking lot users in cases of medical or similar emergencies. Vehicle stopped in a driving area longer that a certain amount of time can be recognized by the control system and appropriate action can be taken. Parking lot personnel can then inspect the incident vehicle using a pan tilt camera with zoom function, contact the driver and dispatch appropriate assistance.

A significant problem to parking lot owners can be the abuse of parking lot purpose. This can often happen in parking lots close to shopping malls, touristic resorts and large companies where control system is kept rather simple to cut costs and alleviate its usage. Drivers searching for a free parking place and a different destination occupy the parking lot and its designated users are left without a parking space.

Again, usage of the surveillance video footage in combination with a license plate recognition system connected with a designated user data base can be used for statistical analysis of parking lot usage. Individual user behaviour can be monitored during longer periods thus creating trends needed for planning purposes without significant financial investment.

6. Conclusion and future work

This article gives an overview of parking lot management systems with emphasis on computer vision systems. Requirements for such systems are discussed in terms of ITS and their application possibilities regarding universality. In this term, universality means that no additional components have to be added or mounted on a standard road vehicle. Current state of the art of parking lot management systems provides today's drivers with a more comfortable travelling experience and with less time spent in an appropriate parking lot search. Comparison of different parking lot management systems relying on non-vision sensors reveals that a significant economical, construction and maintenance effort is needed in order to retrofit or build a controlled parking lot. The effort is mostly related to the number of necessary sensors and their wiring.

Computer vision systems for parking lot management and corresponding driver information systems enable a relative economical and fast upgrade of uncontrolled parking lots. The used vision sensor camera, with or without a pan-tilt unit, can cover a larger parking area while also providing additional high level information. Therefore the needed number of necessary sensors and amount of wiring can be reduced. Drawback of such systems is that individual parking places have to be labelled manually in the system commissioning. Outdoor environment influence can also be problematic for such systems and further robustness on lighting condition change, wheatear influence, and high level object recognition improvement is needed.

Authors future work will be related to building a simulation environment for a computer vision managed parking lot. It will consist of a small scale testing model for indoor usage, and a full scale outdoor parking lot. Aims of the author future research include creation of a video footage data base of typical situations in parking lots (different weather conditions, driver behaviour, different lighting conditions, etc.), automatic detection of individual parking places in a parking lot, incident detection, and system robustness regarding outdoor usage improvement.

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References

Anagnostopoulos, I.E.; Psoroulas, I.D.; Loumos, V.; Kayafas, E., 2008. License Plate Recognition from Still Images and Video Sequences: A Survey. *IEEE Transactions on Intelligent Transportation Systems* 9 (3): 377 - 391

ARH Inc., 2012. CARMEN FreeFlow ANPR/LPR Software Technical Specifications. Available from internet: <http://www.arhungary.hu/contleft/1011/content.htm >.

Bong, D.B.L.; Ting, K.C.; Lai K.C., 2008. Integrated Approach in the Design of Car Park Occupancy Information System (COINS), *IAENG International Journal of Computer Science* 35 (1): 7 -14

Bong, D.B.L.; Ting, K.C.; Rajaee. N., 2006. Car-park occupancy information system, In *Proceedings of 3rd Real-Time Technology Application Symposium*, 65 -70.

Chinrungrueng, J.; Sunantachaikul, U.; Triamlumlerd, S., 2007. Smart parking: an application of optical wireless sensor network. In *Proceedings of the 2007 International Symposium on Applications and the Internet Workshops (SAINTW'07), Hiroshima, Japan*, 66-69.

Fleyeh, H. 2010. *Traffic Sign Recognition.* Lambert Academic Publishing AG & Co. KG, Germany. 239 p.

Hampapur, A. L.; Brown, J.; Connell, A. E.; N. Haas et al., 2005. Smart video surveillance: Exploring the concept of multiscale spatiotemporal tracking. *IEEE Signal Processing Magazine* 22: 38-51.

Idris, M. Y. I.; Leng, Y. Y.; Tamil, E. M.; Noor N. M.; Razak, Z., 2009. Car Park System: A Review of Smart Parking System and its Technology, *Information Technology Journal* 8 (2): 101-113.

Maršanić, R.; Zenzerović, Z.; Mrnjavac, E., 2010. Planning model of optimal parking area capacity, *Promet – Traffic&Transportation* 6 (22): 449-457

Romić, K.; Galić, I.; Baumgartner, A., 2012. Character recognition based on region pixel concentration for license plate identification. *Tehnički vjesnik – Technical gazette* 19 (2): 321-325

Sakai, A.; Mizuno, K.; Sugimoto, T.; Okuda, T., 1995. Parking guidance and information systems. In *Proceedings of Vehicle Navigation and Information Systems Conference in Conjunction with the Pacific Rim TransTech Conference, 6th International VNIS*, 478-485.

Shaheen, S.A.; Rodier, C.J.; Eaken, A.M., 2005. Smart parking management field test: A bay area rapid transit (BART) district parking demonstration. Available from internet: <http://pubs.its.ucdavis.edu/download_pdf.php?id=44>.

Wen, Y.; Lu, Y.; Yan, J.; Zhou, Z.; von Deneen, K.M.; Shi, P., 2011. An Algorithm for License Plate Recognition Applied to Intelligent Transportation System, *IEEE Transactions on Intelligent Transportation Systems* 12 (3): 830-845

MODERN TECHNOLOGIES FOR SOLVING PARKING PROBLEMS IN CITIES

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Abstract: The parking problems are one of the biggest problems in the urban areas. Number of passenger cars is increasing day by day, and the capacity of parking space remains constant, so there is a problem where to leave a vehicle. This problem is especially significant in towns, which are not so familiar to a driver. In most cases, free areas, designed to be parking facilities are narrow, small and inappropriate for parking organization according to standards. This paper describes how using some modern technologies can solve some common parking problems.

Keywords: parking problems, modern technologies, parking organization

Introduction

Modern society is faced with serious problems related to traffic, because there is increasing number of vehicles on the roads in the major cities. In addition to problems with the capacity of urban roads, the problem exists in stationary traffic. Specifically, for each vehicle in the traffic is necessary to provide two parking spaces - at the source and at the final destination of travel. The problem becomes even greater because the vehicles are often irregularly parked on the street, at the curb, as this allows the closest contact with an object that represents the purpose of the travelling (Putnik, 2007).

Travels start in residential areas mostly and ending in the center of town, near the administrative, cultural, sports and other institutions and facilities, and vice versa, when they are returning to their homes. In residential zones, vehicles remain a long time in the stationary state, so it should be organized enough parking spaces on these sites to meet the parking needs of all residents. There is less retention in of vehicles in parking areas, but there are more changes and hence in these areas must be satisfied the need for parking.

Parking problems can be categorized into three groups:

- Capacity of parking spaces;
- Location of parking spaces;
- Information about the location of available parking spaces.

The first two problems permeate and interact. Due to an increasing number of vehicles in the traffic, the need for parking in certain areas increases, so it is necessary to provide more parking spaces. The second type of problem is inherited street network of roads, buildings and other facilities. There is not enough space for parking lots and parking garages to be organized what is best for a given location and date of need, but they are mostly improvised and etc.. The third type of problem is the psychology of a man to leave his vehicle closest to the target location of his trip. The problem arises when he cannot find a place near the end, so he has to wander through the surrounding roads to find a free place for parking.

Unique System of Organized Parking Lots

Finding adequate free parking spaces in the central zone of the city, near the administrative, cultural and sports establishments and facilities in certain situations is a common reason for a longer ride, because there is not free place to park on the first try and therefore the driver wastes time. The problem becomes even greater if you are coming from another city or some smaller communities.

In this situation, the circulation on the surrounding roads and search for free parking places make the situation more difficult because you do not know the areas (a system of one-way streets, streets where traffic is banned, etc.). And especially you do not know the locations where the parking lots are organized.

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One solution is to merge all organized in a city parking lots and networking into a single system. This system is used in some U.S. cities - New York, Los Angeles, Houston, Cincinnati, Atlanta, etc. All car parks are organized in a networked system in the city, and they are located in a common network in the whole state. The system is called Central Parking System, which is the largest park system in the United States. (Central parking New York)

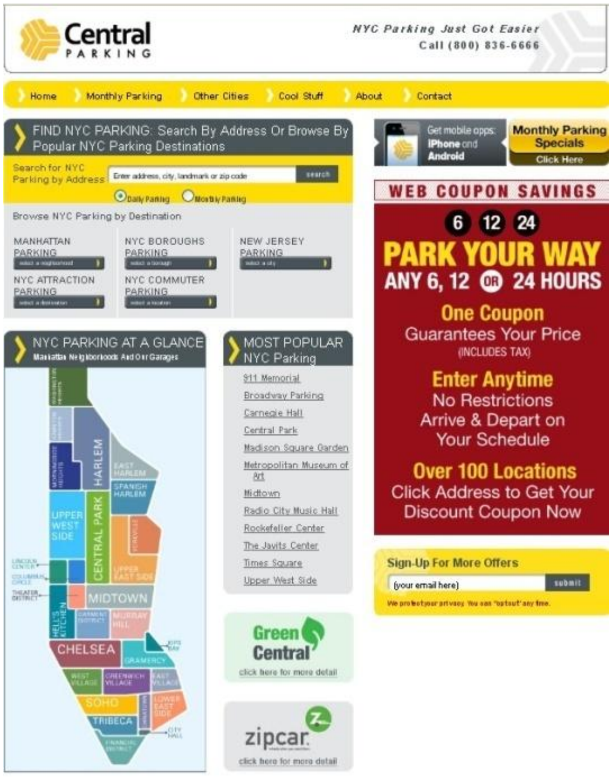

Fig. 1.
Home Web page of CP NY. (Central parking New York)

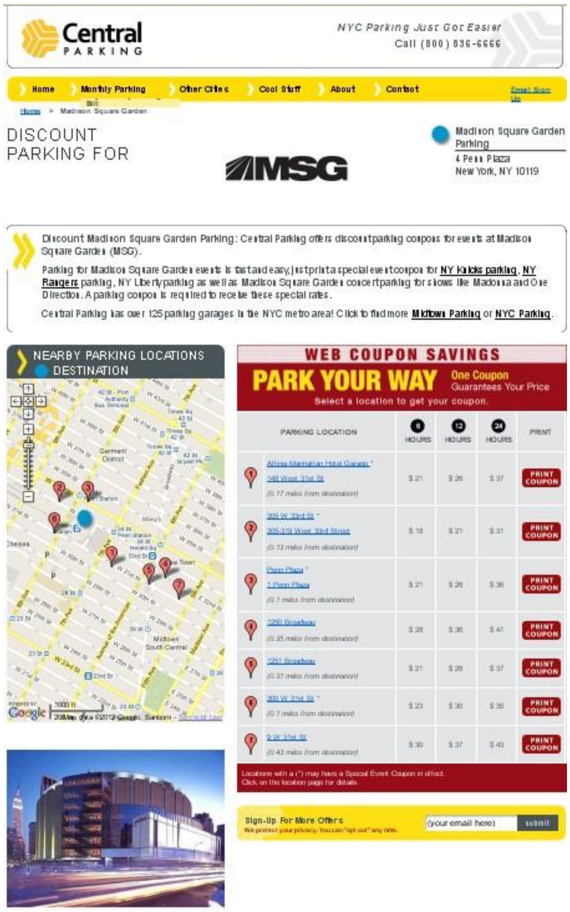

Fig. 2.
Possibility to select location of the parking lot. (Central parking New York)

In this way we get a clear picture of the location of all parking lots, as well as current status on them - the number of available and occupied spaces. However, there is another option, and that is the possibility to reserve parking spaces. If you are familiar with the city and the location that is the goal of traveling, you can find the nearest parking lot and booked for a specific date and for a specific time period. The advantage of this is that if you do not know the city which is the goal of travelling with this system you can find an adequate location to park your vehicles for short or long term. This system makes it possible, on the basis of some of addresses or larger objects, exactly locate the target position, and also the most suitable location to leave the vehicle. Then you choose the date and time to keep the parking lot, and the system will calculate the price of the services offered on the screen. Offer could be accepted, and it could be also chosen some other locations for parking. If the user is satisfied with the place where he left his car, and a price, he may reserve a place. Also, another option is offered to the user, it is a place that can be booked per day or for the entire month. (Central parking New York)

Fig. 1 shows the website of NY Central Parking System, which is a networked system of organized parking lots in the city of New York. These systems cover about 300 parking lots in the city of New York and New Jersey. In Fig. 1 it is indicated the place where you can type the address of travelling. Also, you can see the most attractive sites and choose one of these options.

Selecting a location that is the goal of traveling, a new window opens, in which the system pops up the most suitable parking where you can leave your car (Fig. 2). A price is given for each site, depending on the retention time. The user chooses where he wants to leave his car and buy a coupon.

The advantage of this system is that there is no wasting time in searching for free space, unnecessary driving and cycling around the target site. Also, for those who are unfamiliar with larger, urban areas, it reduces the possibility of wasting time on the roads in search for parking spaces.

Capacity and Location of Parking Garages

Parking garages are the best solution to the parking problem, for example, this property can best utilize the space reserved for parking. Multi-level parking in one place achieves great use of space thus satisfies multiple users. However, there are factors which may, in some cases, limit the capacity required.

Storage allocation for the construction of the parking garage is the first limiting factor. Planning regulations dictate the number of floors of the building, which can significantly limit the capacity. Then, there is the possibility that the area of the location is too small and there is not enough parking space that can be organized in the way that completely satisfies customer needs and ensures the best use of parking garages.

The prospect of achieving the required capacity depends on the possibility of lodging a sufficient number of inputs and outputs. It is often impossible to achieve planned or required number of inputs and outputs, and this is one of the limiting factors. (Putnik, 2007)

Most of the surface area of the parking garage occupies place for parking. Economy of building the garage depends on the choice of angle and way of parking, size of parking passes and parking spaces. In the design of parking garages should take into account the position of the pillars, as this affects on the possible savings in space. Pillars should be at the end of each parking stave. (Kostić & Davidović, 2012)

One of the ways to increase the capacity of the parking garage is a parking garage with staff. Namely, user drives his vehicle to the garage entrance and delivers it to the staff, which is end of parking process for him. He takes the coupon and goes on, and the vehicle is driven off by the staff to the free parking space. his system has the advantage that the staff knows exactly the location of vacancies and no time is lost in finding one. Another advantage is that the staff is trained to manage and maneuver the vehicle, unlike most drivers, and the need for parking space is reduced (has the smaller width and breadth of parking passes), and therefore it can be organized more parking spaces in the same area.

Mechanized Parking Lots and Parking Garages

Using modern technology, parking systems solve problems with lack of parking space. Mechanized parking lots and parking garages use maximum of every possible space for parking, because it could be build up in a small area. They are particularly suitable for use in situations where the space is narrow, where parking spaces and adequate width for the passage of vehicles could not be arranged.

The division of mechanized parking garage can be made to:

- System of independent parking;
- System of dependent parking. (Techno Team System)

The essential difference between systems of independent and dependent parking is that in the system of independent parking, each vehicle can be parked or moved at any time, without moving any other vehicle by the owner, as opposed to the system of dependent parking, where, if you want to park or move your vehicle on the upper platform, you first must move vehicle located on the lower platform.

System of independent parking multiplies the number of parked cars at parking area with high comfort of parking, with minimal waiting time. Compared with the systems of dependent, systems of independent parking are much more advanced and easier to use. They can be set up both indoors and in open spaces, with adequate equipment and protection from precipitation and temperature extremes.

The system of dependent parking multiplies the number of vehicles parked at parking place with comfort at a lower level because the organization of parking. Compared with systems of independent parking, systems of dependent parking are cheaper and easier.

They are suitable for increasing the potential of parking spaces on open parking lots and garages, or wherever it is possible to organize the coordination of maneuvering the car, and hotel staff for the parking of vehicles, or in companies with a large number of official vehicles. (Techno Team System)

There are many types of parking systems that can successfully solve almost any area intended for parking. The general distribution of parking system is as follows:

- hydraulic platforms for parking;
- semi-automatic parking systems;
- automatic parking systems. (Wőhr, parking systems)

Hidraulic platforms for parking

Hydraulic platforms allow bigger number of parking spaces for two to three times in the same area for parking. At one level two to three cars could be independently park.

Fig. 3.
Application of hydraulic platform for parking (Techno Team System)

This system can be applied to indoor and outdoor parking facilities, as well as private use, private garages, in order to solve the problem of parking several vehicles.

Features of this system are as follows:

- Equipment is applied with a high degree of operating and functional safety;
- Hydraulic systems are implemented with low wear;
- Low maintenance costs;
- Possible application of the system of double width;
- Double-width systems require less total width of the two individual systems and they are easier to park.

They are also more economical, since the total width is available for platforms without structural parts that could be damaged.

This system includes a rotary platform that is used for narrow and limited approach. It allows the vehicle rotation for 360 degrees in both directions of movement. The application of this system is in the garage with a reduced space where the maneuver is difficult or impossible. With this system, the vehicle can be turned easily to the desired position.

Semi-automatic parking systems

In semi-automatic parking system it is applied a combination of lodging and launching vehicles that are next to each other. Compact parking on two or three levels with only one ride level contributes to an increase in capacity and up to 200% compared to the standard car parks.

Features of this system are as follows:

- Independent parking;
- Easily manageable, semi-automatic system with numerous control options, and platform are controlled by remote control or coded keys;
- A high level of "user comfort" and security of parked vehicles.

It is sufficient height of 2.20 m for parking vans, jeeps or cars with trunks on the roof on the top level.

Fig. 4.
Application of semi-automatic parking system (Techno Team System)

This system works on the principle that there is always one platform less than the number of grids (the maximum number of fields in the system taking into account the number of inputs to the system and the number of levels on which parking is allowed). If the garage has three entrances, and the system allows the stacking of vehicles in three levels, this would mean that the garage has eight parking spaces.

If you are looking for a platform that is located on the lower level, sideways platform at the top level will move before the bottom platform boot into the vacated area. Vehicles are parked behind the entrance door with security. In other words, each vehicle can be moved without moving any other vehicle in the system. The space is cleared out by the system of moving platform on the left - right, so vehicle that is required is placed on the level at which there is door where the vehicle could be moved out.

Automatic parking systems

This parking system is widely used for parking of vehicles, especially in public parks. The parking garage can be built underground, partly underground and partly above ground and over, because it takes a minimum light and ventilation. Because of the way the vehicle is driven through the garage, reduced fumes emissions, thus protecting the environment from harmful substances.

Management of the system is done remotely from a central place, from the office which is into the parking garage.

There are ramps instead of lifts which are used to overcome the floors. The user set his vehicle on the lift platform, which leads to the vehicle floor where there are vacancies. The passage width saving is accomplished by moving the platform on a horizontal surface, along the passage. On the platform, the vehicle is moved to the parking lots, which are located right on both side of the aisle. (Automotion)

Speed and capacity depends on the speed of adoption, speed of moving platform horizontally and vertically, as well as the degree of mechanization of loading and unloading of the platform lift. Operating the lift is done by various means, such as pallets, rolls and strips. The capacity of a device depends on the type of the means that is used.

Advantages that are obtained by applying the platform lifts that take cars in parking garages are manifold. Among the first is the elimination of the need for driving in the parking garage and search for free parking places. Then there is no walking in the parking garages, returning for the vehicle and remembering the place where it is left. Therefore there is more comfort for the users. User leaves his vehicle in front of parking garage, gives a signal to leave the vehicle (pressing, swiping magnetic cards or the like.) and he can go. System takes up the vehicle. (MPSystem)

Fig. 5.
Application of automated parking systems (Techno Team System)

This system is fully automated and allows the maximum number of vehicles parking on a relatively small area. Parking space needed is reduced to a minimum. Space savings are obtained at the expense of ramps and wide aisle. Required passage width is reduced to the length of the platform, which transmits the vehicle horizontally, which is smaller than those required to provide when the driver parks the vehicle. Ramps for mastering floors are not required, but the vehicle is transferred from the floor to the floor by the elevator, which is the same width as the gateway. Also, the space savings is obtained as the need for less protective space around the vehicle. Otherwise, when the driver and passengers getting out of the vehicle it is necessary to provide sufficient space, in this situation it is not necessary. The saving is obtained in the amount, because the floors of parking garages can be designed to meet the minimum height that satisfies the passage of vehicles.

There are several types of parking garage equipped with automatic systems (Fig. 6):

- Parking puzzle;
- Parking level;
- Cylinder;
- Tower;
- Carousel. (MPSystem; Techno Team System)

Fig. 6.
Types of parking garages that are equipped with automatic systems (Wőhr, parking systems; MPSystem; Techno Team System)

Conclusion

Problems that occur in traffic because of the increasing number of vehicles, also, affect on the stationary traffic. It is necessary to provide the required number of parking spaces, as at the source, and at the final destination of travel. Residential areas are characterized by extended periods of vehicle restraint, while the central zone is characterized by a short stay and high frequency.

The biggest parking problems are in connection with the capacity and location of parking lots, as well as information about them.

During designing the parking lot it should be taken into account many parameters, as well as nearness of attractive locations. However, inherited street network, as well as residential, administrative, cultural and sports facilities, affect on the parking organization. This is a limiting factor in the design, because the given object cannot jut out and disrupt the environment.

Because of all it has been said it is necessary to apply modern technology to solve problems. There are many types of machinery, and technologies that could be applied as a solution to problems related to the location, where is no sufficient space. On the barren surface the capacity could be increased, which would be obtained only on a larger surface.

Combining organized parking lots into a single, networked system, we get a clear picture of the location and availability. The system is especially suited for users who come from less urban areas and who are not so familiar with bigger places. Using this system, customers are able to find a proper parking place near their destination.

References

Automotion. (n.d.). Available from Internet: http://automotionparking.com/company.php

Central parking New York. Available from Internet: http://nyc.centralparking.com

Kostić, S., Davidović, B. 2012. Parkiranje i javne garaže. Novi Sad: Fakultet tehničkih nauka, Novi Sad.

Putnik, N. 2007. MPSystem. (n.d.). Available from Internet: <http://www.mp-parking.com/01_com/com_01.html.>

Putnik, N. 2007. Autobaze i autostanice. Beograd: Saobracajni fakultet, Beograd. 315 p.

Techno Team System. (n.d.). Available from Internet: http://www.tts.rs/index.html

Wőhr, parking systems. (n.d.). Available from Internet: http://www.parkingsistemi.rs/index.html

THE MARKET POTENTIAL OF M2M COMMUNICATIONS FOR TELECOMMUNICATIONS OPERATORS

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Abstract: M2M (Machine-to-Machine) communication represents the exchange of data between remote devices using wired and/or wireless communication network for telemetry and remote control. M2M services provide exchange of information without human intervention, thus making it possible to reduce costs, improve efficiency and reduce risk. Predictions show that M2M communication is having accelerated development and long-term growth prospects. Great application of M2M services is visible in the field of Inteligent transportation systems (ITS) through segments such as traffic management, navigation of traffic, the impact of traffic on the environment, cargo management and logistics and traffic safety. Technological progress and potential of M2M services represents a significant opportunity in revenue growth for telecommunication operators. Accordingly, logical is the fact that telecommunications operators are introducing new tariff models that are aligned with specificities of M2M communication.

Keywords: M2M, ITS, Telecommunication operator, Tariffs

1. Introduction

The use of new communication services entails a series of changes that affect all segments of the value chain of precisely these services. M2M communication represents a new challenge and a great opportunity in a variety of application areas such as intelligent transport systems, with a tendency of significant growth. One of the segments of the value chain of M2M services represent telecommunication operators. Given the nature of M2M communication and the trends of its greater use, it is necessary adjustment to these services for all segments involved in the chain, primarily by telecom operators. Potential, which is visible in the M2M communication, refers mostly to the increasing amount of traffic and the number of devices that are becoming part of the system. Since telecom operators have seen their ability to earn and business improvement through M2M communication services, it is not surprising that there are visible changes in the offer of tariff models. Given the specificity of M2M communication it is given an adaptation of tariff models, in order to increase the use of M2M communication and creation of additional profit.

2. Machine-to-Machine (M2M) communication

Machine-to-Machine (M2M) communication is a form of communication that involves one or more entities that do not necessarily require human interaction or intervention in the communication process. M2M communication can take place via a mobile network, such as GSM or UMTS. In M2M communication the role of mobile network is largely determined as a transport network service.

M2M communication is different from the current communication models in the ways that it includes (Government of India, 2011):

- lower costs and effort,
- a potentially very large number of communicationg terminals,
- little traffic per terminal, in general
- new or different market scenarios

There are four basic stages that are common to just about every M2M application. Those components are (M2M Communications, 2012):

1. Collection of data
2. Transmission of selected data through a communication network
3. Assessment of the data
4. Response to the available information

Data collection begins with downloading data from the device, so these data can be analyzed and sent through a network.

As for the data transmission through a communication network, there are multiple options for data transmission from the remote device to the center of the network; like mobile communication networks, fixed communication networks, satellite communications etc., and they all are common solutions.

M2M communication is based on the idea that machines are more valuable when they are networked and network becomes more valuable with addition of more machines to it. In order to implement M2M system it is necessary to combine a variety of electronic, communications and software technologies.

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2.1. Elements of M2M architecture

Architecture of M2M communication system consists of:

- M2M Device
- M2M Access network
- M2M Gateway
- M2M Core Network
- M2M Applications

M2M Device is a device capable of replying to request for data contained within those devices or capable of transmitting data autonomously. Sensors and communication devices are the endpoints of M2M applications. M2M Access network provides connectivity between M2M devices and M2M Gateways. M2M Gateway is a equipment that uses M2M capabilities to ensure M2M devices inter-working and interconnection to the communication network. Gateways and routers are the endpoints of the operator's network in scenarios where sensors and M2M devices do not connect directly to the network. M2M Core Network covers the communications between the M2M Gateway(s) and M2M Application(s), and includes technologies like Digital Subscriber Line (xDSL), Long Term Evolution (LTE), WiMAX, WLAN etc. M2M Applications can be targeted to end-users or service providers which may arise sophisticated M2M solutions and services. Such services can be designed and offered by the service provider, but also they may be offered by telecommunications operator through its independent platform (Fig. 1).

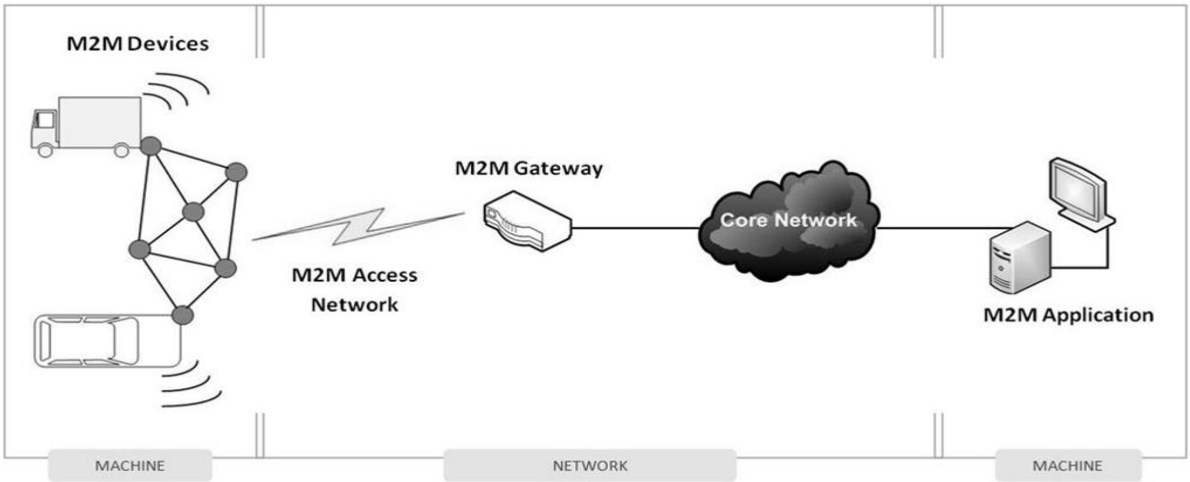

Fig. 1. *M2M communication system architecture*

2.2. Key features of M2M communication

The most important features of M2M communication system are (Government of India, 2011):

- Time controlled – send or receive data only at certain pre-defined periods
- Low mobility – M2M Devices do not move, move infrequently, or move only within a certain region
- Time Tolerant – data transfer can be delayed
- Packet Switched – network operator to provide packet switched service
- Online small Data Transmissions – MTM Devices frequently send or receive small amounts of data.
- Location Specific Trigger – intending to trigger M2M device in a particular area (e.g. wake up the device)
- Monitoring – not intend to prevent theft or vandalism but provide functionality to detect the events
- Low Power Consumption – to improve the ability of the system to efficiently service M2M applications

M2M solutions are typically developed for sending indications of unusual situations, collecting information or setting parameters according to business needs. New M2M applications are contionuously emerging to serve rather comprehensively all business areas – monitoring elevators in shopping centres, downloading new games into amusement machines, checking the temperature of swimming pools, locating trucks on the highways, tracking the use of office photocopiers, etc. (Table 1) (Nokia Corporation, 2004).

Table 1
Application examples of M2M communication

Sector	Example applications	Effects
Smart buildings	Automated monitoring of heating, ventilation and cooling	Reduced energy costs
Smart cities	Street lights that dim when roads are empty	Cost savings
Automotive	Emergency calling and accident alerts	Regulatory reqiurements
Consumer electronics	Connected satelite navigation devices to monitor traffic jams	Product inovation
Health	Remote monitoring of patients and personal health monitoring	Cheaper, home-based care
Transport and logistics	Fleet optimisation and supply-chain tracking and tracing	Cost savings
Emergency services and national security	Disaster response and critical infrastructure protection	Proactive maintenance
Retail	Wireless payments	Retail inovation

Source: Machina Research; Economist Intelligence Unit.

3. Trends in M2M services

With a potential market of probably 50 million connected devices, M2M offers tremendous opportunities as well as unique challenges. These devices vary from highly-mobile vehicles communicating in real-time, to immobile meter-reading appliances that send small amounts of data sporadically (Government of India, 2011).

From the perspective of telecom operators, M2M communication solutions meet customer needs for IT applications in processes of monitoring, controlling, planning, remote measuring, collecting data and remote diagnostics of the data. M2M traffic growth trends have strong growth, with increasing annual growth.

Globally, M2M traffic will increase 22-fold between the 2011 and 2016, and the amount of M2M traffic in 2016 will be 508 petabytes per month (Fig. 2).

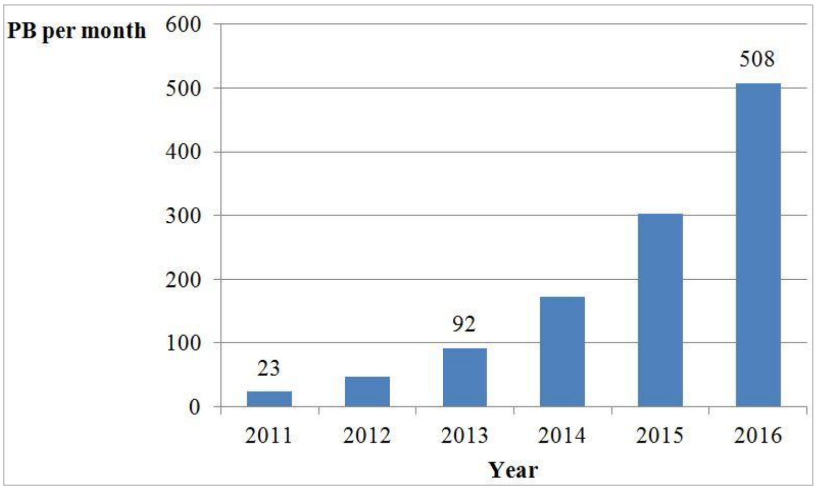

Fig. 2.
M2M traffic growth between 2011 and 2016
Source: Cisco VNI Mobile, 2012

Compound Annual Growth Rate (CAGR) of M2M mobile data traffic between 2011 and 2016 will be 86%, while the increase in the number of M2M devices at the same period will be 42% (Table 2).

Table 2
Comparison of Global Device Unit Growth and Global Mobile Data Traffic Growth

Device	Growth in users, 2011-2016 CAGR[1]	Growth in Mobile Data Traffic, 2011-2016 CAGR
M2M module	42%	86%

Source: Cisco VNI Mobile, 2012

[1] Compound Annual Growth Rate

M2M communication represents a significant and growing opportunity for telecom operators to increase their revenue. Technological progress and the potential of M2M applications across numerous markets will bring a huge number of transactions. Investing in M2M communication is the key of further success of telecom operators.

Some of the opportunities of M2M communication that telecom operators can take advantage are:
- New revenue stream
- Ensuring customer satisfaction
- Improving the use of the existing infrastructure
- Inovative user's terminal equipment
- Increase in the number of users

4. M2M and Intelligent Transportation Systems

One of the functions of Intelligent Transportation Systems is to optimize the flow of vehicles and their cargo, streamline their management and reduce costs, and with potential dependence of intelligent M2M communication. M2M technology has the potential to improve transport systems in five major areas: traffic management, navigation of traffic, the impact of traffic on the environment, cargo management and logistics and traffic safety. This offers convenience, simplicity and safety of Intelligent Transportation System that provides real-time information, such as the weather and road conditions and automatically warns travelers to hazards such as slippery roads or accidents (Fig. 3).

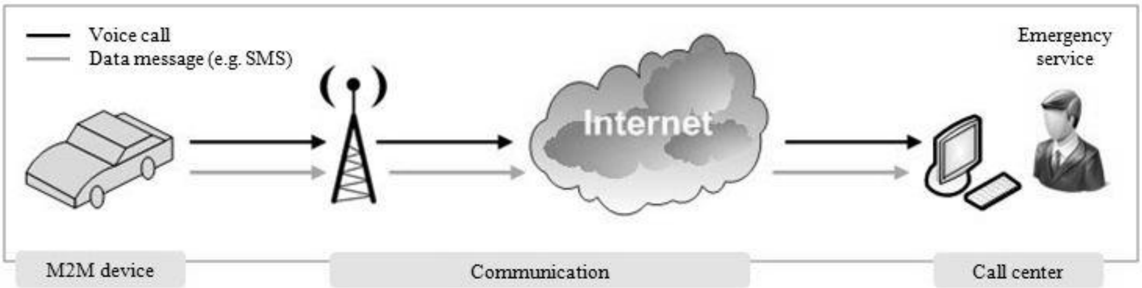

Fig. 3.
Architecture of an emergency call system

Governments, car manufactures and consumers are realizing that wireless technology holds the key to changing travel lifestyles and cleaning up, greening up and optimizing modern transportation systems. Of course, machine-to-machine vehicle telematics on its own cannot fully mitigate the global challenges of automotive traffic. Wireless Intelligent Transportation Systems (ITS) work in conjunction with telematics transmitting real-time data about traffic and the environment (i.e. the networked interconnection of cars, busses, traffic lights, roads with embedded sensors and emergency road crews) (Cinterion, 2012).

The role of M2M communication in vehicle telematics and applications is evident through (Smith, 2012):
- Stolen vehicle tracking (theft protection)
- Remote ignition disablement
- In-vehicle emergency call services
- Live traffic reporting and rerouting around road congestion
- Fleet management
- Cargo monitoring
- Remote diagnostics and maintenance
- Onboard entertainment

The automotive sector represents one of the greatest opportunities for machine-to-machine. From less than 90 million connections globally in 2010 the automotive M2M market will grow to almost 1.4 billion connections by the end of 2020 (Fig. 4). There are numerous vehicle-related applications that would benefit from being connected. By 2020 the emergency assistance device will be the dominant type of M2M connection (Machina Research, 2011).

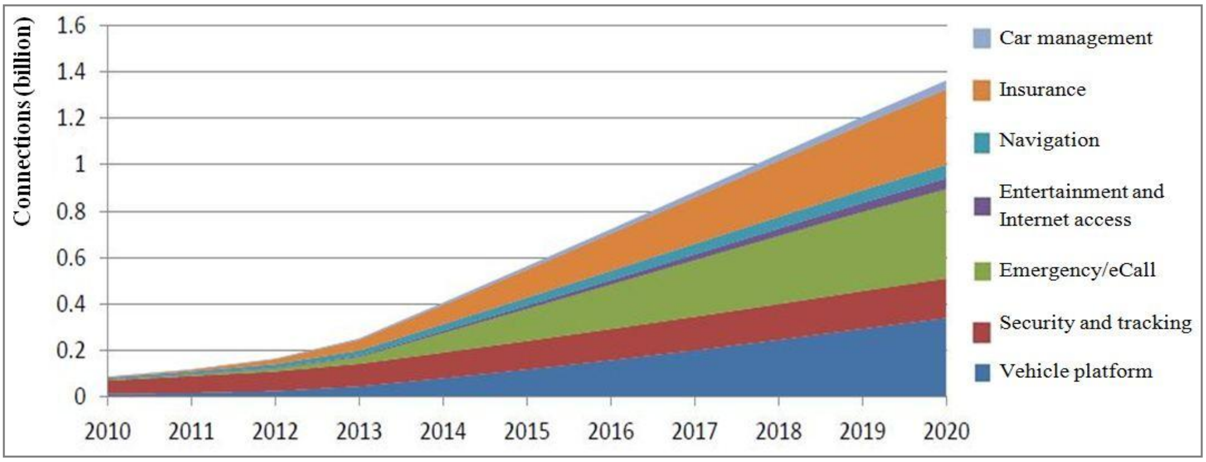

Fig. 4.
Global automotive M2M connections 2010 – 2020
Source: Machina Research, 2011

5. Tariff systems

5.1 The structure of the tariff models

M2M market requires a completely different structure of tariff models in relation to any of the traditional models, for either residential or business customers, and telecommunication operators yet need to respond to this kind of requests by offering new tariff M2M models. In Republic of Croatia existing operators (T-Mobile and Vipnet) offer four tariff models related to M2M communication. As already mentioned, only two operators in Republic of Croatia offer packages for M2M communication as a part of tariff models for business users. Basic packages are (at the time of writing paper): M2M Total (T-mobile), M2M Ideal (T-mobile), Data Profi (Vipnet) and Smart Data (Vipnet). It is possible, in particular packages, to activate various options like cheaper communication while roaming, data transfer etc. Also, as with the tariff models for residential users, there are two types, depending on the method of payment: proactive and retroactive payment.

When talking about the structure of the tariff models, an important factor are the services for which the user is required to pay. For example, for the package for residential users of mobile communication network, there are three basic services: calls, messages and data. In M2M communication core services are: transfer of data (service that involves the transmission of data using GPRS/EDGE/UMTS/HSDPA technology), messages (textual and multimedia, i.e. SMS and MMS), data calls (Circuit Switched Data Call, CSD), fax messages and voice services (optional).

5.2 Creating a mathematical model

Getting insight to the M2M communication services, it can be concluded that there is a whole range of factors that can affect the final cost. Based on this, it is necessary to measure some sort of quantification of the total cost of ownership, called TCO (Total Cost of Ownership). The main factors that largely affect the costs are:

a) Call (data and voice) and call billing unit
b) Messages
c) Data Transfer
d) The amount of the monthly subscription

The basic model for calculating the cost of ownership for a specific period *t* in months of use is (Eq. (1)):

$$\text{Total Cost of Ownership (t)} = (\text{Average monthly fee} + \text{Average cost of data transfer} + \text{Average cost of data calls} + \text{Average cost of messages} + \text{Average cost of voice calls}) \cdot t \qquad (1)$$

The mathematical model includes only the retroactive tariff models. As the cost of data transfer depends on the quantity and price (per data unit) of transferred data, a cost of data calls depends on the duration of CSD calls, time required to send fax messages and price (per time unit), the cost of messages depends on the number of messages and the cost of messages (per message) and the cost of voice calls depends on the duration of the call, the price of one call (per time unit), the number of calls and call set-up fee, it can be easier to write (Eq. (2)):

$$TCO\,(t) = (M + TC_{DATA\text{-}TRANSFER} + TC_{DATA\text{-}CALLS} + TC_{MESSAGES} + TC_{VOICE\text{-}CALLS}) \cdot t \qquad (2)$$

Where it is:

$TCO \equiv$ Total Cost of Ownership [KUNA]
$M \equiv$ The amount of monthly fee [KUNA]
$TC \equiv$ Total cost for a particular service
$t \equiv$ Time period [months]

It should be mentioned that the above model is valid only for national traffic.

The formula for calculating the cost of data transfer (Eq. (3)):

$$TC_{DATA\text{-}TRANSFER} = N_{DATA\text{-}TRANSFER} \cdot R_{DATA\text{-}TRANSFER} \tag{3}$$

Where it is:

$N_{DATA\text{-}TRANSFER} \equiv$ Amount of data transferred (Data unit - MB)
$R_{DATA\text{-}TRANSFER} \equiv$ Price of transferred data [KUNA/MB]

If there is a certain amount that is subsidized, it enters into a monthly package, the following is valid (Eq. (4)):

$$TC_{DATA\text{-}TRANSFER} = (N_{DATA\text{-}TRANSFER} - N_{DATA\text{-}TRANSFER\text{-}SUB}) \cdot R_{PP} \tag{4}$$

Where already existing labels are valid and $N_{DATA\text{-}TRANSFER\text{-}SUB}$ denotes the number of subsidized units of information. The expression in brackets is used for checking whether the subsidized amount was spent.

Cost of data calls is calculated by the formula (Eq. (5)):

$$TC_{DATA-CALLS} = TC_{FAX} + TC_{CSD} \tag{5}$$

Where it is:

$TC_{FAX} \equiv$ Cost of fax calls [KUNA]
$TC_{CSD} \equiv$ Cost of data calls (Circuit Switched Data Call) [KUNA]

Cost of fax traffic is (Eq. (6)):

$$TC_{FAX} = T_{FAX} \cdot (1+y) \cdot R_{FAX} \tag{6}$$

Where it is:

$T_{FAX} \equiv$ Duration of all fax calls [min]
$y \equiv$ Average increase of duration of fax calls depending on the billing unit
$R_{FAX} \equiv$ Price of one fax call [KUNA/min]

Regarding the calculation of the cost for data calls, the formula is similar as for calculating the cost of fax traffic, but different access numbers for achieving CSD connection and different pricing should be taken into account, i.e. the price depending on the number which is dialled, e.g. if access number of the parent operator has been dialled, then one price is valid, and in case of dialling another operator, another prices are valid (this is the case of so-called selective billing). Therefore, it is necessary to introduce the concept of zones[1]. Let *m* be the total number of *zones*, then the following applies (Eq. (7)):

$$\sum_{k=1}^{m} = (T_{CSD} \cdot X_k \cdot (1 + y) \cdot R_{CSD\text{-}k}) \tag{7}$$

Where it is:

$T_{CSD\text{-}k} \equiv$ Length of CSD calls to the zone [min]
$X_k \equiv$ Proportion of calls to a particular zone
$y \equiv$ Average increase in the CSD call duration depending on the billing
$R_{CSD\text{-}k} \equiv$ Price of CSD calls for zone k [KUNA/min]
$m \equiv$ Total number of zones

The cost of messaging consists of two parts: the cost of text messages (SMS) and the cost of multimedia messaging service (MMS) (Eq. (8)):

$$TC_{MESSAGES} = TC_{SMS} + TC_{MMS} \tag{8}$$

[1] The term zone is used for a call destination - a specific network, networks, or even an individual user for whom selective billing and various benefits when making calls to a particular zone are valid.

Where it is:

TC_{SMS} ≡ Cost of text messages (KUNA)
TC_{MMS} ≡ Cost of multimedia messages (KUNA)

The cost of the text messages and multimedia messages is calculated using the following formulas (Eq. (9) and Eq. (10)):

$$TC_{SMS} = N_{SMS} \cdot R_{SMS} \tag{9}$$

$$TC_{MMS} = N_{MMS} \cdot R_{MMS} \tag{10}$$

Where it is:

N_{SMS} ≡ Number of sent SMS messages
R_{SMS} ≡ Price of text message [KUNA/message]
N_{MMS} ≡ Number of sent MMS messages
R_{MMS} ≡ Price of multimedia message [KUNA/message]

If there is certain number of text messages, which is subsidized, that enters into a monthly package, then the following is valid (Eq. (11)):

$$TC_{SMS} = (N_{SMS} - N_{SMS\text{-}SUB}) \cdot R_{SMS} \tag{11}$$

The cost of voice calls is optional for certain models and several factors should be taken into account: the price of calls (may vary for calls made towards certain operators or individual users. If this is the case, the so-called zones should be introduced), call duration, billing unit, the number of calls and the fee for setting up a call.
Taking into account the specified items, the cost of voice calls can be calculated by the following formula (Eq. (12)):

$$TC_{VO}\textstyle\sum_{k=1}^{m}{}_{LLS} = \quad T_{VOICE\text{-}CALLS} \cdot X_k \cdot (1 + y) \cdot R_{VOICE\text{-}CALLS\text{-}k} + N_{VOICE\text{-}CALL} \cdot F \tag{12}$$

Where it is:

$T_{VOICE\text{-}CALLS}$ ≡ Duration of all calls [min]
X_k ≡ Proportion of calls to a particular zone
y ≡ Average increase in call duration depending on the billing
$R_{VOICE\text{-}CALLS\text{-}k}$ ≡ Call price per minute for a given zone (KUNA/min)
$N_{VOICE\text{-}CALLS}$ ≡ Number of calls
F ≡ Set-up call fee
m ≡ Total number of zones

When calculating the cost of voice calls, data calls and fax messaging, it is necessary to take into account the amount of the call billing unit – T_{OBR}. An amount of billing unit may directly affect the actual time that is used for billing and calculation of call cost. If the billing unit is greater than one second, actual call duration gets increased for a certain amount that is equal to the billing unit's remaining time, in which the current call has stepped into (i.e. it has finished).

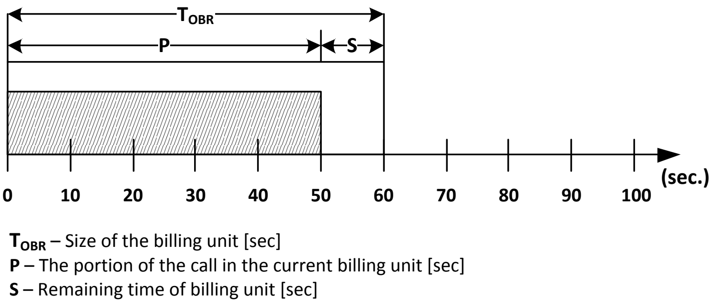

Fig. 5.
Call billing unit

According to Fig. 5 there are three variables (size of the billing unit – T_{OBR}, the proportion of the call in the current billing unit – P, the remaining time of billing unit – S) and every call's duration P gets increased by S.

6. Conclusion

M2M communication systems opens up new and great opportunities for telecommunication operators. Wholesale market and easy implementation of such services is a major factor in their significant growth. M2M communication can be utilized in various fields, and especially in the field of intelligent transportation systems, offering additional features and improvements to existing systems. The fact that M2M communication system in their work does not require human intervention allows it to work every day without stopping. This means that this system allows generating traffic all day, therefore it is not surprising such a large growth of M2M traffic. In all of that essential is adaptation of telecommunication operators to new services and tariff plans. Improved tariff models provide new market opportunities and increase the number of users and their satisfaction. M2M communication systems and services enable the increase of customer satisfaction as well as satisfaction of telecommunication operators. Users often receive a quality service that ensures their needs, while telecommunication operators are increasing their profits thanks to the increasing number of users and devices.

References

Cinterion, a Gemalto company. 2012. Green, Clear and Intelligent Transportation Systems: Automotive M2M Comes of Age. Available from internet: <http://www.cinterion.com/m2m-world/m2m-markets/vehicle-telematics/automotive.html>.

Cisco Inc. 2012. *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016*. USA.

Government of India–Telecommunication Engineering Centre. 2011. White paper Machine-to-Machine Communication (M2M). Available from internet: <http://www.tec.gov.in/tec_hindi/studypaper/White%20Paper%20on%20Machine-to-Machine%20%28M2M%29Communication.pdf>.

Economist Intelligence Unit. 2012. *Rise of the machines – Moving from hype to reality in the burgeoning market for machine-to-machine communication.* United Kingdom.

Machina Research. 2011. *Machine-to-Machine (M2M) Communication in the Automotive Sector 2010-2020*. United Kingdom.

M2M Communications, an EnerNOC Company. 2012. What is M2M Communications? Available from internet: <http://www.m2mcomm.com/about/what-is-m2m/index.html>.

Nokia Corporation. 2004. *White paper Machine-to-Machine, Let your machines talk*. Finland.

Smith, J.O. 2012. *Standardization in Machine-to-Machine (M2M) Communications*. ITS America Webinar Series. USA.

HOW TO CHOOSE THE RIGHT NAVIGATION DEVICE IN TRAFFIC?

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Abstract: Today GPS devices have become a reality in navigation and traffic. Satellite coverage of the area is extremely good and reliable, so it makes navigation more secure. Acceptable price of different GPS devices makes them available to most persons who need them, in any possible manner. It still doesn't mean that a need for classic maps in navigation has been completely eliminated. Classically prepared geographical maps for navigation require certain graphical preparation. Novelty in graphical industry represents a possibility of steganography protection of the prepared data – in this case, maps. On the other side, as possible alternatives, electronic auto and navigation maps could be named, as well the mobile communication devices and computer technique.

Keywords: Navigation Map, GIS, Traffic, GPS, Devices, Steganography

1. Introduction

The interconnection between organisations and individuals, regardless to their field of work is within present conditions of global organising, a necessity. Functions and modes of these connections determine a required space and time. Such defined and described functionalities ask for technical means and tools in order to get realized. Development and sophistication of such tools provide individuals with maximal possibilities for mobility and orientation towards fulfilling needed activities and diversified obligations. Connections between urban and sub-urban areas and quality of these connections specify a level of development of a certain society. Construction of communication and telecommunication infrastructural elements allows an active individual, group or a society to completely plan and realise defined plans in appropriate and qualitative mode. In the process, static or dynamic behaviour of all dynamic elements in a society are specified exactly by the possibilities provided by a certain infrastructure. Also, every organised dynamic activity connotes traffic of goods and commodities needed for realisation of the planned activities. Nevertheless, it is especially important to underline a human component of the above mentioned – traffic and mobility of people who are also carriers of activities, and especially people authorised to completely control and manage individual activities and processes.

For a longer period of time, people were put in a position to separate physical locations of their homes and business assignments and activities, so they have to continuously travel from one position to another, spending their time in the process. Naturally, this isn't the only situation where individual is forced to change his momentarily physical location, but is certainly the most usual, on the daily basis. The other travels have sporadic and occasional character, but are also possible. Those would be different travels of a private character, according to the private needs such as vacation or touristic travels.

According to the general definition, traffic is „The passage of people or vehicles along routes of transportation...“, that is, „The business of moving passengers and cargo through a transportation system…“, or, „The commercial exchange of goods; trade“, etc. (AHD, 2012).

2. Some considerations

Though, the above mentioned definitions imply a traffic of messages as well, it is not the solely matter of consideration and it could be assumed that traffic of messages is included in the third part of definition, the one that mentions goods and materials. For purposes of this research, it is necessarily to combine mentioned definitions with emphasis put on business needs for traffic of people, goods and services, consequently the messages as well. In this sense, from the pragmatic aspect, it is necessarily to include into the consideration a component of transportation or transfer in a physical sense. In a technological aspect, all traffic, regardless to their sort, demand a proper organisation and regulation. At the same time, primarily and basic purpose of traffic regulation is safety of all traffic participants.

Due to the specification, it is required to define term of traffic safety. Let the definition, for purposes of this research, be: "Safety is the biggest possible probability that the complete traffic system or its certain sub-system will safely function, according to the prior defined working conditions.

If, from any possible reason, threats to the regular traffic occur, the implemented appliances should be projected and programmed in order to unconditionally, reliably and automatically pass to the higher level of safety, even if it means the abolition of traffic. Development and organisation of traffic in present frames are a consequence, of primarily development of technical tools and infrastructural possibilities.

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However, it could also be put vice versa, good infrastructural possibilities are incentive for development of technical tools, means and appliances, used for a qualitative management of traffic, regardless to the its sort and shape.

Besides term of traffic, in its general sense, and transportation, this research also requires a definition of term navigation as well. Though originally navigation was connected to maritime travels, within present traffic possibilities one could mention navigation in any sort of traffic: road, maritime or, even space.

Navigation, orientation or regulation of traffic can be observed from several aspects, but traffic safety is beyond doubt, the most important.

Navigation refers to the process of monitoring and controlling the movements of objects or vehicles between two spatial positions in traffic. Positions are determined by spatial coordinated within metric space applied to the physical space where the movement takes place (Bowditch, 2002). The second important fact connected to the traffic safety is the environment in which traffic or movement generally occurs. In general sense the basic demands of navigation are identical for all traffic modes. However, there are some specificities that differentiate individual sorts of traffic. Therefore, maritime traffic in certain characteristics differs from inland or air traffic.

Term navigation itself (lat. Navigare) was generally connected to the navigation and characteristics of maritime traffic where demands for elements of orientation and consequently navigation, are different, that is more demanding than the ones for inland and inland traffic. Hence, the urge for terrestrial navigation as a scientific sub-discipline emerged. According to the metrics of applied coordination system on Earth, every point – a physical location is accompanied by pair of coordinates (latitude -φ, longitude-λ) as measure of distance from the agreed original points represented by equator and meridian. The Earth, as celestial body and environment in which all sorts of traffic occur, is the environment in which people apply, according to their notifications, rules of Euclid space. However, the applied metrics is of the agreed character and submerged to changes. With its form and relationships in its environment, the Earth imposes somewhat different modes of description, so the geographic coordinates are connected to the sphere geometry which puts Euclid norms of planar environment into the situation of re-evaluating their application and importance. Navigation in such way can be observed within frames of geometry – globally and of the Euclid planar geometry – locally, within situation of locally bounded movement from one position to another in a space.

At the same time navigation connotes usage of tools such as navigation geographical maps. Geographic maps, the ones that are presently in use, are projections of three-dimensional space to two-dimensional form with data of position of a single point T (φ, λ), latitude and longitude. The third coordinate, altitude, is significant when position of an object is observed in comparison to the local horizon. Already by its purpose, map is a visual outline of certain area, described by proper symbols, which underlines relationship between elements of the space displayed. The form of map is also connected to the concrete circumstances and according to the situation it can be significant. Within present frames of technical possibilities and concrete digitalization and application of information communication technologies, this complete area is submerged to drastic modifications. Besides consideration of forms of tools that can be used for communication and navigation, this paper analyses their acceptance from participants according to traffic and transportation safety. Since some tools and their performances have a character of innovations, the results of conducted researches can be observed with a certain attention, but tools themselves can be accepted as a possibility.

3. Overview and categorisation

The subject of this research is acceptance of individual tools for navigation and orientation in traffic. At the same time, as bounded factors were observed, the application of tools, their availability in general and economic sense, functionality and pragmatic character. For this purpose, one could use strictly scientific definition of navigation, indeed in maritime conditions, as skills and sciences of managing and navigating the ship through the best route from one place to another (FMS, 2012).

A simpler, traditional definition considers navigation as the best way to return home. If definition of navigation is projected to a more appropriate way to the definition of traffic, holistic approach should be applied.
For instance, some authors (Kerner, 2009) claim that traffic is a phenomenon connected to the complex dynamic behaviour according to spatial-temporal patterns.

This definition seeks to underline traffic within frames of space and time which define it and related problems as well (Gazis, 2002).

Strict holistic approach of traffic includes:

- Infrastructure – physical object and location where traffic of people and goods is executed. Basic objects refer to: roads, railroads, airports, ports, commodity terminals, traffic terminals and similar.
- Vehicles or means used for traffic – usually adjusted to specific mode of traffic
- Belonging and apposite operations – navigation, regulation and signalization of traffic – maps, signs, light signalization, regulation and control of traffic and similar.
- Time or duration of transportation and traffic of goods and people.

If all the above mentioned resumes to the navigation and orientation in traffic, then physical object should be replaced by belonging codes and symbols that will be organised in forms most similar to navigation maps, popularly called “auto-maps”.

Concrete presentation of such maps in present technical and technological possibilities can overtake different forms, with the same purpose as before. Basic purpose is help in navigation and objective insurance of safe traffic and transportation defined in certain time and space.

Holistic observation of pragmatic aspects of traffic refers to the mentioned terms and specifications, but concrete situations can require fulfilment of additional specific terms (transportation of special and specific cargo). Traffic safety is unquestionably the most important aspect of traffic. However, its specificity is usually the consequence of enlarged or increased need for safety conditions which should be provided during transportation of specific cargo, such as hazardous cargo.

Insisting on spatial-temporal frame of traffic demands an integral approach for appreciation of specificities, or at least, providing frames in which these specificities will be considered. In spatial sense, traffic requires physical environment for its realisation. Temporal component isn’t independent, or individual. Traffic is a process made of line of activities, so it does have its duration, or, it is timely limited. Duration as indicator or variable determines traffic in a way that it specifies or limits range of individual factors which indirectly define traffic as unity. At the same time, concrete situation of traffic considers if not ideal, than at least optimal conditions which provide such a space. The same conditions are basics for determination and calculation of time that is duration of traffic as a concrete process.

Further on, space as determinant of traffic, should be considered as physical and geographical determinant realised through infrastructural possibilities and options which still define duration of traffic activity or its temporal component. Weather conditions, in sense of momentarily climate conditions, are also important factor which influence duration of the process and can emerge as consequence of spatial conditions. Equally, traffic is necessarily connected to the infrastructure and infrastructural possibilities. That connection reflects through two basic features of traffic: compactness and safety.

Traffic as scientific discipline corresponds to other scientific disciplines in such mode where basic subject of consideration is connected to appearances, processes and subjects through which other sciences and scientific disciplines influence or determine traffic. This helped basic sciences, such as maths and physics, to get involved in theory of traffic, in line with construction science and other applied sciences, more or less specific to their subject of analysis.

When several sciences or scientific disciplines correspond in a certain mode, then they also share perceptions of terms, facts and data of interest to all of them. Strictness of mutual definition that will consider required specificities is a prerequisite of qualitative research and concrete conclusions.

For purpose of this paper it is important to valuate importance of two sciences: geodesy and cartography. Namely, connectivity between geodesy and cartography is pragmatically involved in traffic as science. On basic level of abstraction, one can obviously notice dependence between qualitative traffic of people and goods and accomplishments and applied scientific facts of these two sciences.

4. Navigation and orientation in space and basic tools

Cartographic projections actually enable mapping the points of curved surface, whether sphere or rotational ellipsoid of planet Earth or other celestial bodies into a level, through application of mathematical procedures. Their application is multipurpose, especially in geodesy and navigation (Brewer, 2005). Cartographic mapping determine dependence between coordinates of points of Earth ellipsoid and coordinates of their projections on level. Achieved projections or planar overview of bodies is usually connoted as map. Map, a geographic one or navigation, is basic tool in navigation, regardless to traffic sort. Accordingly, map can have a specific purpose which makes its creation more complex since it requires additional data.

Traffic cards or maps intended for navigation and orientation in traffic, aside from positional coordinates contain a whole line of symbols that determine through their shape and colour the importance of an object recorded on a map. In time when one can easily use devices as GPS (Global Positioning System), discussion of navigation maps could lose its importance.

GIS is American space global navigation satellite which provides reliable positioning, on all points available through contact with four or more satellites. Satellites provide a signal for geo-positioning anywhere on the Earth, with momentarily 28 active satellites of which four are reserves.

Neither temporal and climate conditions neither day period represent limitation. However, GPS appliances as basic element of satellite managed navigation are still not available to all since their price is limitation factor. This however doesn't eliminate need for maps since there is always a possibility of damage on the appliance or a problem of communication character on a global level. On contrary, GPS is a useful tool for creation of maps and land measurement, which involves in this specific problem both geodesy and terrestrial (and even space) navigation.

Besides, navigation by GPS appliance is semi-interactive, meaning that a navigator or person who navigates vehicle has to communicate with appliance audio-visually that decreases momentarily safety of traffic. Equally, the navigator is completely adrift to the information received by satellite. Combined with visual control of space, navigation still possesses a high safety. However, one should in every moment be aware of the surprise factor.

Screen of GPS appliance is interactive cartographic projection of navigator's environment which, besides certain dynamic characteristics, retains all other features of a regular map. In its display and symbolism it is even poorer than traditional maps, but not in sense that it questions traffic's safety.

5. Research and hypotheses

Research, mostly undertaken in the Republic of Croatia, within one year (March 2011 – March 2012) tried to accumulate relevant indicators which would connote a relationship between active participants – navigators in traffic according to some specific values which define it. These indicators were determined according to authors' opinions. Hypotheses of this research are connected to safety in navigation and traffic in general and usage of tools and devices for navigation and orientation. Some other elements important for safe and regular traffic supported in navigation by some tools available or which could become available to participants in traffic.

When making these hypotheses some facts were neglected, such as the fact that active participants in traffic cannot recognize some of the offered tools in the future as well. In so far that some tools were presented as a possibility of a momentarily realisation and significant application in practice. Since navigation tools in space, and time, are only a part of traffic safety prerequisites conditions put by research, participants of this research were also asked about other indicators such as vehicles' safety. Hypotheses were:

- The examinee is an active participant in traffic who possesses the competencies of navigating the traffic medium.
- The examinee is participant in different forms of traffic and according to modes and duration with major emphasis put on duration of traffic.
- The examinee uses some of tools in navigation and orientation in space and time of trafficking.
- The examinee has a personal perception of quality and importance of individual tools with emphasis put on a quality and reliability of tool's technical performance.
- The examinee will try to use more modern forms and technical solutions of tools since they provide a better safety in traffic.

Due to confirmation of the quoted hypotheses, a questionnaire has been undertaken among population which hasn't been categorized in any way except by discriminatory question about the competencies in navigating the vehicle. Also, it should be noted that population refers to road traffic and personal vehicles so this questionnaire has been limited by its character, since it doesn't cover other sorts of traffic or other types of road traffic. Limitations within road traffic are derived in purpose having in mind that, for example, a truck driver has also a personal car, which mostly covers the mentioned area. Naturally, freight traffic of goods can be specific by some factors, such as transportation of a hazardous cargo, which still doesn't influence basic conditions of navigation and orientation. The other hypothesis is the assumption that majority of traffic participants act in space-limited area, that is, they rarely travel on longer destination or in the areas classified as unfamiliar. This implies the necessity of tools such as navigation maps regardless to their performance. The third hypothesis should be a confirmation of users' conscience of exquisite technical solution as a reliable element of traffic's safety. The fourth hypothesis is connected to device or tool in navigation and orientation during traffic and transportation. Any sort of appliance the user could handle during the trafficking, practically presents a certain copy of a real environment where traffic takes place. This indicates a map regardless to its shape: printed, digital, electronic and others. Therefore, it is absolutely certain that some forms of maps are used during the trafficking.

5.1. Questionnaire and interpretation of questions

The questionnaire was undertaken among population of 119 examinees. Pool was of integral type and included 115 questions of all sorts. Questions were made so to confirm the a priori defined hypotheses. The questionnaire read:

1. *What's your gender?* The question wasn't supposed to be discriminating, but in case of factor analysis in which gender could be important for analysis, this kind of data would be useful.

2. *How old are you?* Similar to the question above, this either shouldn't have a discriminatory character in a gerontology sense, but answers could be valuable when analysing correlations of other answers related to the age of examinee – traffic's participants.
3. *How long (in years) do you have a driver's licence?* Experience in driving and lengths of the official licence is extremely important and so is the correlation with other questions related to the competencies and experience.

4. *How many cars do you have?* The offered brands of vehicles were given according to the European classification of personal vehicles. This question was important for analysis of relationship between participants of traffic and other important elements of safe traffic.
5. *How often do you drive a car?* The question should have revealed whether a person regularly participates in traffic.

6. *How often do you drive on more distanced routes?* This question could have been separated to two in order to get an answer to question whether this concerns the regular distant relations – tours or whether it concerns occasional longer travels to different destinations. This ambiguity was partially eliminated in seventh questions which read

7. *How often do you drive in new and unfamiliar area?*

8. *Arrange according to significance, to your opinion, the following element of traffic*: Safety in traffic, Good regulation and signalization of traffic, Good signalization on highways, Proper distribution of restaurants and gas stations, Reliable navigation devices, Technical validity of vehicles, Health condition of all passengers, qualitatively constructed highways, Qualitative and safe help on highways, and choice nothing of the mentioned. Answers offered for categorization cover the main conditions of safe and reliable traffic. The following group of questions relate to sorts of tools in navigation and orientation during the trafficking. Along the explanations of questions, examines are also offered the explanation of forms of tools considering their realisation and usage. Some of the offered solutions are only the propositions with no practical importance so besides them, the way of application and advantages of their usage were also described.

9. *E-paper is a screen technology designed to imitate look of regular ink and paper by reflecting the daylight. It is made of plastics so that it can be furled and occasionally filed with new contents. Would you buy such an e-Map for navigation in driving?* Electronic paper has two different parts, of which the first one is electronic ink (e-ink), and the other is electronics which enable overview of text and images on electronic ink, that is places on the front side of electronics. E-Paper reflects light similar to regular paper and it doesn't require back lightning. There are several different technologies in production of e-Paper. Some of them use a substance of plastic bottom combined with electronics, which enables the deflection. It also provides easier reading from screen so it is not required to refresh it on regular basis. Application of e-Paper includes readers of eBooks, capable to present digital versions of books and e-Magazines, time tables on bus stations and electronic commercial panels. Similarly auto maps can be prepared and used for navigation in traffic. E-Paper isn't a digital paper so one can write on it with e-Pencil.

10. *Infrared-design is a new publishing technique which enables printing of two different contents on the same bottom, readable under infrared light. Would you buy such navigation maps which would contain much more additional data for safe traffic?* The usual maps which are used in road traffic, besides positioning based upon two coordinates (latitude and longitude) can also include data of third coordinate, altitude, though without impression of three-dimensional space. On the other hand, too much data can make map hard to read and use, though some of data on these maps could be necessary. Another important fact is that maps, just after they are published, very quickly become inaccurate since the presented locations change regularly. Infrared-design as publishing technique represents a group of rules which enable a combination of two prints or two pictures. Both pictures aren't visible at the same time, under the daylight or artificial light, since one of them is visible only under the infrared-design. Infrared-design can that way play an important role in protection of data that is a steganography technique which protects specific document, or map in this particular case map, from the falsification. Naturally, there are additional possibilities. Infrared-design as publishing technique, within this research, shouldn't be changed with application of devices used in combination with infrared rays, such as night recordings. For more information, check (Ziljak at al, 2011).

Things visible to human eye under the normal conditions is only a segment of spectrum which includes radio waves, infrared and ultra-purple, x-rays and gamma rays as forms of electromagnetic radiation. A possibility of expanding the visibility due to electronic devises represents a very powerful technique and application of IR part of spectrum when it can be seen. Infrared light has less energy than visible light, with proportionally higher wave lengths.

11. Infrared part of spectrum has wave length of 1 to 15 microns or 2 to 30 times longer wave length (and 2-30 times less energy) than visible light. Infrared design is a new technique that has primarily found its application in different aspects of product's protection from falsification since every scanning or photocopying of those documents destroys picture readable under the infrared light. In such way highway maps can be supplemented with different data, such as tourist information, locations of important objects with description of their offer, and those can be helpful to participant of traffic.

12. *If you have a possibility, would you buy GPS (Global Positioning System) navigation devic*e? GPS devices and GIS system were already described in upper text. GPS is surely the most modern navigation device that is device which provides the highest level of safety in orientation and navigation. However, the usual rule is that improved devise in case of their failure have higher risks. The crash of communication system is possible, though with small probability, while location process engages at least 4 to 38 satellites. However, GPS devices do have two disadvantages, at least known till this moment. One of them is of economic nature and it limits users in procurement. The other is the required level of knowledge in order to handle them, though it doesn't connote large effort but it does demand certain adjustment of users. In conditions of development and improvement of such devices one could expect broader application and lower prices of these devices.

13. *For navigation in driving you will use the possibilities of mobile phones (Google navigation and alike)?* In general trend towards mobility in executing all activities, the producers of mobile phones have started to implement software which enables similar possibilities, though not completely, offered by producers of GPS devices through Google navigation on mobile phones. Regarding the broad application of mobile phones, one could expect that this aspect is the most common under the assumption that users are able to apply all possibilities offered in this way.

14. *If you were asked to decide between offered devices and appliance it would be?* This question motivated examinees to choose one of the options offered in questions 9-12.

15. *Do you believe GPS device should be a standardised part of the car equipment similar to air-pillows or space sensors?* Question should have revealed the opinions of examinees about the necessity of supplementing the vehicles with equipment which should fulfil required conditions in traffic navigation and orientation.

16. *According to your opinion, grade the following navigation tools in comparison to their reliability?* Since tools and devices mentioned in questionnaire are also factors of safety in traffic, this question asked examinees to range, according to their own opinions, the importance and reliability of described tools and appliances. The offered possibilities included traditional navigation map and making inquires by local population in line with needs and possibilities during the traffic realisation.

5.2. Results of questionnaire and profile of examinees

Questionnaire took 119 examinees of which 2 questionnaires are considered unfinished so they aren't taken into consideration. Between 119 examinees, 71 (59.66%) is male while 46 (38.66%) were females. Questioned population, according to their age mainly belongs to the age group 20-39, 46 examinees (38.66%) are younger than 30 and 33 (27.73%) are younger than 40 which makes ¾ of examinees. The rest of app 25% belongs to age group of 40-60. According to length of their driver's licence, examinees are almost uniformed distributed so percentage varies from 20 to 25% with interesting deviations in class of 16-20 years old. Upon automobile's brands examines mostly own middle class of cars, with 74 (62.18%) or with lower class of cars 29 examinees (24.37%). Since 92 examinees (77.31%) stated that they daily drive cars, a correlation can be explained between categorisation of cars and their purpose as everyday trafficking vehicle. At the same time, almost 2/3 (64.31%) examinees drive on longer relations, in average once a month. Navigation in new and unfamiliar field indicates once again a uniformed distribution with an average of app 32% in category of very rare, once a year and once a month.

Collected indicates that 51.26% considers traffic safety as the most important, while 19.33% puts safety on the second place. The second factor is technical validity of vehicles which 29.41% examinees put on the first place, while the same percentage puts it on the second place. The other factors primarily choose otherwise neglected values. Reliable navigation tools are nevertheless recognized by 26.89% examinees as an important factor in traffic.

Analysis of application of tools and devices for navigation implies that readiness for purchase of e-Map is uniformed distributed between purchase and indecisiveness while only ¼ (25.21%) state negatively. Infrared design map would choose 47 examinees (39.50%) while others are equally indecisive or they don't want to buy such a map. GPS devices, with acceptable price would buy 98 examinees (82.35%). A smaller number of 70 examinees (58.82%) would use a mobile phone in navigation while 35 of them wouldn't (29.41%)
If they have to choose between offered possibilities, 90 examinees (75.63%) would use GPS device while the others would use either mobile phone or a tradition map.

These results could have been expected considering the fact that e-Paper and infrared design are still not in usage so their possibilities aren't familiar. However, interesting fact is that only 55 examinees or 46.22% believe GPS devices should be a standardised part of vehicle's equipment. Categorisation of navigation tools is visible in Table 1. The majority, or 66.39% examinees considers GPS device as the most reliable device so they put it on the first place, while 17.65% puts the traditional map on the second place. The third place was given to it in case of providing the required information.

Table 1
Grade upon reliability

According to your opinion, grade upon their reliability	I	II	III	IV	V	VI
e-Map (e-Paper)	2,52%	12,61%	17,65%	18,49%	25,21%	21,01%
regular navigation map (paper)	17,65%	12,61%	18,49%	13,45%	20,17%	15,97%
infrared design map with several different data of the field (double print)	0,00%	13,45%	15,13%	27,73%	21,01%	21,01%
regular mobile device with possibility of navigation	3,36%	31,09%	19,33%	23,53%	12,61%	8,40%
GPS satellite device (according to its price)	66,39%	14,29%	9,24%	3,36%	4,20%	0,84%
local population	8,40%	14,29%	18,49%	11,76%	15,13%	30,25%
unfinished or un-displayed	1,68%	1,68%	1,68%	1,68%	1,68%	2,52%

6. Conclusion and suggestion of further researches

Safety in traffic depends upon different factors. However, within present frames with developed network of highways of high quality all these factors (quality of highways, quality of signalization and traffic regulation, factors depending on individuals such as technical validity of vehicles and drivers' competencies) make traffic safe in a satisfactory level.
Situation changes when traffic is re-allocated in local and additional network of highways. Navigation then becomes more demanding and usage of tools and devices more required. If conclusions are to be derived from accumulated data, average opinion can be profiled about the navigation and orientation of users/participants of traffic.

Participant of traffic is mostly oriented on shorter traffic relations which probably connect residence with working places, meaning that traffic becomes a routine in which navigation and orientation do not represent a problem. Longer traffic relations are rare and usually take place on highways, though this claim is assumption that cannot be derived out of accumulated data. If participant of traffic required device for orientation and navigation within present frames he could have chosen different tools and devices. Their usage requires certain practice and knowledge regardless to the traditional map or contemporary GPS device.

The assumption that car industry will try to include such a sort of devices into the standardised equipment, is primarily based upon keeping the track with industry in area of telecommunication. Somebody once said that were cars improved with speed of improving and developing computers, the whole traffic would already be executed in the air.

Regardless to the all above mentioned the main direction of development in this area should be realisation of safe traffic in which human lives will be maximally protected. In the process the same attention should be given to the protection of the environment in which traffic occurs.

References

American Heritage Dictionary. 2012. Traffic. Available from Internet: <http://www.answers.com/topic/traffic#ixzz1wW6IWHLb>

Bowditch, N. 2002. *The American Practical Navigator*. National Imagery and Mapping Agency, USA. 879p.

Brewer, C. 2005. *Designing Better Maps: A Guide for GIS Users*. ESRI Press, USA. 220p.

Fakultet za Mediteranske poslovne studije. 2012. Predavanja. Available from Internet: <http://www.fms-tivat.me/predavanja3god>

Gazis, D.C. 2002. *Traffic Theory (International Series in Operation Research & Management Science)*. Springer. 280p.

Kerner, B. 2009. *Introduction to Modern Traffic Flow Theory and Control: The Long Road to Three-Phase Traffic Theory*. Springer. 265p.

Ziljak, V.; Pap K.; Stanimirovic, I.; Vujic, J. 2012. Managing dual colour properties with the Z-parameter in the visual and NIR spectrum, *Infrared Physics & Technology* DOI: http://dx.doi.org/10.1016/j.infrared.2012.02.009, 55(4): 326-336.

FUEL CONSUPTION ANALISYS OF CNG AND HYBRID BUSES ON THE ROAD NEWORK

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Abstract: In this paper fuel consumption and fuel costs of CNG and hybrid buses is analyzed in intercity bus service on the territory of the Republic of Serbia. In order to define and forecast transport demands in average annual daily traffic, on every section of created multimodal transport network, application Transtools was used. This application of Transtools was specially adapted to suit territory of the Republic of Serbia. By applying HDM model and regression analysis, in accordance with type of terrain and International Roughness Indicator (IRI), functional dependency between speed of diesel bus and its fuel consumption was determined as polynomial of second level. By determining fuel equivalents of CNG and hybrid buses and based on the research which was carried out in real operating conditions, projection of fuel consumption for alternative concepts was made on entire road network for three different scenarios which describe different road and operating conditions. Fuel cost analysis is carried out on the entire modeled road network. Also, the economic analysis of using CNG and hybrid buses on a real intercity line was made considering investment, operating and maintenance costs of buses from the standpoint of bus fleet owners.

Keywords: CNG bus, hybrid bus, road network, fuel consumption.

1. Introduction

More than a hundred years of exploitation and prevalence of liquid fuels (diesel and gasoline) in traffic has led to certain undesired consequences. First is reduction of liquid fuel reserves and their most probable future deficit on the market. Second is increasing environmental pollution, which is present as a consequence of worse fuel burnout and unoptimized fuel quality. Modern requirements, with new quality standards for diesel and gasoline, make them more expensive and even more difficult to acquire on the world market. From the beginning of the 1980s, people have been working hard to find alternative fuels and alternative drive systems in order to replace classical vehicle concepts. The best known alternative fuels for motor vehicles are: natural gas, most commonly stored in compressed condition in a vehicle (CNG), liquid propane gas (LPG), methanol, ethanol, methyl-esters, oils from rapeseed oil, etc. (Matijosius and Sokolovskij, 2009; Tzeng et al., 2005). Alternative drive concepts are: electric drive, hybrid drive, fuel cell drive systems.

Of all mentioned solutions, world has shown increased interest in natural gas as a fuel for bus engines, which is presented through data on number of CNG buses currently operating. In 2007, around 164 000 of these buses was registered, and in 2011 the number was around 435 000. (NGV report, 2011). According to different evaluation criteria, especially ecological, energy and transport, hybrid buses are more common in passenger transport. Since problems with air pollution are more noticeable in urban areas, where speed of vehicles is between 20 and 40 km/h, applying these two bus concepts is characteristic for them, so a great number of published papers focus on research of these buses' performances in cities. Taking into consideration advantages of CNG and hybrid buses, regarding ecology and energy saving (lower exhaust emission, more rational energy saving-reduced consumption and increased substitution of diesel fuel), it is expected that these buses will be used in passenger transport in non-urban areas, as well. In this paper we analyzed performances of CNG and hybrid buses on intercity road network in the Republic of Serbia, regarding fuel consumption and fuel costs.

2. Concepts of alternative fuel buses – CNG and Hybrid technologies

Compressed natural gas fueled bus. For many years natural gas has been accepted in the world as one of the most perspective alternative fuels for buses. Advantages of natural gas vs. liquid fuels (gasoline or diesel) are: better mixing with air, more efficient burning, relatively high heating value, it burns almost without residuals and has lower base price comparing to liquid fuels (Ahouissoussi and Wetzstein, 1998; Cohen, 2005; Turrio-Baldassarri et al., 2006; Ullman, 2003).

These characteristics result in lower exhaustion gases emission as well as reduced levels of noise and vibration in operating mode. There are few different ways how the natural gas is used to fuel buses:

Dedicated natural gas technology: There are two solutions. In the first case, the originally installed diesel engine is modified and tuned to work using only natural gas. Sparkplugs and electronic system is installed instead of diesel injectors and diesel injection pump. In order to reduce risk of detonative combustion, compression ratio has to be reduced to between 8 and 12 (Bhattacharjee et al., 2010) by increasing volume of combustion chamber and intervention on the piston head. The second option includes use of the engine originally manufactured for use of natural gas.

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There are two ways currently used to produce combustion mix: stoichiometric mixture of gas and air (λ=1) and lean mixture of gas and air (λ>1, λ=1.4-1.6).

Dual fuel technology: This concept is actually use of diesel engine that is powered by natural gas without any changes on the engine. There are two ways of regulating engine used in this concept:

- Dual-combustion engine with "pilot" diesel fuel injection. Natural gas and air are mixed at the air intake in required proportion and then, due to pressure, differential enters the chamber. The mixture is compressed, temperature rises, at the right time a small quantity of diesel fuel is injected into the chamber and self ignited. This also ignites the mixture of gas and air that is compressed in the chamber. This quantity of diesel fuel is called "initial" and is in the range of 10-15 % of nominal diesel fuel consumption. Due to the intake of significant quantity of gas and air homogeneous mixture, in case of full load, a detonation can occur. In order to prevent it, the compression ratio or the quantity of the mixture has to be reduced at the full load which results in engine power reduction.
- Dual-combustion engine with variable quantity of fuel injection (progressive injection). In order to prevent detonation in combustion at the full load, unlike in previous case where a constant small quantity of diesel fuel is injected, in this case the quantity of injected diesel fuel is increased from the initial level proportionally, with the increase of quantity of gas and air homogeneous mixture in the chamber. Then, at the full load of the engine, the quantity of the gas and air mixture is reduced to about 50 % and makes the mixture so lean that prevents detonation even if the compression ratio stays the same as the classic diesel engine. With this, the engine is unchanged, but the regulation of injected diesel fuel and amount of natural gas is somewhat complicated and the substitution of diesel fuel is lesser than in the previous case.

Hybrid buses. Hybrid drive on a bus includes two power aggregates using different energy sources. Often, it is combination of a small size diesel engine (volume of about 6-7 dm^3) and electromotor with usable power of about 150 kW. There are two different hybrid systems: serial and parallel. In the serial system, the moment on the wheel is provided only by the electromotor. Classic diesel internal combustion engine drives electric generator which then produces electric energy for charging batteries necessary for work of electromotor. Working regime of the internal combustion engine is continuous and does not depend on operating conditions (acceleration, deceleration, resistance, etc.), so the fuel consumption is reduced, as well as exhaust emission, and the longer life service of vehicle.

In parallel system, both power aggregates provide the moment on the wheel at the same time in different proportions, depending on certain conditions of exploitation. Electromotor works more at low speed, but while driving in rural conditions, at higher speeds, internal combustion engine works more. Batteries can be charged while braking when electromotor takes the role of the generator. Special parallel hybrid drive is "Power Split Hybrid System" which provides drive either by usage of electromotor solely or by usage of both electromotor and internal combustion engine at the same time, but this technical solution is rarely applied. According to energy efficiency, in matters of fuel consumption, serial hybrid buses are more adequate for "stop and go" city rides, while parallel hybrid buses are more suitable for constant and higher speed rates out of the city (Callaghan and Lynch, 2005).

Main advantages of hybrid drive buses are presented through (Moseley, 1999; Barnitt and Chandler, 2006):

- Reduced consumption of liquid fuels due to the usage of electric power,
- Significantly reduced levels of noise, smoke and toxicity of exhaust emission,
- Possibility to use only electric drive when leaving stops, since pollution and noise are especially intensive at that time,
- Higher movement radius in comparison to buses with solely electric drives,
- Possibility of increasing efficiency during regenerative braking, which additionally charges batteries.

Main disadvantages of this technology are in high quantity the same as disadvantages in buses with electric drive. Few principal disadvantages are: increased total mass of the vehicle, which can be seen in traction and dynamical characteristics; increased investment costs in comparison to conventional solutions, and higher level of maintenance, since two different drive systems are applied.

3. Methodological approach to fuel consumption analysis on the road network

Methodological approach to fuel consumption analysis on the Serbian road network is shown in Fig. 1. It consists of three main segments or three successive phases of fulfillment.

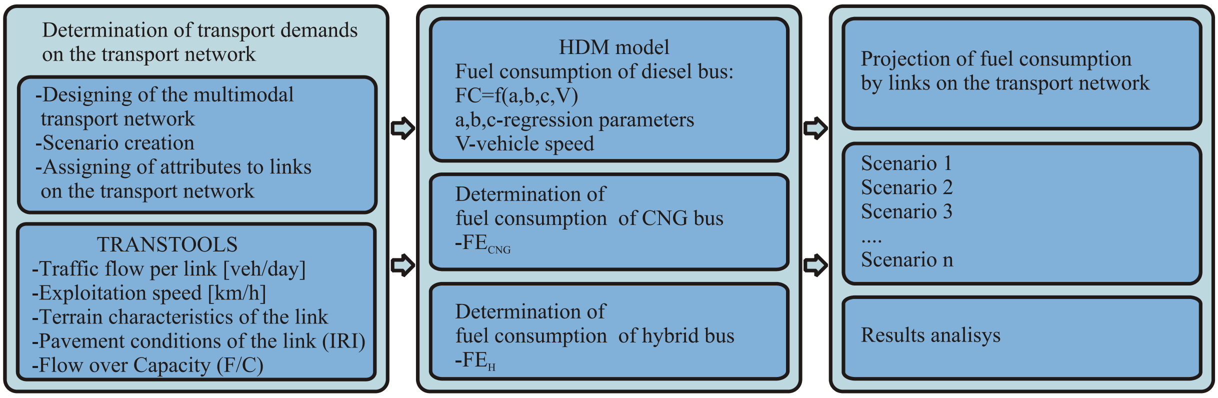


Fig. 1.
Methodological approach to the fuel consumption analysis on the road network

In the first phase it is necessary to design transport network with multi modal character as well as to define transport demands in average annual daily traffic per each network section (link). Multi modality is reflected in existence of road network, rail network and inland waterways network.

In order to see the impact of road and transport operating conditions (traffic flow, intensity, capacity, flow over capacity, operating speed) or the impact that development of transport infrastructure has on fuel consumption, analysis is carried out for different scenarios of transport infrastructure development on the level of non-urban roads on the territory of the Republic of Serbia. All towns and cities are considered to be traffic nodes except big cities as Belgrade, Novi Sad and Niš, whose territories have several links which are part of Pan European routes, important highways and regional roads in Serbia.

After defining transport requirements, in the second phase, by applying HDM model, fuel consumption of buses with conventional diesel drive is determined, depending on type of the terrain and international roughness index (IRI) for different speeds. Based on the research of fuel consumption for CNG buses and hybrid buses in real exploitation conditions, fuel equivalent (FE) values are determined, based on fuel consumption of the diesel bus. In the third phase projection of fuel consumption for alternative bus concepts is made for all links in road network and according to all defined scenarios. After these phases it is possible to calculate fuel consumption and fuel cost, for every section separately or for the entire road network.

3.1. Designing multimodal transport network

Total length of multimodal transport network on the territory of the Republic of Serbia (Fig. 2) is about 10 632 km. It is modeled on the base of WorldNet network which includes entire Europe and most of the world. Road network consists of intercity traffic sections, roads of first and second category and some links of local roads, with total length of 6 518 km. Rail network consists of all lines of international, national and regional importance in total length of 2 793km. Inland waterways network in total length of 1 321 km consists of rivers Danube, Sava and Tisa, as well as channels DTD of the third, fourth and fifth category.

As a result of the modal split of traffic on the network, in the process of defining transport demands by simulations in software package Transtools, rail network and inland waterways network are taken into consideration, even though the field of research is limited on the road sector. The nature of air traffic at the moment is not suitable for modeling in the Transtools package. Two airports which are functioning at the moment are airport “Nikola Tesla” in Belgrade and airport “Konstantin Veliki” in Niš, and they are described as traffic nodes.

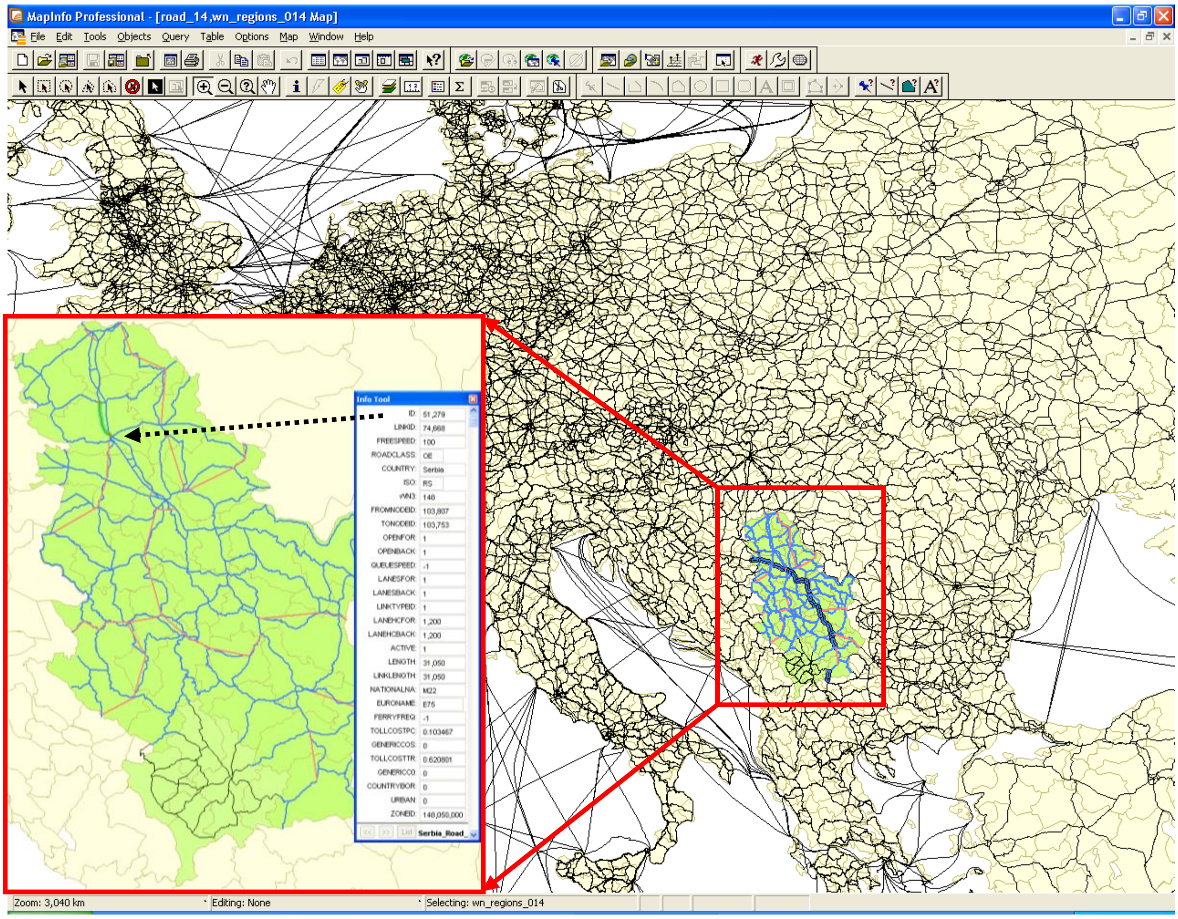


Fig. 2.
Modeled road transport network on the territory of the Republic of Serbia implemented on European level.

Traffic links in multimodal network have homogeneous technical operating characteristics. Every link in road, rail and inland waterways network has 50 (Table 1), 39, 23 attributes respectably to its values, which describe technical and operating characteristics of that same link.

Table 1 (1/2)
Attributes allocated to sections on modeled road network

No.	Attribute	Description	Reference
1	ID_TT	Link identification number	WorldNet database
2	FreeSpeed	Free speed (km/h)	Determined by traffic signs
3	Road Class	Road Class: OE-other European roads; O-other roads; ME – European motorway; M-Motorway	WorldNet database updated with local data
4	Country	Country where the link is situated	Filled: Serbia
5	ISO	Country letter identification	Filled: RS
6	WN3	Country code	Filled: 148
7	FromNodeID	ID number of origin node of the link on the network	WorldNet database
8	ToNodeID	ID number of destination node of the link on the network	WorldNet database
9	OpenFor	Road link open in forward direction	WorldNet database updated with local data
10	OpenBack	Road link open in backward direction	WorldNet database updated with local data
11	QueueSpeed	Speed without free speed calculation when capacity is exceeded.	WorldNet database updated with local data
12	LanesFor	Number of lanes directed forward	Filled 1 or 2 WorldNet database updated with local data
13	LanesBack	Number of lanes directed backward	
14	LinkTypeID	Link type defining speed flow curve 1 = Motorway; 6 = Rural road; 9 = Urban road	WorldNet database updated with local data
15	LaneHCFor	Hourly capacity per lane forward direction	WorldNet database adapted to the type of the terrain, average speed and functional class
16	LaneHCBack	Hourly capacity per lane backward direction	

Table 1 (2/2)
Attributes allocated to sections on modeled road network

No.	Attribute	Description	Reference
17	Active	If the link is allowed to use in assignment: 1 = the link is allowed for assignment 0 = not allowed	WorldNet database adapted to the type of the terrain, average speed and functional class
18	Length	Length in meters; 0 if it is ferry boat	Local database
19	LinkLength	Link length in meters	Local database
20	NationalName	National name of the road	Local database
21	EuroName	European name	Local database
22	FerryFreq	Ferry frequency per day	Not necessary
23	TollCostsPC	Toll costs for passenger cars with Serbian registration (€/km per passenger car)	Official prices, personal calculation
24	GenericCostsPC	General national toll for passenger cars	Official prices, personal calculation
25	TollCostsTR	Toll costs for freight vehicles with Serbian registration (€/km per freight vehicle)	Official prices, personal calculation
26	GenericCostsTR	General national toll for freight vehicles	Official prices, personal calculation
27	CountryBorder	Link located on critical border used in calculation of road freight LoS: 1 = country border (critical) 0 = it is not country border	Local database
28	Urban	1 = link is situated in urban area 0 = link is not situated in urban area	Local database
29	ZoneID	Zone where link is situated	WorldNet database
30	PreLoadFor	Preloaded short distance traffic in forward direction	WorldNet database
31	PreLoadBack	Preloaded short distance traffic in backward direction	WorldNet database
32	LinkCostPC	Total costs for passenger cars with Serbian registration (€/km per vehicle)	Calculated
33	LinkCostTR	Total costs for freight vehicles with Serbian registration (€/km per freight vehicle)	Calculated
34	FerrySailingTime	Ferry sailing time on the section	Not necessary
35	FerryWaitingTime	Ferry waiting time for calculating frequency	Not necessary
36	Comments	Comments	
37	Functional_class	1 = Motorway; 2 = Main road; 3 = Regional road 4 = Local road	Local database
38	Counter_nr	Number of counting spots	National traffic counting
39	Car_traffic	Number of passenger cars (total number per day, in both directions)	National traffic counts, Statistical office for border links, expert estimations for links missing counting data
40	Bus_traffic	Number of buses (total number per day, in both directions)	
41	L_Trucks_traffic	Number of light freight vehicles (total number per day, in both directions)	
42	M_Trucks_traffic	Number of medium freight vehicles (total number per day, in both directions)	
43	H_Trucks_traffic	Number of heavy freight vehicles (total number per day, in both directions)	
44	Sum_Bus_Truck_traffic	Total number of buses, light, medium and heavy freight vehicles (total number per day in both directions)	Calculated
45	Art_Veh_traffic	Number of articulated freight vehicles (total number per day in both directions)	National traffic counting
46	Total_Traffic	Total number of vehicles (traffic scope)	Calculated
47	Toll_Cost_PCF	Toll costs for passenger cars with foreign registration (€/km)	Official prices, personal calculation
48	Toll_Cost_TRF	Toll costs for freight vehicles with foreign registration (€/km)	Official prices, personal calculation
49	Terrain_type	Type of terrain: 1 = flat 2 = rolling/hilly 3 = mountain	Assessed based on national data
50	IRI	International roughness index	To be assessed by survey

3.2. Defining scenario

Research and calculation of fuel costs for CNG and hybrid buses on the road network of the Republic of Serbia are carried out in three different scenarios. First or Base Scenario includes transport requirements on traffic network that are valid for 2009 and for the existing transport infrastructure. Second or DoMin Scenario includes transport demands on transport network gained by simulation in transport model Transtools for year 2027. Simulation obtained "origin-destination" matrixes of exchanging goods and passengers between zones defined in and outside the Republic of Serbia for 2027 (according to WorldNet database, integrated in Transtools model), so domestic and international traffic flows are included.

According to this scenario, minimal investment is predicted for transport infrastructure: investment in existing projects (bypass around Belgrade: sector A Batajnica-Dobanovci, sector 5 Orlovača-Avalski put and sector 6 Avalski put-Bubanj potok) and investment in local networks and highways. Third scenario, or Total Scenario, includes same as DoMin Scenario transport demands on transport network for the year 2027, but additionally 12 potential development projects on the road network (Fig. 3), and 15 development projects on rail network, for the reasons mentioned in the first part of this paper. The goal of these selected scenarios is to calculate direct costs of fuel consumption, and to analyze the extent of influence on these costs by using CNG buses for passenger transport in rural conditions, and in different traffic conditions which are result of finishing developing projects on the road traffic network.

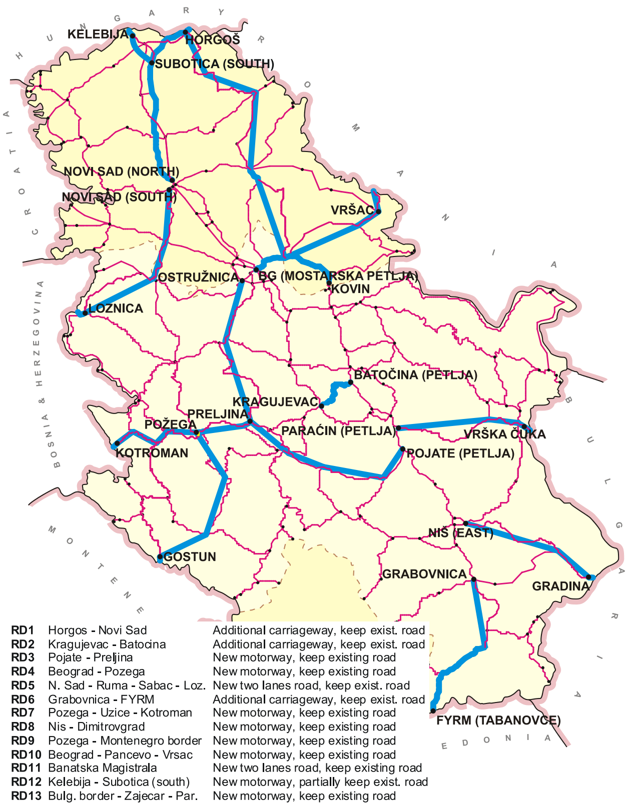


Fig. 3.
Potential development projects on road network

3.3. Defining transport demands

For defining transport demands on transport network, Transtools 2.31 modeling package has been used. For purposes of this research application has been adapted to suit territory of the Republic of Serbia by availability of data for requested links. Structure of Transtools model is very complex, and its most important segments are:

- Economy model based on modified and simplified version of the CG Europe model,
- Freight model for creating transport demands that includes: ETIS matrix for exchange of goods between origin and destination regions, the goods are classified in 11 categories, NEAC modal split of goods transportation, model forecast of trade exchange with two sub models, global trading exchange and trend of increased scope of trading exchange,
- Passenger model for creating transport demands based on models VACLAV and ASTRA. Result of passenger model working is modal split of passengers' network without assignment on transport network,
- Freight logistic model,
- Assignment model on network for different modes of traffic, road, rail and waterways.

Transtools four-step model (generating/distribution/modal split/assignment) is calibrated for base year (in this case 2009.) in order to tune characteristics of traffic flow by link model with characteristic of traffic on the same link, gained by counting in real conditions.

In group of most important input data which are collected and used for successful work of Transtools are:

- Multimodal transport network with corresponding attributes defined in 3.1, as well as traffic assignment by network for base year, as a result of modeling.
- Adopted zone system, which consists of 25 counties with data for each county: name of the county, population, household, number of passenger vehicles, number of employed people, and number of motorized and non-motorized members of household. Creating zones out of the Serbian territory is made on the level of NUTS3, that is for number of citizens in the zone, which fluctuates from minimum 150 000 to maximum 800 000,
- Origin-destination matrixes (national and international) of passenger traffic for corresponding years by defined scenarios,
- Travel data for base year: origin and destination by modes of traffic, purpose of travel (business and other), car ownership, generating traveling from home,
- Origin-destination matrixes (national and international) of goods exchange for corresponding years by defined scenarios,
- Increase rate of gross domestic product in the Republic of Serbia for modeling period of transport demands or by sub-periods if prediction period is longer than four years,
- Increase rate of gross domestic product outside the Republic of Serbia for modeling period of transport demands or by sub-periods if prediction period is longer than four years,
- Time value of business and other travels with corresponding coefficients of elasticity for the year predicted,
- Value of kilometer in the base year and in the year when transport demands is predicted on traffic network,
- Occupancy of passenger car in the base year and in the year when transport demands is predicted on traffic network,
- Occupancy of buses in the base year and in the year of prediction,
- Percentage of households that have more than one passenger car,
- Variables per scenario.

Extraordinary results for every link in transport network include following data: Link Identifier, Link Length, Link Type Based on functional classes, Terrain Type, International Roughness Indicator (IRI), Design Passenger Speed, Design Freight Speed, Adjusted Passenger Speed, Adjusted Freight Speed, Daily Cars, Daily Buses, Daily Light Trucks, Daily Medium Trucks, Daily Heavy Trucks, Daily Articulated Trucks, Hourly Capacity in PCU), Intensity to Capacity Ratio-ICR.

When calculating operating speed of the vehicle, BPR formula (US Bureau of Public Roads) is used, according to HCM (2000). BPR formula provides dependency of traveling time at non-free traffic flow in traveling time function at free traffic flow, in relation flow/capacity and BPR parameters α i β, Eq. (1):

$$t = t_{sl} \cdot \left(1 + \alpha \cdot ICR^{\beta}\right) \tag{1}$$

so the operating speed will be [6.2]:

$$V_o = \frac{s}{t} = \frac{s}{t_{sl} \cdot \left(1 + \alpha \cdot ICR^{\beta}\right)} \left[\frac{km}{h}\right] \tag{2}$$

where:

- t - calculated traveling time (at non-free traffic flow),
- t_{sl} - traveling time (at free traffic flow),
- ICR - intensity to capacity ratio,
- α and β - coefficients given in Table 2.

Table 2
Values of BPR coefficients

Type of the link	α	β	Road category
1	0.45	4	Motorway
2	0.50	2.5	Two-lane road
3	0.80	1.5	Rural road

Source: (Newton, S. 2009)

3.4. Determining fuel consumption on the road network

Determining fuel consumption in the first step involves consumption calculation for buses that use diesel fuel. For this purpose HDM model was used. For operating of this model, information are needed on vehicle usage, average age of vehicle fleet, average number of passengers and tones of freight. According to the reference (SORS, 2009) data used for this research are: average annual mileage of the bus – 80 000 km; average annual operating time – 2000 h; average total time of bus exploitation – 14 years; total number of kilometers per year – 1 120 000 km; average number of passengers – 36 passengers.

Input data provides possibility to calculate annual fuel consumption for buses that use diesel fuel according to average terrain characteristics (Table 3), based on the HDM model. By pairs (vehicle speed and fuel consumption), functional dependency of fuel consumption and vehicle speed have been determined by using regression analysis. Function FC (fuel consumption) = f (V) is second level polynomial, Eq. (3):

$$FC = a + b \cdot V + c \cdot V^2 \, [\text{lit/km}] \tag{3}$$

where:

- a, b i c - regression parameters,
- V - speed in km/h.

Table 3
Average characteristics of the road in accordance to the terrain type

Average road characteristics	Unit	Two-lane roads			Motorways	
		Flat	Hilly	Mountain	Flat	Hilly
Slope (Rise + Fall)	m/km	10	15	25	3	25
Average horizontal curvature	°/km	15	75	150	15	25
Average altitude	m	100	200	500	100	200
Speed limit	km/h	80	80	60	100	100

Source: (SORS, 2009)

Relation between speed and diesel fuel consumption for type of the terrain and for every of 4 values of international roughness index (IRI: 2, 5, 8, and 12) has been made, using regression analysis. Results of this analysis are shown in Table 4.

Table 4
Calculated values of regression factors for determining fuel consumption

	Flat				Hilly				Mountain			
IRI	*a*	*b*	*c*	R^2	*a*	*b*	*c*	R^2	*a*	*b*	*c*	R^2
2	0.349117	-0.00638	0.000059	0.977954	0.347710	-0.00595	0.000056	0.990012	0.359716	-0.004460	0.000043	0.965232
5	0.365289	-0.00668	0.000061	0.975478	0.363594	-0.00621	0.000058	0.988547	0.369716	-0.004471	0.000043	0.971257
8	0.387864	-0.00708	0.000065	0.985632	0.380856	-0.00517	0.000049	0.992154	0.391856	-0.005077	0.000049	0.989754
12	0.388856	-0.00506	0.000049	0.999652	0.4235996	-0.00681	0.000073	0.993252	0.432599	-0.006719	0.000073	0.999752

Source: (Ivković et al., 2011)

Depending on the bus speed it is possible to determine fuel consumption on the entire road network for different operating conditions, based on Table 4 and Eq. (3). Because of the dependency of all vehicles in traffic, it is necessary to correct diesel fuel consumption with corrective factors.

Corrective factors represent increase in consumption (comparing to consumption in the design speed) at average operating speed, which is caused by mutual interactions of vehicles in traffic flow. Matrix of correction factors for increased fuel consumption for buses is shown in Table 5.

Table 5
Correction factors of increased fuel consumption

	Operating speed [km/h]						
Design speed [km/h]	40	50	60	70	80	90	100
40							
50	1.008						
60	1.060	1.044					
70	1.173	1.120	1.065				
80	1.350	1.305	1.208	1.101			
90	1.640	1.565	1.444	1.312	1.180		
100	1.790	1.705	1.569	1.424	1.270	1.061	

Source: (Kuzović, 1994)

Using regression analysis, based on Table 5, dependencies of corrective factors of fuel consumption (CFFC) are formed as a function of speed change (from design to operating) as polynomial of second level, Eq. (4):

$$CFFC = a + b \cdot V + c \cdot V^2 \tag{4}$$

where:

- a, b i c - regression parameters,
- V - speed in km/h.

Regression curves are presented in Fig. 4. according Eq. (4)

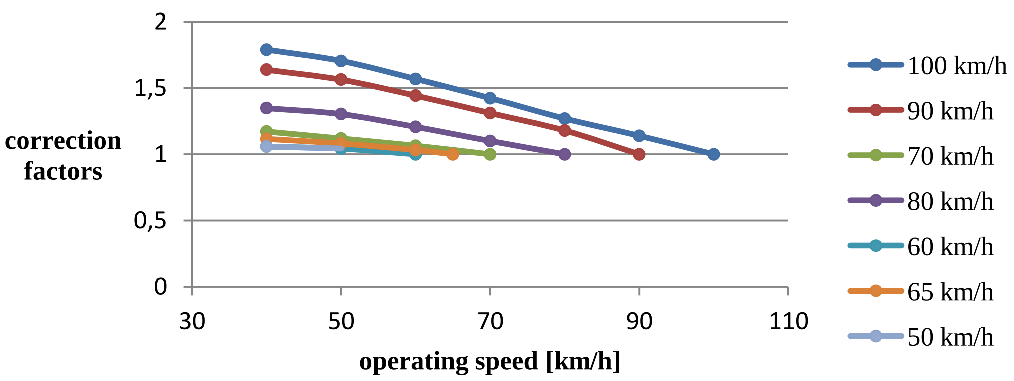


Fig. 4.
Dependencies of corrective factors of fuel consumption (CFFC) as a function of speed change

3.5. Determining fuel consumption of CNG and hybrid buses

In the second step, it is necessary to determine compressed natural gas consumption equivalent to diesel fuel consumption in form of Eq. (5):

$$\frac{1\ \text{liter of diesel fuel}}{100\text{km}} = FE_{CNG} \cdot \frac{1\text{m}^3\text{NG}}{100\text{km}} \tag{5}$$

Volumetric lower heating value of natural gas is 37-41 MJ/m^3, and diesel 42.5 MJ/dm^3 so, for the same quantity of energy theoretical ratio is obtained Eq. (6):

$$\frac{1\ \text{liter of diesel fuel}}{100\text{km}} = (1.03 \div 1.11) \cdot \frac{1\text{m}^3\text{NG}}{100\text{km}} \tag{6}$$

This ratio is changeable in different operating conditions and depends on: transport factors (transport volume in number of passengers per hour, vehicle operating regime, vehicle operating time, technical maintenance conditions), road factors (road profile and plan elements, type and condition of surface course, characteristics of traffic flow), climate conditions (air temperature, wet of road, visibility) and quality of fuels. According to the research carried out in 2008. on the territory of Belgrade, in urban conditions, value of fuel equivalent was between 1.12 and 1.18 (GSP, 2009).

Determining fuel equivalent used in this article was carried out based on the research of fuel consumption of bus IK 104 CNG, with optimized factory engine for natural gas usage RABA G10 DE-TURBO. Research was carried out in period of three years from 2002 to 2004; and in 2008 on intercity lines Belgrade-Jagodina-Belgrade, Belgrade-Vrnjačka Banja-Belgrade and Belgrade-Loznica-Belgrade. Results are shown in Table 6.

Table 6

Results of natural gas consumption research of the bus IK 104 CNG in real operating conditions

	Kilometers [km]	Gas pressure in tanks of origin-destination [bar]	Gas temperature in tanks of origin-destination [C]	The amount of gas in tanks, of origin-destination [m³]	Total fuel consumption [m³]	Average fuel consumption [m³/100km]
Direction: Belgrade-Jagodina	159	195/150	9/15	187.28/141.28	46.00	28.93
Direction: Jagodina-Belgrade	158	150/100	15/10	140.28/96.17	45.11	28.55
Direction: Belgrade-Vrnjacka Banja	215	160/100	23/24	146.57/91.64	54.93	25.54
Direction: Vrnjacka Banja-Belgrade	222	98/25	21/24	91.03/23.60	67.43	30.37
Direction: Loznica- Belgrade	140	101/50	26/24	92.22/46.28	45.94	32.81
Average consumption	29.01					29.01

Source: (Stevanović et al., 2004)

Results from Table 6 are compared with results of fuel consumption for buses with diesel power aggregate on same lines (Table 7), which are result of simulation in Transtools (when bus transport demands on the network are set) and later through application of HDM model (when fuel consumption is calculated directly, taking into consideration operating speed of the bus, which depends on transport demands on the road network, type of terrain and international roughness index).

Table 7

Fuel consumption of diesel buses obtained by simulation on lines Belgrade-Jagodina, Belgrade-Loznica, Belgrade-Vrnjačka Banja

Link ID	Terrain	IRI	Link length [km]	Operating speed [km/h]	Transport demands per link [bus/day]	Fuel consumption per link[l/day]	Fuel consumption of diesel bus [l/100 km]	Itinerary Bgd-Jgd	Itinerary Bgd-Lzn	Itinerary Bgd-V.Bnj
74520	1	2	24.35	57.44	147	656.56	18.34			+
74537	1	2	21.04	99.31	407	2 652.63	30.98	+		+
74566	1	2	9.95	99.32	484	1 492.03	30.98			+
74567	1	5	4.49	59.91	23	19.30	18.67	+		
74570	1	2	11.30	99.38	392	1 370.69	30.94			+
74583	1	2	6.86	99.52	395	836.66	30.88	+		+
74592	1	2	10.37	99.10	511	1 646.96	31.08	+		+
74599	1	2	27.05	52.84	275	1 399.96	18.82		+	
74600	1	2	12.10	99.38	439	1 643.70	30.94	+		+
74607	1	2	6.79	39.88	411	522.93	18.73	+		+
74615	1	2	22.15	99.28	449	3 082.18	30.99	+		+
74618	1	2	40.16	99.93	228	2 808.88	30.68		+	
74620	1	2	14.29	99.62	448	1 973.58	30.83			+
74623	2	2	35.59	58.91	70	486.87	19.54			+
74625	1	2	6.82	99.84	226	473.66	30.72		+	
74679	1	2	10.36	97.29	602	1 993.40	31.96	+		+
74683	1	2	46.79	51.84	176	1 538.02	18.68		+	
74684	1	2	9.16	49.75	281	486.03	18.88		+	
74689	2	2	23.62	96.18	568	4 514.17	33.65	+		+
74690	1	2	23.30	99.73	376	2 695.81	30.77	+		+
Average consumption	26.93									

Comparing average fuel consumption of KPG and diesel buses, from Tables 6 and 7, the value of fuel equivalent has been determined Eq. (7):

$$FE_{CNG} = \frac{29.01\,[m^3\ NG/100km]}{26.93\,[lit.of\ diesel\ fuel/100km]} = 1.08 \qquad (7)$$

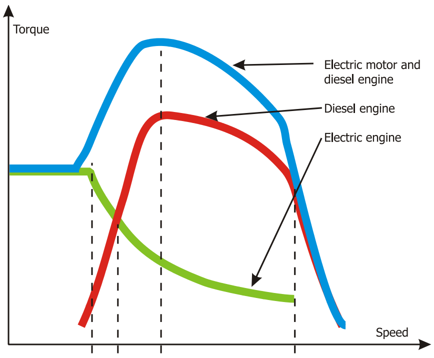
Usage of hybrid buses is present in the cities all over Europe. Around 600 buses are exploited in Great Britain (London-190; Manchester-116), Germany 120 (Dresden-18; Bohum-13), Belgium 130, the Netherlands 74, France 31, Switzerland 24 (Mišanović, 2010). Thanks to “stop-and-go” operating regime and low and medium speed in urban areas, these buses can preserve enough energy because of the more frequent and intensive use of electromotor in comparison to diesel power aggregate. That results in significant fuel savings, up to 35 % comparing to conventional solutions for city buses. From aspect of applying these buses in rural passengers transport, research is poor. For this article we used results of fuel consumption testing that was carried out in Switzerland by its leading company in the field of public mass passenger transportation “PostBus”. In the mid April 2010, as part of the pilot project which lasted for four months, hybrid bus “Volvo 7700 Hybrid” and three conventional buses “Volvo B7L”, “MAN Lion’s City” and “Mercedes-Benz Citaro” were tested. Results of fuel consumption of these buses in rural areas outside Bern are shown in Table 8.

Table 8
Hybrid and conventional buses fuel consumption in rural operating conditions

	Volvo 7700 Hybrid	Volvo B7L	Mercedes-Benz Citaro	MAN Lion’s City
Kilometers	15 075	29 219	21 114	23 945
Fuel Consumption [l/100 km]	28.6	39.9	35.8	40.6
Difference [%]		28.2	20.0	29.4
Average Difference [%]	26.59			

Source: (PostBus, 2010)

In vehicles with hybrid drive ecological sustainability is easily recognized, together with economic sustainability, regarding fuel consumption. Average savings for all three diesel buses is around 26 %. After considering data from Table 8, and speed characteristic of hybrid bus “Volvo 7700 Hybrid”, shown on Fig. 5, following values of fuel equivalents, depending on the speed of the bus, are adopted (Table 9).



Volvo 7700 Hybrid

Diesel engine D5F215
Bore .... 108 mm
Stroke .... 130 mm
Displacement ....4.76 dm3 (l)
Compression ratio .... .17,3:1
Output ISO 1585 ....61 kW (216 hp)
at ....2200 rpm
Torque ISO 1585 .... .800 Nm
at ....1200-1700 rpm

Electric motor I-SAM
Power output, max ....120 kW (161 hp)
Torque ISO 1585, max ....800 Nm
Power output, continous ....70 kW (94 hp)
Torque ISO 1585, continous ....400 Nm

Fig. 5.
Speed characteristic of hybrid bus “Volvo 7700 Hybrid”
Source: (Volvo, 2011)

Table 9
Fuel equivalent values of hybrid bus for different speeds

V_o [km/h]	FE_H [%]
0-20	0
20-40	50
40-60	70
60-V_{max}	85

$$\frac{1\ lit.\ of\ diesel\ fuel (conventional)}{100km} = FE_H \cdot \frac{1\ lit.\ of\ diesel\ fuel\ (hybrid)}{100km}$$

Source: (PostBus, 2010)

Based on designed multimodal transport network, length of links on road network, defined transport demands, determined specific fuel consumption, correction of fuel consumption, and adoption of fuel equivalent, fuel consumption is determined for every link on entire road network for buses with compressed natural gas in m^3 and hybrid buses in liters of diesel fuel.

4. Results and Discussion

In Table 10 summarized results of transport-volume are shown. It is presented in vehicle-kilometers (vehkm) for whole road transport network in Serbia and for three different scenarios. In the first, Base scenario, in 2009. transport volume of 7.97 million vehicle-kilometers had been carried out. Biggest percentage of operating work was made in the field of passenger cars, 6.59 million vehicle-kilometers, while percentage in the field of buses and all freight vehicles was 259 million and 1.12 billion vehicle-kilometers respectively. By analyzing data from DoMin scenario (2027.) the increase of realized transport volume for all categories of vehicles can be noticed: 201.20 % for passenger cars, 17.26 % for buses, 134.78 % for freight vehicles in total, which is consequence of socio-economic growth by 2027. It is characteristic for Total scenario that, in comparison to DoMin scenario, transport volume of passenger cars has increased for 16.10 %, but number of kilometers for buses decreased for 34.01 %. As previously mentioned, Total scenario includes 12 potentially developing projects in road transport sector, which is the main reason for redistribution of one part of the passengers from bus transport to passenger car transport. Cause is primarily connected to improvement of the level of service on certain links of road network which are included in Total scenario and on which, because of speed increasing of passenger cars, total time of traveling is reduced from origin to destination point.

Table 10

Realization of transport volume for different vehicle categories by different scenarios

vehkm/year [in milions]	Base Scenario	DoMin Scenario	Total Scenario
PC gasoline	3 430	10 330	11 993
PC diesel	3 166	9 535	11 071
Bus	**259**	**304**	**200**
Total pass. v.	6 854	20 169	23 264
L. Truck	79	186	177
M. Truck	222	520	494
H. Truck	349	820	779
A. Truck	470	1 103	1 048
Total fr. v.	1 120	2 630	2 498
Total all veh	7 974	22 799	25 762
Average design bus speed V_d[km/h]	**64.77**	**64.79**	**68.90**
Average operating bus speed V_o[km/h]	**62.70**	**47.62**	**56.15**

Total annual fuel consumption on the entire road network in Serbia and average fuel consumption per 100 km for diesel, CNG and hybrid gas are presented in Table 11.

Table 11

Fuel consumption for different bus concepts

Fuel consumption	Base Scenario	DoMin Scenario	Total Scenario
Diesel bus [lit/year]	62 729 132	81 033 137	56 363 209
CNG bus [m^3/year]	67 747 463	87 515 788	60 872 266
Hybrid bus [lit/year]	49 606 311	56 536 592	43 029 563
Diesel bus [lit/100 vehkm]	24.21	26.67	28.12
CNG bus [m^3/ 100 vehkm]	26.15	28.80	30.36
Hybrid bus [lit/ 100 vehkm]	19.14	18.61	21.46

In Base scenario on the entire road network annual fuel consumption of diesel buses was 62.73 million liters. The increase in transport volume of buses in DoMin scenario for about 17 %, as well as higher traffic flow of all vehicles categories on the network (Table 10), resulted in the increase of total fuel consumption for 22 %. Situation is opposite in Total scenario, where fuel consumption is reduced by 10 % in comparison to Base scenario, because of the redistribution of passengers to passenger cars tranport mode. In this scenario, due to speed increase on links under the project and due to the higher traffic density , average fuel consumption for 100 km is higher than in Base and DoMin scenario, and that is 28.12 l/100km (Table 11). By applying CNG buses for passenger transport on whole road network, and taking into consideration FE_{CNG}, equivalent quantity of natural gas consumption in m^3 increased by 8 % in all three scenarios. Diesel fuel consumption of hybrid bus comparing to conventional diesel bus consumption is reduced in Base scenario for approximately 21 %.

The biggest savings of hybrid bus fuel comparing to diesel bus took place in DoMin scenario (30 %) because of smaller values of operating speeds by separate links on whole road network, which can be concluded from Table 10. The average operating speed on network is V_{oDoMin}=47.62 km/h. Because of the lower speed, engagement of electromotor is higher than engagement of diesel motor, hence fuel consumption is reduced. Average fuel consumption of hybrid bus is the highest in Total scenario 21.46 l/100km. Reasons of this situation are identical as those of total diesel fuel consumption for conventional bus on the entire transport network.

Based on fuel price, data from Table 11 and defined transport requirements on every link by Transtools model, it is possible to determine fuel cost for all three types of buses and for all three scenarios. According to NIS data (2012) price of one liter of diesel fuel with VAT on September 15th was 1.39 €, while total price for one m^3 of natural gas (with VAT and energy costs of 0.2 kW/m3 for compressing on 200 bar) was 0.59 €. Economic effects of application of CNG buses and hybrid review on road network of the Republic of Serbia are shown in Fig. 6.

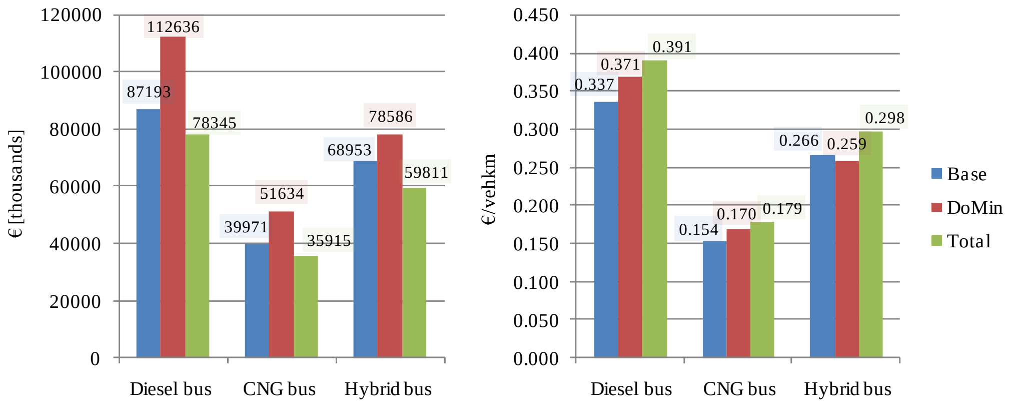


Fig. 6.
Fuel costs for different types of buses on the road network of the Republic of Serbia

Due to the highest realized transport volume, which is 304 million vehkm, out of all three bus concepts, fuel costs are highest in DoMin scenario. Lowest costs are noticed for CNG buses and they are lower for 54 % for all three scenarios, compared to diesel bus. Using hybrid buses, fuel costs become lower in comparing of diesel bus and percentage decreasing are 21 %, 30 % and 24 % for Base, DoMin and Total scenarios respectively.

Unlike CNG and diesel buses, lowest costs per vehkm of the hybrid bus is in DoMin scenario, because of generally higher traffic flow density on road network, which affects reduction of operating speed and higher engagement of electro motor.

From the standpoint of bus fleet owners considering total bus life cycle cost, the cost of procurement and ownership, operating and maintenance costs are most important in analyzing of the economic effects when using possible alternative concepts of buses instead of conventional ones. Such analysis is shown in Table 14 for intercity line Belgrade-Loznica. Fuel consumption characteristic of different bus concepts per link of itinerary Belgrade-Loznica are given in Table 12.

Table 12
Fuel consumption characteristics of different bus concepts and in different scenarios on itinerary Belgrade-Loznica

				Base					DoMin					Total				
Link ID	From Node	To Node	Length [km]	V_d [km/h]	V_o [km/h]	FC_D [l/100km]	FC_{CNG} [m^3/100km]	FC_H [l/100km]	V_d [km/h]	V_o [km/h]	FC_D [l/100km]	FC_{CNG} [m^3/100km]	FC_H [l/100km]	V_d [km/h]	V_o [km/h]	FC_D [l/100km]	FC_{CNG} [m^3/100km]	FC_H [l/100km]
74664	Beograd AS	Beograd (M. petlja)	1.39	40	16.59	21.38	23.09	0.00	40	6.56	22.00	23.76	0.00	40	6.13	22.03	23.79	0.00
74541	Beograd (M. petlja)	Beograd (Čukarica)	3.58	50	43.07	20.91	22.58	14.64	50	43.83	20.83	22.50	14.58	50	43.07	20.91	22.58	14.64
74576	Beograd (Čukarica)	Ostružnica	6.89	70	68.21	21.02	22.70	17.87	70	67.96	21.05	22.74	17.90	70	62.84	21.73	23.47	18.47
74538	Ostružnica	Dumača	66.67	70	69.75	21.73	23.47	18.47	70	43.86	25.02	27.02	17.51	70	39.16	25.52	27.56	12.76
74595	Dumača	Šabac	0.87	80	75.30	25.55	27.59	21.72	80	51.60	31.10	33.59	21.77	80	43.35	32.47	35.07	22.73
74684	Šabac	Majur	9.16	55	49.75	18.88	20.39	13.22	55	34.16	20.26	21.88	10.13	100	80.07	35.35	38.18	30.05
74683	Majur	Loznica	46.79	55	51.84	18.68	20.17	13.07	55	45.10	19.32	20.86	13.52					
74624	Loznica	Loznica AS	0.43	80	73.09	25.59	27.64	21.75	80	42.92	31.83	34.37	22.28	80	32.97	33.05	35.70	16.53

Bus prices and maintenance costs are presented in Table 13.

Table 13
Bus prices and maintenance costs

	Diesel bus	CNG bus	Hybrid bus
Price [€]	215 000	240 000	345 000
Maintenance cost [€/km]	0.219	0.210	0.244

Source: (Callaghan and Lynch, 2005; EESI, 2007)

Taking into consideration data for average annual mileage of a bus, which is 80 000 km (SORS, 2009) analysis was carried out comparing procurement of 6 buses for bus service on intercity line Belgrade-Loznica. Since total length of the line is 135.78 km, adopted average daily mileage per bus is 270 km.

Table 14
Analysis of alternative bus concepts' economic profitability in intercity bus service on itinerary Belgrade-Loznica

	Base			DoMin			Total		
	Diesel bus	CNG bus	Hybrid bus	Diesel bus	CNG bus	Hybrid bus	Diesel bus	CNG bus	Hybrid bus
Number of vehicles	6	6	6	6	6	6	6	6	6
Price of the vehicle [€]	215 000	240 000	345 000	215 000	240 000	345 000	215 000	240 000	345 000
Investments [€]	1 290 000	1 440 000	2 070 000	1 290 000	1 440 000	2 070 000	1 290 000	1 440 000	2 070 000
Kilometers per day [km/bus]	270	270	270	270	270	270	270	270	270
Fuel consumption per day, per bus [lit./line; m^3/line]	55.57	60.01	43.36	60.97	65.84	41.94	79.57	85.94	54.80
Fuel price [€/m^3; €/lit.]	1.39	0.59	1.39	1.39	0.59	1.39	1.39	0.59	1.39
Total fuel cost [€/year]	169 152	77 539	131 981	185 604	85 076	127 659	242 230	111 040	166 812
Total Maintenance cost [€/year]	129 495	124 173	144 277	129 495	124 173	144 277	129 495	124 173	144 277
Saving on fuel and maintenance costs comparing to diesel bus per year [€]	0	96 935	22 388	0	105 850	43 162	0	136 512	60 635
Saving on fuel and maintenance costs for 14 years exploitation period [€]	0	1 357 085	313 432	0	1 481 896	604 264	0	1 911 167	848 896

According to data shown, based on the difference between fuel and maintenance cost for using of CNG buses, between 97 000 € (Base scenario) and 137 000 € (Total scenario) can be saved annually. This depends more on quantity of fuel consumption on the link and less on the maintenance costs. Negative difference is shown in starting investment for procurement 6 new CNG buses, in which case investment costs would be made up in Base scenario for 19 months operating period, in DoMin scenario for 17 months operating period and in Total scenario for 13 months operating period.

In case of using CNG buses, starting investments can be increased through additional equipping of fuel station which costs around 250 000 €, if it is in possession of the bus fleet owner, and, to repay these costs would require additional 22 to 31 operating months. In case of using hybrid bus initial investment is higher for 780 000 €. Because of the saving of diesel fuel but increased maintenance costs, difference in initial investments would be made up after 35 years of operating in Base scenario, 18 years of operating in DoMin scenario and 13 years of operating in Total scenario. Biggest influence on reduced profitability period by using hybrid buses instead of diesel buses has increased diesel fuel consumption on the line (in Total scenario) and lower speeds on the line sections, which engages electro motor in higher quantity during operating (in DoMin scenario; otherwise average speed per scenario are: V_{avBase} = 58 km/h; $V_{avDoMin}$ = 41 km/h; $V_{avTotal}$ = 48 km/h). Replacement of battery that is additional maintenance cost of 6 300 € (Callaghan and Lynch, 2005) annually per bus, additionally negatively affects profitability of hybrid buses.

5. Conclusion

Conventional diesel buses are used in whole Serbia in over 99% of the cases for city and intercity bus service. They are big sources of pollution and significant fuel consumers: on modeled Serbian road network consumption is between 62 and 81 million liters of diesel fuel per year, depending on traffic flow density and development of traffic infrastructure.

By using CNG buses in intercity bus service, significant savings in diesel fuel consumption can take place; hence, fuel costs are reduced by complete substitution of fuel with natural gas, which has considerably lower price. Depending on traffic flow density on road network and characteristic of road infrastructure, defined in three different scenarios, fuel cost saving is between 42 million euros and 62 million euros per year, on the entire modeled network. For owners of vehicle fleet, implementation of CNG buses on intercity lines is very lucrative.

By saving in total fuel and maintenance costs for real intercity line, in current conditions (Base scenario) for fourteen years of operating period (average lifecycle of buses in Serbia), costs are almost the same as the price of procurement for 6 new CNG buses, which cost 1440 000 €. With increasing traffic flow density, vehicle interactions in traffic flow (DoMin scenario) and possible increase of operating speed on certain links which are included in Total scenario, savings in fuel and maintenance costs of CNG buses are higher for 124 800 €; that is 554 000 € for 14 years of operating period, according to the existing condition defined by Base scenario.

By using hybrid buses in intercity bus service on the entire modeled road network, from 13 million liters (Base scenario and Total scenario) to 24.5 million liters (DoMin scenario) of diesel fuel is saved each year. Total fuel costs are reduced in range from 18 to 34 million euros, depending on the applied scenario or operating conditions of the network. By analyzing economic advantages of hybrid buses from standpoint of bus fleet owners, on the intercity line Belgrade-Loznica, it is concluded that these buses at this moment are not profitable comparing to diesel buses in period of average operation of the bus which is 14 years. Main cause of this fact is high price of hybrid bus and increased maintenance costs for replacement of batteries. Development of more successful battery technology with longer lifetime and mass production, as well as with stimulus in tax policy and legislation, can result of investment costs reduction in these bus concepts in the future.

Acknowledgements

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References

Ahouissoussi, N. B. C.; Wetzstein, M. E. 1998. A Comparative Cost Analysis of Biodiesel, Compressed Natural Gas, Methanol and Diesel for Transit Bus Systems, *Resource and Energy Economics* 20(1): 1-15.

Barnitt, R.; Chandler, K. 2006. *New York City Transit (NYCT) Hybrid (125 Order) and CNG Transit Buses. Final Evaluation Results*. Technical Report NREL/TP-540-40125. Golden, CO: National Renewable Energy Laboratory. 62 p.

Bhattacharjee, G.; Bhattacharya, S.; Neogi, S.; Das, S. K. 2010. CNG Cylinder Burst in A Bus During Gas Filling, *Safety Science* 48(10): 1516-1519.

Callaghan, L.; Lynch, S. 2005. *Analysis of Electric Drive Technologies For Transit Applications: Battery-Electric, Hybrid-Electric and Fuel Cells*. Washington: Federal Transit Administration. 54 p.

Cohen, J. 2005. Diesel vs. Compressed Natural Gas for School Buses: A Cost-effectiveness Evaluation of Alternative Fuels, *Energy Policy* 33(13): 1709-1722.

ESSI. 2007. Hybrid Buses: Costs and Benefits - Transportation & Communities Papers [online]. Available from internet: <http://www.eesi.org>.

GSP. 2009. *Exploitation of Bus MAZ-BIK-203 CNG-S in GSP Belgrade*. Belgrade: GSP. 25 p.

HCM 2000. 2000. *Highway Capacity Manual*. Washington: TRB. 1207 p.

Hesterberg, T.; Bunn, W.; Lapin, C. 2009. An Evaluation of Criteria for Selecting Vehicles Fueled with Diesel or Compressed Natural gas, Sustainability: Science, Practice & Policy 5(1): 20-30.

Ivković, I.; Janjoš, Ž.; Žeželj, S.; Jovanović, V. 2011. Research into the costs of vehicle exhaust gases from the standpoint of using natural gas-powered buses, *African Journal of Business Management* 5(22): 9304-9321.

Kuzović, Lj. 1994. *Vrednovanje u upravljanju razvojem i eksploatacijom putne mreže*. Beograd: Saobraćajni fakultet. 274 p.

Matijosius, J.; Sokolovskij, E. 2009. Research into The Quality of Fuels and Their Biocomponents, *Transport* 24(3): 212-217.

Mišanović, S. 2012. Iskustva u eksploataciji autobusa sa hibridnim pogonom u gradovima EU-strategija daljeg razvoja [CD], in *Jedinstvena evropska transportna oblast–u susret konkurentnom i efikasnom transportnom sistemu*. 15 p.

Moseley, P.T. 1999. High-rate, Valve-regulated Lead-acid Batteries—Suitable for Hybrid Electric Vehicles?, *Journal of Power Sources* 84(2): 237-242.

Newton, S. 2009. *Serbian National Transport Model System*. Zoetermeer: NEA. 54 p.

NGV. 2011. *Gas Vehicle report*. Buenos Aires: Brapack. 36 p.

NIS. 2012. Products and Services-Fuel prices [online]. Available from internet: <http://www.nis.rs>.

Postbus. 2010. Hybrid Postbus passes practice test [online]. Available from internet: <http://www.postauto.ch>.

SORS - Statistical Office of the Republic of Serbia. 2009. *Transport, storage and communication - Bilten*. Beograd: Statistical Office of the Republic of Serbia. 250 p.

Stevanović, A.; et al. 2004. *The Analysis of Exploitation Data on Board Bus IK104- CNG*. Belgrade: NIS Energogas and Ikarbus A.D. 45 p.

Turrio-Baldassarri, L.; et al. 2004. Emission Comparison of Urban Bus Engine Fueled with Diesel Oil and “Biodiesel” Blend, *Science of the Total Environment* 327(1–3): 147-162.

Tzeng, G. H.; Lin, C. W.; Opricovic, S. 2005. Multi-criteria Analysis of Alternative-fuel Buses for Public Transportation, *Energy Policy* 33(11): 1373-1383.

Ullman, T.; et al. 2003. *Comparison of Exhaust Emissions, Including Toxic Air Contaminants, from School Buses in Compressed Natural Gas, Low Emitting Diesel, and Conventional Diesel Engine Configurations*. 2003-01-1381.

Volvo. 2011. Fact sheet-Volvo 7700 Hybrid [online]. Available from internet: <http://www.volvobuses.com>.

CONTRIBUTION TO DETERMINING THE COMPETITIVENESS OF CONTAINER TERMINAL SEAPORTS OF RIJEKA AND KOPER

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Abstract: The research subject of this paper deals with comparing the seaports of Rijeka and Koper in terms of equipment and productivity of container terminals. New transhipment capacities, optimal acceptance quality at container terminals directly affect the developing growth of container traffic. The increase of seaport traffic is the basis for entering a new investment cycle in order to modernise the existing port facilities and build up new modern terminals. Using calculation of the aggregate index, the level of equipment of the Rijeka port container terminal and the parallel port of Koper has been determined in the observed time interval. Given that the level of seaport equipment has a significant impact on competitiveness between the neighbouring ports, the parametres of subsystem productivity at the pier and on the operational area have been comparatively analysed from the proposed model.

Keywords: seaport, container terminal, productivity, competitiveness

1. Introduction

Containerization as transport system is a collection of a determined number of interconnected and interdependent elements which form up a relatively independent entity. For successful functioning of the system as a whole, adequate transport facilities are required in addition to certain knowledge and organizational skills. Containerization is an integrated transport system which provides the ability of transport from “door-to-door“ or from “terminal-to-terminal“ in the combined land, sea and air transport. Seaport container terminal is a part of the port system which is a specially built and equipped facility designed for transhipment of containers being handled directly or indirectly between sea vessels and land transportation means. Container terminal connects at least two transport systems and in order to successfully operate the processes, specialized transhipment means have been used.

Given the fact that the increase of container traffic is carried out much faster with the growth of the supporting infrastructure running behind, the ports are likely to expand and adapt their capacities and facilities according to new circumstances. The trend of rapid development of new technologies refers to container traffic of the ports of Rijeka and Koper. Successful business of container terminal depends on the available equipment, facilities and the quantity of cargo handled. The purpose of this paper is to compare container terminals of two neighbouring seaports of Koper and Rijeka with regard to equipment, facilities and productivity of individual terminals. Likewise, it is important to indicate the competitiveness of both ports as crucial North Adriatic seaports as well as show their established potentials which will place them among optimal ports on container routes targeting the markets of Central and Central-Eastern Europe.

2. Characteristics of seaport competitiveness

The increase of container cargo transport, constant specialization and increasing vessels' capacities enhance operators' focusing onto a limited number of ports. Shipping companies, as a key stakeholder of the seaport system, expect and require an integrated approach to transport and providing logistics services. Globalization processes, trade liberalization, development of transport infrastructure and logistics development, particularly in the organization of international transport of containerized cargo, have significantly influenced the development of seaport activities. The most important changes in seaports are:

1. Ports have become more capital intensive,
2. Proportion of workforce is continuously decreasing due to the use of intelligent transport systems,
3. Increase of the size of the seaport area,
4. Greater competitiveness among seaports, reduction of port fees, shorter time of the ship's stay in port,
5. Increased risk of overcapacity.

Development of containerization and intermodal transport enabled an effective, continuous, safe and fast flow of cargo.

Trade liberalization, substantial investments into transportation, logistics and information-communication technologies have positively influenced the development of seaports.

Mobility of containerized cargo units, developed mainland lines of communication and expanded hinterland enhance competitiveness among container ports. In fact, each activity for development of a specific port and its financing and pricing policy have an effect on neighbouring ports of the same and/or other countries. Beside the above mentioned changes in the transportation field below are listed changes and consequences of a dynamic environment affecting directly competitiveness of seaports:

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1. Reduction of transport costs generates the increase of demand,
2. Port expansion and occupation of space generate the increase of negative externalities due to the increased containerization and overcapacity,
3. Overlapping of the gravitational area and hinterland of the port result in the increased flexibility.

However, to achieve the increase of container traffic it is necessary to constantly invest into port machinery and infrastructure, which contributes to raising the competitiveness of container terminal at both European and world market.

3. Container terminals of Rijeka and Koper seaports being competitors in the common gravitational area

The size of the traffic in seaports depends on their geo-traffic position, size of their gravitational area, size and modernity of port facilities, their infrastructure and superstructure, development of the port front (liner service numbers), organization of work in the port and expertise of port staff and management.

In present conditions the ports of Rijeka and Koper operate as competitors in the common gravitational area but in different political and economic circumstances, whilst sharing at the same time the fate of the port system in relation to stronger, current European seaborne routes. North-Adriatic ports of Rijeka and Koper have a leading position in national port systems in the countries where there are traditionally important import-export points for Central European countries without their respective exit to the sea (Hungary, Austria, the Czech Republic, and Slovakia). That transit area, which is regularly considered the most valuable zone for the seaport development, transport routes and transport system as a whole is the most unsafe due to competitiveness of other ports and land transport routes existing in that area.

The main transport service market of the most important Croatian Corridor Vb is the Central European transit hinterland which represents simultaneously common interest area of North Adriatic and other traffic routes. In this regard, it is significant to compare the equipment, facilities and productivity of container terminal of North Adriatic port, in this case, the port of Koper which is connected to the Corridor Vb by hinterland. Apart from the countries of Austria, the Czech Republic and Slovakia, a particularly important segment of transit market in the Corridor Vb is the Hungarian market.

The most direct competition to the Corridor Vb and the port of Rijeka as being a reference point of the Corridor, is located within North Adriatic transport route. Since the ports of Koper and Rijeka share the common transit hinterland, it is interesting to compare the amounts of container throughput of the ports. Croatian domestic traffic from national foreign-trade exchange is important for business and development of the port as it represents safe cargo which is reliable as well as accurate regarding the amounts and structure of the traffic. However, the local substrate is usually not enough for optimal utilization of port capacities and ensuring greater development, so affirmation on the foreign market is more than needed as well as the effort to gain as much cargo as possible from the hinterland countries. Such need is supported by generally known statement that transit traffic is non-traded goods export which generates foreign exchange revenues and enables attracting significant amounts of cargo as an essential prerequisite for a stronger development of the port and the capacity engagement.

4. The index of container terminal equipment

The index is a type of relative number used for comparing two frequencies of the same statistical weight. It shows the relative change of one frequency versus comparison frequency. The relationship of certain phenomena in a group of variety of them can be traced by individual indices. Therefore the index can be used for calculating the relationship of certain factors of a port in relation to another. By applying this model, the index of annual capacity of container terminal can be calculated.

The formula for calculating individual index is (Eq. (1)):

$$I=\frac{f_1}{f_2}\cdot 100 \tag{1}$$

hence:

f_1 - frequency of statistical weight

f_2 - other frequency of the same statistical weight taken for the basis of comparison.

In order to illustrate this, there is a method of calculating the index of annual capacity of container terminal in the port of Rijeka compared to the port of Koper. To calculate the index of annual capacity, the data from Table 1 will be used.

Table 1
Facilities and equipment of container terminals (2011)

	Koper	Rijeka	Individual indices
Quayside	596 m	464 m	78
Maximum allowed vessel`s draft	11,4 m	11 m	96
Container cranes	8 pcs	4 pcs	50
Operational area	180 000 m^2	80 000 m^2	44
Annual capacity	700 000 teu	250 000 teu	36

Source: Kos, et al., 2010.

The index of annual capacity by the formula (1) is as follows:

$$I = \frac{250\,000}{700\,000} \cdot 100 = 36$$

The results given, show that the annual capacity of the container terminal in the port of Rijeka is less convenient by 64%, in regard with the annual capacity of the container terminal of the Koper port.

In order to determine the size of overall container terminal equipment of the Rijeka port in regard with various factors (length of quayside, maximum allowed vessel's draft, container cranes, operational area, and annual capacity) as well as compare with the level of equipment of the Koper port, it is necessary to calculate the index of equipment of container terminal. It's a number with the expressed relation between the values of observed factors of the port of Rijeka for which the level of container terminal equipment and the parallel port of Koper has been determined in the observed time interval.

The index of container terminal equipment is the aggregate index calculated as arithmetic mean of individual indices. Aggregate indices are numbers used to measure relative changes in the heterogeneous group of phenomena. As a rule, the frequencies of sequences are given in various units of measurements or at different value levels.

It is necessary to numerically describe the relative change of the unit using aggregate index, whereat the relationship of parts should entirely and correctly be revealed. For that purpose, arithmetic, geometric and harmonic mean is applied. The choice depends on particular cases, but in most cases arithmetic mean is applied. Mean values mentioned can be weighted or simple. Simple mean is a good indicator of value for the group only if each aspect of the group has equal importance, as is the case in this model.

Calculation of aggregate index, as simple arithmetic mean of individual indices can be derived using the following formula (Eq. (2)):

$$I_0 = \frac{I_1 + I_2 + \ldots + I_n}{n} \tag{2}$$

hence:

I_0 - index of container terminal equipment

I_i - individual index; i=1,...,n.

The following is calculation of the index of container terminal equipment:

$$I_0 = \frac{78 + 96 + 50 + 44 + 36}{5} = 60{,}8$$

Based on the calculation, it turns out that the port of Rijeka is at disadvantage by 39,2% in regard with the port of Koper in terms of container terminal equipment.

The port of Koper has numerous container STS cranes (ship – shore – ship), namely, four of Panamax and four of post Panamax generation. The port of Rijeka provides berthing for two container vessels; *Kostrena quay south*, 300 metres long with 2 newer container STS cranes of Panamax generation, and *Kostrena quay west*, 164 metres long with 2 container STS cranes, 23 and 31 years old, which are sufficient for berthing and operation with smaller feeder ships.

Considering that the same container services operate in the ports of Koper and Rijeka, the draft limitation of 11 metres maximum in the port of Rijeka currently represents limited development. For this reason, Rijeka cannot be the first port of call in rotation of services of the North Adriatic ports and thereby take advantage of gaining the cargo targeted for the Central European market.

5. The index of productivity of container terminal seaports of Rijeka and Koper

The port equipment with the machinery for cargo handling and their exploitation productivity are very important elements for the operator when choosing container terminals as the most suitable points of connection for mainland and maritime transport. At the same time, the level of port equipment has a significant impact on competitiveness among neighbouring ports or terminals in the region. For this reason, the container terminal management must constantly measure productivity on all subsystems, on berth, yard and in acceptance-delivery zone.

Various indicators of productivity can be used for simulation. Those are dynamic variables which are subject to constant changes. They show the productivity of individual subsystem as well as utilization of infrastructure and loading-unloading equipment. The simulation model uses four main parametres of productivity indicating major infrastructural utilization.

Therefore, berthing productivity and operational area have been processed by parametres of productivity as follows:

- number of TEU units per length of a berth
- number of TEU units per container crane
- number of TEU units per hour of individual container crane
- number of TEU units per 1000 m^2 of the container operational area

Table 2
Productivity parametres of container terminals of the seaports of Rijeka and Koper

	port Koper	port Rijeka	individual index
container traffic in TEU for 2010	476 731	137 048	29
number of TEU per container crane	59 591	34 262	57
number of TEU per length of quayside	800	295	37
number of TEU per hour per one crane	7	4	57
number of TEU per 1000 m^2 of the operational area	2 804	1 713	61

Source: Beskovnik and Twrdy, 2009

In order to determine the size of the overall productivity of the Rijeka port container terminal concerning various factors (container traffic in 2011, number of TEU units per container crane, number of TEU units per length of quayside, number of TEU units per hour per one crane, number of TEU units per 1000 ^{2} of the operational area) as well as compare with the level of productivity of Koper's container terminal, it is necessary to calculate the index of productivity using the formula (2).

The example stated is the procedure of calculating aggregate index of productivity of Rijeka's container terminal in regard with container terminal in the port of Koper. For calculation of this index, necessary data can be found in Table 2. Below is the index of productivity of container terminal:

$$I_p = \frac{29+57+37+57+61}{5} = 48{,}2$$

According to the calculation, one can come to conclusion that container terminal of the port of Rijeka, concerning the productivity of Koper's container terminal is at disadvantage by 51,8%.

6. Potentials for improving business at the container terminal of the port of Koper

Despite the global recession, in relation to the year 2008, the decline of container traffic in 2009 in the port of Koper was minimal amounting to 3% as compared with other ports represents a relatively small loss. The main reason for such a small loss and successful business of container terminal in 2009 can be attributed to investing into the expansion of the first quay, which was completed in June of the same year and enabled the acceptance of ships with more than 5000 TEU of capacity. The investment helped to expand the quay by 300 metres and in addition, new container cranes were bought. With this investment, the port gained another berth and a new area for containers transhipment.

The main goal of the port of Koper remains building of the third quay, which would increase transhipment capacity of up to one million of TEU, and it would enable the inclusion of Koper's container terminal amongst mid-sized container ports. The construction of the third quay in the upcoming period will the port of Koper to secure the acceptance of the most modern container ships which are currently not able to dock alongside the Quay I because of the limitation of maximum sea depth. In terms of infrastructure minimal standards that must be met are the coastline of 350 metres, 14,5 metres of sea depth, as well as sufficient coastline area for setting up „post-panamax“ cranes.

The construction of the third quay is due to be carried out in two phases:

1. 700 m length of the coastline which will allow transhipment of 800.000 TEU.
2. 350 m length (total 1050 m) which allows overall transhipment of 1.000.000 TEU.

In 2011 storage capacities at the terminal was extended allowing additional capacity to 700.000 TEU. The container traffic could be achieved with the optimization of equipment and facilities at the container terminal. In order to accept larger quantities of container traffic the port of Koper should raise the level of operative efficiency. Due to space constraints that prevent further expansion of container terminal, the port of Koper and the port operators need to increase the capacity of the terminal together with the improved business productivity. By purchasing new post-panamax cranes, the port of Koper increased its facilities and became an important competitor to neighbouring ports. As a result, there is also an increased number of direct lines between Asia and northern Adriatic which had an impact on the increase of container traffic in 2010. Due to annual growth of the quantity of handled containers as well as construction of larger container ships, the capacity of the Koper port became insufficient and consequently, there is need for investments into modernisation of container terminal. This means that container terminal can now accept larger vessels transporting more cargo (up to 8.000 TEU), and before the expansion of the quay the only ships which could dock alongside container terminal were small ships of the capacity up to 5.000 TEU.

7. Potentials for improving business at the container terminal of the seaport of Rijeka

The project Rijeka Gateway has a great importance on the development of container traffic which aims primarily to expand port capacities, especially container terminal in response to increasing growth of container traffic determining the construction of large container ships in the world and demand of the ports for wider and deeper quays and terminals.

The programme will modernize strategic port facilities, increase participation of private sector in the port, improve business of the Port authorities of Rijeka as well as integrate Rijeka into international traffic corridors, and particularly improve the traffic in the pan-European corridor Vb with the port of Rijeka at the beginning. Rijeka Gateway-Project II is the continuation of Gateway-Project and they make an integrated whole including a range of urban, infrastructural and economic activities whose goal and purpose is modernization, privatization and reconstruction and revival of Rijeka's traffic route.

The new strategic partner International Container Terminal Services has committed to invest over 54 million Euros into the terminal of Brajdica, and within the project, additional 330 metres of the coastline will be developed, which will increase the annual capacity of container traffic to 600 000 TEU.

It will focus on implementation of modern technologies which will enable the automation of monitoring unloading, storage and shipping containers, raising operating standards of business of Brajdica as well as upgrading of railway infrastructure in the vicinity of the terminal.

The capacity of the existing part of container terminal is estimated to 250.000 TEU per year, primarily due to limited space for storage of containers. In order to increase operational capabilities, the phase II of the terminal construction includes the construction of 50.000 m^2 of storage area. Upon completion of the works, sea depth along newly constructed coastline will be 14,5 m which will enable container terminal of Brajdica to accept container mega-ships of last generation. The reconstruction of operational areas will enable greater flow of terminal increasing the existing transhipment capacity and the quality of terminal service.

The increase of container traffic through the port of Rijeka imposes the need for a further development of the transhipment capacity. A logical sequence of development would be a new container terminal construction in the western part of the seaport area. The container terminal at the Zagreb pier, which will finally take up an area of approximately 22 hectares is conceived as a pier of 680 m in length with average terminal width of 300 m. The minimum planned depth of the sea alongside the pier is 20 m. The terminal would be built in two phases. The first phase includes 400 m long pier. The second phase envisages the expansion of the terminal to the total pier length of 680 m so as to achieve the capacity of 500 000 TEU per year.

8. Conclusion

Containerization offers safe and fast transportation of goods by all transportation means. That is one of the reasons for the growth of container throughput in seaports in the last decade. In order to meet growing demands, seaports should increase capacities. One possibility is expansion of container terminal to increase the capacity and improve the productivity of the terminal. Space limitation is usually an obstacle to the expansion of container terminal. In this context, a sustainable solution is the expansion of port capacities. This can be achieved by improving the productivity of facilities at the terminal.

Since the ports of Koper and Rijeka share common transit hinterland, they act as joint competitors resulting in an increased need for flexibility. According to the calculated index of container terminal equipment, where diverse factors were taken into account (length of quayside, maximum allowed vessel's draft, container cranes, operational area, annual capacity) it turns out that the port of Rijeka is at disadvantage by 39,2% in relation to the port of Koper. When operating, simulation model shows productivity of individual subsystem and utilization of infrastructure as well as loading-unloading equipment and is used to compare the container terminal of the ports of Rijeka and Koper. According to the results, container terminal of the port of Rijeka is at disadvantage by 51,8% concerning the productivity of Koper's container terminal. The main task of container terminal, as major links in the transport of the goods from producer to consumer, is an efficient, fast and reliable manipulation over container units. The trend of increasing the size of container ship, short ship`s stay in port, and requirement for fast transhipment, significantly affect the operation of container terminal. The competitiveness of port terminals depends upon development of their infrastructure and superstructure.

References

Adriatic Gate. Available from Internet: <http://www.adriatic-gate.hr>.

Barić, S.; Devčić, I.; Valenčić, M. 2008. Analysis of container traffic of the port of Rijeka as compared to competing ports of Koper and Trieste, *Maritime Almanac*, Rijeka 45: 165-179.

Bendeković, J.; Jolić, A.; Jolić, N. 2010. Quality management of port services, *Economic thought and practice* 1: 85-104.

Beskovnik, B.; Twrdy, E. 2009. Productivity simulation model, *Transport Problems* 4(3): 113-122.

Business. Available from Internet: <http://www.business.hr>.

Croatian Association of Port Authorities. Available from Internet: http://www.portauthority.hr.

Dundović, Č. 2002. *Lučki terminali*. Faculty of Maritime studies in Rijeka.

Dundović, Č.; Hlača, B. 2007. A new concept of the container terminal in the port of Rijeka, *Pomorstvo, Journal of Maritime Studies,* 21(2): 51-68.

Dundović, Č.; Poletan-Jugović, T.; Jugović, A.; Hess, S. 2006. *Integracija i koordinacija lučkog i prometnog sustava Republike Hrvatske,* Faculty of Maritime studies in Rijeka.

Hauselmaier, S.; Lončarić, I.; Mataruga, A. 2007. Development strategy of the port of Rijeka, *Maritime Almanac* 45(1): 153-163.

International Container Terminal Services. Available from Internet: http://www.ictsi.com.

Kesić, B.; Jugović, A.; Poletan-Jugović, T.; Perić Hadžić, A. 2008. *Development Projection of maritime economy of the Republic of Croatia with special reference to the possibility of cooperation with neighbouring maritime countries/ports (especially in the Adriatic)*, Port authorities of Pula, project Aplomb, Faculty of Maritime studies in Rijeka.

Kos, S.; Brčić, D.; Karmelić, J. 2010. Structural analysis of Croatian container sea ports, *Pomorstvo, Journal of Maritime Studies* 24(2): 189-209.

Port of Koper. Available from Internet: http://www.luka-kp.si.

Port of Rijeka. Available from Internet: http://www.lukarijeka.hr.

Stojaković, M.; Twrdy, E. 2010. Opportunities for the increase of cargo handling capacity at the container terminal in the port of luka Koper, In *Proceedings of the 13th International Conference on Transport Science.*

Twrdy, E.; Trupac, I.; Kolenc, J. 2012. Container boom in the port of Koper, *Traffic & Transportation*, Vol. 24(2): 169-175.

Vilke, S. 2005. The development concept of North Adriatic ports of Rijeka, Koper and Trieste, *Maritime Almanac*, Society for Study and Promotion of Maritime Affairs of the Republic of Croatia, 43(1): 85-111

Session 5: Urban Transport, Land Use Development, Spatial and Transport Planning

CHARACTERISTIC OF MOVING OF TRANSIT IN MIXED TRAFFIC FLOW

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Abstract: Transit, in towns in Serbia, operates within surface mixed traffic. Using a common area for the movement of passenger cars, trucks, buses, and often bicyclists, complicates and interrupts of movement of transit vehicles. This paper analyzes impact on basic elements of dynamical transit lines in Novi Sad, depending on the size of the flow of traffic routes.

Key words: transit, traffic flow, mixed traffic

1. Introduction

Transit operation in a mixed traffic flow in the most cities, well consequently operate regime of traffic flow have a significant influence on operate elements of the transit. Traffic flow is a simultaneous movement of multiple vehicles on the road in a certain order. During the movement of vehicles in traffic flow, there is an interaction between these vehicles. Parameters of the traffic flow, especially speed, density and flow are varying on depending on a degree of the interaction and characteristics of the traffic flow.

Change of parameters of traffic flow has influence on the changes of parameters of movement of the transit, when they operate in the mixed traffic flow. The transit is organized as a line transport with predefined the operate elements, so it is objectively to assume that there is a correlation between the characteristics of the traffic flow and the operate elements of the transit.

2. The operate elements of the transit and parameters of the traffic flow

The operate elements of transit are defined by schedule, so any deviation, from the planned operate elements, causes certain disturbances in vehicle operation on the lines and on entire system of transit. As a rule, any disturbance in the operation of transit vehicles on the lines has a negative impact on the quality level of service experienced by users. The operate elements of transit are divided into static and dynamic. Considering the characteristics of the traffic flow can be assumed that they have a greater influence on the dynamic elements.

The basic dynamic elements of transit line are:

- operating units per line in characteristic periods of time
- turnaround time in the characteristic periods of time

Derived dynamic elements resulting from the basic dynamic elements, and they are:

- speed
- headway in the characteristic periods of time
- frequency of service in the characteristic periods of time
- transportation capacity on the line in the characteristic periods of time

The traffic flow is defined through the parameters, called the basic parameters of the traffic flow. Considering previous studies, the parameters of traffic flow that relevant for description run of vehicle in the flow and solve specific problems are:

1. flow
2. density
3. speed
4. travel time
5. unit of travel time
6. gap
7. following distance
8. occupation
9. concentration

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Except the basic parameters, the characteristics of the traffic flow are important for defining the connections among the basic parameters. The most important the characteristics of the traffic flow are:

– complexity of the flow
– traffic composition
– general traffic conditions,
– volume variations.

In the mixed traffic flow, the influence of basic parameters of the traffic flow is very pronounced on the dynamic elements of transit, which will be shown in this paper.

3. Research results

To establish a link between the basic parameters of the traffic flow and the basic dynamic elements of transit, it was necessary to carry out a research. Determination of certain the parameters of the traffic flow, as well as some the operate elements of traffic is very complex, so in this paper analyzes the influence of the flow on the headway. The research was carried out in the area of Novi Sad. For the research area, was selected The Boulevard oslobodjenja, which is one of the most important roads in Novi Sad. The research was conducted between 6:00 a.m. to 10:00 p.m.

3.1. Determining the size of the traffic flow

The traffic flow is determined by simply counting of transport vehicles. Traffic counting was carried out at the following intersections:

1. The Boulevard oslobodjenja–The Boulevard Jasa Tomic
2. The Boulevard oslobodjenja– The Boulevard Kralj Petar I
3. The Boulevard oslobodjenja–Novosadskog sajma street–Pap Pavla street
4. The Boulevard oslobodjenja–Futoska street–Jevrejska street
5. The Boulevard oslobodjenja– Maksima Gorkog street
6. The Boulevard oslobodjenja– The Boulevard Car Lazar
7. The Boulevard oslobodjenja–Narodnog fronta street

The research results are presented in the following Table 1.

Table 1
The flow on the observed intersections

TIME	FLOW (veh/h)						
	INTERSECTION						
	1	2	3	4	5	6	7
06:00-07:00	2028	2373	1956	2484	1756	2335	1895
07:00-08:00	2953	3968	3405	4648	3722	3909	3431
08:00-09:00	2904	3787	3572	4537	3992	4467	3188
09:00-10:00	2754	3924	3289	4590	3934	4311	3034
10:00-11:00	2847	3814	3843	4673	4107	4308	2818
11:00-12:00	2836	3903	3719	4842	4309	4285	2631
12:00-13:00	3212	3738	3627	4809	4142	4192	2831
13:00-14:00	2944	3905	3509	4643	4221	4212	2813
14:00-15:00	3002	4032	3632	4660	4295	4610	3403
15:00-16:00	2909	4123	3640	4709	4115	4627	3416
16:00-17:00	2746	3809	3273	4266	3986	4375	3262
17:00-18:00	2484	3536	3171	4253	3901	3839	3157
18:00-19:00	2652	3659	3516	4531	3934	3960	3081
19:00-20:00	2554	3811	3322	4365	3771	3838	3028
20:00-21:00	2377	3490	3328	4309	3593	3718	2736
21:00-22:00	1906	2629	2614	3280	3123	2631	1972
TOTAL	**43108**	**58501**	**53416**	**69599**	**60901**	**63617**	**46696**

The Table 1 shows that the morning peak period appear at the most intersections from 7:00 to 8:00 a.m. or from 8:00 to 9:00 a.m., while the afternoon peak period appear from 2:00 to 3:00 p.m. or from 3:00 to 4:00 p.m. However, at some intersections, there is not clear defined peak period and off–peak period and a traffic volume is approximately equal to the peak period and off–peak period.

3.2. Determining the headway

Headway is an interval between two consecutive vehicles on the line, or the interval between two successive departures of vehicles on the line.

The largest number of urban and suburban transit lines of Novi Sad pass along the route of the Boulevard oslobodjenja. In this paper, was observed three urban transit lines, that pass along the route of the Boulevard oslobodjenja.

The research includes the following transit lines:
1. Line 4
2. Line 7
3. Line 14

The research was conducted in that way that the arrival time of each vehicle for the observed lines was recorded at every stop along the Boulevard oslobodjenja. Vehicles on each line were followed by the garage number. The headways were determined by recording the arrival times of successive vehicle for each line.

The following Table 2 shows the designed headways and the realized headways that were determined during the research. The headways are presented as the average values for any given hour.

Table 2
The designed headways and the realized headways for the observed line

TIME	TRANSIT LINE					
	LINE 4		LINE 7		LINE 14	
	Designed headway $\bar{i}$ (min)	Realized headway $\bar{i}$ (min)	Designed headway $\bar{i}$ (min)	Realized headway $\bar{i}$ (min)	Designed headway $\bar{i}$ (min)	Realized headway $\bar{i}$ (min)
06:00-07:00	9	11.8	9	9.8	27	22.9
07:00-08:00	7 i 8	10.3	9	8.6	20	20.4
08:00-09:00	10	9.1	9	8.6	20	19.6
09:00-10:00	10	10.4	11 i 12	11.3	20	20.0
10:00-11:00	10	11.1	11 i 12	11.4	20	20.4
11:00-12:00	10	10.6	11 i 12	11.6	20	19.6
12:00-13:00	7 i 8	10.6	11 i 12	11.9	20	20.9
13:00-14:00	7 i 8	9.2	9	9.4	20	21.3
14:00-15:00	7 i 8	9.4	9	8.6	20	20.6
15:00-16:00	7 i 8	8.6	9	9.4	20	20.0
16:00-17:00	10	10.6	11	10.3	20	18.5
17:00-18:00	10	10.4	11	11.2	20	19.6
18:00-19:00	10 i 12	10.9	11 i 12	11.7	20	21.3
19:00-20:00	12 i 13	12.6	15	11.5	20	18.8
20:00-21:00	16 i 17	13.1	15	13.2	27	25.3
21:00-22:00	16 i 17	13.8	15	15.0	27	27.4
AVERAGE		**16.3**		**13.5**		**22.9**

4. Analysis of the results

The Table 2 shows that there is some discrepancy between the designed headways and the realized headways. The discrepancies are especially pronounced during the peak period, when the realized headways are larger than the designed headways. The realized headways are similar to the designed headways in off–peak periods, when the traffic volume decreases.

However, can we observe the average values of the realized headways, we does not get a realistic picture about it. If the headways observe, for example, by successive departures, along the route of the Boulevard oslobodjenja, where is determined traffic volume, we get a completely different picture.

The morning peak period, or period from 7:00 to 8:00 a.m. and the off–peak period, or the chosen period from 4:00 to 5:00 p.m. are separated, as an example. The vehicles on the line 7, were observed. The vehicles on the line 7 were followed by the garage number, and each garage number was encrypted. The code is a two-digit number, where the first digit is seven, and the other corresponds to the order of appearance of vehicles.

According to existing schedule, there are seven vehicles that engaged for transportation passengers in the peak periods and six vehicles in the off–peak periods.

Vehicles of line 7, which appeared to existing the stops along the Boulevard oslobodjenja, were recorded in the morning peak period from 7:03 to 8:05 a.m., and chosen off–peak period from 4:02 to 4:07 p.m.

In the following Table 3 and Table 4, will be shown realized headways for the chosen peak period and off–peak period.

Table 3
The headways in the morning peak period from 7:00 to 8:00 a.m.

STOPS	HEADWAYS (veh/h)						
	71–72	**72–73**	**73–74**	**74–75**	**75–76**	**76–77**	**AVERAGE**
1	12	5	7	11	14	1	**8.3**
2	12	5	6	14	12	1	**8.3**
3	11	6	6	15	12	1	**8.5**
4	13	5	6	15	12	0	**8.5**
5	12	6	6	14	13	0	**8.5**
6	13	5	6	15	14	0	**8.8**
7	13	5	6	16	13	0	**8.8**
AVERAGE	**12.3**	**5.3**	**6.1**	**14.3**	**12.9**	**0.4**	**8.6**

Table 4
The headways the off–peak period from 4:00 to 5:00 p.m.

STOPS	HEADWAYS (veh/h)					
	71–72	**72–73**	**73–74**	**74–75**	**75–76**	**AVERAGE**
1	10	12	11	8	10	**10.2**
2	10	12	11	7	12	**10.4**
3	10	12	11	8	11	**10.4**
4	10	12	11	7	12	**10.4**
5	10	12	11	8	11	**10.4**
6	10	11	10	8	11	**10**
7	10	11	10	8	11	**10**
AVERAGE	**10**	**11.7**	**10.7**	**7.7**	**11.1**	**10.3**

For the observed peak period, the projected interval on line 7 is 9 minutes. The average value of realized headways for this period was 8.6, which is close to the designed headway. However, observation of individual realized headways, it can be seen that the realized headways for the morning peak period varies from 1 to 16 minutes. These Tables also show that the vehicle 6 and vehicle 7 in one part of the route to catch up with.

For the observed off–peak period, the projected interval on line 7 is 11 minutes. The average value of realized headways for this period is 10.3. Observation of individual realized intervals, it can be seen that there are not significant differences and variations are much less than in the peak period.

5. Conclusion

Interrupt in the dynamic elements of the transit vehicle can cause different operational problems. The primary causes of interrupt are results operating conditions, one of which is the most significant of condition is flow. Previous researchs in real system indicate to a strong interaction between the regimes of traffic flow and operate elements of transit.

The influence of the flow on the headway was showed in this paper. The researchs that carry out has shown the interaction between these two values.

Therefore there is a need to survey an impact flow parameters on other operate elements of transit in order to define the model of mutual influence. Development of the model for defining the parameters of the traffic flow on dynamic elements of transit would provide an objective analysis effects of measures taken in order to improve the transit operation in traffic system. Difficulties that arise in the operation of transit, when they circulate in the mixed traffic flow, it would be possible to remove, if would be able to predict the realization of dynamic elements of transit vehicles for a previous defined regime of the traffic flow.

References

Banković, R. 1994. *Organizacija i tehnologija javnog gradskog putničkog prevoza (Organization and technology of urban public transport),* Faculty of Traffic of University in Belgrade, Belgrade. 295 p

Kuzović Lj.; Bogdanović V. 2004. *Teorija saobraćajnog toka i kapaciteta (Theory of flow and capacity),* Faculty of technical science of University in Novi Sad, Novi Sad. 319 p

Simeunović M. et al. 2011. *Sistemsko brojanje putnika u javnom gradskom i prigradskom prevozu putnika na području Novog Sada (Systematic counting of passengers in urban transit and suburban transit on the area of Novi Sad)*, Faculty of technical science of University in Novi Sad, Novi Sad.

ORGANIZATION AND MANAGEMENT OF COMPLEX INTEROPERABLE TARIFF AND FARE COLLECTION SYSTEMS - EXAMPLE OF THE CITY OF BELGRADE

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Abstract: The integration in the public transport of passengers is aimed to provide higher-level service quality through conjoint functioning of key processes within transport systems. Integration is one of the main goals of the system development for all key players in the system (users, operators and local government authorities), and it is an important element in the process of designing a whole system of public passenger transport. The implementation of the integration process involves simultaneous providing of multiple types of services to customers in the process of transport services production, which consequently requires a more complex structure, organization and management of these systems. Complexity is especially expressed and delicate in the case of tariff integration in the system where there are more operators with heterogeneous ownership structure, and in which the city authorities have accepted the risk of revenue collection and distribution. This paper presents a methodological procedure of defining the organization and management of the interoperable tariff and fare systems within complex interoperable public passengers transport system. Model of interoperable fare organization and management is shown on the example of the City of Belgrade.

Keywords: public transport passengers, interoperability, tariff system, system ticket, fare collection system.

1. Introduction

The integration in public passenger transport (PPT) means at the same time providing more service to the users (Tica, 2001). One of the main goals of integration is to increase the system attractiveness and easy of use. Integration leads to a significantly higher level of services in the PPT system, and consequently a substantial increase in the market share of PPT services in overall transport model split in city. The degree of integration depends on the core strategic objectives and the impact of each element of integration on the efficiency and effectiveness of the system as a whole.

According to some authors (Office for Official Publications of the European Communities, 1997) there are three different forms of integration. *Physical integration* provides spatial and temporal coordination of services among multiple lines or various modes of transport, at the same time minimizing the loss of passengers during transfers. *Tariff integration* represents an element of quality properties that are related to convenience services to use, by facilitating the implementation of the entire journey with just one ticket. The goal of *logical integration* creating impression for users that PPT system is a single unit, regardless of the variety of transport modes and the number of operators in the system.

As public passenger transport is a public service, an appropriate definition for *interoperability* can be found within the document "European Interoperability Framework for pan-European e-Government Services (EIF) (European Commission, 2004) wherein interoperability is defined as "the ability of information and communication technology (ICT) systems and of the business processes they support, to exchange data and to enable the sharing of information and knowledge". In the final document of the European Interoperability Framework (European Commission, 2011). Interoperability is defined as "the ability of disparate and diverse organizations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organizations, through the business processes they support, by means of the exchange of data between their respective ICT systems". This new definition further improves the previous one by highlighting that the organizations are heterogeneous, that there is a common goal, and that they should all benefit from that interaction.

The concept of Interoperable fare management refers to all systems and processes designed to manage the distribution and use of the product in the fare collection in complex PPT systems, ie systems with multiple subsystems and / or operaters.

The term "interoperable" derives from the characteristics of the system to allow users to use a single medium of payment (e.g. smart cards) with the appropriate equipment (in vehicles, in bus stops, recharge points, etc.) for all types of transport services, and within all PPT subsystems and operators.

Management of these complex conditions can not perform well without the computerization of all processes in the system, and reliable information base. Questions of the integrated tariff system and tariff policies, ticket and fare collection system, as well as integrated fleet management system, are one of the most complex and fundamental prerequisite for an effective and efficient system of public transport passengers.

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The development of interoperable fare management has started with the development of electronic payment systems and electronic tariff and fare management, but the concept of interoperable fare management can be applied to all types of fare collection systems regardless of applied fare collection technology. This approach allows interoperable fare management systems to be technically and organizationally independent, and clearly defined processes and relationships between all participants in the system.

Benefits from interoperable fare management are numerous both for users and operators, as well as other participants in the system. These issues are important for the City government as one of the instrument in the realization of sustainable development and the controlled use of private cars, social policy towards certain population groups, achieve "sustainable" revenue system, and the planned level of subsidies, customer satisfaction by providing one of the most important public services in the city, etc.

On the other hand, transport services price level and calculations, possibilities for optimal choice of payment services (special and combined tariffs), payment of more types of services with one media, convenience of payment services, have a direct influence on the quality of service and customer satisfaction. Also, attractive systems and technology, may be one of the major motives for non-users to abandon the use of private car and switch to public passenger transport.

The system provides reliable information about the passengers, their transport needs and requirements, as well as on the functioning of the system. Operators can achieve better effectiveness and efficiency of the system, with less consumption of resources and their optimal allocation in the system. Through improved control and security (protection) in system allows that revenue distribution on operators based of realized transport work.

The aim of this paper is to define the organization and management of interoperable fare management system in complex PPT systems with multiple transport subsystems and modes, as well as the operators. Organizational and management model is shown on the example of the City of Belgrade.

In the first part of the paper the development of new forms of electronic payment services in the PPT and overview of the relevant standards and projects in this area are given. Especial emphasis is put on ISO 24014-1 standard, which defines the functional architecture of interoperable tariffs and fare management systems.

This is followed by brief presentation of the system of public passenger transport (PPT) in Belgrade, with focus on tariff and fare collection system analysis. Newly introduced BusPlus fare collection (and vehicle management) system is explained thereafter. In the fifth chapter, a macro-organizational model and architecture of interoperable fare management in system in Belgrade is given. Organizational and management model presented in this paper is based on the standards for the interoperable fare management, and adapted to the specific conditions and requirements of the PPT system in Belgrade. Finally, the last chapter provides the conclusions.

2. Organization and management of tariff and fare collection systems

Organization and management mean coordination of all elements - components of the system. Organization defines a set of procedures that ensure optimal operation, while management defines their application. Management in the broadest sense is the process of decision making and taking actions to translate system from an initial state into a desired state, defined by target function. Managing organizational-technological systems, such as passenger transport systems, includes process management, resource management and organization.

The basis of the modern approach to organization is the principle of effective and efficient achievement of the target function of the system with continuous adjustment to system environment. Starting from above definition under organization phase of tariff and fare collection system management, links and relationships between processes, sub-processes and activities are designed and established, in order to achieve approved plans and objectives.

The processes of organization and management tariff and fare collection system in urban passenger transport system depend on the internal and external factors. Internal factors that can influence this process are types of offered services, type of tariff system (number of zones, relation), ticket types and prices, fare collection technology, existing subsystems, operators, and resources in system (vehicles, infrastructure, personnel structure), etc.

On the other hand, the most important external factors influencing tariff and fare collection system are market conditions, level of development of science and technology, institutional conditions, integration processes, objectives, organization and management of higher-level system (i.e. city), etc.

Process of organization of tariff and fare collection system in public transport system consists of the following phases (Tica, 2001.):

- Phase I - defining the target function of the system,
- Phase II - determination of the necessary structure of the system and determination of the processes, sub-processes and activities necessary for achieving objectives,
- Phase III - classifying processes, sub-processes and activities and organize them into smaller parts with clear and precisely defined relationships between them,
- Phase IV - dividing of specific tasks and delegation of responsibilities to appropriate actor in system,
- Phase V – coordination of specific tasks and continuous performance monitoring through indicators of quality of system and services.

First phase, defining goals and target function is specific for every public passenger transport system, while the other phases of the tariff and fare collection system organizations have been subject to standardization and harmonization in the past 10 years due to the development of electronic fare collection systems and interoperable fare management.

The organization and management of tariff and fare collection system and their function is not so complex if the PPT system has only one mode of transport and/or one operator. In systems where there are multiple transport modes and subsystems, and more operators, as is the case in Belgrade, organization and management are much more complicated and complex. Only with the development of electronic payment, tariff integration was possible in these systems.

3. Electronic Ticketing and Electronic Fare Management

Electronic Ticketing and Electronic Fare Management have been attracting the attention of public transport users, operators and authorities for almost two decades. While the first term is commonly applied when a paper ticket is just being replaced by an electronic media storing the same data, the latter indicates a more comprehensive view (UITP, 2002):

- open payment schemes
- intermodal and interoperable journeys
- interservices
- marketing, CRM & price policy
- traveler information
- vehicle & fleet monitoring
- operational & strategic planning
- individual safety
- (road) toll collection
- mobility management

Electronic fare collection systems can be classified according to the medium of payment: magnetic cards, contact cards, contactless cards, mobile phones – SMS or NFC technology, other devices (PDA, etc). Today the most commonly used technology are contactless smart card, which are standardized in ISO/IEC 14443 standard. This is the only approved technology through long year experience and successful implementation worldwide.

The importance of information technologies (IT) in transport has been clearly established in several European documents (standards, directives) and research projects in the last ten years, which are considering the development and impact of technology on society and quality of life. A major initiative was launched in year 2000, entitled "e-Europe", based on Green Paper of information in the public service from 1999.

Due to the specific conditions in the candidate countries for European Union, the "e-Europe+" initiative was launched in 2000, which has the same goals and priorities, but also defines the procedures and actions of the application of IT technologies in these countries. Two of the ten areas are addressed for public transport: smart cards and intelligent transportation. As a result of the aforementioned initiatives within the European Committee for Standardization (CEN) Technical Committee was formed in the area of telematics in road transport and traffic (CEN / TC 278 "Road Transport and Traffic Telematics"), engaged in the technical harmonization and standardization of road transport and transport. The Commission is working to standardize communications between vehicles and road infrastructure, traffic management, user fare collection services, management of public transport and information for users.

Hierarchy of standards in the field of electronic fare management system is shown in Fig. 1. On the basis of technical standards for contactless data interchange (mechanical properties, electronic properties, and operating systems), application standards are developed.

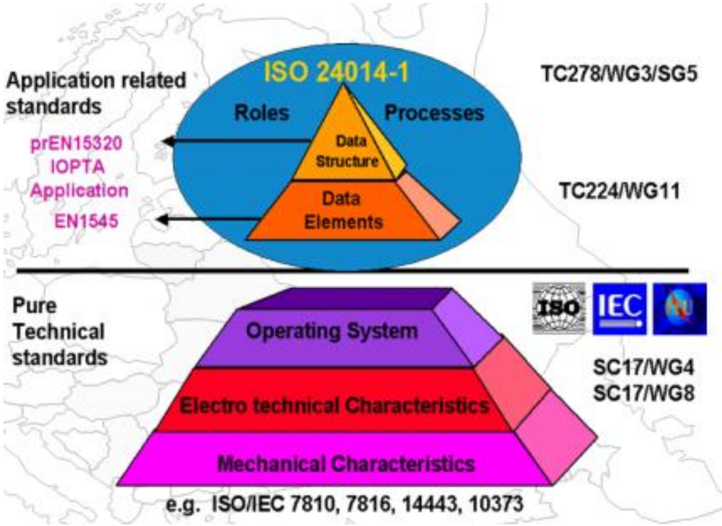

Fig. 1.
Hierarchy of standards in the field of electronic payment system
Source: Franchineau, 2008

As the culmination of efforts to standardize the electronic fare management systems in year 2007 first part of the ISO 24014-1: 2007 Public transport - Interoperable fare management system was adopted, which should provide the basis for the successful management of tariffs and fare collection in interoperable environment. The first part of the standard Part 1: Architecture (2007) defines the general structure of automated collection system in order to guarantee interoperability between various actors in the system. Currently under construction is the second part of Part 2: Report on set of rules.

There were a number of national initiatives, which were based on the above international and European standards. The best known is the organization ITSO - Integrated Transport Smartcard Organization in the UK, whose standards cover the whole process ("end-to-end") from user's request for the purchase and transport tickets, until final allocation of revenues among operators, which ensures the security of data on all levels. Similar national standards exist in Germany (VDV Kernapplikation), France (Intercode, Interbob) and the Netherlands (TransLink). These standards served as the basis for the aforementioned standard ISO 24014, which should allow for integration at the international level.

3.1. ISO 24014-1 Public transport - Interoperable fare management system

Standard ISO 24014-1 Public transport - Interoperable fare management system provides the basis for the development of multi-operator/multi-service Interoperable Fare Management (IFM) in public transport systems.

This standard:
- Defines the logical and functional architecture and the interfaces within the system and with other IFM systems
- Defines requirements for interoperability between actors in system
- Develops existing national and international standards
- Gives use cases describing the interactions and data flows between the different functional entities
- Describes security requirements
- Is applicable regardless of fare collection system type e.g. can be used in non electronic media systems.

Specific requirements of the Interoperable Fare Management (IFM) system model are (International Organization for Standardization, 2007):
- a user shall be able to travel with all participating operators (the seamless journey) using a single
- medium
- there shall be a capability to extract data appropriate to the revenue-sharing and statistical requirements
- of the transport operators
- the opportunity may be provided to use the same medium for other applications and combine those with the transport application
- the ticketing methods associated with the application shall offer the opportunity to reduce the current
- time taken to enter/exit the public transport system and may reduce payment handling costs significantly
- to comply with European data protection and financial services laws/regulations (e.g. privacy)
- to provide the capability to accommodate new product specifications as required regardless of those
- already in existence

- to recognize and prevent internal or external fraud attacks
- to protect the privacy of the Customer
- to guarantee the integrity of exchanged data
- to enable the implementation of additional services e.g. loyalty programs, car sharing, park & ride,
- bike & ride etc.
- to provide interface definitions between identified functions within public transport to enable different
- operator networks to interoperate
- to describe interfaces which shall exist to enable data forwarding functions between different operator
- networks allowing revenue sharing agreements to be met
- to provide a framework from which commercial agreements may be developed.
- to be neutral with regard to different technologies which may be deployed (e.g. contact medium,
- contactless medium (short range, wide range) independent of access technologies).
- to be functionally neutral regarding specific transport organization structures.

ISO 24014-1: 2007 Public transport - Interoperable fare management system, Part 1: Architecture (2007.) gives basic framework (links between operational Entities) of generic IFM model described in Picture 1. Two main IFM domains are (Fig. 2):

1. Operation entities:
   a. Collection and Forwarding
   b. Product Owner
   c. Application Owner
   d. Product Retailer
   e. Application Retailer
   f. Service Operator
   g. Customer Service.

2. Management Entities:
   a. Security Management
   b. Registrar.

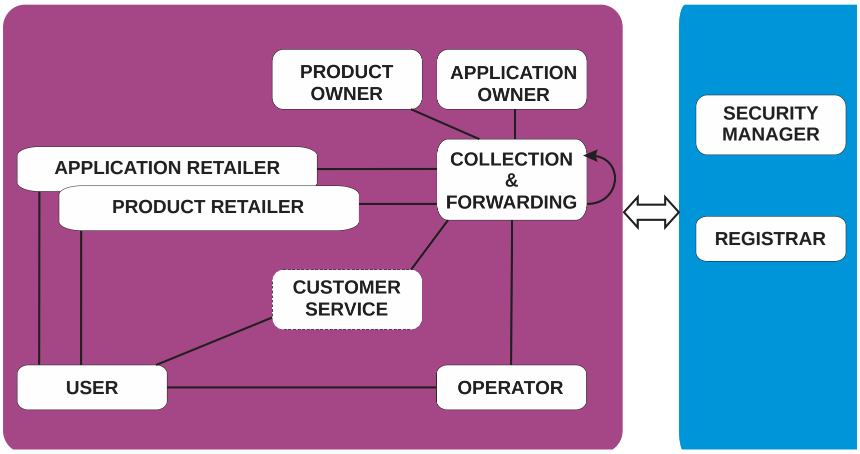

Fig. 2.
Basic Framework of the generic IFM model - Operational and Management Entities

Basic functions of all above mentioned entities will be described through IFM model for City of Belgrade given in following parts of this paper.

4. Public Passenger Transport System in Belgrade - basic facts

Public Passenger Transport (PPT) System in Belgrade is complex organizational-technological system by it's structure, operation and management. Transport service market includes complete administrative area of the city, i.e. 10 urban and 7 suburban municipalities. System complexity is also a consequence of the large number of operators with different ownership status (public and private companies) and different subsystems (buses, trolleybuses, trams, minibuses, urban and suburban railway), engaged with significant resources (1,800 vehicles, more then 10,000 employees, as well as the energy and finance resources). System is partially integrated which involves partially integrated network of lines, non-optimized timetables, partially integrated tariff and fare collection system, etc. The number of passengers carried (about 1.8 million passengers a day), realized transport work, and costs Belgrade's PPT system makes it one of the major systems in Europe.

PPT System in Belgrade has three major subsystems. These subsystems operate almost completely independently of the organizational and managerial terms, except that they are in the same jurisdiction of the City government and the Secretariat of Transport - Directorate of Public Transport. The first subsystem is urban PPT system on the territory of 10 urban municipalities of the city of Belgrade, with more than 1300 vehicles at work every day, 150 lines and about 1.5 million passengers a day. The second subsystem is suburban and local PPT system on the territory of the 7 suburban municipalities of Belgrade and has more then 260 lines. The third subsystem is urban railway, which is entrusted with public company "BG: train". This subsystem is the youngest (only one line in operation) and and does not carry significant numbers of passengers.

In addition to these subsystems, there is express minibus service with 8 lines. In the period from 00.00 up to 04.00 operates night transport with more then 30 lines. On suburban area there is also suburban railway.

Integrated Tariff System (ITS1) was introduced in Belgrade 01.05.2004. as a first step towards the integration of the tariff system. The concept of ITS1 is based on application of the same tariff principles and structure for all subsystems and operators on complete urban PPT network.

Suburban PPT system has a special tariff system, tariff policy and fare collection system. Integrated Tariff System (ITS2) consists of 4 zones for prepaid tickets or 10 zones for single ride tickets in the system. Partial integration of the subsystems with ITS1 was achieved through the introduction of prepaid tickets which are valid for both subsystems.

ITS1 and ITS2 have showed good results, creating benefits for both users, operators and city itself. Therefore, in recent years, significant efforts towards the full integration of all subsystems tariff and fare collection system in the city. One of the conditions for achieving this goal is the introduction of a modern electronic fare collection system, without which the tariff integration was almost impossible. With introduction of new electronic fare collection system total fare collection integration was achieved. Next step is total tariff integration which is planned for next year.

4.1. Basic facts of new automatic fare collection system in PPT in Belgrade

The New tariff and fare collection system study (Filipovic, et al 2008.) suggests complete tariff and fare collection integration and implementation of new zonal tariff system in urban and suburban PPT system in Belgrade. To complete this, the first step was to introduce new fare collection system because of many disadvantages of the previous fare collection system of which most significant are:

- Difficult tariff, physical and logical integration
- Low flexibility to user needs
- Poor information database
- Lack of system control
- High possibility of various forms of frauds
- Low reliability of fare collection equipment.

In year 2010 City Authorities have decided to introduce new automatic fare collection system which will fulfill complex set of requirements:

- Ease of use
- Higher flexibility for passengers, offering different tariff options fulfilling various passenger group needs.
- Better spatial and time accessibility
- Easiness of tariff integration within system and with other systems
- Improvement of information system
- Higher level of security
- Better efficiency of fare collection equipment
- Reasonable level of costs for City authorities and operators.

City has decided not to implement system by themselves and not to rent equipment of electronic ticketing system, due to many shortages, especially high costs. Instead of these, BOT – Build, operate and transfer principle was used in which the company which provides necessary financing, gives technical solutions. The basic advantage of BOT is granting financing for introduction of system practically without attraction municipal or public funds.

System implementation started from October 2010 and was completed until February 2012. Main characteristics of system are:

- Multimodality: opened to various means of transport: buses, trams, trolleybuses, urban railway, minibuses
- Multi-operator: able to manage data of various transport operators
- Interoperable: opened to services offered by other systems.

There are three different types of tickets in system: plastic contactless smartcards (personalized and non-personalized), paper contactless smartcards and paper tickets (sold by drivers).

All tickets in system must be validated at the beginning of trip on validators located near by all doors in vehicles – Check In system. System is flexible for new tariff options, so in alter phases system can be upgraded by introduction of Check In/Check out technology.

5. Interoperable fare management model for public passenger transport system in Belgrade

IFM model for public transport system in Belgrade is given on Fig. 3. The proposed model is a variation of the existing models in the cities of Europe and the world, in accordance with ISO 24014-1 standard.

The main feature of the model is centralization of all functions in the system, and delegation of organization and management to an enterprise, which is the *Manager of ITS*.

Depending on the concept of organization and management of ITS - ITS Manager functions can be delegated to:

- City authorities in charge of PPT system – Directorate for public transport, Secretariat of Transport of the City of Belgrade
- One of the operators in the system or group of operators (such as in the previous system where fare collection services were entrusted to GSP "Beograd" and SP ”Lasta”).
- Special public or private agency.

City of Belgrade has chosen the last option and decided to entrust the above mentioned function to consortium of companies. The new brand which operates in system is called **BusPlus**. Of course, control and monitoring of the system and the work of *Managers of ITS* is the responsibility of the Directorate for public transport, which is responsible for the provision of public transport services the citizens of Belgrade. ITS Manager defines a set of rules in the system with the approval of the Directorate for public transport. Each element in the system must meet certain requirements according to the set of rules, and the process of verifying the compliance requirements is called certification.

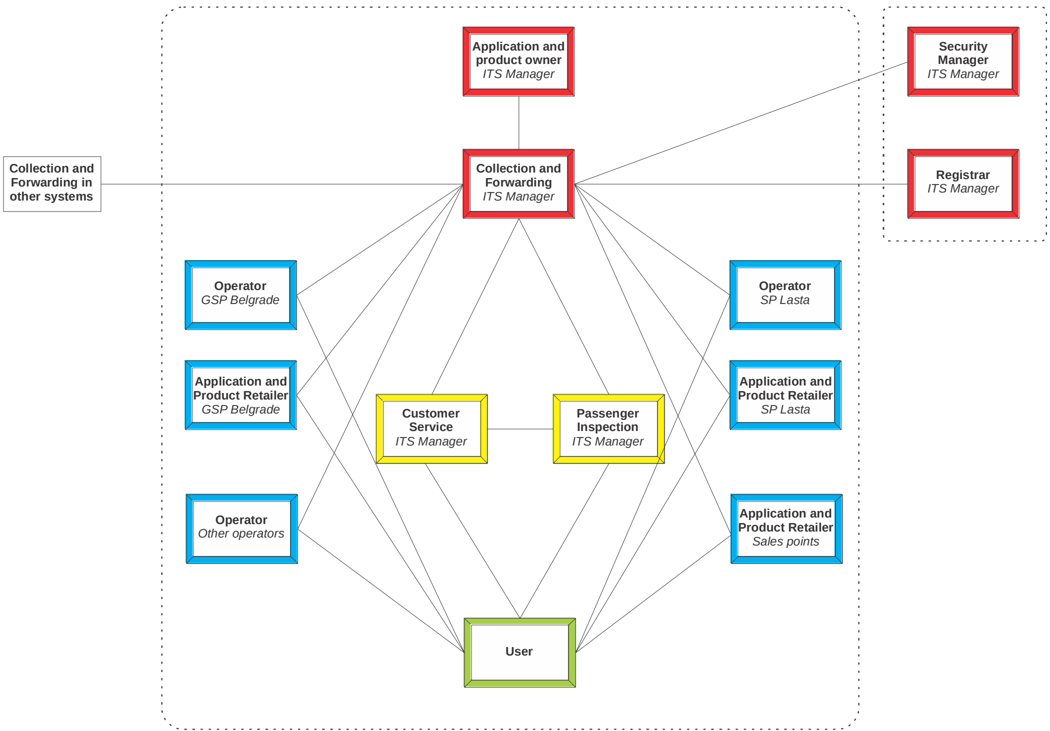

Fig. 3.
Interoprable fare management model for public passenger transport system in Belgrade

Entity performing the role of ITS Manager is responsible for performing the following functions:

1. *Security Manager, which is responsible for security policy in the system are made:*
   - the certification organization (participants in the system), services (applications), components and products,
   - system monitoring and control,
   - control the operation of the safety rules and security keys,
   - the other functions if needed.

Security Manager manages the security key (PKI Public Key Infrastructure). Security system is there to protect both the system (the physical aspect - equipment, maps, network, software and information in the system), and the public interest, not only through financial aspects, but also other human / cultural values. The privacy of customer data (passengers) in the system is of especial importance. Since 2009 in the Republic of Serbia, is a law in place that defines the collection, storage, processing and use of personal data (*Law on the Protection of Personal Data, Službeni list RS, No 97/2008 and 104/2009*). For this reason, during card issuing and personalization user is asked only to give information necessary for the operation of ITS. This data must not be passed on to third parties without the user's consent. For users who agree by signing special form that their data can be forwarded to partners, a special benefit program is provided with various advantages.

Within BusPlus system transport usage data, which are necessary for the planning and operation of the system, is not linked to personal information, i.e. to user, but only the card alias No. Only at the request of users these transport and user data can be linked together by Directorate for public transport. Only one user from Directorate for public transport have access to user personnel data (names, addresses, etc.) and fare collection data (check in data) and can make relationship between two databases which are stored on different locations.

2. *Registrar, an entity that registers all the elements in the system:*
   - Actors in the system: operators, retail outlets,
   - Products – Tickets,
   - Applications,
   - Human resources: drivers, inspectors, technical staff, other staff.
   - Vehicles,
   - All components, hardware and software: security equipment, hardware and software equipment for fare collection (driver panel, validators, inspector devices, rechargers), communication network.

Registrar also designs database of all elements by categories. Each element must have a unique identification number. Identification is important in terms of safety, communication and storage of transaction data.

Well organized databases are essential for efficient operation of the system. Different categories of users have access to specific datasets based on given user rights. This way system takes care of the privacy of data protection.

3. *ITS Manager is owner of all products and applications in the system.*

Products in tariff system are all kinds of tickets. Products are stored in the application, which is built within the card. To be more precise, owner of all products is the City of Belgrade as owner of public transport market, but it has entrusted this role to ITS Manager.

As an entrusted owner of applications and products ITS Manager, with the approval of the Directorate for public transport, performs the following functions:

- Management of tariffs and tickets
  - Organization of tickets sales and distribution
  - Organization and management of inspection service
  - Database management and white and black lists management.
  - User management
  - Other functions if needed.

- Management and maintenance of all hardware and software components, front-end devices and communications infrastructure.

- Clearing all data and financial transactions in the system (daily), through transport usage data analysis, preparation of revenue share and allocation of revenue to all participants.

- Report design
    - Issued ticket reports
    - Ticket recharge and sale reports
    - Driver card usage reports
    - Card usage reports
    - Passenger ride reports
    - Inspection operation report
    - Blocked card report
    - Black list report
    - White list recharge report
    - Revenue reports, etc.

4. Collection and Forwarding

This is the main function of the system which provides data exchange (information on products, applications, all transactions, service usage information) and forward security keys in the system between all participants. Each transaction is assigned a unique number that serves as a key to the validity of the data, based on the defined security rules, all wrong data (duplicates, missing data, data that do not have an owner, etc.) are forwarded to the ITS manager for further security checks. This is a complex task, given that the system collects and analyzes data from approximately 2 million transactions every day.

Exchange of information in the system is done via an internal network that connects database and application servers with Operation Control Center (OCC), and other participants in the system (operators or their depots). Other participants and mobile devices are connected to the system via the Internet Safety protocols. Users can obtain information through a variety of reports, or in real time via short messaging system and alarms.

Other users in the system are:
- Operators,
- Retailers and distributors of products and applications (ticket issuing and sale points),
- Customer service.

The main user groups in the system are operators. Some of them (GSP Belgrade and SP Lasta), apart from transport service, have role of Retailers and distributors of products and applications and conduct the sale and distribution of applications and products. Other (private) operators in the system provide only transport services.

The second user group consists of sales and distribution network and sales points in the system. These entities are entrusted by the owner of the products and applications (ITS Manager) with the sale and distribution of applications and products (tickets) through special commercial contracts.

Another important function in system is customer service. According to ISO 24014 this function is not required for interoperability, but as this is an introduction of a new system of payment services in Belgrade, which users have had not the opportunity to meet with, user help and support services were given special attention. This function is also done within ITS Manager.

The main activities of the customer service are:
- informing users about the ticket types,
- informing users about procedures and locations for ticket issuance / recharge / validity extension.
- providing information to users on how to use tickets and about their obligations in ticket inspection,
- resolving complaints of users.

Support will be available to end users in several ways:
- remotely via the call center / IVR,
- remotely via the web site,
- direct contact, verbally and through prominent notices on customer service locations, and
- through the brochures (booklets) about system.

User complaints and appeals are dealt with according to predefined methods, rules and obligations in the system.

Although not required by ISO 24014 we should also mention one of the most important elements of this IFM model – inspection service. This sector has more the 400 employees and is biggest sector in BusPlus enterprise. Main reason is that Belgrade PPT service is “openned” type, i.e. there are no barriers or gates to enter vehicle so all passengers can enter system no matter if that have or have not got valid ticket. To prevent significant revenue losses due to black ride specific modes and ways of passenger inspections have been implemented in system.

6. Conclusion

The proposed model of interoperable fare organization and management in PPT in Belgrade is defined in accordance with standards ISO 24014-1 and meets all interoperability requirements defined in this standard.

The structure of the system and processes, sub processes and activities in the system necessary to achieve the objectives are given by the proposed model of organization and management. The model clearly defines the relationship between the elements of the system, and gives specific distribution of responsibilities to the appropriate actors in system at macro-organizational level.

The implementation of IFM model in PPT will provide benefits to all interest groups in the system PPT in Belgrade.

Integration of tariff and fare collection system in PPT makes this system more attractive to users. Complete journey can be done by a single transport document - smartcard, regardless of the subsystems or operator. Another benefit is increase in the level of quality of service for users through the PPT adjustment of prices for individual travel services to the real characteristics of the movement of passengers, and the different options in the payment of the same services. The system has virtually no restrictions on the payment option services (all kinds of subscriptions, loyalty programs, rewards and penalties for users.) And their implementation is simple and easy. These benefits have already started to attract users, as number of passengers is increase for about 20% each month compared to the same period in previous year.

One of the main advantages of the new interoperable ITS is the creation of a reliable information base to effectively and efficiently manage costs and revenues from services in PPT, and creating a reliable information base on the characteristics of passengers and travel, and transport demands as a basis for optimization of the capacities and operation of the PPT system. The availability of this information eliminates the need for extensive and expensive research of these characteristics.

The proposed model significantly increases the safety and security of revenue in system. It reduces the possibility of abuse in the system, fraud, forgery and evasion of payment of transportation services. Also, the integration of cryptographic system to solve the problems of revenue collection, clearing and distribution, regardless of the model of contract between operators and the city.

Defined and standardized IFM model is expensive and requires longer time to implement completely, but it becomes economically viable in the long term operation and contributes to significant savings in time execution of all processes in the system. This is confirmed by experiences from other cities and states in the world (Oslo, Paris, Japan and so on.).

There are also opportunities of IFM system integration with other systems in the city, primarily parking system, and other public services.

Further vision of public passenger transport should consider the introduction of a national standard for interoperable fare management, as is already done in the Netherlands and Denmark.

Acknowledgements

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References

European Commission. 2004. European Interoperability Framework for Pan-European eGovernment Services. IDABC Program. European Commission. Available from internet: <http://ec.europa.eu/idabc/servlets/Docd552.pdf?id=19529>.

European Commission. 2011. European Interoperability Framework (EIF). European Union. Available from internet: <http://ec.europa.eu/isa/documents/eif_brochure_2011.pdf>.

Filipovic, S.; Živanović, P. 2008. *Study of a new tariff system with automatic fare collection in public transport (in Serbian: Studija novog tarifnog sistema sa automatskom naplatom usluge u javnom gradskom prevozu)*. Institute of the Faculty of Transport and Traffic Engineering. Belgrade.

Franchineau, J. 2008. CEN TC278 – RTTT WG3 - Public Transport Telematic, IT Trans.

International Organization for Standardization. 2007. *ISO 24014-1: 2007, Public transport - Interoperable fare management system, Part 1: Architecture*. ISO.

Office for Official Publications of the European Communities. 1997. *ISOTOPE – Improved Structure and Organization for Urban transport Operation in Europe*. Transport Research 4th Framework Programme - Urban Transport, *Office for Official Publications of the European Communities,* VII-76.

Petrović, M.; Tica, S.; Živanović, P.; Bajčetić, S. et al, 2011. *Fare collection and Vehicle Management System in public transport in Belgrade – Main project (in Serbian: Sistem za naplatu karata i upravljanju vozilima u javnom prevozu u Beogradu – Glavni projekat).* Consortium: Apex Solution Technology, Lanus and Kent Kart Global Elektronik Ltd.Sti. Belgrade.

Tica, S. 2001. Master thesis. Faculty of Traffic and Transport Engineering. Belgrade.

UITP. 2002. *Tr@nsITS: Intelligent Public Transport Systems - State-of-the-art in Europe*. UITP and “Information Society Technologies” Programme of the European Union. Brussels.

SHADOW COSTS IN INNOVATIVE URBAN INFRASTRUCTURES

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Abstract: Since 2007 a research has started about innovative urban means of transportation, in order to investigate if selection criteria could be developed according to urban context, economic environment and other local needs. Interest has risen in favour of guided bus: those means are almost common buses having very good performance in terms of operating comfort and regularity, and manufacturers declare a very low parametric cost. It has been seen that costs for tramways also contain costs for rail infrastructure building, but nothing comparable to it was found for guided buses construction costs, moreover, even though new buses run on existing roads, those must be reinforced in order to sustain the increased wheel load and the continuous passage of wheels in the same place. In addition life cycle costs must be taken into account. When a new line is going to be built and trams and guided buses means are compared, if complete construction costs and life cycle costs are not taken into account, the cost/benefit analysis will not be realistic. So the Authors, after identifying that a very significant shadow cost in bus way evaluation is hidden in pavement construction and maintenance, decided to develop a design of the optimal pavement with particular attention to permanent deformation due to wheel path for guided buses all along the life cycle period and to minimisation of life cycle costs, compared to LCC of a tramway infrastructure using data coming from least researches. At the end of the article we will not show what is the best guided mean in general, but Authors will point out what are the real costs that an investor would face to build and to put into service a new line. This paper is turned to technician and agencies that are involved in urban infrastructure planning and management in order to give them useful instruments to evaluate benefits and costs in innovative urban infrastructure analysis.

Keywords: Life Cycle Costs, Shadow costs, Guided Buses, Urban Infrastructure

1. Introduction

The decision making process between bus-based or light rail transit systems is still unsettled: even if many steps ahead have been made to define direct and indirect costs which each system causes, there is still some cost that remains shadowed and can cause the wrong choice to be made by transportation planners.

The advantages of a light rail scheme for a transit system are well known:

- higher capacity;
- higher commercial speed;
- most effective urban form;
- generally preferred by travellers;
- being a tool for urban design and improvement of public space than a simple mean of transport.

So that the disadvantages:

- high costs for construction;
- less door-to-door service than bus transit;
- rigid route

At the same time, advantages/disadvantages of a bus-based system are the disadvantages/advantages of light rails.

To mix the advantages of both systems, since the beginning of the 90s, new products have appeared on the transit market, offering same performances as light rails at cheaper costs. Those systems are based on trolley bus vehicles, improved by automatic guided systems.

The automatic guide allows those vehicles be very fluid in operating, adding comfort if compared with normal trolleybuses, having comfort performance similar to the one of a tram vehicle and reducing energy consumption; moreover, these vehicles are very precise in approaching stops, letting the boarding times decrease and the comfort of disabled people getting into the mean improve.

Different companies have developed different technologic solutions in order to allow the automatic guide for trolley buses.

Those solutions are usually divided into three groups:

- optic guide;
- magnetic guide;
- physical guide.

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None of those systems allow vehicles to run alone, but all of them require a driver, just to open/close the doors and check safety issues.

To exploit the automatic guide at its best, reserved lanes are required. If not, the interference between guided buses and other vehicles (cars, bikes, pedestrians) may cause the automatic guide not to be effective and the driver to directly take the control, nullifying the advantages of the guided bus.

This paper has been developed analysing case studies of the most relevant guided systems and light rails in Europe, reading the little available literature, performing interviews to relevant actors in the field, both in private and public sector, and analysing performances of the new systems put into service. Authors found out that the parametric costs of guided buses, at the end of the construction phase, are not so different from the ones of traditional light rail projects, developed in the same years, as we expected. In fact guided buses are offered as systems having performances comparable to, even a little lower than, the ones of tramway systems, but costing from 5 to 10 times less than light rail systems. Splitting costs for both guided buses and light rails it is possible to realize that in the first ones there is a lacking item: infrastructure and track costs, both in the construction phase and in the operating phase. This is usually justified by the fact that guided buses run on existing roads, and do not need new infrastructure to be build and maintained; but this is not completely true. First of all, even if a new system runs on an existing road, it adds some heavy traffic on this road, and so the cost for maintenance will increase; secondly, according to Author’s cases study anyway new pavements are required, because the heavy loads of guided buses cause ordinary roads to quickly degrade. Starting from this, the Authors developed a complete design of an optimum pavement for a guided bus system starting from 5 different alternatives. It includes: cracking and rutting evaluation during pavement life and maintenance costs for a 30 year life period. At the end the best pavement in term of minimum costs in its life cycle has been chosen and compared to the rail parametric costs.

At the end of the paper some recommendations and future development are presented.

2. Life cycle costing for urban public transportation projects

Life cycle costs of a new infrastructure are usually split into construction costs and operating/maintaining costs.

When data collecting of cases started the main goal was to determine a range of parametric costs (per kilometre) of new LR infrastructures. The simplest and quickest way to perform this analysis was to take the overall cost of projects and divide it by the length. Doing this way, very patchy results were found: in fact parametric costs seemed to be up to 4 times one to another, even if the systems compared were almost the same from the technological point of view. It was pinpointed that every authority presented its data in a different way, for example in some cases costs called “infrastructure” contained cost of renewal of historic centre of cities, which are not direct cost of the infrastructure of the LR system, but only work that municipality decided to perform by the LR contract. Moreover, the same costs for punctual works, for example bridges, which must be separated from infrastructure costs in order to determine a parametric cost per kilometre for each mean. Costs called “technology” sometime put together power supplies, signalling and telecommunications costs. To make costs description comparable, Authors decided to split them into standard (and classic) items (Baumgartner, 2001), as shown below:

<u>Construction costs.</u>

- land and rights;
- infrastructure;
- track;
- power supply equipment;
- signalling equipment;
- rolling stock;
- spot costs: bridges, depots.

<u>Operating/Maintenance costs.</u>

3. Life cycle costing of urban projects: ex-post cases studies report

This paragraph figures out the most relevant cases study developed in the last 3 years and to lead the Reader though the path that let us identify shadow costs estimated in the next paragraph. Costs obtained from these cases study are shown in Table 1, in order to provide to the Reader the overall information about cost sustained in completed transit projects, available for further discussion.

3.1. Tranvie Elettriche Bergamasche (TEB)

The new tramway of Bergamo (Italy) was put into service in 2009, and it links the city to its province using the track of a revamped historic railway. The city is in the north of Italy closed to Iseo lake, has 120.000 inhabitants and its province is the 9th in 2009 in terms of per capita GDP ranking in Italy. The analysed line links the city with Albino, a town which is considered the gate of the main valleys of the province. The historic line had only one track, the new light rail has two tracks. The project had some trouble during the executing phase, but today users are increasing and there are plans to extend the line.

3.2. New Florence Tramway

The historical city of Florence has chosen a traditional tramway to develop its urban transportation network. The first line built, T1, links the town of Scandicci to the main rail station area, and will cross the Renaissance historic centre in its further development. The line T1 has been partially put into service in 2010, after major changes in the root of the tramway in the Duomo area have been decided due to citizen committees protesting for the route chosen. The system is technically similar to the one of Bergamo described above, but the significant difference between the urban context of Florence and the one of Bergamo let the Florence system cost per kilometre being almost double (Table 1).

3.3. CIVIS system in Bologna

The Italian city of Bologna in 1999 chose the CIVIS (optic guided bus) to strengthen its public transportation network: almost 19 kilometres split into 4 lines. The project sponsor could be identified in the Guazzaloca municipal committee, settled in 1999, whose sponsorship had highly pushed the project to start. Afterward, a new municipal committee settled in 2004, and weakened the sponsorship to the project, so the length of the system decreased by 5 kilometres without substantially changing the initially allocated budget. Today it is possible to say that the project has substantially failed because the optic guide has been abandoned and the system will be put in service as a trolley bus, with very poor performances in comparison with the designed system. Even if the cost of an optic system is normally considered as the cost of rolling stock plus the costs of the optic (painted) markers on the pavement, in Bologna the whole route touched by the system has been significantly reinforced to face the higher axle load of vehicles, generating extra costs that were not included in the budget.

3.4. Traslohr system in Mestre-Venice

A new mechanical guided system has been chosen to link the city of Venice to Mestre and Marghera (that are in the surrounding area). The network has been conceived 20 kilometres long, split into 2 lines overlapping in the last part crossing the Venice Laguna. Currently only a minor part has been put into service at the end of 2010.

3.5. Bus Rapid Transit (BRT)

Bus Rapid Transit represents a class of bus-based transit systems having a strong hierarchic organization, with express routes and feeder routes. The first prototype has been established in the Brazilian city of Curitiba in 1974, having a capacity of about 11.000 pax/hour, directly comparable with the capacity of most part of light rails systems. The most complete cost data for a BRT are the ones of the Transmilenio in Bogotà, Colombia, put into service in 2000. Those systems are claimed to provide the same performances of light rails transits being more cost effective than the last (Hensher, 1999). For these systems the benefit/cost analysis must take into account costs for building and maintaining road infrastructure, as discussed below in the paragraph 4.

Table 1
Construction costs of some of the cases study

Project	Tot M€/km
Bergamo TEB	12,30
Florence tram	32,3
Bologna CIVIS	9,30
Mestre-Venice Traslhor	8,18
Bogotà BRT (Lines A-B-C)	5,07-21,10

4. Design and life cycle cost analysis of an optimum pavement for bus lane

An optimum pavement for guided bus lane was designed by the Authors in order to estimate the shadow cost related to pavement construction and maintenance in guided bus projects. Five different stratigraphies were considered, they were calculated considering fatigue life and permanent deformation. This pavement is characterized by traffic of buses of about 85.000 passes/year (on two lanes) and wheel tracks with a reduced transversal dispersion. For this reason the main problem of this pavement is the permanent deformation of the surface that can reduce safety especially in case of rain and cause track deflection not acceptable for the bus.

The five pavements were designed in order to accept traffic load characterized by two bus lanes. For each pavement the years which cause fatigue cracking were calculated, then rutting was evaluated for each situation. Two situations in particular were evaluated: the first considers a surface depth of 15 mm, this value was defined as the maximum acceptable for this type of bus lane while the second considers a surface depth of 12 mm, and this value was considered in order to have a better level of safety and to evaluate the difference of costs. Ordinary and modified asphalt concrete layers were also considered in the study.

The design of each alternative was conducted for a period of fifty years, including maintenance, when necessary.

Then a life cycle cost analysis (LCCA) was performed in order to evaluate the economics of the alternatives not only considering construction costs but all the life cycle costs. This was done with two techniques based on the concept of discounting: the present value (PV) (also known as "present worth") and the equivalent uniform annual cost (EUAC).

These five different pavements were called F1, S2, S3, S4, S5. Pavement F1 is characterized by asphalt concrete and an unbound sub base layer. Pavements S2, S3, S4, S5 are instead characterized by a cement treated base and different thickness of asphalt concrete. This last type of pavement presents a better behaviour in case of heavy traffic loads. In Table 2 the different alternatives are presented. Asphalt concrete layers are made with ordinary or modified bitumen and the differences in terms of performances and cost are evaluated.

Table 2
Stratigraphy of the pavements considered in the analysis (AC layers are made with ordinary or modified bitumen)

	Pavement				
	F1	**S2**	**S3**	**S4**	**S5**
Layer	Thickness (cm)				
AC surface course	5	5	5	4	3
AC base course	25	25	20	16	15
Cement treated base	-	15	15	15	15
Unbound layer	25	20	20	20	20
Subgrade	-	-	-	-	-

Pavements were calculated considering fatigue life and permanent deformations. Fatigue life was calculated dividing the year in four seasons and considering different climatic condition that caused a different behaviour in asphalt concrete. The Asphalt Institute method for the design of fatigue life of pavements was used.

Then the depth of permanent deformation was calculated for each alternative with the Thseng Lytton procedure (Lytton and Tseng, 1989) using a reliability of 90%. In Table 2 the depth of permanent deformation calculated at the surface of the pavement in each alternative is presented: it was evaluated in accordance with the procedure analysing asphalt concrete permanent deformations and unbound material permanent deformations (Uzan, 2004). In Table 3 rutting for the pavement after ten year of traffic are presented.

Table 3
Permanent deformations of the pavements after ten years of traffic without any rehabilitation activity (90% reliability)

	Ordinary bitumen			Modified bitumen		
Pavement	**AC rutting (mm)**	**Unbound material permanent deformation (mm)**	**Total rutting (mm)**	**AC rutting (mm)**	**Unbound material permanent deformation (mm)**	**Total rutting (mm)**
F1	5,64	6,90	**12,54**	4,67	6,50	**11,17**
S2	6,95	4,92	**11,87**	5,74	4,75	**10,49**
S3	7,90	5,65	**13,55**	6,37	5,36	**11,73**
S4	8,54	6,55	**15,09**	6,65	6,43	**13,08**
S5	8,72	6,95	**15,67**	6,61	6,83	**13,44**

The design of each alternative was conducted for a period of fifty years, including maintenance, when necessary. As the fatigue life is not the first problem, a surface substitution was chosen at first in order to delete permanent deformation at the surface of the pavement. A substitution of asphalt concrete is done when bottom-up cracks reach the top of the pavement and propagate for a surface along the wheel track as considered in Asphalt Institute method (Finn et al., 1982; NCHRP, 2004). Then the pavement life is evaluated till the crack reaches the surface the second time and permanent deformation is verified with the limit.

In Fig. 1 time history of permanent deformation depth during the analysis period of 30 year for pavement F1, ordinary bitumen, 12 mm depth is presented.

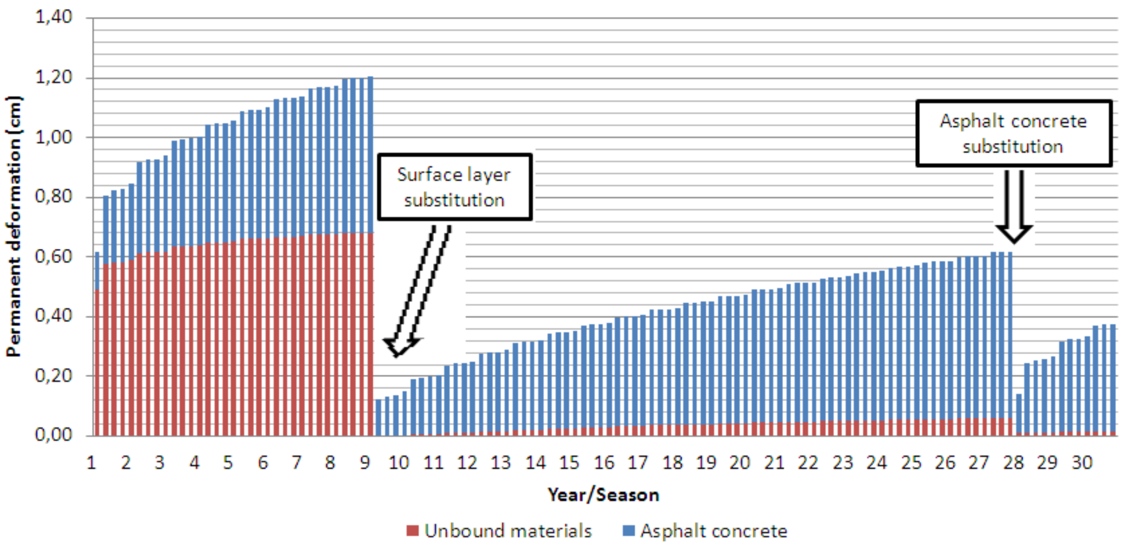

Fig. 1.
Example of permanent deformation evolution during a 30 year period of analysis for pavement F1 with ordinary bitumen, each column represents the total depth of permanent deformation of a season.

In Table 4 the strategy for each alternative considered is presented.

Table 4
Rehabilitation activities planning for each alternative in case of maximum rutting accepted of 12 mm or 15 mm

		Ordinary bitumen			Modified bitumen		
Pavement	**Maximum rutting [mm]**	**Surface course substitution [year]**	**Asphalt concrete substitution [year]**	**End of pavement life [year]**	**Surface course substitution [year]**	**Asphalt concrete substitution [year]**	**End of pavement life [year]**
F1	**12**	9 - Summer	28	50	: 15 - Autumn	36	50
S2		11 - Autumn	-	50	: 18 - Autumn	-	50
S3		7 - Summer	-	41	: 12 - Summer	-	50
S4		4 - Autumn	30	50	: 7 - Autumn	33	50
S5		4 - Summer	24	44	: 6 - Autumn	24	48
F1	**15**	23 - Autumn	28	50	-	36	50
S2		25 - Spring	-	50	39 - Spring	-	50
S3		15 - Autumn	-	50	27 - Autumn	-	50
S4		10 - Autumn	30	50	19 - Spring	33	50
S5		9 - Autumn	24	48	17 - Autumn	24	48

Then those alternatives have been evaluated trough cycle cost analysis (FHA, 1998) the pavements are able to sustain traffic load cycles for the period considered for the analysis: that is a period of 30 years . Costs were evaluated on current Italian market for a pavement 7 meters wide and considering the strategies of maintenance defined in the design procedure and described in Table 4.

At the end, the least expensive alternative over time should be selected. In Fig. 2 a diagram reporting the main quantities and timing of expenditure over the life period of analysis for the pavement is presented. The horizontal arrow segments show the timing of the work zone activities. The vertical arrows show the costs of construction and rehabilitation. The Remaining Service Life (RLS) is represented as a downward arrow because it reflects a negative cost accruing at the end of the analysis period.

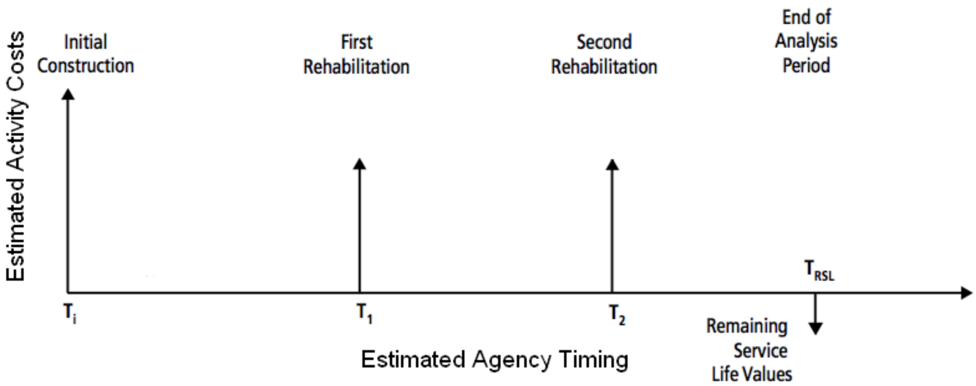

Fig. 2.
Expenditure stream diagram showing pavement activities, costs, and timing for the period of analysis

The different economic indicators used in this analysis, as suggested in the LCCA procedure, are present worth (PW), and equivalent uniform annual cost (EUAC). The present worth method converts all present and future costs to a common baseline. This baseline was set for all the pavements analysed in the year of construction. To determine the present worth at the year of construction, the present worth of each component related to the selected alternative was added over the analysis period. The PW of each component was calculated by multiplying the cost of the task by the present worth factor (PWF) calculated with the equation expressed as follows (Eq. (1)):

$$PWF = \frac{1}{(1+i)^n} \tag{1}$$

where:

PWF = present worth factor for particular i and n;
i = discount rate assumed equal to 3,2 % for a 30 years period of analysis;
n = number of years when the sum will be expended, or saved.

The Present Worth of Costs (PWC) for any pavement considered in the study for the analysis period of 30 years was evaluated with the equation expressed as follows (Eq. (2)):

$$PWC = \sum_{n=1}^{z}\left[C_n \cdot \frac{1}{(1+i)^n}\right] + \sum_{n=1}^{z}\left[M_n \cdot \frac{1}{(1+i)^n}\right] - RSL \cdot \frac{1}{(1+i)^z} \tag{2}$$

where:

PWC = present worth of costs;
C_n = construction costs at year n (usually n=0);
M_n = maintenance costs at year n
RSL = remaining service life of the pavement at the end of the analysis period
z = analysis period;

the other parameters are defined in the previous equation.

During the 30 year period of analysis each pavement was evaluated trough the equivalent uniform annual cost (EUAC): this converts all the initial investments and future costs into equal annual payments over the analysis period. The results present the amount that would have to be invested each year over the analysis period. The equation used to calculate EUAC can be represented as follows (Eq. (3)):

$$EUAC = \frac{PWC \cdot i}{\left[1 - \frac{1}{(1+i)^z}\right]} \tag{3}$$

where:

EUAC = Equivalent Uniform Annual Cost;

the other parameters are defined in the previous equation.

In Table 5 the results of the LCCA are presented.

Table 5
Life cycle cost analysis for each alternative for a period of 30 years

	Ordinary bitumen				**Modified bitumen**			
	Maximum rutting 12 mm		Maximum rutting 15 mm		Maximum rutting 12 mm		Maximum rutting 15 mm	
Pavement	PWC [€/km]	EUAC [€/km year]	PWC [€/km]	EUAC [€/km year]	PWC [€/km]	EUAC [€/km year]	PWC [€/km]	EUAC [€/km year]
F1	453.568,81	23.742,98	429.410,89	22.478,39	529.897,30	27.738,55	441.562,93	23.114,51
S2	443.350,06	23.208,06	410.626,39	21.495,08	546.359,03	28.600,28	464.080,62	24.293,25
S3	411.679,56	21.550,21	386.940,77	20.255,20	500.350,96	26.191,89	456.235,20	23.882,56
S4	**364.292,18**	**19.069,62**	**353.175,85**	**18.487,71**	**445.550,14**	**23.323,23**	**418.954,41**	**21.931,02**
S5	378.597,54	19.818,46	366.217,03	19.170,38	461.721,42	24.169,75	444.719,25	23.279,74

Pavement S4 is the least expensive alternative over time, considering ordinary or modified bitumen and 12 or 15 mm of maximum depth for surface permanent deformation. Considering pavement S4, permanent deformation can be reduced from 15 mm to 12 mm with an increase of safety by increasing costs of about 3,15%. The LCCA demonstrate that the least expensive pavement only considering construction costs (pavement S5), isn't the best solution considering also maintenance costs during its life.

5. Conclusion

In this paper the Authors evaluated the problem of choosing between light rails and bus-based systems. Different cases studies were described and costs evaluated. By providing cost data of completed projects it was showed how parametric costs of bus transit systems and light rail systems are not so different one to another, as it appears in the most part of (commercial) papers. Looking for shadow costs, it was detected that costs for infrastructure construction and maintenance in bus projects are often not considered since the beginning. Guided bus lines routed on an existing road, make this road deteriorate very fast and requiring to reconstruct the pavement. For this reason shadow costs of bus-based systems related to pavement construction and maintenance were deeply analysed. A quantitative assessment based on current Italian market prices was developed and the Authors believe that the procedure presented could be directly used by technician to evaluate new projects and choose the best pavement solution to encompass those cost in benefits and costs evaluation.

For future development the evaluation of indirect benefits, such as the urban shaping made by light rails in particular, should be developed, with the aim of enabling a comparison between the feasibility of a bus based transit against a light rail transit.

References

Baumgartner, J.P. 2001. *Price and costs in the railway sector.* Litep.

Federal Highway Administration. 1998. *Life Cycle Cost Analysis in Pavement Design*, Report No. FHWA-SA-98-079, Federal Highway Administration, Washington, D.C.

Finn F.N.; Monismith C.L.; Shook J.F.; Witczak M.W. 1982. Thickness Design of Asphalt Pavements - The Asphalt Institute Method, In Proceedings of the *Fifth International Conference on the Structural Design of Asphalt Pavements*, Vol. 1, Delft, The Netherlands.

Hensher D.A. 1999. Bus-based transit way or light rail? Continuing the saga on choice versus blind commitment, *Road & Transport Research*, 8(3): 3-21

Lytton R.; Tseng K. 1989. *Prediction of Permanent Deformation in Flexible Pavement Materials. Implication of Aggregates in the Design, Construction, and Performance of Flexible Pavements*", American Society for Testing and Materials, Vol. STP 1016, Philadelphia, USA.

National Cooperative Highway Research Program. 2004. *Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures Guide*. NCHRP Project 1-37A, National Research Council, Washington, D.C.

Uzan J. 2004. Permanent deformation in flexible pavements, *Journal of transportation engineering*, 130(1): 6-13.

USEMOBILITY PROJECT

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Abstract: USEmobility is an EU funded project that surveyed why people switch from monomodal transportation (car) to eco-friendly multimodal public transport chains. USEmobility stands for Understanding Social behaviour for understanding Eco-friendly multimodal mobility. Main part of the project is a survey done among 10.000 European citizens in 10 selected regions in six European countries. This paper gives insights to reasons, approach and methodology of that survey. The survey was concentrated on so called swing-users. This includes both, people who have completely changed to another mode of transport as well as travelers who have altered the weighting (of a particular mode) within their mix of multiple transport modes („mobility-mix"). The survey tried to find out the exact reasons why they decided to do so. Besides the usual so called "hard factors" (time tables, connections, accessibility) also "soft factors" (eco awareness, atmosphere in the vehicles, cleanliness, friendly staff, etc.) were included in the survey. Besides some examples that show the users' opinios in all European countries in general, one region, Varazdin – Medimurje Rail (area), was given here as an example on how a specific region was processed.

Keywords: USEmobility, swing-users, passenger demand survey, eco-friendly, multimodal, intermodal transportation systems

1. Introduction – aims of the survey

USEmobility is an EU funded project that surveyed why people switch from monomodal transportation (car) to eco-friendly multimodal public transport chains. USEmobility stands for Understanding Social behaviour for understanding Eco-friendly multimodal mobility. Main part of the project is a survey done among 10.000 European citizens in six European countries. This paper gives insights to reasons, approach and methodology of that survey. It also brings some results. All results are included in the Deliverable 3.6 document that can be downloaded from (www.usemobility.eu) (Knuth and Krautscheid, 2012).

The survey is solidly anchored in a representative selection of citizens who have changed their preferred mode of transport in the last five years. We call these travellers swing-users. We understand this as including both, people who have completely changed to another mode of transport as well as travellers who have altered the weighting (of a particular mode) within their mix of multiple transport modes ('mobility-mix').

The emphasis of the survey is on so called "soft factors" like socialisation, amenity values of transport, environmental awareness, comfort, cleanliness of the vehicles, etc. That is because many "hard factors" like time tables, network, punctuality and similar have being surveyed many times before.

The survey is very comprehensive. It deals with factors relating to the range of mobility services on offer as well as with factors rooted in the mobility needs and the traveller's personal circumstances. It highlights public transport's potential for attracting new customers and simultaneously examines factors relating to customer retention.

USEmobility surveyed citizens in six European countries to analyse their behavioural patterns when choosing their mode of transport. A representative picture has to be drawn of the findings. The aim of the survey is to discover the individual reasons that exist behind selecting a mode of transport. Particular focus is placed on the reasons that, from the point of view of the survey participant, led them to decide to make more use of an eco-friendly mobility mode, such as public transport. The analysis is set up to reveal the extent of the role played by multimodal travel.

1.1. Survey Approach

From the perspective of users who have already shifted their use of modes, we asked travellers for their main reasons for changing. Participants were additionally asked about detailed reasons for change to find out, which motives are behind the main reasons already stated.

All the travellers who have shifted their use of modes are placed within a USEmobility palette of socio-economic, socio-cultural and psychological characteristics.

The analysis concentrates on the following dimensions: *cause for change*, *direction of change* and the *environment* in which the change took place. What was the situation that led to the change? Was the reason external and did it therefore not primarily have anything to do with mobility issues? Altogether, it is important to factor the user's personal circumstances into the analysis as broadly as possible. From which position did the user change, and where to? The ebb and flow between public transport and motorised personal transport is of particular importance. What mobility choices were on offer when the change was made?

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Once this analysis has been completed, a clear distinction can be made between different circumstances: was it the attractiveness of the new transport mode (pull-in factor) or was it unhappiness with the old transport mode (push-out factor), which primarily influenced the decision? As potential factors for change, the questionnaire did not just list hard, clearly definable parameters such as punctuality and cost, but also 'soft factors' like feeling safe or design issues.

An analysis of the information provided by users made it possible to develop a profile for those users who simultaneously show characteristic behavioural patterns for change and great potential for making increased use of multimodal transport chains. These groups are especially interesting when it comes to making recommendations to policy makers or transport companies.

The USEmobility survey covers issues relevant to transport policy and was carried out in cooperation with six European countries: Germany, Belgium, Netherlands, Austria, Hungary and Croatia. It focuses on the similarities found in Europe but also identifies characteristics distinctive to a specific country. In addition, ten surveys were carried out in ten selected regions, mainly in regions where particularly successful public transport or multimodal transport services had managed to become established (Knuth et al., 2012).

1.2. Scope and Limits of the Survey

USEmobility is following an innovative approach and does not simply rely on the users' stated intentions to make the desired decision on their mobility. To take part in the USEmobility survey, users had to say that they had actually changed their behaviour within the last five years. Depending on the reason for travelling, this was the case for up to 50 percent of those who were initially asked, so that it can be stated that almost half of all travellers can be regarded as swing-users.

The USEmobility team chose a survey methodology that enabled it to reconcile aspects of psychology and sociology, which are hard to grasp, with hard facts. The remarks made by users and other parties in the ten chosen regions with the best public-transport practices were particularly valuable.

Decisive questions guided us through this process: Does the choice of transport mode have a more static and personal character? Was the decision in favour of a new transport mode made suddenly or was the change gradual? The answers to such questions are critical with regard to attracting new customers. Why was the user's role in making the decision to change hitherto not considered? Is it enough to offer a good range of services? Was the importance of soft factors influencing the decision to change previously underestimated? Are there distinct factors for attracting and retaining customers?

Most of the conclusions of the survey are representative of the motivation and behaviour of swing-users. Only a few of the questions were formulated to be representative of all citizens. In contrast with the survey covering a whole country, the regional surveys make no claim to be representative.

Whereas official transport forecasts use transport-performance reference values that make it possible to state the exact market share (modal split) of the different modes of transport, the reference value applied by USEmobility is the change in frequency of use as perceived by users. The survey is not designed to collect data on the exact quantity of transport-kilometres and therefore cannot be used to determine any changes in the modal split.

However, better understanding behavioural change-patterns is a basis for recognising further potential for increasing the modal split of public transport.

2. Region selection

Ten regions were chosen to be investigated. A region can be an area or a line. An area is a geographical area, like a city or a province, and covers all the public transport in that region. A line on the other hand consists of one or more railway lines (Kayser. 2011).

At first, a bulk list of regions in the specific countries (Austria, Belgium, Croatia, Germany, Hungary, Italy, the Netherlands) was created. In theory two regions per country were chosen but after discussion it turned out that in Hungary and in Belgium, it was hard to identify two examples from which good lessons could be learned. Passenger data in **Hungary** is difficult to find and the data that is available has some biases. The counting for passengers per day are not carried out the same day of the year (e.g. Monday versus Friday, rainy day versus sunny day, etc.). Yearly passenger numbers are derived from ticket sales but elderly (65+) and railway employees (both groups travel for free Hungarian trains) and season ticket holders aren’t counted.

In **Belgium** it was hard to find a railway line that is exemplary for the country. Contrary to countries of some other project partners, there is no regional or local influence in railways. Instead of having concessions, all railways are owned by one federal authority, thus flattening out differences between lines or regions. Only regional transport (metro, tram and bus) has regional differences, with TEC in Wallonia, De Lijn in Flanders and STIB/ MIVB in Brussels.

During the project it has been discussed if the regions chosen for the survey reflect a wide range of characteristics of European regions and if there is any need to include additional countries in the survey. Since we found different good examples in regional traffic in Germany, the **German examples** were extended to **three**. We discussed also some regions beyond those in the project (Spain, Italy), and finally included **one region in the Netherlands** (Lewyllie, 2011).

2.1. Including negative examples

In Western Europe car use and congestion are already high and investments in public transport are rising. In Eastern Europe, lagging behind economically, car use is lower and rising. This means it is harder to find swing users moving from car to multimodal travel. In the project description, we said we would also include a negative example, as a mirror for the positive examples. As a consequence of this context, it was logical to look for such an example of rising monomodal transportation in Eastern Europe.

As a negative example, the area of Varazdin-Medjimurje in **Croatia** was selected. Between 2005 and 2009 there was a decline of 15% in passenger numbers on railways. The questionnaire for this region has been adapted in a corresponding way. The outcome of this questionnaire will be an interesting counter-argumentation for the behavioural change from monomodal to multimodal transportation (Lewyllie, 2011).

2.2. Balancing the type of regions

The 10 regions should reflect the European context. There should be a balance between urban, suburban and regional examples, between areas and lines, between countries with high investment and countries with low investment, between countries with a policy towards more public transport and countries were car use is not discouraged… Public transport has a higher success rate and a higher efficiency in urban areas and in highly populated countries but in order to reflect the European context, we also include regional examples and less populated areas.

This shows the importance of the general criteria. If we would choose the regions with only specific criteria, countries with suboptimal public transport would be ruled out and only urban areas would be chosen (Lewyllie, 2011).

2.3. Mixing rural, suburban and urban areas

Because of the difficulties in organizing successful public transport in **rural areas**, these were a **minority of the best practices** in the long list. In Austria, the Pinzgauer Lokalbahn (Zell am See – Krimml) was a good example. Also, the Vinschgaubahn Meran – Mals in Northern Italy was considered.

However, the sample size was too small and they were dropped. In the end the Valleilijn (Amersfoort - Barneveld – Ede - Wageningen) in the Netherlands was chosen.

The Netherlands has the highest population density in Europe, thus making it a good contender for a good sample size and sufficiently large catchment area in a rural region (Lewyllie, 2011).

2.4. Mixing areas and lines

In total, a long list with 30 routes was created, containing one or more railway lines and only 13 areas. In the end though, 6 of the 13 areas were chosen. The reason has been stated: areas benefit from larger catchment areas and higher absolute passenger increases.

In total there were 7 areas (including all the public transport in a region) and 3 lines (with one or more successful lines) in the survey (Lewyllie, 2011).

2.5. High versus low investment

The difference between regions with high investment, contrary to regions with low investment, was mainly achieved by **mixing EU-15 with EU-25 countries**, a mix which is also reflected in the consortium. In Hungary and Croatia, car use is rising and investments in public transport are lower compared to Germany, Austria, the Netherlands and Belgium (Lewyllie, 2011).

3. Methodology – The USEmobility approach

The main objective of the USEmobility survey is to find out: “What factors lead to a **change in behaviour** towards an extended use of environmentally friendly means of transport?” The USEmobility market research places its focus on a change in mobility-behaviour, which already has taken place (ex post-analysis).

USEmobility regards the choice of transport means as an ongoing process, in which valuable insights into future mobility decisions can be drawn from decision processes in the past. USEmobility analyses the participants’ motivation to reconsider and change their use of certain transport alternatives. The core of the USEmobility approach is to identify reasons that have led to an actual change in the individual mobility-mix (complete change or change of intensity). A so-called screener, constructed as initial part of the questionnaire, served to identify persons with a change in their individual mobility mix (so called swing users, see chapter 2.2) in order to identify the target group of USEmobility.

The *primary focus* of the survey is on changes from mono-modal motorised individual transport to multi-modal transportation chains including public transport within the last five years.

The *secondary focus* is on changes away from multi-modal public transport towards mono-modal and / or individual motorized transport. The purpose is to understand why some approaches of public transportation / multimodality are more successful in attracting and keeping users while others are less successful. The study has two main research domains, the country-representative *national surveys* in six European countries including *Austria, Belgium, Croatia, Germany, Hungary* and the *Netherlands*, as well as *case-specific surveys* in ten European regions where substantial changes in the use of public transport have been observed in the last five years. The surveys evaluate a broad range of potential factors leading to a change in mobility behaviour.

They include well researched topics from a structural or technological background (so called ‘hard factors’, having a quantifiable background) as well as new topics that today rarely find their way into common schemes for modelling passenger behaviour. These include factors like socialisation, environmental awareness, amenity values of transport and others (so called ‘soft factors’, having a more qualitative background).The data collection took place in June / July 2011 and in September / October 2011.

The net sample of the national surveys consists of more than 1.000 valid online interviews of swing users per country. A weighting process has secured representativeness on a national level. Altogether 6.357 interviews in six countries form the net data basis of the national USEmobility market analysis. The net sample of the case-specific regional surveys consists of more than 400 valid interviews of swing users per region selected randomly. Altogether 4.075 interviews in ten regions form the net data basis of the regional USEmobility market analysis. In sum 10.432 interviews with swing users form the net data basis of the USEmobility market analysis (Knuth et al., 2012).

3.1. Swing users

The focus of the survey is put on public transport (PUB) and motorised individual transport (MIT). *Bicycle use* and w*alking* are mostly left out of consideration to limit the complexity of the approach.

Swing users, i.e. persons who reported a change in their mobility mix regarding public transport within the last five years are the actual target population of the USEmobility survey. The USEmobility target population consists of both, persons who had a change in their mobility mix towards *increased use of public transport*, as well as those who currently use public transport *less frequently.* Persons who have not changed their mobility mix regarding the use of public transport in the last five years are *not* part of the main-survey.

Therefore, for the rest of the report, swings users shall be citizens that report one of the following two changes for at least one travel purpose within the last five years:

- *PUB+* More frequent use of PUB than before (at least ‘occasionally’ now)
- *PUB–* Less frequent use of PUB than before (less than ‘always’ now)

Sub-populations of special interest are people who have not only increased their use of public transport (“PUB+”), but also have reduced their use of motorized individual transport (“MIT–“).

Similarly people with less use of public transport ("PUB–") and increased use of motorised individual transport ("MIT+") have been analysed, especially those who report a substantial change towards private motorised transport. In short, the national USEmobility survey deals with four types of swing users: Swing users with:

- More public transport or increased mobility in general (1.201 participants),
- More public transport instead of motorized individual transport (1.554 participants),
- Less public transport or decreased mobility in general (1.661 participants),
- More motorized individual transport instead of public transport (1.941 participants).

In contrast to the national survey, the case-specific regional surveys are not sampled from the general public but from the current users of a best-practice public-transport system in the regions.

These surveys therefore predominantly focus on swing users towards public transport, including swing users with:

- More public transport or increased mobility in general (1.915 participants),
- More public transport instead of motorized individual transport (1.621 participants).

Current users of these public transport systems of course also include persons who reduced their share of public transport in the last five years, although to a negligible degree. Exceptions are STIB/MIVB, HZ Varaždin and HZ/ZET Zagreb, where swing users away from public transport form an analysable data basis of participants (71, 139 and 196 interviews respectively). In all other regions, the reasons why users reduced their share of public transport cannot be analysed due to a too limited number of cases. To make the survey comprehensible and focused for the interviewed persons, possible mobility changes were recorded separately in relation to three specific journey purposes:

- On the *Way to / from Work*,
- When *Shopping / Running Errands*,
- For *Leisure Activities*.

Since the survey focuses on persons with a change in their mobility behaviour (swing users), findings can neither be presented regarding persons who have not changed their use of public transport in the last five years or regarding the reasons for keeping their behaviour.

Following the same argument, the survey results do not allow deductions on the behaviour or attitude of *all* public transport users in the countries surveyed, but only for the swing users as defined above.

The surveys in the specific regions are therefore not necessarily representative for all users of the specific means of transport in the countries / regions.

3.2. The USEmobility data

The findings of this report are elaborated on basis of all valid data from the surveys, which forms the *USEmobility data set*. All details on the structure and building process of the data set can be found in deliverable D3.5, including all measures guaranteeing representativeness and data quality.

The answers to all questions included in the USEmobility surveys are laid down in a number of *USEmobility tabulation volumes* (background data). Tabulation volumes exist for each of the USEmobility countries and for each of the USEmobility regions (16 tabulation volumes). Due to their volume, they are not part of this report.

This report contains a great number of *figures*, which are a compilation of key findings of the surveys' data analysis. The figures are interpreted and explained in due detail.

However, in line with possible future requests, further analyses are possible based on the USEmobility tabulation volumes.

If additional explanations are included in the report that do not concern the figures themselves but are based on data from the tabulation volumes, this is indicated by the phrase **"The USEmobility data shows ... "** These additional explanations are included, when the key findings have suggested that a supplementary query would deliver valuable insights. The USEmobility data set provides an excellent extended information base for further research into questions of USEmobility.

3.3. "Top 2 boxes" and "bottom 2 boxes"

In the USEmobility survey, for many questions possible answers had the form of a *scale,* for example:

- 'never', 'rarely', 'occasionally', 'frequently', and 'always'
- 'absolute no influence', 'little influence', 'moderate influence', 'strong influence' and
- 'decisive influence'

Scales are usually ordered by frequency of occurrence, degree of influence, degree of satisfaction etc.

Regarding the answers to questions using such scales, those interviewees are of special interest who show a distinctive position, either 'important' or 'not important' and not just 'somewhat important'.

Therefore, the upper and lower ends of the scales are put into focus. They are grouped for the further analysis. The two groups that are used are:

- **Bottom-2 Boxes** Into the Bottom-2 Boxes all those answers are grouped that fall into the first two modes of a scale, e.g. 'absolute no or little influence'.
- **Top-2 Boxes** Into the Top-2 Boxes all those answers are grouped that fall into the last two modes of a scale, e.g. 'strong or decisive influence'.

The distribution of answers on Top-2 and Bottom-2 Boxes give a good indication in which direction the majority of the answers tend. In many figures of the following chapters, you find analyses based on the percentage that Top-2 or Bottom-2 Boxes have in the total sample. They tell you much about the importance of both ends of the scale.

3.4. List of abbreviations

MIT Motorized Individual Transport
MIT+ Increase in MIT
MIT– Decrease in MIT
MoT Mode of Transport
PUB Public Transport
PUB+ Increase in PUB
PUB– Decrease in PUB

4. Several examples from the survey

Here are the several examples from the survey which show main reasons why citizens change their mobility behaviour and some basic thoughts that European citizens have on public and individual transport.

4.1. Main types of reasons for the changes in mobility

The decision in favour or against a certain means of transport is complex. Usually you come to a decision in a number of steps. Reasons for the first-time usage of a transport system and reasons for continuously using (and not abandoning) it are rarely the same. Single-cause explanations for mobility decisions rarely correspond with the users' decision patterns.

The USEmobility approach therefore groups the main influencing factors for a mobility decision into three major categories:

- REASON 1: Changes in the Personal / Private Situation e.g. change of job, relocation to another city etc. (Personal Factor)
- REASON 2: Attractiveness of the means of transport used more frequently now (Pull-In Factor)
- REASON 3: Dissatisfaction with the means of transport used less frequently / no longer used now (Push-Out Factor)

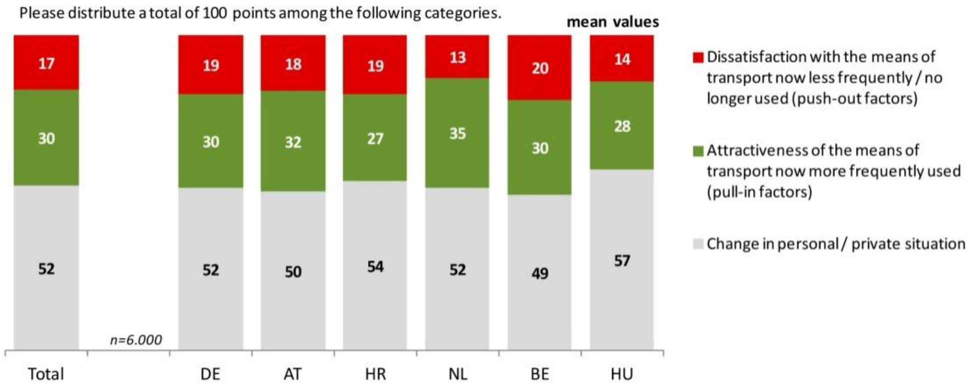


Fig. 1.
Main influencing factors for the swing users change of transport means by country.

The main influencing factors to trigger a change in the choice of means of transport in the USEmobility area are changes in the personal / private situation (Fig. 1). Swing users were asked to distribute a total of 100 points on the three main influencing factors stated above according to relevance. On average, swing users gave a relevance of more than 50 points (%) to the personal / private situation.

Following second with on average 30% relevance is the attractiveness of the means of transport used more frequently now. With 18% relevance, the dissatisfaction with the means of transport used more in the past is the least important of the three main influencing factors. In most cases there are several factors in combination that are relevant for a change in behavior of swing users.

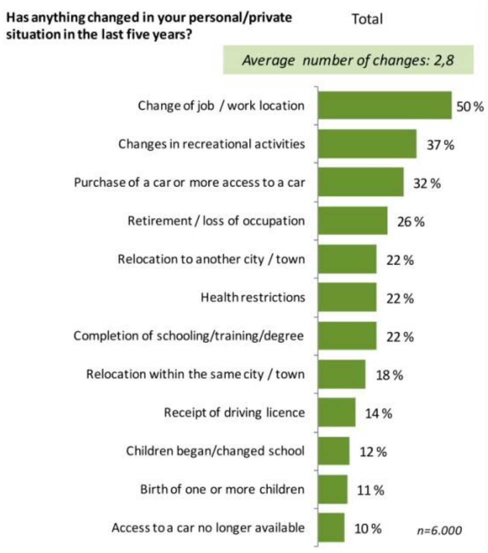
The USEmobility data shows that only about 20% of the swing users base their decision on more or less only one of the main influencing factors, (i.e. give a rating of 90 to 100 for one category only). The dominant single-cause here is clearly with 15% relevance the change in personal / private situation.

Merely 5% of the swing users were predominantly influenced (i.e. give a rating of 90 to 100) by the attractiveness or dissatisfaction. In all six countries, we see a similar pattern of relevance among the three main influencing factors, although with small differences.

In Hungary, the decision is to a higher degree influenced by the personal situation than in the other countries. In the Netherlands, attractiveness has a higher relevance and dissatisfaction is rather unimportant.

4.2. Changes in personal/private situation

Changes in the private / personal situation (Fig. 2) are the most important trigger for a change in theindividual mobility mix. The USEmobility data shows that 90% of the swing users had at least one mobility relevant change in their personal situation in the last five years! On average, every swing user had 2.8 changes. In Hungary, the swing users reported the most changes (3.0), in Belgium the least (2.4).



	DE	AT	HR	NL	BE	HU
Average number of changes	*2,8*	*2,9*	*2,7*	*2,7*	*2,4*	*3,0*
Change of job / work location	49%	53%	43%	49%	45%	63%
Changes in recreational activities	42%	38%	40%	33%	32%	36%
Purchase of a car or more access to a car	32%	37%	31%	32%	29%	29%
Retirement / loss of occupation	22%	25%	21%	26%	28%	34%
Relocation to another city / town	24%	28%	17%	19%	22%	19%
Health restrictions	26%	21%	17%	26%	17%	23%
Completion of schooling/training/degree	22%	20%	29%	20%	17%	22%
Relocation within the same city / town	21%	19%	17%	20%	14%	19%
Receipt of driving licence	15%	15%	17%	14%	12%	14%
Children began/changed school	9%	10%	14%	10%	12%	17%
Birth of one or more children	7%	11%	13%	10%	9%	14%
Access to a car no longer available	12%	10%	12%	7%	8%	12%

Fig. 2.
Changes in private/personal situation by country.

The change of job and / or work location is the most common change in the personal situation of the swing users. Half of the swing-users in the USEmobility area are affected by this type of change, in Hungary even 63%.

Other frequent reasons for change are recreational activities and hobbies (37% of all changes). 32% have purchased a car or have more access to a car. On the other hand, only 10% of the swing users have lost access to their car within the last five years.

Relocations within the same city / town or to another town have been performed altogether by about 40% of the swing users.

The occurrence of changes in the personal / private situation of swing-users produces situations in which a change of the individual mobility mix might become an option. However, it does not necessarily mean that there is no other choice than to change the mobility mix. This depends heavily on the intensity of the influence that the personal change has on the mobility decisions.

4.3. Current evaluation of the primary factors of public transport by country

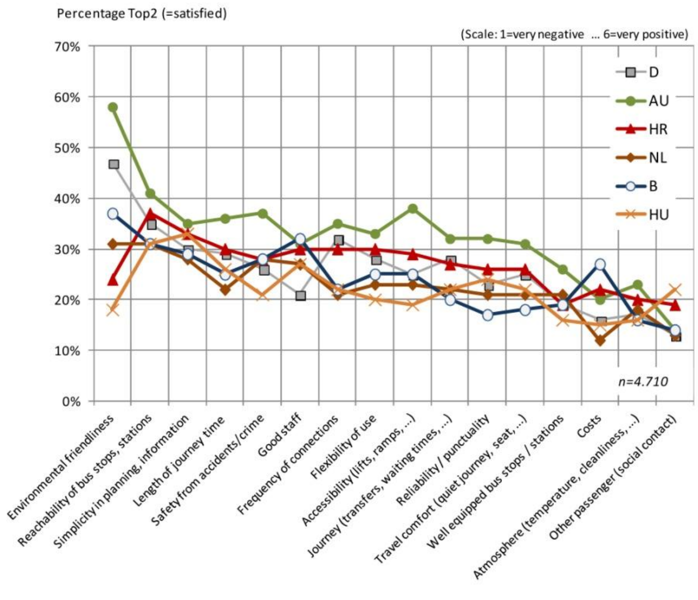


Fig. 3.
Current evaluation of the primary factors of public transport by country

Fig. 3 gives a comparison of the country results. Among all the primary factors of PUB *environmental friendliness* gets the highest ratings in the categories 'satisfied' and 'very satisfied'. However, considerable differences between the countries can be seen. While the environmental friendliness of public transport is rated very well in Austria and Germany, the swing users in Croatia and Hungary are only partially satisfied with the achieved environmental friendliness of the public transport system. Regarding all primary factors, the factors *reachability* and *simplicity of planning* also gather high ratings.

It is possible to see that the lowest ratings for the factors *costs*, *atmosphere* and *other passengers (social contact)*. Regarding costs, especially the swing users in the Netherlands are sceptical. In Belgium, on the other hand, costs are evaluated rather positively. Of all users, Austrian users are the most satisfied with their public transport services. Concerning the primary factors, the public transport in Austria clearly reaches the best ratings.

5. Region E Varaždin-Međimurje (Varaždin Međimurje Rail – VM Rail)

Here are the several examples from the survey from one of the ten surveyed regions. It is the region Varaždin – Međimurje which was conducted mostly on railway stations, on the trains and in tows of Varaždin and Čakovec (center of Međimurje region).

5.1. Monomodality/Multimodality

To start the analysis of the regional data, USEmobility looked at the current use of means-of-transport of the HZ Varaždin-Međimurje Rail (VM-Rail). These swing users, who have changed their mobility mix regarding public transport within the last five years, have access to different means of transport, private and public.

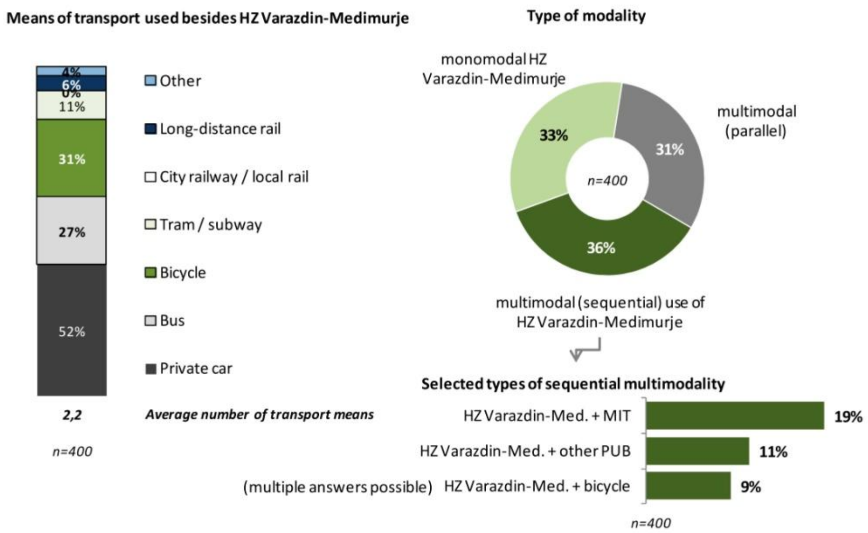


Fig. 4.
Multimodality / Monomodality of VM-Rail swing users

The most frequent means-of transport used by VM Rail swing users besides the VM local rail are private car (52%), bus (27%) and bicycle (31%). VM Rail swing users (Fig. 4) show a moderate percentage of 36% sequentially multimodal use, i.e. multimodal combinations including VM Rail during the journey from the starting point to destination. The most common combination with 19% is VM Rail with motorized individual transport (MIT, 19%). Other typical combinations of the VM Rail include other public transport (PUB, 11%) and bicycle (9%).

5.2. Information behavior and influence

USEmobility looked at possible sources including own experience and information about transport services from other sources that might have informed or motivated swing users to change their mobility mix and compared them to swing users in the whole country (Fig. 5).

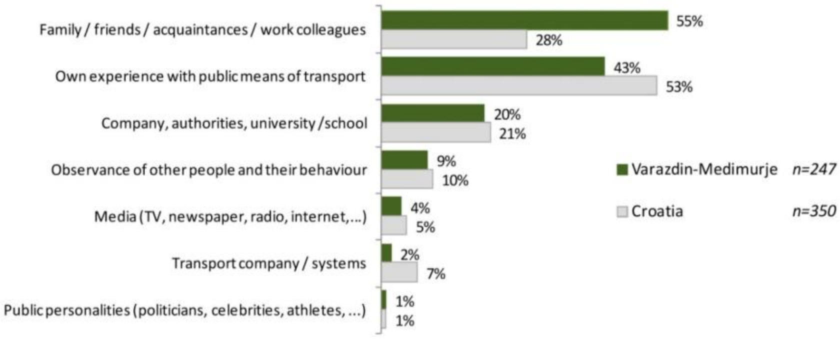


Fig. 5.
Sources of information/motivation to use HZ Varaždin-Međimurje Rail

In contrast to most of the other USEmobility regions, personal contacts like *family*, *friends*, *acquaintances* and *work colleagues* are the leading source of information for the decision to increase use of VM Rail. It plays with 55% a considerably stronger role than on average in Croatia (28%). There is a remarkable is the high influence of companies, authorities and universities / schools (20%).

Information directly from the VM transport company was influential only for 2% of the VM swing users.
Some of the data here are not surprising, especially when it comes to the influence of the transport companies since they practically never had any campaigns that promotes local transportation. However, since the transportation of the pupils and students to schools and universities is an important issue in daily life of many families, it is possible to assume that many students and pupils got much useful information about public transport in schools and universities.

5.3. Changes in Personal/Private situation

Since the changes in the personal / private situation play such an important role in the reason mix, we now look at them in more detail (Fig. 6).

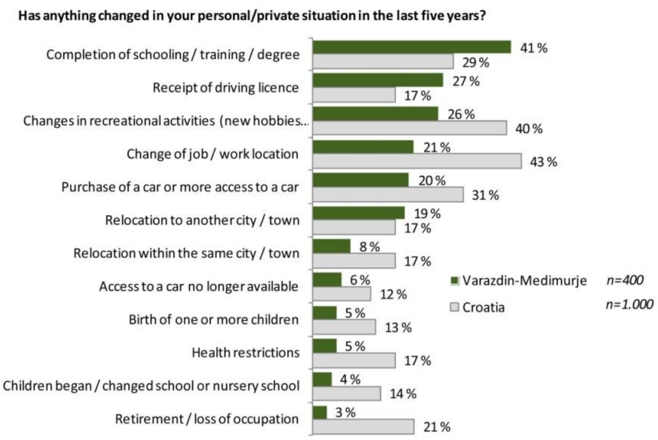


Fig. 6.
Changes in the personal situation of VM-Rail swing users

The personal/private changes of the VM swing users suggest a younger user structure. More than 40% of the VM Rail swing users have completed their schooling or training or have received a degree in the last five years. This is far above the Croatian average among swing users of 29%. Many of the VM swing users have received a driving license (27%, compared to 17% in total Croatia) or have more access to a car (20%). Further decisive changes in the VM area are changes in recreational activities (26%) and a change of job (20%), both on a much lower level as in total Croatia (40-43%).

In comparison to the Croatian Swing users, several types of personal change are rarer especially changes in an older life-phase: *retirement, loss of occupation* and *health restrictions*. Even more than the occurrence, the importance of these types of change has to be analysed. Types of change that have a high leverage on the decision to use more public transport, combine high occurrence and high importance for the decision to change (see Fig. 7).

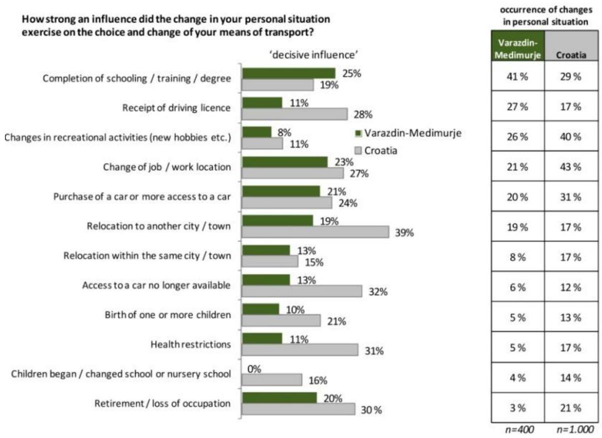


Fig. 7.
Importance of certain changes in the personal situation on the decision to use HZ Varaždin-Međimurje rail

The general influence-level of changes in the personal / private situation is regarded considerably lower by VM swing users than by the average Croatian swing user. The highest influence on the decision to change has a

- Completion of schooling or training (25% decisive influence) and / or
- Change in the job / work location (23% decisive influence)

In comparison with their Croatian counterparts, both factors have a more decisive influence among VM Rail users. The *completion of schooling* has a medium influence and a high occurrence (41%). The *change in the work location* has a high influence and an average occurrence (20%). Both factors therefore have an above average leverage.

6. Conclusion

The approach used by the USEmobility project was groundbreaking. None of the previous research into personal mobility was focused on swing users with the aim of better understand their motivation and to gain useful insights for developing mobility in the future. Although the modal split has hardly changed for years, the USEmobility survey has shown that behind the apparent lack of movement there is considerable dynamism, with fluctuations both towards and away from public transport. The second important insight is that people are afforded a multitude of opportunities for rethinking their choices, and that these often go hand-in-hand with changes in their life circumstance. Above all, changing place of work leads to people questioning their usual mobility behavioral patterns.

Since it can be assumed that there is a general desire for mobility to become increasingly eco-friendly in the future, the opportunity now presents itself to take more notice of users' needs. For the stakeholders who are involved in this project, USEmobility will develop strategic recommendations. These are, on the one hand, the politicians who on a national and local level set the policy framework for sustainable transport. They also include the European Commission, the contracting authority for this project, which wants to develop European transport policy to ensure that citizens' mobility is both environmentally friendly and sustainable in the future. Additionally, the recommendations are also directed at providers of transport services, who can attract new customers with made-to-measure offers. Particularly in metropolitan regions there is considerable potential for public transport, which can use a user-oriented approach incorporating decisive hard and soft factors to attract and retain customers (Knuth et al., 2012).

References

Knuth, K.; Krautscheid, T. 2012. *Deliverable D3.6, Factors influencing behavioural change towards eco-friendly multimodal mobility*, USEmobility project. 240 p.

Kayser, G. et al. 2011. *Deliverable D2.1, State-of-the-art assessment*, USEmobility project. 81 p.

Lewyllie, S. et al. 2011. *Deliverable D2.3, Selection of 10 regions to be investigated*, USEmobility project. 32 p.

ON TERRITORIAL CAPITAL AND GEOGRAPHICAL AND TRAFFIC POSITION OF SERBIA IN THE SPATIAL PLAN OF THE REPUBLIC OF SERBIA 2010-2014-2020 (2010): A CRITICAL REVIEW

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Abstract: The utilization of territorial capital has been a relatively new thematic issue in European spatial planning, also treated in Serbia only as from very recently. The *Spatial Plan of the Republic of Serbia 2010-2014-2020*, adopted in 2010, represented an attempt of the kind, i.e., to address this theme in a strategic document at the state (national) level, paralleling few regional plans also comprising this issue in a more significant way. Apart from dealing with the geographical and traffic position of Serbia, some other aspects of overall territorial capital of Serbia have also been taken into account. However, the aproach and defined concept have been applied rather rudimentary and insufficiently, especially vis-à-vis implementation of the *Plan* and concomitant institutional and organisational support, either at the state (national) or at the regional governance levels.

Keywords: Spatial Plan of the Republic of Serbia; territorial capital; geographical and traffic position of Serbia; regional governance; institutional and organisation arrangements; the renewal of strategic research, thinking and governance

1. Introduction

Over the time period of more than 20 years, there has been a collapse of strategic thinking, research and governance in Serbia. After the political change in October 2000, transition reforms were directed in accord with the *Washington Consensus*, imbued with neoliberal ideological and political *dicta*. As a result, the country recorded the period of "growth without development"[2] (Vujošević, 2010), dynamic though, which however ended in 2008, with the bursting out of global and national economic and financial crisis. After that, GDP was growing at considerably lower annual rates, to denote a growth and development stagnation, or even retrogression. Until the mid 2010s, an anti-growth and anti-developmental stance dominated among the elites ("architects of post-socialist transition reforms"), to be followed by a flux of development documents (strategies, plans, policies, etc.) in recent years. Now, there has been several hundred of the kind in Serbia, at various governance levels (national, regional, and local/municipal). However, they have all not sufficed to work out an effective "exit strategy" for both the current and the predictably prolonged crisis, thereby indicating a particular "developmental schizophrenia" (Vujošević, 2010). Serbia belongs to the group of least developed European countries, and so far it has not worked out the necessary policies and instruments to cope with the key developmental problems. In more spatio-developmental terms, is has been ever more mooring in the so-called "inner peripheries of Europe" (Göler, 2005), now the country hardly surviving as a financial, economic, political and environmental semi-colony of few most influential international actors (''a part of the Archipelago of Balkan banana states'', as put in M. Lazanski, commentator of the daily *Politika*, October 2010), with primitive forms of consumerism spreading and dominating the public scene, stimulated by the government and key economic actors (Vujošević, 2010).

Serbia's comparative advantages and competitiveness have worsened in some key aspects, whereby Serbia's "endogenous capital" and competitiveness lost a large part of their previous value and potential. 'Especially has worsened the so-called "soft territorial capital", together with the weakening capacity for strategic research, thinking and governance.' (Vujošević, Zeković, Maričić, 2012, forthcoming).

2. Approach and method

As relating to spatial strategic development, there were two attempts to redirect the dominant development path, in 1996 and in 2010, when appropriate national spatial plans were elaborated and adopted.[3] While the former had not been implemented, for reasons that will be briefly commented in the sequel, it is still to be seen whether the latter will develop instruments that are needed for its effective implementation.

The analysis is based on a comprehensive development framework approach, in its essence comparative, by means of which geographical and traffic position of Serbia has been examined. This and related issues are discussed in this contribution, focusing, first, on the specific issue of the utilization of the so-called "territorial capital" of Serbia, and second, on the similarities and differences between two attempts in question, in terms of the development substance addressed by two plans and the impact of some contextual factors ("timing"), respectively. In the concluding part, few comments are put forth with regard to the predictable development future of Serbia vis-à-vis available policies and instruments for successful steering of its development.

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[2] This trend was pointed to as early as at the beginning of the past decade (e.g., Vujošević, 2003a), but it did not attracted more attention in professional and political circles.

[3] Here, only specific issue of two *Plans* (i.e., territorial capital and some directly related aspects) is discussed. For a more detailed discussion on integral two *Plans*, see Vujošević, Maričić, 2012).

2.1. Results and discussion

2.1.1. The Spatial Plan of the Republic of Serbia (1996)

Plan (1996; 1997, Abridged version) started from the assumption that Serbia – being a Danube River Basin state, occupying the middle part of the Danube flow (a), a Balkan state, located in the centre of the Balkan Peninsula (b), and a Southern European State, in the immediate vicinity of the Mediterranean Sea (c), i.e., a land-locked country, albeit than still a part of the Federal Republic of Yugoslavia, with Montenegro – has and ''advantageous geographic-communications position'' (p. 6). This makes possible ''the intensification of links with the countries of Central and Western Europe and the countries of Southern and Eastern Europe, and promoting and developing transit and mediator functions between Europe and Asia'', by ''rationally and efficiently developing its spatiat-functional position'' (*ibidem*). Here, of the prime significance is the metropolitan area-corridor Novi Sad-Belgrade-Pančevo-Smederevo, with its concentration and agglomeration of production, service and other activities. This area, relatively small in terms of its size, has been generating a number of polarizing effects on Serbia's overall space (*ibidem*). Starting from this point, in the sequel a number of ''basic reference points of the Plan'' have been formulated (9-11), followed by a number of general goals of utilization of space (11). Very ambitious strategic development schemes were outlined regarding all transport and communications networks (roads, waterways, integral transport network and centres, air transport, railroad transport and telecommunication systems), all supportive to strategic goals and commitments, especially regarding the geographical position of Serbia on the European Corridors. As for the basic reference points and strategic commitments (here: only those relating to its geographic-traffic position), at least two were formulated, which are of relevance for our discussion here, viz.: 1) A higher degree of functional integration of Serbia, paralleled with improving economic and communication links with neighbouring and other European countries, particularly, inter alia, via the Belgrade-Bar railroad line and road corridor (and the port of Bar in Montenegro), and by utilizing the routes towards Thessaloniki. 2) Decreasing/lessening regional disproportions (dis-balances), in the first place by decereasing the concentration of population and activites in the Danube-Sava river belt and the Morava zone through the principe of polycentric development.[4]

As for strategic goals, some ten were formulated, also encomassing the following: 1) Rational utilization of space, in accord with natural and man-made values anddevelopment potentials. 2) More balanced distribution of the population and activities, in the first place by decelerating concentration in the densest populated ares.

Four synthetic ("referal") maps (S 1:300,000) were outlined. Map No. II defines settlement centres and regional organization of space, and defines a number of development axes/corridors, grouped into three categories, of I, II and third priority. The I priority corridors go to the European Corridors VII and X in Serbia (with minor modifications) (90-91).

In the final part of the *Plan* a very ambitious implementation scheme was developed, with the intention to have it further worked out in the mid-term implementation programe for the 1996-2000 time period („Phased implementation of the Plan", p. 58, with the intention to ''...coordinate the key long/term propositions of the Plan with the socio-economic policy for the medium-term period"), consisting of a large number of stipulations on various issues.

Despite this, the *Plan* of 1996 has been implemented only partially[5] It should be emphasized here that the then intention was to work out a strategic document to act as "more than a spatial/physical plan"),[6] i.e., to define a common strategic for coordinating and integration all geneal and specific (sector) policies with spatial implications and consequences, thereby preceding much later European planning discourse on these theme (cf. Vujošević, Petovar, 2010). In effects, Serbia was the first of all ex-communist (socialist) countries with the adopted national spatial plan.[7]

2.1.2. The Spatial Plan of the Republic of Serbia (2010)

The national spatial plan from 2010[8] has replicated the ambitions, approach and structure of the former *Plan* (1996). As did the *Plan* from 1996, it has also demonstrated an ambition to be "more than a mere spatial plan" at the national level, thereby introducing a number of measures and instruments targeted at broader reform of systems, approaches and practices in the sphere of sustainable spatial planning and governance.

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[4] Also, a number of other strategic commitments were defined, relating to the issues of: urban system; rural areas and settlements development; development and investmenrts in specific economic zones (with considerable potentials); development of hill, mountain and border areas; system of public service centres, especially via the so-called "functional areas"; protection and rational use of natural resources and cultural heritage; etc. All this, with some modifications, has been replicated in the *Plan* from 2010.

[5] For more detailed discussion see Vujošević, 2008.

[6] This had initially been worked out as early at the beginning of 1990s, when analogous strategic spatial document, i.e., *Просторни план СР Србије (Нацрт Плана)/Spatial Plan of SR of Serbia (Draft)*, was prepared and discussed within the government circles and in the expert arena, but subsequently suspended with the coming political miss-events.

[7] The *Plan*, an eminently peace-minded document, was presented by Miodrag Vujošević at the preparatory Conference on the European Spatial Development Perspective in Vienna (25-26 November 1998). It ultimately happened that les than 6 later the NATO undertook bombardment of FRJ.

[8] Similarly to the *Plan* from 1996, this *Plan* has also been adopted by special act. The Plan was preceded by national spatial development strategy.

The *Plan* of 2010 consists of the following parts (structure): Part I Assessment of the current situation, visions, goals (aims) and conception of spatial development of the Republic of Serbia: 1) Surroundings and general assessement of spatial development of Serbia (territory of the Republic of Serbia in broader European surroundings; and general assessment of the current conditions. 2) Vision, principles and goals (aims) of spatial development (vision of spatial development of the Republic of Serbia; general principles of spatial development of the Republic of Serbia; key goals; and operative goals). 3) Spatial development scenarios and conception (spatial development scenarios; and conception of spatial development of the Republic of Serbia, viz. social coherency, ecological connectedness, spatial order and sustainability, economic and regional interactivity, conceptual framework and the utilization of territorial capital of the Republic of Serbia and its regions, and institutional responsibility). 4) Regional development (decentralization and regional dvelopment) – regional organisation of Serbia; functional and economic regions and areas; and special development problems areas. Part II Spatial development of of the Republic of Serbia 2010-2014-2020: 1) Nature, ecological development and protection (natural resources, by sectors; environmental protection; and biodiversity, landscape, natural and cultural heritage). 2) Population, settlements and social development (demographic development; polycentric urban system; sustainable urban development; sustainable rural development, and social development and social cohesion). 3) Sustainable economic, transportation and infrastructure development (economy; sustainable transport, networks and objects; sustainable technical infrastructure; and land utilization and land policy). 4) **S**patial integration of the Republic of Serbia. Part III Towards the Plan implementation.

Even more than the former *Plan* (1996), the new *Plan* (2010) insists on adequate implementation of key sustainable spatial development propositions, also by realizing the Program of implementation (2011), elaborated and adopted one year after the *Plan* itself. There has also been some difference among the two.[9] Particularly, the new *Plan* devoted more space to novel categories from the current European planning discourse (e.g. "territorial cohesion", "social inclusion", "urban-rural cooperation", ''spatial banana'' (here: ''Serbian spatial banana'', that is, the broader metropolitan area of Belgrade and Novi Sad), ''social inclusion'', ''territorial capital'' (here: of Serbia), ''European gateway cities'', '' knowledge based economy and society'', ''the role of European Corridors'' (here: particularly VII and X), ''urban-rural cooperation'', ''territorial-regional decentralization'', ''spatial integration of the territory of Serbia'', and so forth.

The new *Plan* (2010) has paid more attention to spatial development scenarios than the *Plan* of 1996 (at least nominally).

Without any more detailed and substantiated corroboration (and analysis of the respective pros and cons either), two basic scenarios have been defined (31-32), i.e., ''scenario of recessive growth with the elements of crisis management'' (''predictably not to last more than 3-4 years''), and ''scenario of sustainable spatial development'', to emulate the above defined vision and subsumed key strategic goals in the sectors comprised by the *Plan*. Within the latter, a number of reform steps have been stipulated with regard to the following ''frameworks'': legal and institutional; market, economic and development; macro economic; demographic; social; ecological; and spatial-urban. Starting from different assumptions regarding the pace of intensity of the integration of Serbia into the EU, this scenario contemplates four specific sub-scenarios (''variants''), viz.: 1) ''negative economic growth and disintegrated spatial system''; 2) ''negative economic growth and integrated and partially regulated spatial system''; 3) ''positive economic growth and disintegrated and partially regulated spatial system''; and 4) ''positive economic growth and integrated spatial system''.

The skeleton of economic and regional interactivity (45-8) are based on development potentials and specific characteristics of seven macro regions, as well as on a number of development axes (corridors). As for macro regions, they are: Autonomous Province of Vojvodina; broader area of the City of Belgrade; Central Serbia; Eastern Serbia; Western Serbia; Southern Serbia; and the Autonomous Province Kosovo and Metohija. Key development corridors are: Danubian corridor; Moravian corridor (along the river of Velika Morava and the river Zapadna (Western) Morava; development belts (zones) of the river Tisa, and traffic corridor (direction) Belgrade-Požega-South Adriatic Coast. Key role has been stipulated for a number of urban centres and other settlements of priority for spatial and economic development of Serbia, especially of centres of medium size. They all form the strategic basis for the utilization of the „hard territorial capital" of Serbia. Particular attention was paid to the balanced development of broaderBelgrad-Novi Sad metropolitan area vs. development of other parts of Serbia, especially of those areas that have been lagging behind the average rate of development and/or are defined as of priority for reactivating of the least developed parts of Serbia (49).

[9] For more detailed discussion of this issue, cf. Vujošević, Maričić (2012), Vujošević, Zeković, Maričić, (2012, forthcoming), and Vujošević (2010). Discussion in this contribution is based on the document Просторни план Републике Србије 2010-2014-2020, which was worked out after the adoption of the *Plan*, as well as on its abridged version.

The part on the conceptual framework and utilization of territorial capital of the Republic of Serbia and its regions (48-9) contains a number of pertinent elements. The key strategic aim, veritably of the utmost relevance, has been defined as (48) „renewal of strategic thinking, research and governance in the Republic of Serbia“, that should be based on a number of principles („key postulates’’), viz.: introducing spatial dimension in all general and sector development policies; striking a balance between economic, social and territorial cohesion; definining republic spatial strategic framework for key development documents at al sub-national governance levels, working out better ways of coordination, with a view to reach more balanced territorial (regional) distribution of population and activities; the neccessity to realize a „shift from government to governance’’ in strategic governace, to assume the role of supreme principle; priority protection of public space, and parallel prevention of its appropriation for private purposes without appropriate compensantion; lessening social exclusion in the appropriation of public space; achieving better input-output reation in production, services; diminishing environmental polution vis-á-vis economic production performance; etc. In this context, and another issue, which is also of relevance here, has been pointed to, viz. „institutional responsibility“, also ambitiously explicated via more constituent elements (49).

While the notion of “territorial capital” was not explicitly mentioned in the *Plan* of 1996, in the new *Plan* it was given a relatively detailed account, as well as it was prior to that, i.e., in the *Strategy* of 2009. In the Glossary of Plan of 2010 (p. 276), the notion “territorial capital’’ was defined in the following way: “…a sum of all developmental factors (resources, potentials, etc.) of certain area. Composed of “hard’’ factors – elements, viz.: geographical, i.e. geostrategic position; climate; size of territory; size of population; abundance of natural resources; quality of life; environmental quality; technical infrastructure and its accessibility; cultural heritage; and human resources, and “soft” factors elements: knowledge, cultural and institutional capital; capacity for innovation; social capital (in a narrower sense); attitudes and habits of individuals, groups and institutions and organizations; informal rules of regional relevance and the capacity and readiness of actors for mutual cooperation, help, participation and reaching of compromise.” In sum, we are adding here, Serbia has been lagging behind the more developed countries in that respect, in the first place as a result of the fact that neither „a shift from government to governance“, taking place in many European and some other more developed countries, has so far not happend in Serbia, nor a shift from more participative and democratic forms of decision-making in planning and other spheres of societal governance. Particularaly weak are almost all elements of the “soft territorial capital“, including overall institutional and organisational adjustmenst for strategic thinking, research and governance, as well as relatively poor planning culture, reflecting mere fact that this notion was then rarely discussed in the professional discourse.

The mid-term *Program* for the implementation of the *Plan* for the time period 2010-2020 was adopted in 2011.[10] In accord with the intention to serve as a common strategic framework for other general and sector policies (with spatio-ecological implications and consequences), in the part of the *Plan* on implementation („Ka ostvarenju Plana’’, 247-66), ih has been emphasized that (249): „Planned elaboration of this spatial plan will be undertaken: directly, via strategic development planning documents...i.e., regional spatial plans and spatial plans for specific areas; and indirectly, via the elaboration of development and regulatory planning documents for which local planning authorities are responsible, i.e., local spatial and urban plans.

3. Conclusion

Having experienced the misfortunes of the implementation of the *Plan* from 1996, similar worries remain regarding the *Plan* from 2010: will it be possible, and how, to reverse the existing institutional and organizational solutions and practices in planning, in order to implement at least the majority of strategic aims from this leading strategic document, on the one hand, and thereby to support the renewal of strategic research, thinking and governance in Serbia, on the other? Almost all key strategic aims of spatial development end environmental protection from the former *Plan* were replicated in the latter, as well as in many other strategic documents over the period of two or threee decades, particularly pertaining to regional and related development, and almost not a single of strategic relevace has been implemented. Appropriate lessons have not been learned from the evident collapes of traditional development policies, mechanisms and instruments, of general and sectoral nature, also paralleled, some times, by a lack of effective political will to implement particular strategic document. The current situation in Serbia is even more complex that it was during the preparation and adoption of the *Plan* from 1996: the foreign debt has in the meantime grown tremendously; problems in the public finances have also been complicated, thereby altogether considerably narrowing the maneuvering space of public authorities at all governance levels for development interventions, and especially for undertaking more complex regional (spatial) redistribution of resources for development; and, following the current crisis, chances for engaging more ambitious sum of FDI for directing them in spatial development have also diminished.

[10] Starting from three key dimensions of development of Serbia (i.e., ecological/physical, social and economic), the Program contains, inter alia: elaboration of some 300 priorities hat have been defined by the Plan untill the year 2014; detailed description of over 100 indicators for the monitoring and reporting on the Plan implementation; priority projects in the sphere of spatial organization (with dynamic plan, financial aspects, responsible actors, indicators for monitoring, etc.); etc.

Especially, the conceptors of the *Plan* from 2010 and its implementation *Program* seem to have failed to ackowledge that traditional development instruments are of almost no use any more, especially for the predictably long period of "Europeanization of Serbia outside the European Union and with its limited assistance", paralleling global and national economic and financial crisis and bleaks development prospects of the country.[11] The realization of *Plan* necessitates enormous sum of financial and other resources, which, simply, will not be at disposal in foresseable time period to come. Finaly, the negative impact of poor planning culture (a lack of a more emancipatory-modernising planning model) seems also to have been neglected, as well as some other part of the „soft territorial capital" of Serbia.

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References

Giffinger, R. 2009. Territorial capital: Meannig for urban and regional development. In *Proceedings Regional development, spatial planning and strategic governance, International Scientific Conference,* Institute of Architecture and Urban&Spatial Planning of Serbia, Belgrade.

Göler, D. 2005. South-East Europe as European Periphery? Empirical and Theoretical Aspects', in: *Serbia and Modern Processes in Europe and the World,* Faculty of Geography, University of Belgrade, Belgrade: 137-142.

Republička agencija za prostorno planiranje. 2011. *Program implementacije Prostornog plana Republike Srbije od 2010. do 2020. godine za period od 2011. do 2015. Godine /Implementation Program for 2011- 2015*. Belgrade.

Ministarstvo životne sredine i prostornog planiranja, Republička agencija za prostorno planiranje. 2010. *Prostorni plan Republike Srbije 2010-2014-2021 (Nacrt), Skraćena versija/Spatial Plan of the Republic of Serbia, Draft, Abridged version.* Belgrade.

Prostorni plan Republike Srbije/Spatial Plan of the Republic of Serbia. 1996. Službeni glasnik, Beograd.

Petovar, K.; Vujošević, M. 1997. *Spatial Plan of the Republic of Serbia* (Abridged version, based on the integral version of the Spatial Plan). Ministry of Science and Technology and Institute of Architecture and Town Planning of Serbia, Belgrade.

Ministarstvo životne sredine i prostornog planiranja. 2009. *Strategija prostornog razvoja Republike Srbije 2009-2013-2020/Spatial Development Strategy of the Republic of Serbia*. Republička agencija za prostorno planiranje, Belgrade.

Vujošević, M. 2010. Collapse of strategic thinking, research and governance in Serbia and possible role of the Spatial Plan of the Republic of Serbia (2010) in its renewal, *Spatium,* 2/2010: 22-29.

Vujošević, M. 2008. Implementacija *Prostornog plana Republike Srbije* (1996): iskustva i pouke za pripremanje *Strategije prostornog razvoja Republike Srbije,* Institut za arhitekturu i urbanizam Srbije, Beograd.

Vujošević, M. 2003a. Tranzicija bez rasta i razvoja? Još jednom o novoj planskoj heuristici i usklađivanju razvojnih politika/Transition without growth and development? Once more on new planning heuristics and adjustment of development policies', u/in S. Stanković, D. Filipović i V. Šećerov (ur.), *Planska i normativna zaštita prostora i životne sredine/Planning and Normativa Protection of Space and Environment*. Geografski fakultet, Beograd: 129-146.

Vujošević, M. 2003b. *Planiranje u postsocijalističkoj političkoj i ekonomskoj tranziciji/Planning in the Post-socialist Political and Economic Transition,* Institut za arhitekturu i urbanizam Srbije, Beograd.

Vujošević, M.; Maričić, T. 2012. The Conundrum of a State Spatial Plan Implementation: The Spatial Plan of the Republic of Serbia (2010), *AESOP 25th Annual Congress, Ankara.*

[11] Serbian rulers seem to have not acknowledged either the flaws in the existing institutional and organizational arrangements for strategic governance or the burden of current miserable development conditions, or even predictably worse development prospects of the country in the next 10 to 15 years, as they envisaged the following ''long term vision of the spatial development of Serbia'': ''…Serbia…defined in territorial terms, balanced in regional terms, comprising sustainable and competitive economic growth, socially coherent and stable, equipped in infrastructural terms of good transport accessibility, with conserved/preserved and protected natural and cultural heritage, and environment of high quality, and integrated in functional terms in the broader regional environment.''

Vujošević, M.; Petovar, K. 2010. Evropski planski diskurs i obnavljanje evropskog prostornog planiranja održivog razvoja: nekoliko pouka za jednu zemlju u tranziciji (Srbiju)/European planning discourse and the renewal of European spatial planning', *Sociologija i prostor*, 2/2010.

Vujošević, M.; Zeković, S.; Maričić, T. 2010. *Postsocijalisitčka tranzicija u Srbiji i teritorijalni kapital Srbije. Stanje. Neki budući izgledi i predvidljivi scenariji/Postsocialist Transition and Territorial Capital of Serbia. Some Future Prospects and Predictable Scenarios*, Institut za arhitekturu i urbanizam Srbije, Beograd.

Vujošević, M.; Zeković, S.; Maričić, T. 2009. Undermined territorial capital of Serbia, some future prospects and predictable scenarios'. In *Thematic Conference Proceedings Regional Development, Spatial Planning and Strategic Governance*, Volume I, 21-52, IAUS, Belgrade.

Vujošević, M.; Zeković, S., Maričić, T. 2012. Post-socialist transition in Serbia and its unsustainable path, *European Planning Studies*, forthcoming.

Waterhout, B. 2008. Territorial capital and the territorial agenda of the EU *Territorium*, 8: 25-42.

Zakon o Prostornom planu Republike srbije od 2010. do 2020. godine/*Act on Spatial Plan of the Republic of Serbia 2010-2020*, Službeni glasnik Republike Srbije, 88/2010.

IMPACT OF THE LAND USE PLANNING ON THE MODAL SPLIT CHANGES IN CITIES – CASE STUDY

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Abstract: Spatial planning could have an impact on the motorized congestion reduction. This process should ensure sustainability in land use planning, but also an improve of transport efficiency and minimize transport needs in areas. The spatial indicators, as density and accessibility to the public transport, could influence on transport behaviors among citizens. In Polish city, Krakow, there were carried out the researches in a housing estate, where this impact was proved. The research shows that (for example), the changes in density in spatial planning have impact on use of the individual transport. It is significant in areas, where the density is on medium size. This article will show the relation between the land use planning indicators and modal split, and impact on the congestion reduction.

Keywords: transport planning, public transport, land use planning

1. Introduction

One of the priorities for municipality is the land use creation as sustainable development. At the same time, the city planners should consider the citizens' transport demand from existing and planning city zones. The parallelism of this activities and its synergy, could have an influence on the motorized congestion reduction. Lack of the synergy among land use planning and transport, have a significant influence on public transport financing or ineffectiveness useful of the roads and streets. Most of the medium and big cities in Poland have a motorized congestion problem in peak hours. The municipality try to minimize it by planning new engineering solutions (new streets, additional lanes on the street, the effectiveness signaling systems), however it has a temporary impact on the congestion. Those solutions do not affect the traffic beginning essence, but temporarily improve the transport condition. That is why this solution should be investigated, which could have an impact on the traffic generated size and changes in modal split. One of this ways is the impact on the land use planning, mainly in the residential areas. The spatial indicators, as density and accessibility to the public transport, give the chance for controlling the number of traffic generated by individual transport. The new public transport line in the area and a shorter distance to public transport stops could change a modal split, in the way of the priority for the public transport. The spatial planning indicators are an effective instruments, which the city planners can use for minimize a traffic congestion by transfer a part of the travel from individual transport to the public transport.

2. The spatial planning indicators – a short description

There were few indicators which could describe a city spatial structure and could have an impact on the transport congestion reduction. Those indicators are: an area size – defining by the number of population, location and distance from an area to the city centre, density and intensity in reference to development, population and number of the employment, mix land use in reference to area function and its development, accessibility to the infrastructure (mainly to the public transport stops, to the main roads, etc.), parking policy and street network parameters (Banister, 2005; Song, 2003; Bramley and Power, 2008; Chmielewski, 2001). For the parameters which could be analyzed in the aspect of reducing traffic congestion, it could be also counted the socio-economic indicator. However, the parametric of this indicator is very difficult to describe. In the article, there were taking into account only two indicators – density and accessibility to the public transport.

2.1 Density as spatial planning indicators

Density patterns are obviously closed to the transportation, because of its impact on the energy use. Density in an urban reference expresses relation between the development surfaces to the land surface. Density diversify can have an influence on the traffic generated and minimize the transport congestion. In Polish planning documents, the development intensity is used (it is more economic useful). This indicator is useful when the planners prepare the development plans, mainly for housing areas and rebuilding zones in mix use shape. In the same time, they have to predict the attractive public transport network, for minimize the number of travel generated by private transport. Therefore, it is not common practice. In city centre or in the typical housing areas, where the public transport exist, the planners have quite simple work – they only increase the number of building in area.

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While in the areas, where the density is low, the public transport offer is usually unattractive. In that case, planning new development will cause high share of individual transport generated by zones. Therefore, it is necessary to prevent for development decentralization. Dispersed development is characteristic by low developing costs, but in the same time by high public costs (by providing new public transport network, high ecological costs – the motorized congestion in areas, when the public transport doesn`t exist, etc.) (Rudnicki, 2009). In city development plans, it is necessary to prevent the urban sprawl and to transfer development to the areas, where the offer of public transport is attractive. It is required to increase the number of building along the public transport corridors with polarization next to terminal or public transport stops. Density development indicators are possible to get only for zones with defined development surface. For planning areas or for undefined development, it is much easier to use the density population (as relationship between population numbers to land surface).

2.2. Accessibility to the public transport

Accessibility is the area distinctive, which determines the attractive of it. Accessibility can be considered as: urban accessibility and accessibility to the public transport. Urban accessibility is defined as proximity of the many travel goals, which can be managed by public transport. Accessibility to the public transport is defined as easy access to the few sorts of transport means (as short walking distance to this means). However, the access by individual transport to the transport infrastructure has to be controlled. When we taking into account the accessibility to the public transport in the area, we have to provide the synergy between the structure development and the transport corridors in following ways: the diameter public transport route and the outskirts private transport ring road. In that way, we can have an influence on the traffic generated mainly by the private transport. In the accessibility to the public transport (PT), the walking access to the PT stops has to be considered. It is necessary to provide a shortest way to the stops, without any steps, with a friendly and an interesting surroundings – the access to the PT stops should be comfortable for pedestrians. In that approach, it is possible to impact on the PT network and shape of the PT service. That attitude can be much more economic effective than operation investments in the infrastructure. In this article, the accessibility to the public transport is analyzed as distance to the public transport stops.

3. Case study – Górka Narodowa housing estate in Krakow

The Górka Narodowa housing estate is situated in the north part of the city Krakow. The estate is situated by the main road leading to the Polish capitol – Warsaw. This road is the only connection from the other parts of the city to this estate. The lack of the alternative connection with the city centre causes the daily motorized congestion. The housing estate is quite new with many young people. The number of citizens is about 4000 people (in the east and west part of the housing estate (Panstwowa Komisja Wyborcza, 2011). The distance to the city centre is 5 km. However, the daily motorized corridors cause that the travel time to the centre is quite long – 30 minutes by private car and 40-50 minutes by PT (the passengers has to be transfer form bus to the tram).

The each part of the housing estate is connected to the main road by local streets by traffic lights. Those intersections are very close located of themselves – it causes the congestion on the junctions. The west side of the housing estate is also connected with the street network by the other street. However, this street is also very congested (the influence of the other housing estates and the villages located by the north border of the city). The housing estate is also operated by public transport. There are 6 PT lines: one city line, four PT suburban lines and one supporting line. The city line and supporting line provides connection between the housing estate and the city centre – however from the city line the passengers has to be transfer for other PT means (to get to the city centre), and the frequency of the suburban lines is not very attractive – one trip for an hour. The suburban lines provide one trip for an hour in the peak hour. Therefore, the PT access from this housing estate to the city centre is unsatisfactory. Because of that, most of the trips are serving by the private car.

In 2011, on the PT stop, there were carried out the research of the PT punctuality (Kus, 2011). The 64% of the courses were delayed in the am peak hour and 50% in the pm peak hour. The research also concerned the passengers count in the buses. In the am peak hour, 67% of buses were high full (>39 passengers in bus), in the pm peak hour, 53% buses had occupied by only few sitting places. There were carried out also the volume of car on the main road – in the pm peak hour there were 1900 veh/hour. The capacity of this main road is 1730 veh/hour. In the future, each additional building investment will cause more traffic generated and wore traffic condition on the main road.

Fig. 1.
The Górka Narodowa housing estate
Source: www.google.pl

3.2. Górka Narodowa housing estate development plan

Górka Narodowa housing estate is not extensive. There are many possibilities to develop this area. However, without any restriction, that area could be developed with uncontrolled kind of development. That is why, in 2006, the city planners prepared the Local Land Use Development Plan (City Council of the Cracow, 2006). The main idea of that plan was recommendation for land purpose, mainly for the housing and green areas. The Local Development Plan also predicted the main road rebuilding and providing new local street which could connect two parts of the estate (west and east parts). There was also proposed the new tram line passing thru the west part of the housing estate. It was also proposed to locate a PT station and P&R parking.

In that document, the number of prognostic citizens on the estate will be 20 000 (City Council of the Cracow, 2010). The pictures below show the land purposes and tram lines for the housing estate. Following signs are: MW – Multi-family development, MN – single family housing, UP – commercial and industry development, KT – tram line, blue line – present and forecasting street roads (Cracow University of Technology, 2003).

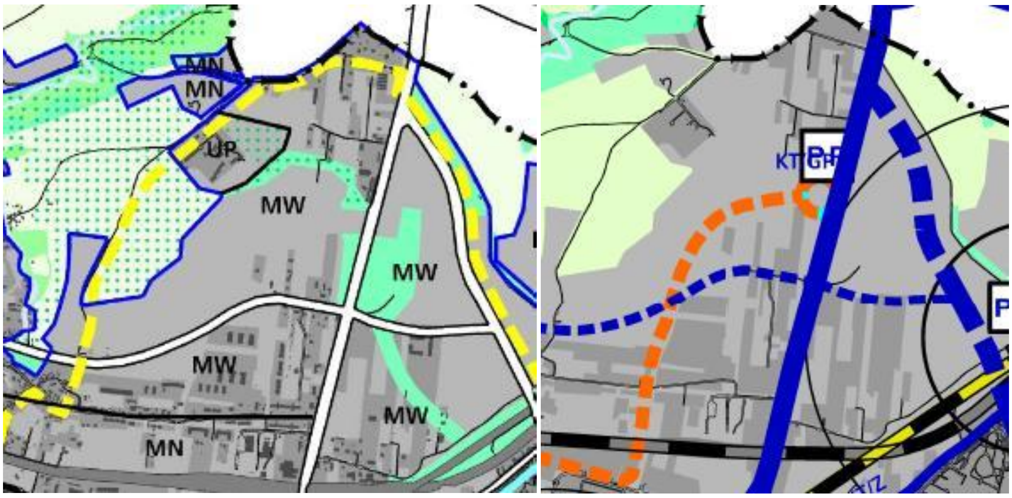

Fig. 2.
The Górka Narodowa housing estate – the land purpose and transport predicted in the area
Source: Cracow University of Technology, 2003

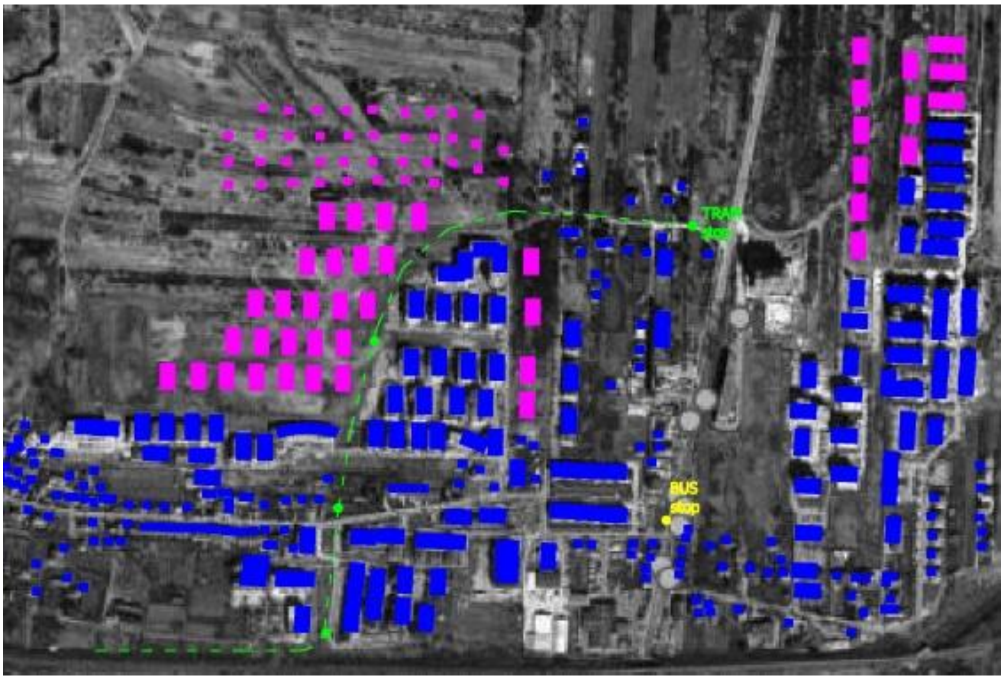

Fig. 3.
The Górka Narodowa housing estate – planning development in the area
Source: www.google.pl

When we start to analyze the planning documents concerning this housing estate, we can notice that the planners tried to provide the attractive PT in the area. However, the tram line route passing by the housing estate wasn`t quite obvious on the beginning. This area was very attractive for the developers, because is located quite close to the city centre and on the city boarder (the beautiful forests is located very close to the estate). This location is also very attractive because of the main road toward the Polish capital). Therefore the north part of the city is very interesting for the potential investors. However, when the first buildings were finished, the transport congestion started to be very uncomfortable. That is why the attractiveness of the area was diminished. From that time, the city planers decided to prepare the local development plan, which will control the area purpose and the new investments. In the preparation plan stage, there were many problems, mainly with the free plots under the new tram line, the developers and citizens oppositions. Finally, after the months of the work, the plan was granted.

3.3. The public transport influence on the traffic generated in the Górka Narodowa housing estate

For the article needs, there were prepared two conceptions of the transport network in the area. The first conception predicted the transport network without the new tram line, only with the bus lines and existing roads. Second conception taking into account the new tram line route with the defined number of the stops, the tram frequency and tram speed in the area. After defined the assumption, there were carried out the traffic forecasts, using the existing transport model for the city. The traffic forecasts were used the VISUM program for macro simulation. The transport model was prepared for 2015 year and predicted all transport investments in the city (without the new tram line in the analyzing area). The tram line route was defined in the VISUM based on the document - "New tram line conception for connecting the two housing estates - Krowodrza Górka and Górka Narodowa". The new tram line was connected with existing tram network in the Krowodrza Górka housing estate. In the transport model, there were also predicted the changes of the land use indicators - density and the accessibility to the public transport (as distance to the tram stops), for finding the influence those indicators for the modal split changes. For this aim, there were calculated two values for each land use indicators: density for the existing year is 18 per/ha and for the future will be 89 per/ha; and the accessibility for the public transport (as mean walking time to the tram stops) for the existing year is 10 minutes and for the future will be 5 min. For the transport simulation, there was established the 30 km/h tram speed in the area. The new tram predicted 3 lines towards the south, east and west direction. Mean distance to the next tram stops is 300m. The length of the new tram line (from the Górka Narodowa to Krowodrza Górka estate) is 4050 m. Including all predicted indicators and tram parameters, the simulation in the VISUM get following results: the mean travel time by PT form the estate to the city centre – before the tram investment was 40 minutes, after the investment is 25 minutes; the passengers in the tram line in the pm peak hour is 660 pass/h.

On the picture below, there is presented the VISUM simulation as individual transport and public transport volume (for two situations – for the same number of citizens in the area – with and without the tram line).

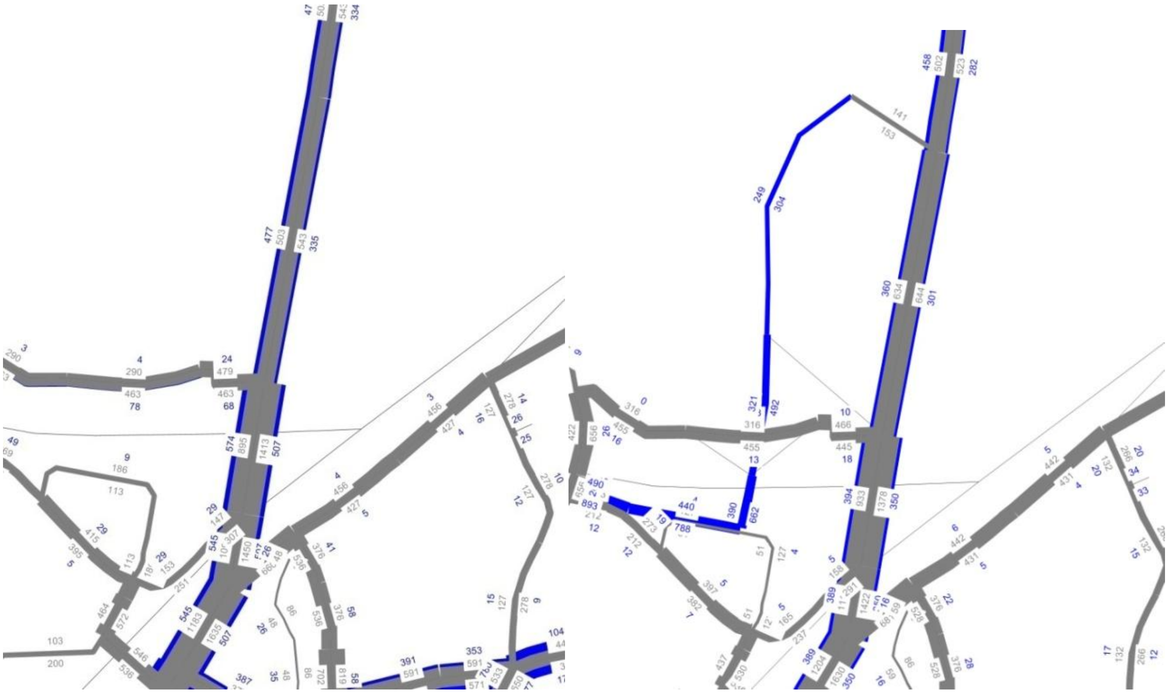

Fig. 4.
The traffic volume in the pm peak hour for the area development – grey color represents a private transport and blue color - the public transport

In the reason of providing the new tram line in the area, the number of trips by PT, finished in the estate, was increased from 400 to 480 trips/h and by private transport decreased from 795 to 716 trips/h. Therefore the modal spilt was changed because of the new offer of the PT and shorter distance to the tram stops. The traffic analyzes shown that the modal split was changed about 8 %, taking into account the synergy between the travel time by this two transport means and modal split. In the analysis, there was predicted following assumption: three tram lines with the frequency – 10-20 minutes. In reality, it should be much more properly to verify all PT network and changes in the PT timetables. For the articles needs, it was enough, because it was possible to describe the relationship between the land use planning indicators and modal split in the traffic generated. The values of the modal split for two PT service conception in the housing estate is shown below

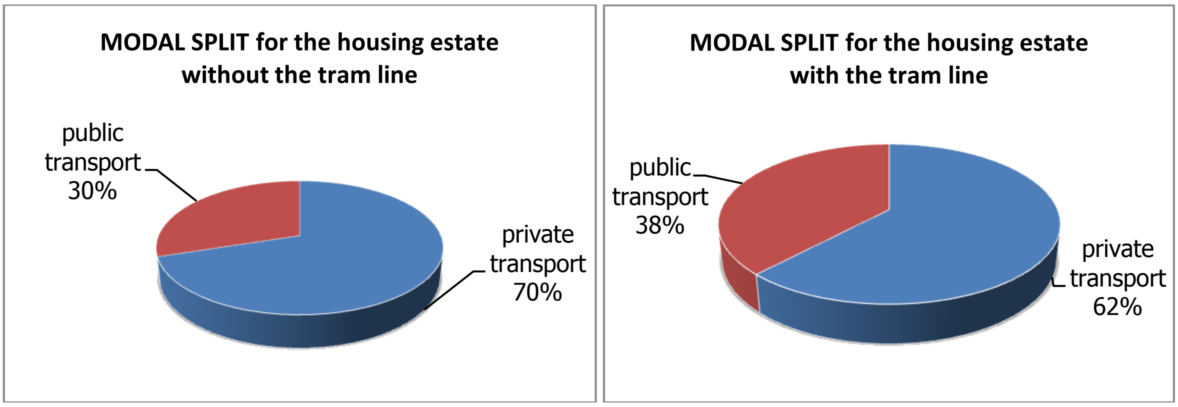

Fig.5.
The modal Split for the transport means in the Pm peak hour in the Gorka Narodowa housing estate – with and without the tram line

The ridership expresses in passengers/kilometers and passengers/hours for PT are represented below.

The ridership in all city was increased from 647630 to 652510 [pass.km] – in fact of the longer PT network (new tram line) and decreased from 32999 to 32923 [pass/h] – in fact of the shorter time in all network of the passengers travel. This effect is quite satisfied. In the table below, the main parameters was shown as a consequence of the new tram line in the housing estate.

The kind of the parameter	PT network without the new tram line in the estate	PT network with the new tram line in the estate
Travel time to the city Centre by PT a [min]	40 min	25 min
Modal Split (for the housing estate): Public transport Individual transport	 30% 70%	 38% 62%
Ridership pass.km pass.h	647 630 32 999	652 510 32 923

Fig. 6.
The main parameters of the public transport network in the housing estate

3.4. Walking accessibility to public transport stops in the Górka Narodowa housing estate

The problem of walking accessibility to public transport stops in the housing estate is not very bed. The analyzes which are presented in the article are the attempt to do the finding the relations within the density and the walking distance to the PT stops to the walking accessibility indicators in the area. The relations between a density (also the walking distance) and the walking accessibility indicators include the model of the walking accessibility created by Piotr Olszewski. This sub-modal split model was estimated for the Transit Station in Singapore and includes the number of the buildings in the walking range (in the straight line and equivalent walking distance), number of road crossings, traffic conflicts and number of ascending steps. Based on the model coefficients, the "equivalent walking distance" equation is proposed which reflects the relative effect of these factors on the generalized walking effort. As equivalent walking distance represents the extra effort required to overcome obstacles, it can be used as an indicator of the quality of pedestrian facilities. The following equivalency coefficients were obtained: one street crossing is equal to 43 m of walking, one ascending step corresponds to 2.7 m of level walking and one traffic conflict is 26 m of walking. This method of assessing walking accessibility of a station or PT stops is defined as: walking accessibility index WAI is defined as the ratio of the actual "walking potential" of the area to the "maximum walking potential", obtained assuming ideal walking conditions.

This method was used for the housing estate with the following assumptions: there is only one PT stop for the area (on the main street), the multi-family buildings were only analyzed (the number of the single family building is not significant), this method include only existing land use development. On the picture below it presents the main formulas of the walking accessibility model (Eq. (1)):

$$EWD=DISTW+42{,}8*NCROS+2{,}7*NSTEP+26{,}4NCONF \quad (1)$$

Where: EWD – equivalent walking distance
DISTW – real walking distance
NCROS – number of road crossing
NSTEP – number of ascending steps
NCONF – number of traffic conflicts

This method also gets the possibility to define the probability of the walking reach to the PT stops (Eq. (2)):

$$P_w(EWD) = 1/1+\exp*(-6{,}4755+0{,}00494*EWD) \quad (2)$$

Finally, in the next step, it is possible to define the walking accessibility index WAI (Eq. (3)):

$$WAI=\frac{\sum_{k=1}^{K} Wk*Pw(EWD)}{\sum_{k=1}^{K} Wk*Pw(DISTA)} * 100\% \quad (3)$$

Where:

Pw(EWD) – probability of the walking reach including EWD for building "k"
Pw(DISTA) – probability of the walking reach including walking distance in the straight line for building "k"
Wk – number of traffic generated for building "k"
K – number of the buildings in the area

Including the assumptions above, the model indicators were defined for each of 86 buildings. The buildings has from 12 to 120 flats (depending of the residential department type) and it assumed that each flat has 2,5 person/flat. For the existing development, the walking accessibility index WAI amounts 79%. It means that the conditions of the walking to the PT stop are not very good. Therefore, a choice probability of the PT means in daily travels is lower, than WAI index will be 90%. The WAI index was also define for developed area for the future. It was assumed that it will be about 40 additional building in the area (each of it will has 50 flats and 2,5 person/flat). The WAI index for that variant amounts 69%. When we increase the number of the traffic generated, the walking accessibility index will be lower. Therefore, a choice probability of the PT means in citizens travel depending from a density as well as a walking distance to the PT stops and its condition.

4. Conclusion

Based on the calculated results, concerning the changes in the land use planning indicators (density and accessibility of the public transport – new tram line), it could be state that modal split in Gorka Narodowa housing estate was change. The PT means share was higher when the tram line was included in transport network. Those results show that the planners have to include the public transport aspects in land use development plans. The city planners should demand from the investors and developers a special plan, which consider the public transport service of their significant investments.   Without that approach, the sustainable development of the city won`t be possible.

References

Banister, D. 2005. *Unsustainable transport – City transport in new century",* Transport, Development and Sustainable Series, Routledge.

Song, Y. 2003. *Impacts of Urban Growth Management on Urban Form: A comparative study of Portland",* National Center for Smart Growth Research and Education University of Maryland.

Bramley, G.; Power, S. 2008. *Urban form and social sustainability: the role of density and housing type",* Paper presented in Environment and Planning Website – Planning and Design, www.envplan.com

Chmielewski, J.M. 2001. *The theory of the urbanism in the city and regions planning*. Warsaw University of Technology, Warsaw.

Rudnicki, A.; 2009.. Skuteczne zmniejszenie zatłoczenia miasta – „Polityka rozwoju przestrzennego a zatłoczenie komunikacyjne", *Conferences materials.* Poznań – Rosnówko.

Panstwowa Komisj Wyborcza. 2011. Available from Internet: www.pkw.gov.pl

Kus, A. 2011. *Badanie zachowań komunikacyjny mieszkańców osiedla Gotyk w Krakowie.* Graduation work of Cracow University of Technology.

Resolution Nr CXIX/1283/06 of the City Council of the Cracow and resolution CXV/1193/06 of the City Council of the Cracow. 2006. Local land use development plan for Gorka Narodowa housing estate. Available from Internet: http://www.bip.krakow.pl/_inc/rada/uchwaly/show_pdf.php?id=30983

Resolution Nr XII/87/03 of the City Council 16 April 2003 with the changes Nr XCIII/1256/10. 2010. *Land use development plan for city Krakow.*

Cracow University of Technology, Department of Transportation Systems. 2003. *Tram line conception for connection of the Krowodrza Gorka and Gorka Narodowa housing estates*. Archival materials.

LEVEL OF SERVICE – A MEASURE OF PERFORMANCE OF ROAD NETWORK

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Abstract: In the present scenario, the rapid pace of industrialization and economic development has made considerable impact on transportation and the related traffic plying on roads in rural and urban areas and it will continue to do so in coming times. The growing vehicle population and non- expanding road infrastructure have forced the automobiles to travel under congested conditions including increased stopped delays at intersections. The present capacity of the road networks has reached their optimum level and the urban growth has left no space for expansion of facilities. This condition is one of the reasons for increasing congestion and thereby reducing the Level of Service of roads. A study project was conducted for the arterial roads of Port Blair, capital town of Andaman and Nicobar Islands, India, for analyzing the traffic parameters and the present Level of Service. Six major roads were selected for the study and the traffic volume data were collected for both peak tourist season (September to January) as well as for off-peak tourist season (February to July). Most of the studies reveal various ways to observe the perception of user/customer to assign a Level of Service to any facility. Levels of Service (LOS) are rated much like a report card, with "A" generally representing the most favorable driving conditions and "F" representing a complete breakdown of free flow–in other words, stop and go traffic. There is a need to redefined LOS based on the various factors which may affect the facility both technically and economically. The LOS prescribed by various guidelines are usually for listed ideal conditions of lane width, shoulder width etc. but in the absence of such road margins and other geometric features the facility can be evaluated for those Level of Service. In case of Port Blair roads the rolling terrain and demographic factors with respect to land area available to island population, the roads needs to be assessed differently for preference as well as for land use reasons.

Keywords: Capacity, Level of Service (LOS), Demographic factors, Traffic Parameters, Measures of Effectiveness (MOE)

1. Introduction

In the present scenario, the rapid pace of industrialization and economic development has made considerable impact on transportation and the related traffic plying on roads in rural and urban areas and it will continue to do so in coming times. The importance of transportation in world development is multidimensional. In a rapidly urbanizing country, transportation and communications are usually the sectors that show the maximum growth. Traffic engineering is mainly concerned with the flow of traffic. Traffic flow is a complex phenomenon. It requires more than casual observation while driving on a roadway to discover that as traffic flow increases, there is generally a corresponding decrease in speed. Traffic flow is a stochastic flow (Khisty and Lall, 2006) process, with random variations in vehicle and driver characteristics and their interactions.

India the seventh largest country in the world and second largest in Asia has a population of more than 1027 million and area of 329 million hectares. The consumption of energy in transport sector is 16 percent of total use of energy (Indian Highways, 2006). The growing vehicle population and non- expanding road infrastructure have forced the automobiles to travel under congested conditions including increased stopped delays at intersections.

The present capacity of the road networks has reached their optimum level and the urban growth has left no space for expansion of facilities. This condition is one of the reasons for increasing congestion and thereby reducing the Level of Service of roads.

2. Basic Definitions

Capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions.

When a road is carrying traffic equal in volume to its capacity under ideal roadway and traffic conditions, the operating conditions become poor. Thus the service which a roadway offers to the road user can vary under different volumes of traffic (Kadiyali, 2007). The Highway Capacity Manual (TRB, 1985) has introduced the concept of “Level of Service” (LOS) to denote the level of facility one can derive from a road under different operating characteristics and traffic volume. It is a qualitative measure describing operational conditions within a traffic stream and their perception by motorists and /or passengers. Capacity and Level of service are two related terms.

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Capacity analysis tries to give a clear understanding of how much traffic a given transportation facility can accommodate. Thus LOS gives qualitative measure of traffic, where as capacity analysis gives a quantitative measure of a facility. Capacity and level of service varies with the type of facility, prevailing traffic and road conditions etc.

The other definitions of LOS include:
- "Levels of Service describe the quality of service provided by the asset for the benefit of customers." (Highway Asset Management guidance Note, UK Roads Board). It goes on to say that these are composite indicators that reflect the social, economic and environmental goals of the community (both for those using the asset and affected by it).
- A further definition appears in the Code of Practice for the Maintenance of Highway Structures (UK Roads Board). "A statement of the performance of the asset in terms that the stakeholder can understand". These Levels of Service cover the condition of the asset, as well as non-condition demand aspirations i.e. a representation of how the asset is performing in terms of both delivering the service to stakeholders and maintaining its physical integrity at an appropriate level. Level of Service typically covers condition, availability, accessibility, capacity, amenity, safety, environmental impact and social equity.

3. Assessment through Research

In the beginning the Level of Service was measured only for Freeway/Highway facilities. Three parameters were used under this and they were speed and travel time, density, and delay. One of the important measures of service quality was the amount of time spent in travel. Therefore, speed and travel time were considered to be more effective in determining LOS of a facility. Later it was realized that LOS represents a range of conditions defined by a range of one or more operational parameters. Although the concept of LOS attempts to address a wide variety of operating conditions, limitations on data collection and their availability make it impractical to consider the full range of operational parameters for every type of transportation facility. The parameters that are selected to define LOS for each facility type are called Measures of Effectiveness (MOE). In turn they represent those measures that best describe the quality of operation on the facility. Some of the details/findings published in this context are given below;

Table 1
Parameters defining LOS in various publications

SN	Source	Findings/Recommendations
1	Indevlopment (2004)	- The flow conditions can be labeled as Free, Stable, high density, near capacity and breakdown for the Level of Service starting from LOS A to F respectively - The service volume, density and speed also varies with LOS. The service volume is ranges from 700 vh/hr/ln for LOS A and it goes to unstable condition for LOS F. The speed varies from 60 m/hr to 30 and the density varies from 12 veh/miles to 67 veh/miles for LOS A to LOS F respectively. - These are the capacities and service-levels for traffic in the US under ideal conditions. The ideal conditions relate to the lane width (3.5 meters) and to the fact that it is a motorway. Thus slow traffic does not interfere with fast traffic. The maximum capacity in the US is around 2000 vehicles per lane. - The Highway Capacity Manual proposes using the following example relation to express the influence of non-ideal conditions c=Cj N fw fHV fp where c = capacity (veh/h), Cj = lane capacity under ideal conditions with design speed of j , N = number of lanes, f w = lane width and lateral clearance factor, f HV = heavy vehicle factor, fp = driver population factor
2	Multimodal Level of Service Analysis for Urban Street, NCHRP (2008)	-The major issues for establishing a multimodal level of service framework are as follows: 1. Establishing comparability of meanings for LOS grades across modes, 2. Establishing models for predicting LOS that reflect the interactions among modes in an urban street setting, and 3. Establishing a credible national basis for the multimodal LOS framework and models.
3	Highway Asset Management Quick Start Guidance Note, UK Roads Boards (2008)	- Levels of Service should be public facing, high-level statements, described in comparatively broad terms. By their nature they are likely to be few in number, perhaps no more than six, and many of these will represent a common public pressure in most, if not all, local highway authorities. - They will be concerned with issues like safety, the highway environment and journey reliability. - As ”public facing” statements they are written in a non-technical way that can be easily understood by customers. - They make no reference to the way that engineers measure our progress in improving the asset, or in the way that its condition, or technical performance, is assessed.
4	Journal of Transport and Land use (2011)	- The study has developed an innovative approach to systematically define preferred land use type and intensity based on desired traffic level of service goals expressed in terms of the volume-capacity ratio - The method suggested is to use the initial land use scenario based on the development master plan to run the transportation model to achieve an initial trip table. - Then Applying the Origin-Destination Matrix Estimation (ODME) methodology to adjust the initial trip table based on target traffic volume to achieve the desired Level of Service.

Thus most of the literature reveals various ways to observe the perception of user/customer to assign a Level of Service to any facility. Levels of Service (LOS) are rated much like a student's report card, with "A" generally representing the most favorable driving conditions and "F" representing a complete breakdown of free flow–in other words, stop and go traffic. Levels of Service at intersections are calculated somewhat differently but have the same effect on design decisions (Context Sensitive Solutions, 2009). Therefore with time and available constraints the selection of a target LOS has become a policy decision and is based on a particular jurisdiction's philosophy on whether or not to accept congestion. In Indian context though most of the work have been done based on the Highway Capacity Manual (HCM) guidelines but the designated LOS for urban roads does not go with the perceptions of any such facility unless otherwise all the conditions are met. There is a need to redefined LOS based on the various factors which may affect the facility both technically and economically.

4. A Perspective from a Case Study

A study project was conducted for the arterial roads of Port Blair, capital town of Andaman and Nicobar Islands for analyzing the traffic parameters and the present Level of Service. Six major roads were selected for the study and the traffic volume data were collected for both peak tourist season (September to January) as well as for off-peak tourist season (February to July). The island population of 3-4 lakh (as per the 2001 census) has its major part, more than 60%, residing in and around the Port Blair town. The total geographical area of these islands is 8300 Square kilometers. These islands spread across the total distance of 780 kilometers and nearly 6400 Square kilometers land area of Andaman group consists of reserve forest and is protected areas. The factors identified for contributing to traffic problem were:

- The width varying from 7 meters to 15 meters from place to place.
- The lanes demarked my road markings.
- Steep gradient roads making grade separated intersections.
- Close distant intersections.
- Restricted or absence of right of way
- Increase in vehicular population restricting the speed and capacity.
- Underutilized road stretches connecting to higher volume roads.

The observed traffic volume data was converted into PCU for different class of vehicles [IRC: 106-1990][40]. Practical capacity i.e. the maximum number of vehicle that can pass a given point on a lane or roadway during one hour, without traffic density being so great as to cause unreasonable delay, hazard or restriction to the driver's freedom to maneuver under the prevailing roadway and traffic conditions was calculated. The graphical representation between Volume Capacity Ratio (V-C Ratio) and PCU was obtained in a single graph. As shown in Fig. 1 to Fig. 4, the blue lines show the averaged traffic volume (in terms of PCU) distribution for the 12 hour count for a day and the yellow line shows the V-C Ratio. The left vertical axis gives the distribution of volume in terms of PCU and the right vertical axis is showing the V-C Ratio with abscissa having the 12 hours time distribution as observed in the field.

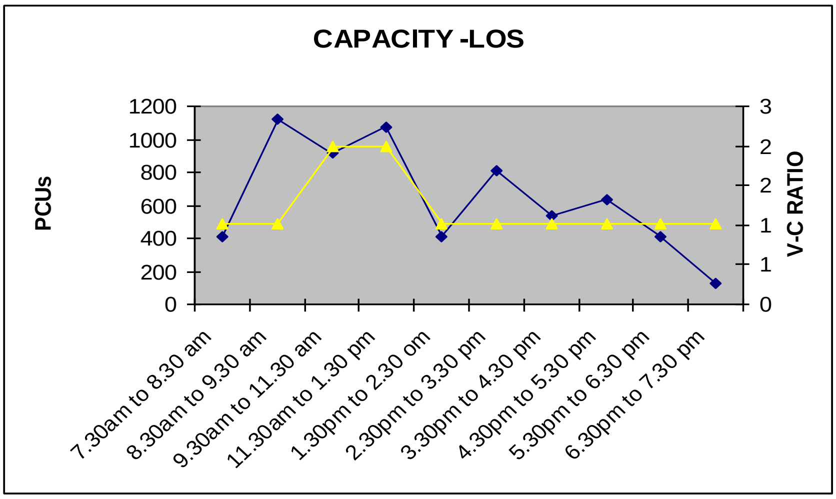

Fig. 1.
Capacity Distribution of Traffic for Kamraj Road (Arterial Road in September)

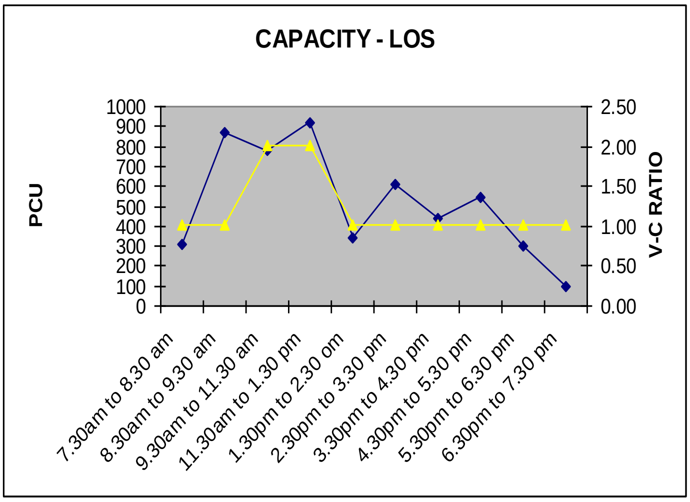

Fig. 2.
Capacity Distribution of Traffic for Kamraj Road (Arterial Road in May)

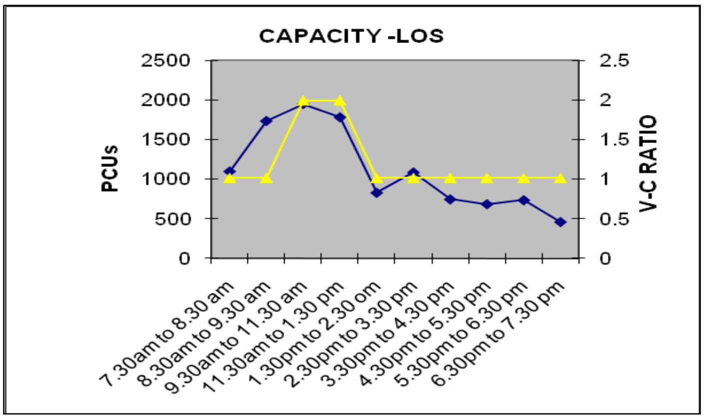

Fig. 3.
Capacity Distribution of Traffic for School Line Road (Downtown Road in September)

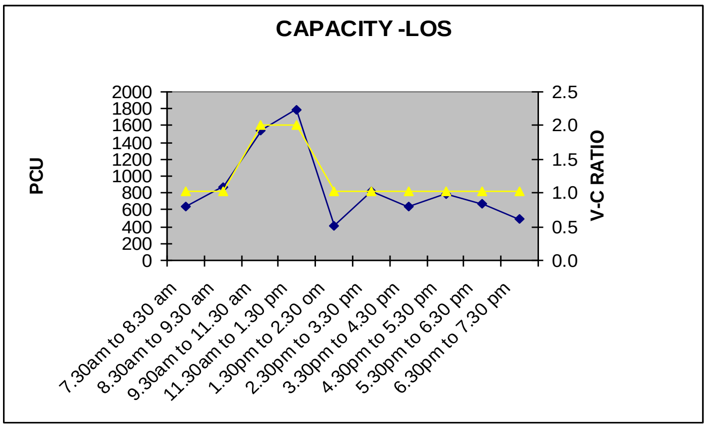

Fig. 4.
Capacity Distribution of Traffic for School Line Road (Downtown road in May)

The findings from the analysis for the said roads, with respect to Capacity the Level of Service (LOS) as per HCM (LOS for Urban Arterials and Downtown Roads, AASHTO), is tabulated below (Table 2);

Table 2
Capacity and LOS for the selected six roads

Name of the Road	Capacity	LOS
Kamraj (VIP) Road (Fig. 1 and Fig. 2)	- The peaks are almost same for both the season - The flow remains more than the capacity till 5.30 pm (except during off peak-between 1.30 p.m. to 2.30 p.m) - The traffic volume is high in the direction from Kamraj/VIP road towards Dairy farm Junction in both the seasons.	- The flow indicates that it approaches unstable state with tolerable delay for the peaks above V-C Line. - Average overall speed remains between 25 K.P.H to 30 K.P.H, therefore these characteristics brings the LOS between "C" and "D".
School Line Road (Fig. 3 and Fig. 4)	- The traffic volume flow is higher from Dairy farm junction to School Line direction. - The flow is below the capacity after 2.30 p.m. as the traffic remains high in forenoon - This being the airport road and the flight timings to and fro from Port Blair is during forenoon hour, which is the reason for fall in the flow during afternoon time.	- Though the spacing of intersection is comparatively large but this stretch affords service to local business, residence and similar abutting properties therefore can only be considered as Downtown Street. - The LOS keep shifting between "B" and "C" , as designated for Downtown streets, with average overall speed varying between 25 K.P.H. to 30 K.P.H
Goalghar –Dilanipur Road	- The traffic flow is high in the direction from Goalghar towards Dilanipur - In peak season, (as measured in Septemebr'2007) the flow remains higher than the capacity from the early hour of the day and remains the same except during afternoon off-peak hour. - Whereas in off –peak season the flow except for morning and evening peak remains within the capacity	- This road too falls in the category of Downtown Street/Road therefore LOS remains within the conditions of "B" and "C"
Middle Point Road	- Traffic flow is higher in the direction from Goalghar junction towards Bengali Club. - Conclusively the flow remains very high than the capacity during the peak season, whereas in off-peak season the flow after the morning peak, remains below the capacity of the road.	- With abutting properties and buzzing with commercial activities, this Downtown Street approaches to a LOS "C"
Junglighat Road	- In this road the traffic flow is higher in the direction from Goalghar junction towards Junglighat - The graph shows that, in peak season the flow remains on or top over the capacity whereas during off-peak season after 2.00 p.m. the flow is well below the capacity of the road	- Being the ribbon for the developing market area, this road has more commercial activity than the old Aberdeen Bazar. Thus LOS varies between "B" and "C".
Bengali Club Road	- Flow of traffic is higher in the direction from Bengali Club towards Light House. - The flow remains higher than the capacity during peak season whereas for off –peak season the flow is above capacity only for the morning and evening peak hour traffic.	- This is the shortest road of all the other selected six roads connecting two main intersection of Port Blair City. - Due to steep gradient the average overall speed, for the direction of high volume, remains near 30 K.P.H, thus LOS approaches "B" indicating a stable flow for such Downtown Street/Road

5. Conclusion

The Level of Service as per the guidelines given in HCM, AASHTO publications as well as by IRC is applicable for the suggested standard conditions. The operating conditions of these arterial and downtown roads are totally dependent on the land use pattern, terrain, positioning of intersection, commercial activities and other demographic characteristics of the area, The number of lanes that will be built on a roadway project , for an urban area, have generally been targeted for free flowing LOS C or D. The LOS prescribed by various guidelines are usually for listed ideal conditions of lane width, shoulder width etc. but in the absence of such road margins and other geometric features the facility can be evaluated for those Level of Service.

In case of Port Blair roads the rolling terrain and demographic factors with respect to land area available to island population, the roads needs to be assessed differently for preference as well as for land use reasons.

Therefore it envisages the scope of finding the role of demographic factors and related geometric features in assigning Level of Service for measuring the performance of road network.

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References

Agarwal, O.P. 2002. Institutional and Regulatory Framework For The Management of Transport in Indian Cities. Paper presented at the *Land Use and Transport Workshop* at the Administrative Staff College of India, Hyderabad.

Ashalatha. R; Satish, C. 2006. Capacity of Uncontrolled Intersections under Mixed traffic Conditions, *Highway Research Bulletin November*: 73-80.

Chakroborty, P.; Das, A. 2003. *Principles of Transportation Engineering*, Prentice Hall: 1-3, 17-21.

Department of Civil Engineering, Indian Institute of Technology, Bombay. Available from Internet: <http://www.civil.iitb.ac.in>.

Dey, P.P.; Satis, C.; Gangopadhyay, S. 2006. PCU Factors for Two-Lane roads, *Highway Research Bulletin September*: 111-118.

Dua, A.; Sarkar, P.K.; Choudhry, S. 2006. Traffic Diversion Scheme during Construction of Delhi Metro at Connaught place Area, New Delhi-A Case Study, *Indian Highways March*: 23-33.

Hobbs, F.D. 1981. *Traffic Planning and Engineering*. McGraw Hill Book: 18-22.

Junevičius, R.; Bogdevičius, M. 2007. Determination of traffic flow parameters in different traffic flow interaction cases, *Transport* XXII (3): 236–239.

Kadiyali. L.R. 2007. *Traffic Engineering And Transport Planning*, Khanna Publishers: 1-3, 515-552, 553-559.

Khanna, S.K.; Justo, C.E.G. 2001. *Highway Engineering*, Nemchand and Bros: 167-173.

Khisty J.C.; Lall, K.B. 2006. *Transportation Engineering-An Introduction*. Prentice Hall: 1-3, 119-135, 224-230.

Ministry of road transport and highways. Government of India. Available from Internet: **<**http://morth.nic.in/index2.asp>.

Pattara-atikom, W.; Pongpaibool, P.; Thajchayapong, S. Estimating Road Traffic Congestion using Vehicle Velocity. Available from Internet: < http://wiki.nectec.or.th/ngiwiki/bin/viewfile/Paper/Traffic?rev=1;filename=paper6.pdf>.

Satish, C.; and Vishnu, P. 2006. Capacity of Multilane Divided Urban Roads under Mixed Traffic Conditions, *Highway Research Bulletin October*: 97-103.

Speed, flow and density relation in road traffic. Available form Internet: <http://www.google.co.in/search?q=speed,+flow+and+density+relation+in+road+traffic&hl=en&start=50&sa=N>

The Indian Road Congress. 1990. *Guidelines for Capacity of Urban Roads in Plain Areas*. IRC: 106-1990, New Delhi: 1-12.

Transport and Mobility Laboratory. Available from Internet: <http://transp-or2.epfl.ch/tristan/FullPapers/010wynter.pdf>.

SOME SURVEYS IN ORDER TO STATIC TRAFFIC LIGHT COORDINATION

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Abstract: The traffic light coordination is often considered as a measure to improve traffic speed reducing car emission per meter. Although the dynamic approach has been widely developed in theory and application, static approach can be still useful in many design problems. Often design is made by static approaches and is also verified with dynamic models. The static approach study, in this paper, starts from flow profiles of vehicle platoons departing from a traffic light. Several past studies have concerned on the definition of flow profiles and in this paper it considers the collecting data modeling using the approach of cyclic flow profiles (TRANSYT TRRL) who gives the arrival distribution of flow platoons as a function of the distance from the first intersection through a recurrent computing. So it can know the car number in late for the green phase at the second light and then decide to increase the second green time according to the access waiting time or, conversely, reduce the green time at the first light accepting a queue. The last results obtained seem, in part, to confirm those by last surveys already performed. These results give basically always and still different from the values of the two coefficients (dispersion and transit time) registered in the U.S. The estimated values can be used as is, however, if it is essential a level of approximation in order to the model very detailed then, as usual, is best to check the model coefficients with some localized surveys and measures. The experimentation showed the validity of static approach and also some its limit discussed in the paper.

Keywords: Light coordination, Green time, Traffic flow, Platoon, Driver behavior.

1. Objective

The objective of this work is to investigate the behavior of drivers in traffic platoons moving from defined traffic lights. This study is required to right model the shape changes of the traffic platoons on the different sections along the road. This allows understanding and forecasting the evolution of traffic platoons over a road segment aiming, for example, at defining an adequate phase plan to successive traffic lights. It is well known in practice that traffic light coordination works well only for short length. This can be due to many factors among which relevant are the hypothesis of constant platoon characteristics.

In this work the dispersion of vehicular platoons starting from a traffic light has been studied by a survey of the transit flows on a road section of about 600 meters having moderate interferences. The data have been analyzed according to the cyclic flow profiles (CFP, with the recurrence relation; Robertson, 1969, 1974, Seddon, 1972b, Capaldo et al. 1998, Capaldo, Guzzo, 2002). The experimental cyclic flow profiles show, in some control sections along the road, the trend of the average flow transit time as a function of fixed time intervals which sum to the entire cycle time. The CFP, which parameter values are calibrated to fit flow profiles, well represent the trend and dispersion of platoons of vehicles on the road section observed. The values of the calibration parameters supplied by literature for this function in order to experiments on equivalent geometric conditions were compared with those taken from the actual experimentation. From this point of view the current work may be regarded as a continuation and extension of the previous surveys.

2. Cyclic flow profiles and Robertson model

Fig. 1 shows an intersection with two entrances, both regulated by traffic lights. It is assumed that from the first access, from top to bottom, starts a saturated flow. The saturation flow rate for a lane group is the maximum number of vehicles from that lane group that can pass through the intersection during one hour of continuous green light under the prevailing traffic and roadway conditions. Under this hypothesis the flow, null during the time of red, grows rapidly during the green time until it reaches the saturation flow, and then rapidly returns to zero during the yellow period. In the Fig. 1, rather than real times of green, yellow and red, two light periods are considered, treated as effective green and effective red, during which the flow rate is alternately equal to the saturation flow or zero; in this way the transient phenomena during the start and the intersection clearance are ignored.

In the further hypothesis that all vehicles in the platoon traveling at the same speed (constant) the graphs (1, 2, 3 and 4 of Fig. 1) show the theoretical instantaneous flows that can recorded in various sections downstream of the traffic light and are plotted as a function of time. Each graph keeps the same start instant represented by the first period of green light for the flow.

The time taken by the first vehicle in the platoon to arrive at the next finish line depends on the distance between the lines and on the speed of the vehicle. The speed value provides the inclination of the dotted lines that join the next homologous graphs, and representing the transit of platoons in next sections. The time gap between the transit of the first platoon and the start of green time is the «time loss» for the starting platoon.

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The real cyclic flow profile for any point on a road section can be obtained if the laws of variation over time of traffic flows within a single cycle are known.

In practice, these hypotheses are excessively restrictive both because vehicles traveling at different speeds and because the flows vary from cycle to cycle but also the saturation flow is not constant during the entire green time. The cyclic flow profiles, moreover, vary with the layout of the road section and with the characteristics of the traffic flows.

In Fig. 2 is shown a cyclic flow profile more realistic: it is a histogram showing the traffic flows during the green time of the traffic light cycle. By convention the time origin starts with the beginning of the first green period. On the ordinate shows the instant average of flows expressed in vehicles/hour. The average is made on some number of cycles.

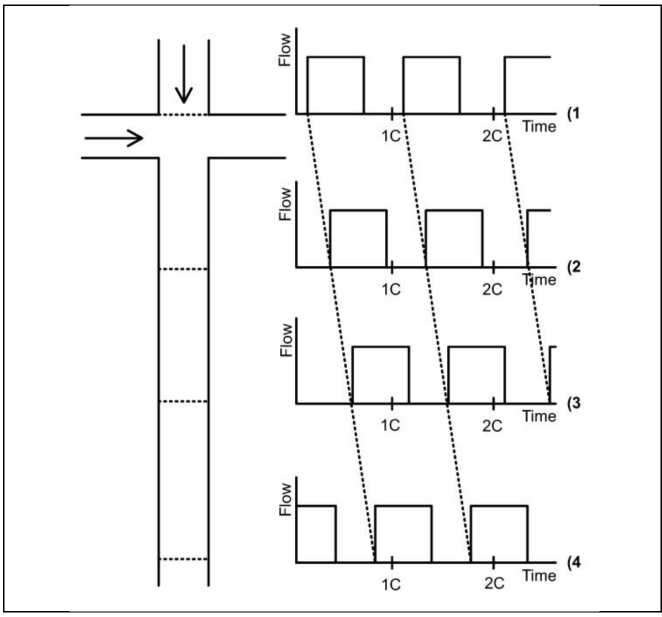

Fig. 1.
Theorical Cyclic Flow Profiles

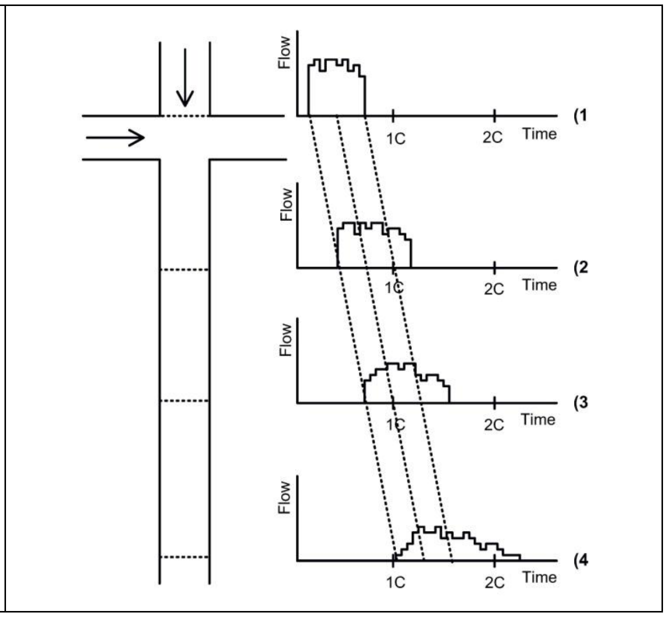

Fig. 2.
Realistic Cyclic Flow Profiles

The analysis of cyclic flow profiles provides information about:

- average traffic flows: the graph area is proportional to the average flow: examining the graphs of different sections of urban road it can easily identify sections with greater flows;
- coordination of traffic lights cycles: the height variations of the cyclic flow profiles are a measure of the coordination need of the traffic light cycles: does not have considerable advantages when the heights of the profiles are kept sufficiently uniform during the whole cycle, conversely if peaks of the cyclic flow profiles are pronounced, corresponding to well-defined platoons, then these indicate situations that can take advantage from coordination of traffic lights cycles;
- saturation flows: by the trend cyclic flow profiles, if exists a sufficiently large number of vehicles waiting for the green time, it is possible to derive the saturation flow: during some parts of the cycle it will probably a decrease of the flows and knowing the duration of the green time and the height of the peaks can check the duration of the saturation flow;
- dispersion of platoons: the hypothesis that all vehicles traveling within a platoon at the same speed is very unrealistic; if it measures the cyclic flow profiles along a road section at different distances from the first stop line then is obtained profiles of different shape; these vary their shape «scattering» more when the distance from the starting line increases.

The dispersion of flow platoons downstream of an intersection with traffic light depends, in same geometric conditions and environmental factors, both from the differences in performance of road vehicles and from the driver behavior. It has been studied through the kinematic wave theory (Lighthill and Witham, 1955), the diffusion theory (Pacey, 1956) and the recurrence relation (Robertson, 1969).

The platoon model based on the recurrence relation is simple, from the numerical point of view (can be implemented, for study, with a spreadsheet), but requires an experimental data base on which this may be calibrated. It mainly is adopted in the «fixed time» simulation program TRANSIT-7F.
The recurrence relation is (Eq. (1)):

$$q_2[i+\beta*t] = F*q_1[i] + (1-F)q_2[i+\beta*t-1] \tag{1}$$

where: $q_1[i]$ = traffic flow measured in the starting section, during the interval [i], including the transit time of the platoon; $q_2[i+t]$ = expected traffic flow at interval [$i+t$] in control section; t = average travel time on the distance between the two sections (measured in the same intervals used for q_1 and q_2); α = experimental factor of dispersion, between 0 and 1; β = experimental factor of the travel time given as the ratio of the average travel time of the vehicles of platoon and the average travel time of the entire platoon, and is between 0 and 1; F = smoothing factor given by (Eq. (2)):

$$F = 1/(1 + \alpha * \beta * t) \tag{2}$$

The speed is a function of the geometric characteristics of the road section and of the flow characteristics determined by the presence of the same platoon. The dispersion of the platoon depends on the values of the two experimental factors considered: α and β. An absence of platoon dispersion is characterized by α = 0 and β = 1; the maximum theoretic dispersion on the section, instead, is described by α = β = 1.

The determination of the two experimental factors α and β, at the end, influences the accuracy of the flow profiles calculated: they describe numerically the influence of other factors that vary in time and in order to environmental realities such as the platoon disturbances, the vehicle performances and the driver behaviors. Specifically α sums up the operating conditions (road layout, performance of horizontal and or vertical alignment, etc.) and the causes of noise extraneous to the traffic flow (presence or absence of parking, turning maneuver), while β expresses the perturbations internal to traffic flow (speed of disengagement, the composition of traffic flow, interference phenomena). Robertson, using the results of a survey conducted by Hillier and Rothery (1967), has obtained good results with α = 0.5 and β = 0.8. Those surveys were carried out under conditions of high and very disturbed traffic flows.

Table 1
Parameters Values of α e β show in Report NCHR 233 and in the manual TRANSYT 7-F (surce: McCoy et al., 1983)

Degree of interference	□		□	
	Report NCHRP 233	**Manual TRANSYT 7-F**	**Report NCHRP 233**	**Manual TRANSYT 7-F**
High	0,50	0,50	0,80	0,80
Moderate	0,37	0,35	0,80	0,80
Low	0,24	0,25	0,80	0,80

The manual of the TRANSIT (version 7-F) encodes three distinct operating conditions (noise or interference low, moderate or high) for which it offers three distinct values for α and β (Table 1).

The low interference is representative of situations as the absence of parking, with separation and limitations for turning maneuvers, lanes of 3.65 meters and roads with a high flow level, kind suburban; moderate interference is reached, instead, for reduced turns of traffic flow, reduced traffic of pedestrian crossing, lanes between 3.30 meters and 3.60 meters, typical of central city streets well-designed; at end, high interference is characteristic with presence of different modes of parking, fewer turns of heavy vehicles, moderate pedestrian flows, reduced lane width, flow conditions typical of central city streets.

Subsequent experiments (McCoy et al., 1983) have allowed the calibration of the parameters of the diffusion model, regardless of the entity of heavy vehicles, in conditions of low perturbed traffic flows. The analyses were conducted in six different sites characterized of major highways (separate carriageways with two lanes for direction, single carriageway to two-way traffic with one lane for direction) in suburban areas, with speed limits between 50 and 70 km/h on straight sections, zero slope, with no parking. It was considered platoons of only cars, excluding platoons delayed or disturbed for vehicle turning movements or pedestrian crossings contemporaries, for a total of 1691 platoons analyzed, ranging in size between 5 and 38 vehicles.

The lowest values for α (0.13 - 0.16) and, conversely, higher for β (0.97 - 0.99) was observed, through statistical analysis of regression, for separate carriageway roads with two lanes in each direction.

Under the conditions analyzed was suggested values of α equal to 0.21 and β equal to 0.97 for single carriageway roads and two lanes, and of α equal to 0.15 and β equal to 0.97 for separate carriageway roads with two lanes in each direction.

Some Italian surveys, finally, (Capaldo et al., 1998, Capaldo, Guzzo, 2002) have supplied good calibration results with the values: α equal to 0.05 and β of 0.97.

3. Surveys

The survey was conducted on a road section having some defined characteristics needed to obtain a reliable data base. In particular, road section should:

- be entirely visible to be well filmed;
- be sufficiently lighted to distinguish vehicles and referring points;
- not have any singularity point which can modify drivers behaviour;
- have a good visibility;
- have no slope (or a very light slope);
- not have any parking facility;
- not present intersections;
- not have any noise due to the opposite vehicles.

Thus a large road, named via Caracciolo (Fig. 3 and Fig. 4), was chosen free from parking, easily filmable from a building in front of it. The segment considered starts from a traffic light at the beginning of the straight part and ends at the third traffic light on the corner of Vittoria square. Via Caracciolo was the most important urban corridor of Napoli linking west and east areas of the town. Nowadays it is included in a restricted traffic zone causing lots of traffic problems. Road characteristics are: one roadway having three lanes in the direction examined and two in the opposite direction; lane width is 3,30 meters; section length is 633 meters from the first traffic light to the third one (square corner).

Those characteristics allowed us to follow the vehicle stream gathering information about all kinematics characteristics of each vehicle in different driving condition. Flow is mainly composed by cars with some motorcycles and few buses and light goods vehicles.

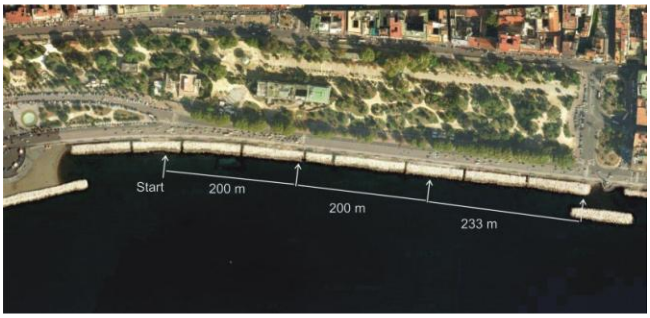

Fig. 3.
The survey road with measured bases

Fig. 4.
The survey road from the taken movies

Table 2
Average speed, acceleration and time at base lines

Base line (m)	200	400	633
Speed (km/h)	65.7	74.3	58.9
Acceleration (m/sec^2)	0.82	0.14	-0.33
Time (sec)	10.96	9.69	14.24

Data were gathered by using a digital camera installed on the top floor of a building in front of the last considered traffic light. The films were done during a week day in 2011 July during one hour in three different periods: from 8.00 am, from 2.00 pm and from 5.00 pm o'clock. Data gathered are relative to: type of vehicle, flows per vehicle class, headways, vehicle speed acceleration and density, platoon average speed. Measurement base lines were put on the pedestrian crossing and traffic lights (Fig. 3).

The most congested period was relative to the morning from 8 o'clock, with traffic flows average about 4500 vehicles/hour and peaks of approximately 7500 vehicles/hour, and it is been considered for this research.

The first traffic light at the beginning of the section has a pedestrian control since no intersection is present while the last light has fixed green times. The number of flow interruptions due to red light at the first traffic light was of 15 in the first hour and the pedestrian red time length was of 36 anticipated by a 4 second yellow light. Moreover, among such 15 observation of vehicles flows, it is considered the uninterrupted platoons which cross the last traffic light when it is green.

4. Results

The first step following the data collection was the computation of average characteristics relative to the platoons starting from the first traffic light. Such value are showed in Table 2. As it can be argued, beneath the last light is green, platoons decelerate in average as they approach the intersection. This can be due to two causes: the former is relative to safety; the latter is relative to the maneuver of turning to the left which is possible about 50 meters after the traffic light.

The data were used to calibrate both the two travel time dispersion coefficients (α and β) of the above mentioned traffic flow propagation model. Starting from the Robertson values of α = 0.5 and β = 0.8, we considered both the Mc Coy (Mc Coy et al., 1983) proposed values of α = 0.27 and β = 0.97 and the Capaldo (Capaldo et al., 1998, Capaldo, Guzzo, 2002) calibrated values of α = 0.05 and β = 0.97. The last values are relative to two Italian case study and thus more similar to this survey. After several calibration attempts, another dispersion coefficient couple has been considered which is slightly different from the last mentioned. The coefficient values of α = 0.07 and β = 0.97 are the ones which better approximate experimental flow profiles as can be seen in the following Fig. 5 to Fig. 8.

In such figures experimental versus computed CFP profiles are drawn relative to the last section considered (633 m) which corresponds to the greater platoon dispersion. It can be easily argued as the first two coefficient couples which were gathered for very different traffic contexts badly describe Italian drivers experimental data (Fig. 5, 6). In both cases experimental data present a narrowest profile that is few dispersion; Italian platoons seem to be more compact.

The other two couples of coefficient values give raise to two profiles which better reproduce actual CFP.

The differences between coefficient couples can be well visible by the scatter diagrams of Fig. 9 and Fig. 10.

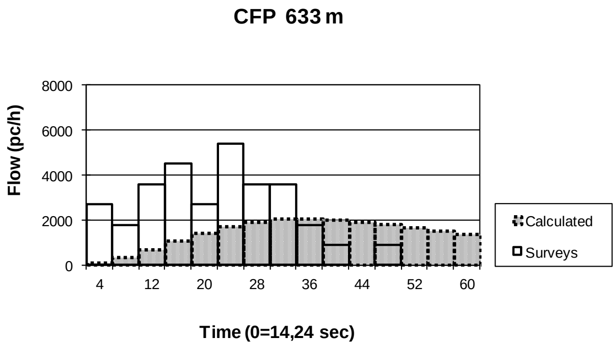

Fig. 5.
CFP at 633 m line (Surveys and calculated with α=0.5 and β=0.8)

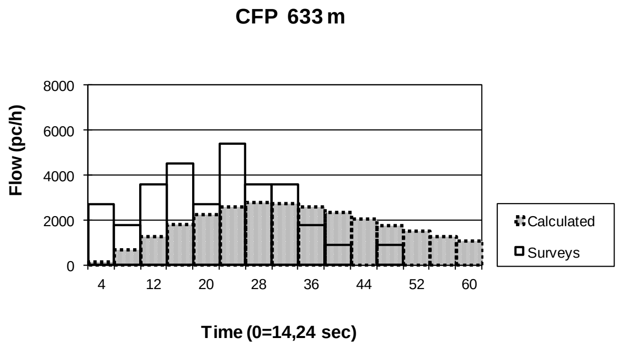

Fig. 6.
CFP at 633 m line (Surveys and calculated with α=0.27 and β=0.97)

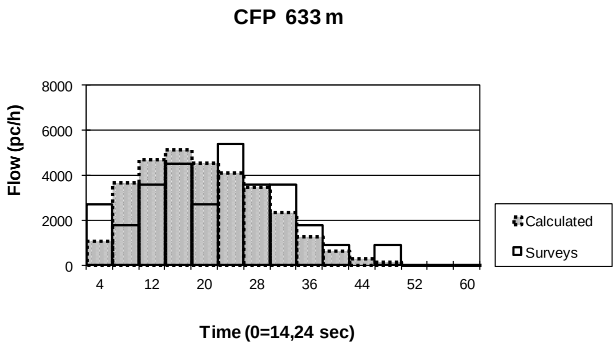

Fig. 7.
CFP at 633 m line (Surveys and calculated with α=0.05 and β=0.97)

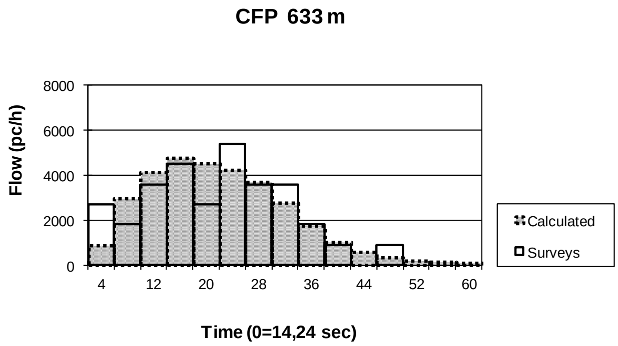

Fig. 8.
CFP at 633 m line (Surveys and calculated with α=0.07 and β=0.97)

According to the scatter diagrams, Table 3 shows the result of correlation analysis between experimental and computed data for each couple of recurrence method coefficient. As it can be seen, the coefficient values calibrated for Italian contexts present a greater goodness of fit with value of R^2 index close to one. Coefficient values proposed by Robertson and Mc Coy give results substantially different from the experimentation.

Through the chosen parameters, the cyclic flow profiles have been computed both for the other two considered distances of 200 and 400 meters. In Fig. 11 the flow profile at the starting point is reported. As it can be seen, the profile is not constant and it has composed by two part: the first describes the behaviour of the vehicles close to the starting point which move like a real platoon; the following vehicles, more distant from the starting point, has a greater headway which reduce the flow rate.

Table 3
Regression analysis of coefficients of recurrence relation α and β

α	β	R^2	Std. Err.	Σ Res.
0.50	0.80	0.698	1,993	1.192E+08
0.27	0.97	0.778	1,709	8.760E+07
0.05	0.97	0.918	1,037	3.229E+07
0.06	0.97	0.921	1,019	3.113E+07
0.07	0.97	0.922	1,016	3.094E+07
0.08	0.97	0.920	1,026	3.158E+07

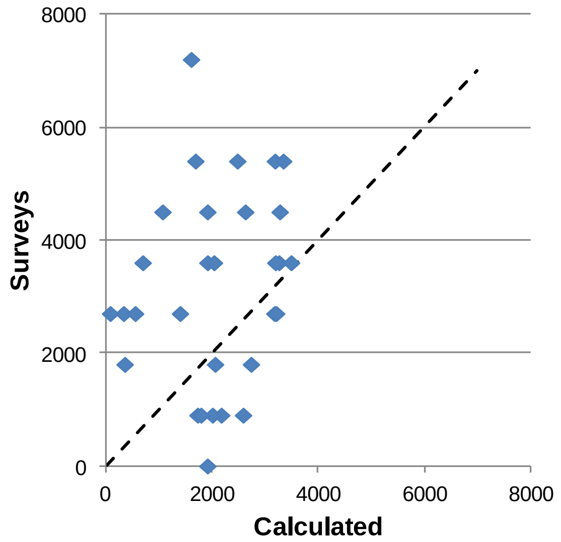

Fig. 9.
Surveys and calculated flows with α=0.5 and β=0.8

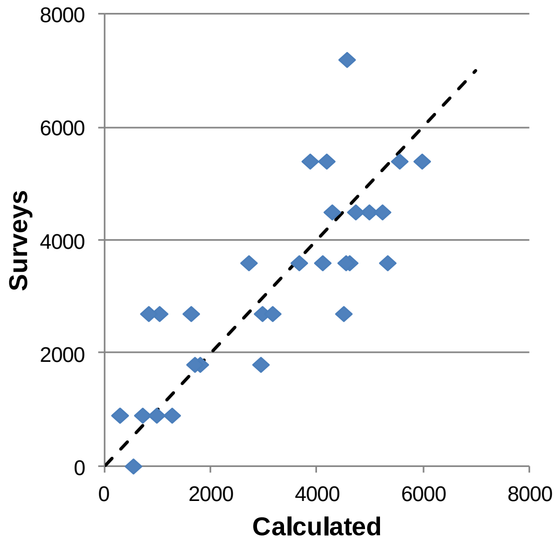

Fig. 10.
Surveys and calculated flows with α=0.07 and β=0.97

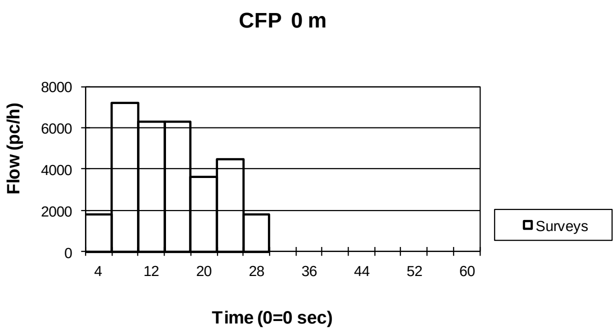

Fig. 11.
CFP at start line (Surveys)

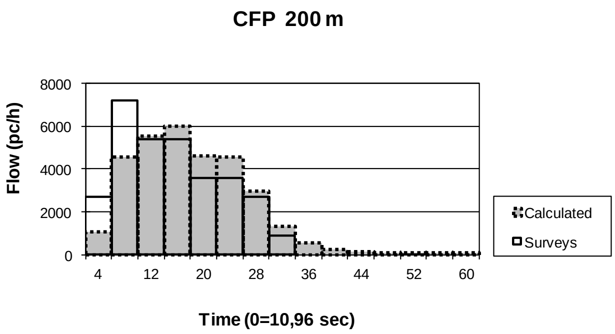

Fig. 12.
CFP at 200 m line (Surveys and calculated with α=0.07 and β=0.97)

Observing computed versus experimental flow profiles of Fig. 12, relative to the 200m distance, the differences between the two profiles seem to be evident since the experimental profile is similar to the one at the 0 distance while the computed profile presents a greater dispersion. This implies that the starting platoon seems to vary less than expected by the models. This situation change as distance increase as it can be seen in the Fig. 13 and Fig.14 where the experimental and computed profiles appear to be very similar.

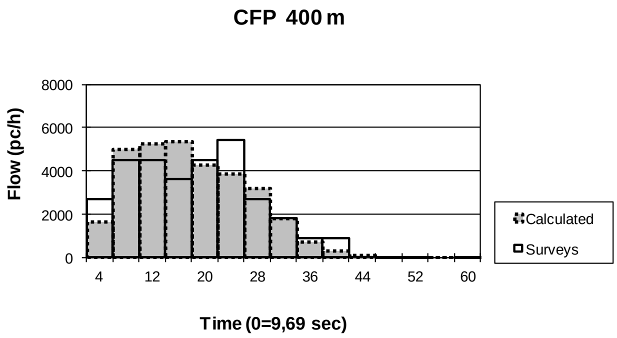

Fig. 13.
CFP at 400 m line (Surveys and calculated with α=0.07 and β=0.97)

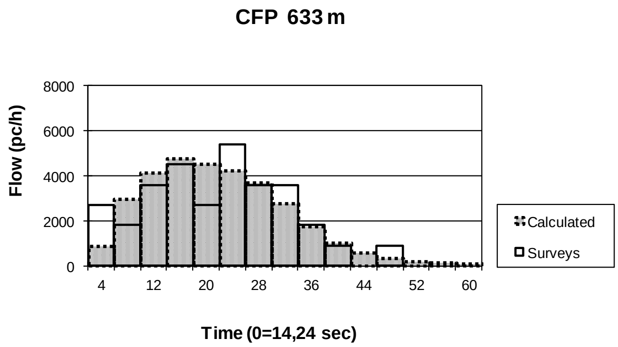

Fig. 14.
CFP at 633 m line (Surveys and calculated with α=0.07 and β=0.97)

5. Conclusion and discussion of results

In this paper a experimental survey on the behaviour of a traffic flow profile and its simulation on a real urban arterial road has been described. This work starts from other surveys present in literature carried out for different urban and people contexts and proposes new calibration results comparing them to the literature results showing the relevance of the context that is of average driver behaviour.

As a matter of fact, the two parameters describing the flow profiles obtained by the different Italian surveys showed to be quite similar but significantly different from the corresponding parameters relative to U.S. surveys. Thus it is induced to suppose a high relevance of the driver behaviour that, in average, depends on the type of infrastructure and the driving rules and styles. Such assumptions are confirmed by the value of the two coefficient α e β. The former is also called «dispersion coefficient» since it varies with the platoon dispersion due to factors different from speed; the latter varies with the platoon speed and the values of speed average vehicles. The result obtained shows how in the Italian context almost all vehicles have the same speed value in the whole platoon and this explains the high value of α coefficient. On the other side the dispersion of the platoon can depend on the driver reactivity to the green signal at the traffic light. The very small value of α coefficient can be due to the fact that all the drivers start very fast when the green light turns on denoting an aggressive driving style and gives raise to a compact platoon. This seems also depend to the hour of survey. As a matter of fact, the traffic of 8 o'clock and of 5 pm o'clock is, in general, due to work or study trips which are highly motivated to go fast to arrive at work or at school in time.

Moreover no noise from parking or from pedestrian crossing is present and this, according with results from Robertson, surely influences the low value of α coefficient. A correlation analysis between experimental and computed data for each couple of coefficient confirmed the above statements. If the goodness of fit was poor with U.S. contexts coefficients, on the contrary Italian context coefficients reached values of R^2 parameter close to one, with small differences among the different Italian contexts.

The considerations above described show the relevance of surveys and experimentations to understand the average characteristics of traffic flows which can be more different in various context. Thus such surveys will be extended to different day hours, to catch the effect of average trip purposes on drivers' behaviour, and to different road characteristics to understand the stability of the coefficients with respect to type of road.

Moreover, another development can be seen in searching a probability function suitable to describe flow profiles at the progressive distances. This approach, recently followed also by Brilon (Brilon et al., 2005), can result useful in the design of traffic regulation measures such as traffic light plans and coordination.

References

Brilon, W.; Geistefeldt, J.; Regler, M. 2005. Reliability of Freeway Traffic Flow: A stochastic Concept of Capacity, In *Proceedings of the 16th International Symposium on Transportation and Traffic Theory*, College Park, Maryland: 125 – 144.

Bruno, G.; Improta, G. 1990. The influence of platoon effect of traffic flow on network equilibrium calculations. In *Seminario AIRO: «Modelli e metodi per il supporto alle decisioni»*, Capri.

Capaldo, F.S.; Festa, D.C.; Guzzo, F. 1995. *Sull'analisi dei profili ciclici di traffico: metodologie di indagine, sperimentazione e risultati*. Quaderno DIPITER n. 56, Dipartimento di Pianificazione Territoriale, Università della Calabria, Arcavacata (CS).

Capaldo, F.S.; Festa, D.C.; Guzzo, F. 1998. Analisi sperimentale dei profili ciclici di traffico. In *Rilievi e Modellizzazione del Traffico Veicolare,* Franco Angeli ed.: 244-264.

Capaldo, F.S.; Festa, D.C. 2002. Modellizzazione del deflusso veicolare tra due intersezioni semaforizzate ed analisi sperimentale per la valutazione delle emissioni inquinanti. In *Rilievi, Modellizzazione e Controllo del Traffico Veicolare,* Franco Angeli ed.: 45-55.

Capaldo, F.S.; Guzzo, F. 2002. Modelli di previsione della dispersione dei plotoni veicolari: determinazione sperimentale dei parametri caratteristici. In *Rilievi, Modellizzazione e Controllo del Traffico Veicolare,* Franco Angeli ed.: 123-147.

Denney, R.W. 1989. Traffic dispersion modeling. *Journal of Transportation Engineering.* 115(2): 193-207.

Gerlough, D.L.; Huber, M.J. 1975. *Traffic flow theory*. TRB Special Report 165, National Research Board, National Research Council, Washington, D.C.

Hillier, J.A.; Rothery, R. 1967. The syncronization of traffic signals for minimum delay. *Transportation Science*, 1(2): 81-94.

Holoroyd, J.; Hillier, J.A. 1969. Area traffic control in Glasgow, a summary of results from four control schemes. *Traffic Engineering + Control*, September.

Lighthill, M.J.; Witham, G.B. 1955. On kinematics waves II - a theory of traffic flow on long crowded roads. In Proceedings *of Royal Society*, Sez. A, 229, London, repr. in HRB (1964), Special Report 79.

Mc Coy, P.T. et al. 1983. Calibration of TRANSIT platoon dispersion model for passenger car under low friction traffic flow condition. *TRB Preprint, 62nd Annual Meeting of the TRB*, Transportation Research Board, National Research Council, Washington, D.C.

Pacey, G. M. 1956. *The progress of a bunch of vehicles released from a traffic signals*. Road Research Note n. RN/2665/GMP.

Robertson, D.I. 1969. TRANSIT method for area traffic control. *Traffic Engineering + Control*, October.

Robertson, D.I. 1974. Cyclic flow profiles. *Traffic Engineering + Control*, June.

Seddon, P.A. 1971. Another look at platoon dispersion: 1. The kinematic wave theory. *Traffic Engineering + Control*, August.

Seddon, P.A. 1972. Another look at platoon dispersion: 2. The diffusion theory. *Traffic Engineering + Control,* September.

Seddon, P.A. 1972. Another look at platoon dispersion: 3. The recurrence relationship. *Traffic Engineering + Control*, October.

Seddon, P.A. 1972. The prediction of platoon dispersion in the combination methods of linking traffic signals. *Transportation Research,* Vol. 6.

TRB. 1994. *Highway Capacity Manual*, Special Report 209 (Third Edition), Transportation Research Board, National Research Council, Washington, D. C.

Weibull, W. 1951. A statistical distribution function of wide applicability. *Journal of Applied Mechanics-Trans. ASME* 18(3): 293-297.

Wortman, R.H.; Fox, T.C. 1994. An evaluation of vehicle deceleration profiles. *Journal of Advanced Transportation*, 28(3): 203-215

Session 6: Logistics and Supply Chain Management

HUMAN RESOURCES MANAGEMENT SYSTEMS IN THE LOGISTIC CHAIN

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Abstract: Developmental trends in the modern economy require a new approach to resource management through logistics and supply chains optimization. Ever-expanding logistics market demands a different approach to key potential of the economy development, and those are employees with their knowledge and skills. Strengthening of human creativity, innovation and efficiency increases organizational skills and the creation of logistics intellectual capital, which includes three important components such as: human capital, structural capital and customer capital. A well-organized human resource management enables companies to achieve competitive advantage, increase productivity, market share, reduce costs and increase profit of the companies in the logistics chain. To achieve the goals and mission of the company's strategy is necessary to build a quality motivational system based on motivational techniques that correspond to each company or corporation in the entire logistics chain. Motivational system can be based on a variety of motivational techniques, such as: material compensation, intangible compensation, benefits, creativity encouragement. Based on these assumptions, it is necessary to create incentive systems for human resources management, which increase efficiency, creativity and greater business efficiency and competitiveness of logistics companies in the supply chain.

Keywords: The Logistics Market, Supply Chains, Logistics Intellectual Capital, Logistics Management, Motivational System, Motivational Techniques

1. Introduction

Development trends in the modern economy imply human resource management in logistics as a requirement of supply chain optimization. Logistics companies integrate different logistics functions that can be divided into primary and supporting functions, of which the most important are transportation, inventory and order management production support and maintenance of constant quality products and services, supply of material resources and informational support. Supporting functions are storage, processing freight, packing, reverse logistics and after-sales. Employees within the contemporary logistics markets represent a fundamental resource development business and the basis of competitive advantage over other companies. The complex and demanding business environment limits the scope for the market ratios of the company which can be compensated for development and investment in human resources, acquiring new knowledge and skills.

Investment in human resources is an imperative in order to achieve competitive advantage which in times of economic crisis is generally neglected because companies are trying to survive the crisis, and in fact the investment planning and selection of human resources can increase efficiency and getting out of the crisis faster. Professional development of managers and workers in logistics encourages competitiveness, creativity in finding new competitive products and services, has appeared on the market and achieve better business and financial results.

Human Resources Management in the medium developed markets as in Croatia, are still not stable in basic conditions of business, but it depends on various factors such as the lack of overall strategic and sector strategies, underdeveloped capital markets, the impact of the crisis in the environment, excessive influence administration and other negative factors.

Motivational system as both material and immaterial compensation of employees in logistics is not clearly established because the collective agreements, tax conditions and financial performance are subject to frequent changes and impacts, the external environment of the company.

Encouraging the development of creativity in Croatian logistics companies analyzed through monitoring and evaluation of work performance, and results obtained are indicators of management success of logistics companies.

2. Analysis of human resources management in logistics companies

Achieving competitive capabilities and performance of logistics companies in the logistics chain linking primary production to final consumption depends on the position in the market, competition, and the most creativity and leadership staff.

A company that constantly innovates and expands the range of its products and services, while maintaining a stable quality, can maintain or expand its position in the market, based on investment in human resources at its disposal and management.

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2.1. Achieving competitive advantage of logistics companies by investing in human resources

Employees within the contemporary logistics markets are the primary development resource based business and competitive advantage. Inside the complex, uncertain and challenging business environment to increase market share of the company is directly dependent on the development of resources, knowledge and skills to new employees. With the numerous factors that influence the optimization of logistics services (geographical and traffic, economic, technological, organizational, historical, religious, etc.), human resources in the last ten years represent one of the primary factors.

How knowledge is produced and resources, rather than natural, as the main resource development and distribution of global wealth has changed in recent decades, and the majority of wealth in developed countries with a low content of natural and a significant proportion of human and produced capital. According to research in industrialized countries during the engagement of circulating capital in the direct production of 5% - 10% of the total time in the process of playing the rest of the 90% - 95% are on hold, handling and transport, and logistics, which means that the factor of increasing the competitiveness of Contemporary company lies in optimizing logistics services (Šamanovic, 1994). Increasing the quality of logistics services while lowering costs and creating a fluid organizational structure that can anticipate and timely respond to market requirements, is only possible by investing in the quality of human resources in order to find new ways of adding value logistics services.

U.S. consulting firm A.T. Kearney uses an index of global logistics operation (Global Logistics Performance Index - LPI) developed by the World Bank (2009) to rank the countries in the logistic operations. Seven indicators covered by the index include: customs, infrastructure, and international transport, logistics competence, tracking of goods, domestic logistics costs and timeliness of delivery of the items to the desired destination. The index is a comparison of the average performance of 150 countries according to these indicators and rating the quality of individual indicators nominal scale (ranging from 1 to 5, where 1 is the worst and 5 the best score) as well as the ranking of the country compared to other countries. According to the index logistical implementation, the leading country in the logistics operation is Singapore (LPI value = 4.19), while Croatia is on the 63 place with the LPI value of 2.71 (Fig. 1). From these indicators, Croatia is most notable on delivery shipments in the desired destination, with the score value of 3.45 (Renko et al., 2009).

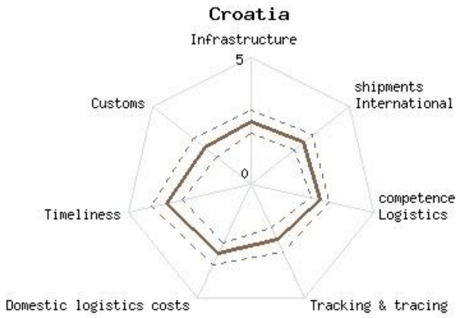

Fig. 1.
LPI value index in Croatia
Source: The World Bank (2009): „Country scorecard Croatia“

Contemporary Conditions organizations focus attention on the degree of knowledge, experience and creativity of employees, entrepreneurial spirit, flexibility and acceptance as a new basis for achieving competitiveness and success. Only creative and inventive managers can make decisions quickly and efficiently, and an optimal mix of human and financial resources, putting resources into operation logistics companies able to market logistics services (Zelenika and Pupovac, 2001). Creative logistics manager is responsible for business development and logistics companies. Innovation and creativity involve strategic action, creating alliances and encourage the development and change.

There has been a certain lack of knowledge and skills within the logistics activities with different shares in European and global opportunities. Developed economies in determining the insufficient level of knowledge logistics organize training packages to help increase the level of knowledge of employees impacted by the increase in business performance.

2.2. Planning and selection of human resources in supply chain and logistics

Human resources management plays a more prominent place in the organizational chart logistics companies although many companies still prevails declarative rather than their actual orientation of the employees. Quality human resource management and development through attracting employees provide support for the realization of competitive advantages, increasing productivity and financial results.

Organization of the Human Resources Department can be vertical, which is also commonly applied form in Croatia (Croatian Railways, Croatian Post) and the horizontal. Managers of human resources services and have an advisory role within the organization and can have functional responsibility or make and implement decisions within a specific area.

Prevailing models of human resource management in the logistics companies are (Zelenika and Pupovac, 2001):

- The model of administrative efficiency emphasis on administrative activities and staff is not treated as a source of competitive advantage. The primary tasks of this model are to reduce absenteeism, information and scheduling of workers, rights of employment, termination, litigation management, organization, payroll and the like.
- Partially strategic model includes providing necessary information on human resources management, or information about the possible implications of various strategic plans on human resources.
- The model is characterized by professional management support for the involvement of human resources in the process of strategic planning. This model is most applicable to companies with a large number of employees with college ready, aimed at increasing the quality of logistics services to build their competitiveness on innovation and knowledge of employees.

Planning the number and structure of employees in logistics companies includes an analysis of market structure, the degree of liberalization, competition, competitiveness and vision of the organization and its objectives, trends in the labor market, labor relations legislation, predicting trades workforce, due to the introduction of modern technology, new means of transport and working procedures and preparation skills inventory list.

Inventory lists of skills give management insight into jobs that existing employees based on their education, work experience and qualifications can be conducted. Analysis of the structure of human resources reveals a tendency of increase / decrease in the total number of employees or the number of individual organizational units, identifies reasons for the increase / decrease in the number of employees, defining the existing staff qualifications and desirable, necessary and funds for the realization of the desired structure, technological change and recognize the consequences will have on the existing structure of human resources, estimated the flexibility and adaptability of the organization based on the age structure, work experience and special skills, and analyzes and explores the problem of fluctuation.

The planning process of human resources provides the answer to the question: How many employees and what skills, knowledge and abilities to the logistics organization to achieve its business objectives. Way to provide the necessary structure to employees and existing employees to prepare for the future needs and requirements of the logistics market.

The selection process involves the selection of candidates to the fullest extent possible; meet the requirements of the job. Selection process prior to the determination of the key features (five to seven attributes) based on which the selection is made. Characteristics which are helpful in making the required profile of a future employee: motivation, thinking (to process information and make decisions), action (to execute tasks) and the interaction (how to communicate with others).

Logistics Companies commonly used pre, which should be as short as possible and cheaper, and can consist of filling out forms, test or interview and serves to eliminate undesirable candidates. Forms for employment gathered significant information about the candidates and serve as an aid to prepare the individual interviews. Interviews allow candidates personally meet and differ according to the number of participants, the number of pre-prepared questions and duration. Often with a narrow selection of candidates by more than one interview for optimal selection. Check health capability is often needed in jobs that require physical fitness. There are several types of tests that are applied in the selection process: tests of mental abilities, motor skills tests, mechanical tests, sensory abilities, and specific skills tests, tests of knowledge, interests and personalities.

2.3. Professional development of employees and managers in logistics

In an entrepreneurial society, individuals are before continuing need for continuous learning and development (Drucke, 1992). Individuals who were educated were the exceptions in traditional societies that were based on applying the knowledge acquired during the training by the end of its working life. In today's business environment such individuals become role models and imperatives of progress.

Education system that is in use today, with significant modifications still based on the European educational system in the seventeenth century and since today need a whole new thinking and a new approach to the challenge of improving education is highly educated adult individuals. Individuals are increasingly responsible for continuous learning and revising skills, personality development and career (Drucke, 1992). Challenges related to learning are more demanding because the skills, knowledge and production are changing at shorter intervals so that it can be expected that individuals will change over its lifetime goals and often career.

There are four approaches to employee development and a combination of approaches tailored to the specific company: formal education, assessment, work experience and interpersonal relationships. Formal education programs include programs designed for employees of the company in the form of short courses, master's degrees in business administration, university programs. Assessment includes gathering information and giving feedback to employees about their behavior, style and communication skills. Work experiences include relationships, problems, requirements, tasks, and other features with which the employees encountered during their employment. Interpersonal relationships in the form of employee development often involve mentoring (experienced employee - a mentor helps the development of less experienced colleagues - dependent) and coaching (a process in which a colleague or manager as coach working with employees in order to motivate, develop skills and provide feedback).

Human Resource Managers are made and training programs to employees and these programs should be the result of cooperation of managers and human resource managers from other logistics companies departments to achieve the performance of employees. Education and training of staff is a continuous process that should ensure the growth and development of the organization. Objectives of training and education of employees are learning with modern technologies, exploring the current state of the market, training for work in accordance with the security measures, developing work habits, creating a solid base for further career development, developing a positive attitude towards the employees themselves, by their own workplace and the organization for which they work, and to cause to be useful within your company and society as a whole. These programs can be organized within the company in the performance of managers, or they can hire experts from outside the organization.

The Research Sector Skill Councils for the Freight Logistics Industries (Skills for Logistics, 2011) resulted in interactive competence" steps" that provide a valuable tool for planning and career development within logistics organizations. This tool starts with the initial level jobs progressing to global managerial positions and can be grouped into three levels: operational, middle management and top management. Logistical steps competencies include 470 located at 34 different positions within the logistics sector.

According to the report by the Lisbon Council for Economic Competitiveness and Social Research in 2007, the Economics Human Capital Index in Croatia, Bulgaria and Poland is placed at the very bottom of the scale with respect to four criteria: the stock of human capital, its use, productivity and demographic features (EHCI, 2007). The main problem is considered a declining population, the continuous brain drain, chronically high unemployment and inadequate investment in education and skills which are specifically related to the age of 45 (Verdiš and Jurišić, 2008). Business School for logistics and inventory management of the Faculty of Transport and Traffic Sciences in Zagreb is one such initiative by a system of lifelong education officials in logistics companies offering development of the existing knowledge according to current knowledge of science and the profession.

3. Characteristics of the employee performance management practices in logistics companies in Croatia

3.1. Motivational system in logistics companies in Croatia

Research motivation and satisfaction of employees should be a significant factor in any human resource strategy for several reasons. First, the company acquires the ability to track trends in the level of employee satisfaction through a certain period of time and through acquired knowledge has the ability to create and use appropriate techniques to prevent voluntary turnover. Second, systematic testing company acquires satisfaction findings on the effects of changes within the organization (change in business policy, personnel, etc.) on employee attitudes. Thirdly, the use of standardized instruments (questionnaires, etc.) gives the company the possibility of comparison with its competitors and use insights gained to achieve the desired level of satisfaction. Fourth, insights allow control between business units and selection of the best practices that can be applied at all levels. Fifth, employees are given the opportunity to express their thoughts and concerns in the workplace, which gives them more opportunities to resolve them. It is crucial to a company that conducts employee satisfaction survey is ready to act on the basis of the information gathered. In the process of employee motivation in logistic companies and businesses operating in the supply chain, it is necessary to elaborate the elements that can affect employee motivation and increase the company's fortunes. Very often, we assume that the wages fundamental motivating factor, but studies that have been conducted in this study through a questionnaire that contains up to 40 questions that affect the motivation and other factors.

3.2. Tangible and intangible compensation in logistics companies in Croatia

As a first indication of the motivational systems in logistic companies take the regularity of conducting investigations of employee satisfaction and confidence of respondents to the motivational system that is in the application best suited to their company.

In Croatia logistics organizations motivational system is only partly based on the features of each company separately. Motivational techniques by 66% of respondents report their company (including a 33% full and 33% partial) while 33% is worth the contrary, the motivational system is not appropriate for their company. 33% of companies regularly conduct employee satisfaction survey and as many as 66% never or very rarely.

Research shows that Croatian companies devote most attention to the mandatory pension and health insurance (100% of companies). 100% company paid reimbursements and Christmas bonuses, of which 83% regularly. 83% of companies take into account the internal pay equity and 66% on the outside. Wage levels affect the employer's ability to attract, motivate and retain the best employees who will invest the optimal level of effort to achieve the objectives of employers.

In 66% of the surveyed companies, there are fixed and variable pay and the same shall ensure that employees are clear grounds and criteria for the variable part of the salary. Of that 50% of companies use the system to reward teamwork versus 16% of the companies applying for the bonus system based on individual performance. Only 16% of company loyalty rewards and 33% of companies reward learning different skills. 16% offer subsistence and other insurance. Most employees in 83% of companies have permanent contracts.

Permanent contracts in the Republic of Croatia, as well as EU member states are still fundamental form of hiring workers. The research results indicate the high level of awareness in Croatian logistics companies on the importance of job security for their employees.

83% of companies are investing in employee education. We have no data for those groups of employees are most invested in education, however, and without this information the results are optimistic.

83% of the company ensures that the goals are clear about achievable, allowing independence in performing tasks, invest in an external image of the company through an elaborate marketing strategy.

66% of companies provide some of the benefits (discounts on some of the company's products, membership interest clubs, paid time off and absence that are not included in the annual leave, use of a company car, some form of care for children and the elderly, such as the company's nursery and dependent children, seminars for retirees, etc.). These benefits fall into one of the most used in Croatia with the benefits provided meals (restaurants, vending machines food) covered travel expenses, paid accommodation and a company car which is used for private purposes. Also, 66% taking into account the working conditions suit the needs of employees, organizes seminars on teamwork, invests in managers through some of the programs (such as internships, visits to targeted organizations, consultation, organized with the help of self-education, organization of seminars and specializations covering costs and graduate studies), provides the opportunity to participate in setting goals and decision making, and their managers take into account differences in personality, needs and attitudes of employees when assigning certain activities.

50% of companies awarded an impressive title in workplaces that allow it.

33% of companies provide opportunities to expand work assignments, advancement through internal recruitment and their managers use an oral or a written acknowledgment.

In only 16% of companies there is a possibility of the property, carried out enrichment work tasks that were previously performed superior, formed an autonomous working groups and offers one of the following: the division of work between two or more employees with part-time in a job, the ability to work distance learning, flexible working hours. Possibility of profit sharing for employees and job rotation is not applicable, no company.

4. Creativity development in logistics companies in Croatia

4.1. Monitoring and evaluation of work performance

Basis for monitoring and evaluating the work performance of employees creativity development that can stimulate a variety of ways, such as bonuses, rewarding creativity and innovation.

Unfortunately very few companies, only 33% of the rewards creative achievements and innovation, while only 16% of companies use some of the analytical techniques or creative group has formed to find new creative ideas, and none of the companies surveyed by no rules of inventions and patents.

Monitoring and evaluation of employee performance carried 66% of the company.

50% of companies use some of these techniques to evaluate the work performance of its employees and provides feedback to employees about the results of the assessment.

The analysis showed that almost is not applicable employee satisfaction survey, the tangible and intangible compensation is mostly related to the satisfaction of the need for job security while the higher-order needs are ignored. Monitoring and evaluating work performance of the companies performed only while the development of creativity in their infancy. Given the results of the opinion that the first hypothesis should be accepted and concluded that logistics companies in Croatia with underdeveloped function of management for Employee Performance.

4.2. Indicators of Performance Management in logistics companies

Indicators of success of business analyzed in this study were: total income, profit after tax, the share of income in the total income, the share of income on equity (ROE Return on equity / return on equity shows how much profit per capital invested curse, ROE = net profit / capital) and the relationship between profit to total assets (ROA Return on assets / return on assets, ROA = net income / total assets). The financial statements for year 2009 for each of the surveyed companies take with the Register publicly available annual financial report (RGFI). On the Internet, everyone, starting with the business year 2008 year, available financial statements and other documents that the contractors according to Article 20 Labor Law, shall provide for publication of the annual financial statements of the Register kept by FINA.

Correlation analyzes were performed using IBM SPSS Statistical Software Data showed the following: 1) the total revenues of the company are associated with the existence of the bonus for individual results and the possibility of employee profit sharing 2) profit after tax associated with the possession of the invention Regulations 3) share gain in total revenue associated with the possession of regulation on inventions 4) ROE was significantly associated with 7 variables and 5) ROA was significantly associated with owning ordinances invention and use of analytical techniques and creative groups to come up with new ideas. Dependent variables and objective indicators of success associated with 8 independent variables. Ownership rules of inventions associated with the four indicators of success, which indicates the importance Croatian logistics companies should devote this indicator[2].

Table 1
Objective performance indicators in correlation with the results of research in logistics companies in Croatia

Statement	Indicators of success				
	1	2	3	4	5
We apply the system of bonuses in the form of cash payments based on individual employee performance.	X			X	X
There is a possibility of profit sharing for employees to participate in improved business performance.	X			X	
Our company invests in employees training on one of the following ways: by covering the cost of tuitions and scholarships, granting leave (one day to several months) for the needs of education, organization of seminars or investing in professional and technical training.				X	
Our managers use oral or writing recognitions for employees as a form of feedback.				X	
In our company, there is at least one of the following options: the division of work between two or more employees with part-time in one job, the possibility of teleworking, flexible working hours.				X	
We allow the formation of autonomous work groups responsible for the implementation of specific projects.				X	
We own rules of inventions.		X	X	X	X
When there is a need for creative ideas we use analytical techniques (listing, Input – Output, pro and con), or organize creative groups (Brainstorming, Gordon technique, Hum Groups)					X

Source: Made by authors

[2] *Var 15 – Pearson coefficients 0,834, Kendall's tau_b coefficients 0,775, Spearman's rho 0,845*
Var 23 - Pearson coefficients -, Kendall's tau_b coefficients 0,856, Spearman's rho 0,926
Var 26 - Pearson coefficients -, Kendall's tau_b coefficients 0,856, Spearman's rho 0,926
Var 31 - Pearson coefficients 0,864
Var 32 - Pearson coefficients 0,906
Var 36 - Pearson coefficients 0,914, Kendall's tau_b coefficients 0,775, 0,775, 0,775, 0,802 Spearman's rho 0,878, 0,878, 0,878, 0,891
Var 37 - Pearson coefficients 0,814

On the basis of the indicators we conclude that the successful logistics companies in Croatia (Table 1) reward individual results and allow employees to participate in the profits. In these companies invest in employee education through some of the existing programs, there is a possibility of flexible working hours in order to allow employees balance work and private life. Managers use oral or written confession and implicated in the formation of autonomous work groups and creative groups that will generate innovative ideas. Successful logistics companies have rules about inventions. Results of statistical analysis showed an association between seven indicators of management success and objective indicators of financial performance of the company and gave guidelines for further action and improvement of the existing system of human resource management on the basis of which we conclude that the second hypothesis should be accepted.

3. Conclusion

The realization of the strategic potential of logistics and its role in the logistics supply chain, which is presented in a continuous improvement of the flow of goods and services, it is possible through the integration of key components of the logistics system. An important internal factor for competitive advantage and performance of logistics companies in the structure of the supply chain consists of four basic resources, such as: financially, physically (material resources), and systematic human and technological resources.

Human resources in the logistics and supply chain management are fundamental to the success of the assumption of a high level of knowledge, skills and competencies of employees, whose creativity and dedication we have to stimulate the various tools and models.

In the global market of individual functions and activities are geographically dispersed, including a growing number of participants in the logistics supply chain, different payment systems (currency), macroeconomic risk (crisis), mismatch of infrastructure, laws and standards on environmental and consumer protection, different standards products, and there is a gap under the influence of cultural habits of the population of some countries, which emphasizes coordination of logistics activities that may have a significant impact on business performance.

The introduction of new, highly sophisticated technologies that have a huge impact on the quality of logistics services and customer-supplier, require a high level of knowledge of staff who can offer solutions to customers by prime ministers, identify requirements and needs and find the appropriate range of logistics solutions and services. Performance management of human resources working in the logistics companies in Croatia can leverage to better business performance and achieve competitive advantage in the market through increased satisfaction and employee motivation.

The results of the statistical analysis presented in this paper, have shown an association between seven indicators of management success, financial results, and all provides guidelines for future action and improvement of the existing system of human resource management.

The results of studies and surveys have shown that successful logistics companies should encourage and reward individual and group results and enable employees to participate in the profits of the company. You need to invest in various forms of education, such as external logistics schools, seminars, forums, postgraduate studies, and internally through the stimulation of what awaits them in the market, team building and other forms of lifelong learning.

Managers should provide for flexible working hours in order to create balance work and private life, then use oral and written confession successful individuals, creative and autonomous working groups that will generate new and innovative ideas. It is very important that logistics firms adopt ordinances on inventions and patents, and various forms of innovation to further stimulate employees to improve logistics and logistics processes in logistics companies and logistics supply chains.

References

Analiza poslovanja poduzetnika prijevoza, skladištenja i veza RH u 2007. Godini. 2008. FINA, Zagreb, Available from Internet: <http://www.fina.hr>

Bahtijarević Šiber, F. 1999. *Management ljudskih potencijala*. Golden Marketnig, Zagreb

Bloomberg, D.J.; LeMay, S.; Hanna, J.B. 2006. *Logistika*. Mate. Zagreb.

Bogdanović, M. 2008. Prilog teoriji ljudskog kapitala: koja svojstva radne snage treba smatrati bitnim sastavnicama ljudskog kapitala, *Ekonomija, 15(1*): 45-82.

Brčić, R. 2002. Organizacijska kultura u funkciji djelotvornosti upravne organizacije, *Ekonomski pregled*, 53(11-12): 1048 – 1069

Cooper D.; Robertson, I.T. 2006. *Psihologija odabira zaposlenika*, Naklada Slap.

Denali Consulting. 2009. Logistics Trends – Achieving Supply Chain Integration. Available from Internet <http://denaliusa.com/whitepapers/41]>

Dil, P. 1985. *Psihologija motivacije*. Prosveta. Beograd

Drucke, P.F. 2007. *Upravljanje u budućem društvu.* M.E.P. Consult, Zagreb.

Drucke, P.F. 1992. *Inovacije i poduzetništvo, praksa i načela.* Globus nakladni zavod, Zagreb

Ederer, P.; Schuller, P.; Willms, S. 2007. European Human Capital Index: The Challenge of Central and Eastern Europe, The Lisbon Council for Economic Competitiveness and Social Renewal, Available from Internet: <http://www.lisboncouncil.net/publication/publication/41-european-human-capital-index-the-challenge-of-central-and-eastern-europe.html>

Edgell, S. 2006. *The sociology of work: continuity and change in paid and unpaid work.* Sage Publications Ltd.

Edvinsson, L. 2003. *Korporacijska longituda, navigacija ekonomijom znanja*, Differo, Zagreb.

European Human Capital Index: The Challenge of Central and Eastern Europe, the Lisbon Council for Economic Competitiveness and Social Renewal, 2007.

Marušić, S. 2001. *Upravljanje ljudskim potencijalima*, Adeco, Zagreb.

Miljković, D.; Rijavec, M. 2007. *Organizacijska psihologija*, Ekološki glasnik d.o.o., Donja Lomnica.

Noe, R.A.; Hollenbeck, J.R.; Gerhart, B.; Wright, P.M. 2006. *Menadžment ljudskih potencijala-postizanje konkurentske prednosti*, Zagrebačka škola ekonomije i menadžmenta, Zagreb.

Nordstrom, K.A.; Ridderstrale, J. 2002. *Funky Business – Kapital pleše samo s darovitima.* Differo d.o.o.

North, K. 2008. *Upravljanje znanjem – Vođenje poduzeća usmjereno prema znanju*. Naklada Slap, Zagreb.

Performance Index and its Indicators. 2009.

Petar, S.; Vrhovski, I. 2004. *Ljudska strana upravljanja ljudima.* Mozaik knjiga, Zagreb.

Petar, S. 2005. *Tamna strana upravljanja ljudima.* Medus Biro d.o.o., Zagreb.

Renko, S.; Fičko, D.; Petljak, K. 2009. Novi logistički trendovi kao potpora maloprodaji. In Proceedings of the *IX. međunarodni znanstveni skup Poslovna logistika u suvremenom menadžmentu*, Osijek: 33-34.

RGFI – public disclosure. Available from Internet: <http://www.fina.hr>

Šamanović, J. 1994. *Mikrologistika kao funkcija gospodarenja i instrument prilagođavanja poduzeća promjenama na tržištu*, *RIF*. Hrvatska zajednica računovođa i financijskih djelatnika: 102.

Skills for Logistics. 2011. Available from Internet: <http://www.skillsforlogistics.org>

The World Bank. 2009. *Trade Logistics in the Global Economy – the Logistics.*

Verdiš, M.; Jurišić, D. 2008. Cjeloživotno učenje i fleksigurnost – pozicija Hrvatske, Pravni fakultet Zagreb, katedra za ekonomsku politiku. Available from Internet: <http://www.liderpress.hr/Uploads/2475/38150/Cjelozivotno_ucenje_i_fleksigurnost_pozicija_Hrvatske.doc>

World Bank. 2009. Available from Internet: <http://siteresources.worldbank.org/INTTLF/Resources/lpireport.pdf]>

Zelenika, R.; Pupovac, D. 2001. Intelektulani kapital – razvojni resurs logističkih kompanija za 21. stoljeće, Izvorni znanstveni rad, *Ekonomski pregled*, 52(9 – 10): 1034 – 1052

POSSIBILITIES OF THE BUSINESS INTELLIGENCE MODEL APPLICATION IN SUPPLY CHAINS

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Abstract: Business Intelligence (BI) is a data-driven Decision Support System (DSS) that combines data gathering, data storage, and knowledge management with analysis to provide input to the decision process. Business Intelligence emphasizes analysis of large volumes of data about the company and its operations because analyses ranges from simple reporting to slice-and-dice, drill down, answering ad hoc queries, real-time analysis, and forecasting. In this paper we will analyze application possibilities of BI in supply chains because some logistics companies still do not know the structure of their logistics costs, and the information is not managed effectively, and consequently, real people do not have accurate information at the right time and right place. Successful application of this approach contributes to minimizing costs, increasing efficiency of the entire supply chain more efficient use of working capital, the right choice of suppliers, optimizing inbound and outbound logistics, inventory carrying out active and growing, developing and improving the overall business. Analytical data processing combines the use of different methods to a series of processed fragmented data to obtain useful information. When we take into account how much capital is spent on the inefficient practice of supply and distribution, it is clear why companies need a business intelligence function in consolidating, optimizing and increasing the transparency of this process of transformation and purchasing functions to obtain a function with the help of corporate portals. The aim of this paper is to show that the analysis of relevant data of supply chains is to identify trends and patterns, and formulating a series of scenarios, can predict probable future outcomes and uncover potential opportunities and barriers in the supply chain.

Keywords: logistics, supply chains, business intelligence

1. Introduction

More than ever, organizations are today faced with such challenges as globalization, product portfolio complexity, competitive pressures to innovate, necessity to implement cost reduction measures, increased competition from rivals, market pressures as well as external pressures from stockholders. For manufacturing, distribution and logistics companies, efficiency of their supply chain operations is really key, as it reflects how effectively their inventory, plant and warehouse capacity and capital resources are utilized. Some of the more obvious areas that companies have historically looked into for improvements include optimizing stock levels, improving inventory turnover ratios (or days-on-hand), and improving on-time deliveries.

Globalization has created enormous opportunities and alternatives for organizations as well as customers and, whilst an increase and diversity in product offerings has been a welcome outcome, nonetheless, the global scale of sourcing and manufacturing has added to the complexity of these organizations' business processes and their supply chains. For these organizations to continue to compete successfully, it is becoming increasingly imperative to improve both the efficiency and effectiveness of the overall supply chain operations. Managers must ensure their supply chains are flexible, responsive, and reliable and they need to focus on improving quality, service, and yields as well as better leverage their customer supplier relationships and strategies (Langley, 2007). They need to think about some of the following:

- How do I increase fill rates and accelerate the flow of goods through the chain?
- How do I improve flexibility to meet changing demand and improve overall service levels?
- How do I strike just the right tradeoff balance between efficiency and flexibility – i.e. maximizing capacity and minimizing inventory, while still retaining the flexibility to respond quickly to unanticipated demand and producing/delivering products in varying quantities with flexible lead times?
- In addition to reducing the fulfillment and replenishment lead times, how do I focus on driving cash-to-cash time down to a minimum (ideally, this metric should be down into the negative range by getting paid by customers prior to paying suppliers).

Managers need to evaluate, monitor, and improve their supply chain performance and efficiency by looking into such metrics as time, cost, efficiency, and effectiveness.

They need tools that can help them gain visibility and insight into their constantly changing supply chain operations related to sourcing, manufacturing, delivery and returns to make smarter decisions about their business.

In order to make effective decisions, companies must have a consolidated 360 degree view of their business operations and the underlying data.

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Analytical data processing combines the use of different methods to a series of processed fragmented data to obtain useful information. When we take into account how much capital is spent on the inefficient practice of supply and distribution, it is clear why companies need a business intelligence function in consolidating, optimizing and increasing the transparency of this process of transformation and purchasing functions to obtain a function with the help of corporate portals.

The aim of this paper is to show that the analysis of relevant data of supply chains is to identify trends and patterns, and formulating a series of scenarios, can predict probable future outcomes and uncover potential opportunities and barriers in the supply chain.

2. Supply chain definition

It was found in the literature and through the interviews that various terms are used interchangeably for 'supply chain', such as 'demand chain' and 'value chain'. However, these terms convey slightly different conceptual meanings. For example, the Massachusetts Institute of Technology (MIT), a leading US institute researching supply chain issues defines 'supply chain' as the flow of materials, information and funds between different parties or organizational functions (Mentzer, 2004).

According to MIT, a single-stage supply chain, typically representing a single organization, incorporates a range of material flow functions (receiving, processing, distributing and delivering), a complex array of information processing and decision making functions (based on information flows from customers, suppliers and internal functions), and functions for handling incoming and outgoing funds. In this model, materials flow in one direction, funds flow in the other direction, and information flows in both directions between all functions. As more organizations become involved in the chain this basic single-stage model is multiplied rather than expanded, with each organization representing a single-stage.

However, the MIT view of the 'supply chain' is not the only definition. Others, such as the UK-based Institute of Logistics (IOL) highlight a multitude of definitions of supply chain, from the process of supplying customers from the factory 'to the total process from raw materials to the customer'. However, both point out that supply chains are intended to satisfy customers. This definition is much more closely related to the concepts of value chain and demand chain described above; the initial desk research, it seems that at present, there is no one agreed definition of supply chain.

These differences demonstrate a significant lack of consensus in the scope and understanding of the term 'supply chain' in many organizations, across all sectors. Often the difference related to the position of the interviewee in the organization and his/her particular perspective. In other words, people in the purchasing department most often defined supply chain exclusively in terms of the organization's upstream suppliers, while those in other functions had different perspectives and different definitions.

Simply it can be said that supply chain is the movement of materials as they flow from their source to the end customer. Supply Chain includes purchasing, manufacturing, warehousing, transportation, customer service, demand planning, supply planning and Supply Chain management. It is made up of the people, activities, information and resources involved in moving a product from its supplier to customer.

3. Concept and content of Business Intelligence

The concept of Business Intelligence (BI) first appeared in 1989. This concept involves the use of various methods of research, collection and analysis of information contained in various databases. This was supposed to deepen insight into the totality of the enterprise and enable better information's and make better decisions. Shortly after the appearance of the concept of Business Intelligence, computer manufacturer IBM has developed a strategy for Business Intelligence. After that Business Intelligence was established in thousands of businesses across the globe. The concept of Business Intelligence can be fully explained by analyzing its contents. As an intelligence activity in the business world Business Intelligence (BI) has three features:

1. It is the process of collecting data and information who after appropriate treatment (making analytical reports) become "knowledge"
2. BI has focused on information which can predict future processes, events, actions or movements
3. BI is an instrument that has a pivotal role in the decision making process

BI is not an illegal activity, not espionage. It's a legal activity that involves the collection of available public information. In other words, it is aimed at collecting data from open sources.

Due to the characteristics of modern markets (open competition), it is imperative that BI has an ethical dimension, namely the collection of data used not only legal, but also ethical funds. But the modern practice and the contemporary world convincingly prove that it is often very difficult to draw the line between legal BI espionage and illegal business.

Modern business corporations as part of their business policies have to determine the general level of what is acceptable and unacceptable behavior of their employees (Majta, 2012).

BI has two aspects which can tentatively be defined as offensive and defensive. Attacking aspect involves collecting data in order to realize a profit. Defensive goal is focused on achieving their own safety and preservation of existing business position.

Final results of the data collection activities are BI reports (analytical reports, comparisons, expert reports) that are associated with the cognitive activity management into "business knowledge". As such grants they are in the process of decision making. The fact that the final BI reports meet the requirements of the decision making process means that BI, or his final result contains an action element. Intelligence analysis are actually knowledge that leaders of business entities, along with other factors take into account when making decisions and who enables them to gain a fuller and more accurate insight into the environment in which they operate (Majta, 2012). Accurate picture of the conditions in the logistics environment, i.e., strategies and objectives of logistics partners, their position in the market, the habits and demands of consumers, to logistics operator not only allows how to precisely determine its position in the market, but also before others recognize and take advantage of favorable business opportunities and avoid any dangers and threats. We can determine that the use of the final results of BI enables business subject (in this case the logistic operator) how to make better strategic plans and specific business decisions in the logistic system. BI is a circular activity; therefore, regardless of the possible differences in the definition of the cycle, it is undeniable that this cycle has several basic stages:

1. Planning and management
2. Data collection
3. Processing and data analysis
4. Distribution of final analysis and their use

To make the BI process to be successful it is necessary to successfully achieve each of its phases, with the next phase can begin only after it is fully completed in the previous section. Each of the stages is different, which means that each phase requires careful planning and systematic implementation.

4. Business Intelligence in logistics operations

The logistics industry is extremely varied in the types of services it provides. At one end are conventional freight movers involved in transportation of shipments from one location to another. Generally these services are restricted within a geographical area and use limited modes of transportation. At the other end there are logistic operators who can execute complex end to end supply chain projects involving multiple countries and multiple modes of transport.

Accordingly they are classified as asset based and non-asset based logistic operators. Currently the logistic industry is in a state of transition. Players are adding more and more services to their portfolio as customers demand more integrated solutions. Logistic operators are viewed as strategic partners who can optimize the supply chain, reduce the cycle time, and provide unprecedented customer responsiveness. The key to effectively provide these services is Information Technology. More sophisticated logistic operators have quickly embraced IT to enable better coordination of activities by providing tracing and tracking facility to its customers.

But this is hardly enough to ensure sustained competitive advantage. To squeeze out the last drop of inefficiency from the supply chain, eliminate bottlenecks, and continuously seek process improvement, the ability to analyze all the activities in the logistics process is vital.

Business Intelligence can help the logistic operators in three ways (Srinivasa and Saurab, 2001):

1. *Service Improvement:* Traditionally logistic operators have been providing services like transportation management; warehouse and inventory management; and value added services like light assembly, kitting, etc. Business Intelligence can improve the effectiveness of these services by in-depth analysis and reports on various functions involved in these services.
2. *Provide Information Technology Based Services:* With the help of BI, logistic operators can provide their clients with analysis and reports specific to their supply chain. These can significantly help the customers increase their responsiveness and time to market.
3. *Improve Organizational Support Functions:* BI can significantly improve organizational support functions like HR and financial management by providing an integrated view of these functions and supporting their specific decision making requirements.

5. Business Intelligence in supply chains

The emergence of business intelligence solutions for the supply chain industry has presented many opportunities for improvement of supply chain processes and realizing significant benefits such as service improvement, cost control, improved delivery and fulfillment, inventory control, better forecasting, reduction in working capital, improved asset utilization, improvements in product quality and the list goes on. Supply chain intelligence technologies can provide strategic information to key decision makers and help them identify inefficient business processes and maximize productivity by identifying variances in such things as material usage, downtime, labor and overhead by shift (Langley, 2007). You can determine: Which suppliers, customers and services are the most valuable? How are the material forecasts in relation to the actual results? How many days of inventory exist in each warehouse?

Are we meeting demand? How long is it taking to fulfill an order? Do we carry excess inventory to compensate for variability of performance or lack of visibility?

Business Intelligence can provide significant benefits across a range of supply chain processes, from optimizing order quantities, pooling suppliers and reducing inventory levels to better forecasting of demand, measuring and managing vendor performance and improving order to cash cycle times. The application of Supply chain intelligence to various processes and the potential benefits that can be expected will depend on a number of factors and will vary from business to business. We will look at some general areas and the potential improvements that can be realized using business intelligence by considering the supply chain processes as defined by the SCOR model (Plan, Source, Make, Deliver and Return) (Langley, 2007).

Plan

In the plan process, BI can help enhance supply chain efficiency by enabling you to monitor your cycle time, which can then point you to opportunities to shorten lead times. You can analyze your flexibility, reliability, and responsiveness for improvements by benchmarking your efficiency by location, cost, productivity, and error incidence. BI can also help you analyze the movement of goods through your organization as well as monitoring days of sale so that you can plan for the right levels of inventory at the right place.

Inventory deterioration, shrinkage and damage costs can be tracked with BI and their impact on overall supply chain costs and margins can be analyzed to guide you in planning to meet future demand.

Source

Supply chain intelligence can help you track key metrics to optimize supplier network and overall procurement processes. By analyzing cycle time, monitoring sourcing costs, and tracking receipt variance, you can track and measure your supplier’s performance. You can analyze contract compliance, vendor performance, opportunities to consolidate suppliers, goods received, fill rates, inventory deterioration, and late orders.

With BI, optimization of inventory turns and reduction of stock levels can be achieved to improve the yield on assets. Reducing lead times and improving order accuracy, cycle times and on-time deliveries can enhance consistency and responsiveness. BI can also help you perform historical and forecast analysis, cost-value analysis and statistical analysis of your inventory data for guidance on optimal inventory levels as well as identifying the range of inventory levels above which the inventory carrying costs are higher than inventory value, or bands below which lost sales could result from product unavailability. You can see trends in inventory value compared with inventory turns and days of coverage to identify opportunities and issues related to materials management. Visibility into usage and coverage trends can help in reducing excessive or unnecessary carrying costs and inventory write downs.

Make

BI can help in managing manufacturing costs and efficiency related to the make processes, including throughput, work in progress inventory levels, unscheduled downtime and use of resources. With BI, you can identify trends that require immediate attention by analyzing cost variance, yields, work-in-progress inventory levels, scheduling efficiency and defects attributable to machinery/equipment, products or operating shifts. By measuring and tracking performance of your processes and analyzing cycle time, schedule compliance, and efficiency over time against targets you can look at opportunities to maximize throughput. Resource management can be improved by monitoring and analyzing utilization levels, production variance, quality levels and defect rates.

Deliver

This process can present opportunities to optimize fulfillment and delivery performance in the outbound supply chain, whilst reducing inventory costs and improving customer satisfaction.

BI can also help in analyzing various issues that impact customer satisfaction and costs including delivery cycle time and fill rate monitoring, late deliveries, and inventory movement, deterioration and delivery costs. Analytics related to stock turn and stock deterioration can help identify opportunities to reduce inventory costs.

Moreover, you can also set up alerts for late deliveries, fill rates and inventory unavailability to optimize delivery performance and meet product availability, fill rate and delivery targets. BI can provide real-time visibility into such areas as backlog, order entry, shipments, customer credit history and inventory positions. By analyzing delivery, payment and order size, you can improve customer satisfaction as well as monitor trends and patterns to identify customers who are likely to switch to another supplier or service provider.

Return
By being able to get insight into reasons for product returns, disposal costs as well as the value of the returned goods, you can analyze which of the returned products are contributing the most to the overall cost of returns. With the ability to drill down into lower levels of granularity in the analysis process, you can discover additional information pointing to improvements needed in warehouse picking operations in the event of excessive errors or problems at the supplier end which could prompt elimination of suppliers or renegotiation of supplier contracts.

5. Conclusion

A new solution for supply chain management is the concept of business intelligence, being the continuous, conscious, legally and organized collection of available data on markets, suppliers, customers, competitors, distribution channels, industry and technology, their analysis and conversion into new or previously concealed knowledge to support strategic management. Although at first glance it might get the impression that business intelligence aims to create large quantities of data and information, the opposite is true, because this concept is based on generating better and better information that are needed for company management, in the same time they are reducing their amount and increasing quality.

Business intelligence is based on personalization and proactivity, and its most basic form is the company's strategy, as it has become a crucial factor of the future business and operations. Supply chain intelligence is the ability to analyze processes included in chain, components and materials to which these processes are applied and products that implementation of these processes occur, so in some way business intelligence provides visibility of supply chain. The resulting knowledge results from these analyzes are used to efficiently measure, monitor, control, predict and manage the supply chain to minimize costs and time required for each process.

The success of this new concept in company's is most on company management. It is biggest contributor to its awareness of the need to use organized information for efficient supply chain management. Business intelligence is a strategic commitment of every company so the decision on its implementation should be seen as a key strategic decision for gaining competitive advantage.

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References

Langley, W. 2007. *Driving Business Value through Supply Chain Intelligence*. Exactus Inc. White paper, Rockvile.

Majta, J. 2012. *Analiza informacijskih sustava za provedbu i kontrolu logističkih operacija*. Diploma work, Faculty of Transport and Traffic Sciences, University of Zagreb.

Martin, A. 1995. *Distribution Resource Planning: The gateway to true quick response and continual replenishment*. John Wiley & Sons. 352 p.

Mentzer J.T. 2004. *Fundamentals of Supply Chain Management-Twelve Drivers of Competitive Advantages*. Knoxville, Response books, University of Tennessee, New Delhi. 304 p.

Poirier, C.; Reiter, S. 1999. *Supply Chain Optimization: Building the strongest total business network*. Berrett-Koehler Publishers, San Francisco.

Srinivasa, R.P.; Saurab, S. 2001. *Business Intelligence and Logistics*. Wipro Technologies, White Paper, Bangalore.

INFORMATION AND COMMUNICATION TECHNOLOGIES SHAPING THE INTELLIGENT LOGISTICS SYSTEMS

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Abstract: Nowadays logistics has to provide answers to a wide range of issues including planning optimization, organization, managing and controlling the flow of materials, people, energy and information, and thus logistics systems are constantly being developed and changed. Therefore, it is very important for logistics development to implement techniques that reduce time and cost in processes and improve efficiency and performance. The objective of this paper is to identify, describe and analyze the integration of different kind of Information and Communication Technologies (ICT) and logistics into a unique system. Obtained results indicate that ICT innovations have significant influence on logistics, defining it as intelligent logistics. Intelligent logistics framework should help the logistics branch to change the view of the contemporary dynamic processes and to create new logistics solutions for many problems that occur constantly. During these "changes" the main goal remains the same: materials and products are shifted whenever and wherever are required, in whatever form. Basically, Intelligent Logistics Systems (ILS) are designed to provide better solutions for different logistics problems and elevate the level of logistics services and logistics efficiency in the concept of modern technology. Information technology has become an important dimension of third and fourth party logistics service providers (3PLs and 4PL) business as their competitive advantage increasingly depends on the ability to create value for customers, through ICT applications. ICT applications are the result of the integration of hardware, software and networking (both wired and wireless) resources. Particular focus is sited on wireless technologies with different frequency band. In addition, an overview of the wireless logistics systems which have the greatest level of significance from the consumer perspective is presented and discussed. The impact of ICT to ILS with all the relevant factors is emphasized.

Keywords: information communication technologies, intelligent logistics systems, transportation management, frequency band.

1. Introduction

Traditionally, logistics is defined as the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements (Langley and Holcomb, 1992). Implementing different kind of Information and Communication Technologies (ICT) into logistics management can successfully improve and redesign logistics system, as whole, and also change customer's view on logistics. The new trend of globalization causes logistics to reshape its usual ways for solving many different problems and to define new strategic directions of development, in order to define logistics as intelligent logistics. Thus, the original definition needs to be redesigned. Modern logistics systems require new approaches and change of perception of logistics experts in order to provide prompt responses to customer's requirements.

The purpose of this paper is to explore the main characteristics of Intelligent Logistics Systems (ILS), focusing on different technologies with wide frequency band. ICT have a very important role in today's technological progress. Improvements in ICT have significantly changed how information can be processed and communicated (Lewis and Talalayevsky, 1997).

Still, a relatively small number of papers have dealt with the incorporation of ICT and logistics into ILS, until now. Considering the importance of this topic, integration of the most practical applications of ICT in logistics is shown. Primary, barcode, Radio Frequency IDentifications (RFID), Global Positioning System (GPS), Global System for Mobile communications (GSM) and Wireless Fidelity (Wi-Fi) technologies are elaborated, in detail.

The paper is organized as follows. The second Section provides a brief theoretical description of present logistics trends and impact of ICT on logistics. The third Section describes the main concept of this work, emphasizing the wide range of applications of ICT in logistics. The fourth Section analyzes wireless technologies and frequency spectrum with particular focus on Wi-Fi. The fifth Section describes ILS, and final remarks and conclusion are in the last Section.

2. Impact of ICT and logistics trends

Over the years, logistics has been constantly shaping its basic definition, due to high scale changes on the market and its constant goal to satisfy the needs of its customers. During that time, many different trends have been noticed and defined: restructuring of logistical systems, realignment of supply chains, rescheduling of product flow, refinement of transport and warehousing management, changes in product design and Integration of logistics (OECD, 2002). Because of all of the above described trends, the integration of ICT into logistics branch will bring multiple benefits.

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Purchasing, inventory control, warehousing, transportation, packaging and parts service support are the main components of the logistics function (Lewis and Talalayevsky, 1997). In order to optimize any of these logistics sectors, ICT has to be implemented. In this paper, emphasis is sited on the integration of barcode, RFID, GPS, GSM and Wi-Fi which can improve logistics processes.

Worldwide competition and very prompt development of the ICT sector have created new trend toward outsourcing of logistics operations. The movement to outsource distribution is also consistent with a tendency to reduce the number of suppliers and establish closer, longer-term relationship with those that remain. These partnerships encourage mutual investment in ICT in order to support innovation and responsiveness (Lewis and Talalayevsky, 2000). Many global industries are restructuring their logistics systems by concentrating production and inventory capacity in fewer locations. ICT facilitate the creation of a new concept in business. The need for outsourcing is indispensable because of recent trends, mostly one worldwide trend – globalization. Globalization drives a higher level of complexity in the logistics supply network, highlighting the important role of distribution and transportation to enhance market value of products (OECD, 2002). The result of this inclination is that logistics activities are being shifted by manufacturers to Third Part Logistics (3PL) companies. 3PL concept enables greater flexibility of logistics operations, resulting in lower costs and better service quality (OECD, 2002). A new trend, Fourth Part Logistics (4PL), is emerging as a path to surpass one-time operating cost reductions and asset transfer of a traditional outsourcing arrangement (OECD, 2002). All of these trends have a strong influence on the integration of ICT and logistics, as well as on the conception of the logistics information system.

Logistics information system is an integrated information network system that integrates communications positions, communications lines and means of communication in order to ensure the smooth flow of information in the process of logistics operations and logistics management. Logistics ICT refers to the hardware, software, and networking (both wired and wireless) resources. Hardware resources are the material components of an information system designed for the processing and data transfer. Software resources are non intangible components of the system in the form of computer applications imbedded in the hardware. These resources determine the method of data processing. Network resources enable long-distance transmission of information. Special emphasis is sited on wireless technologies.

3. A review of ICT applications in logistics

There are many different types of ICT which have application in logistics. In this paper, the focus is sited on barcode, RFID, GPS, GSM and Wi-Fi. These technologies integrated into logistics processes facilitate the functioning of a logistics system.

A **barcode** is an optical representation of data, which shows information about the object to which it is attached. Originally, barcodes represented data by varying the widths and spacing's of parallel lines, and may be referred to as linear or one-dimensional (1D) (Galo et al., 2011). Later they evolved into rectangles, dots, hexagons and other geometric patterns in two dimensions (2D). Initially, barcodes were scanned by special optical scanners called barcode readers. Later, scanners and interpretive software became available on devices, including desktop printers and smart phones, by global network. In logistics, a barcode technology has broad application in warehousing.

Radio **F**requency **ID**entification (RFID) is one of the most promising, rapidly developing and easy-to-use technologies, which use radio-frequency (RF) signals for automatic identification of objects and items. RFID is not a replacement for the bar coding, but a complement for distant reading of codes (Amit, 2009). This technology is used for automatically identifying persons, packages or items. To do this, it relies on RFID tags. These are small transponders (combined radio-receiver and radio-transmitter) that transmit identity information over a short distance, when requested. The other piece to make use of RFID tags is an RFID tag reader. An RFID tag is an object that can be applied to or incorporated into a product or person for the purpose of identification and tracking using radio-waves. Some tags can be read from several meters away and beyond the line of sight of the reader. Most tags carry a plain text inscription and a barcode as complements for direct reading and for cases of any failure of RF electronics (Amit, 2009).

RFID has wide range of implementation. At first place, RFID finds its applications in the warehousing. In order to improve productivity and control, many warehouses use RFID technology in order to optimize functioning of the system. This wireless technology increases efficiency of warehouse management because, unlike bar codes which must be scanned manually to feed the information on the computers, RF tags broadcast a signal with two kind of information. The first is about the product they are attached to and the second is about location of the product in the warehouse. RFID also increase effectiveness of organization daily operation in warehouse, defining it as intelligent system.

Global **P**ositioning **S**ystem (GPS) is a space-based satellite navigation system that provides information about location and time, anywhere on or near the Earth, where there is an open line of sight to four or more GPS satellites. GPS structure is supported with about 24 satellites. This number of satellites, and theirs appropriate distribution, ensures that there are at least four satellites above every location on the Earth, at all time.

Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS system and implement the next generation of GPS (Wei et al., 2010).

GPS has an important role in logistics, especially in GPS tracking. The timing of deliveries and pickups is critical to the profitable operation of the company. To ensure this, GPS tracking and logistics are integrated, making logistics system more efficient. GPS technology can be installed in the trucks that deliver e.g. the raw materials to the factory. The installation of GPS technology ensures that the delivery of the materials will be made at a certain time.

When the minimum level is reached, the logistics company knows that the needed material is on a specific truck and where the exact truck is.

Deliveries of finished goods from the factory to either regional distribution centers or the wholesaler are simplified by the use of GPS technology. Many logistics companies utilize a technique known as cross docking. This technique removes goods from an inbound trailer and distributes the goods directly to an outbound trailer, without ever stocking the goods in the warehouse. The proper coordination of inbound and outbound trailers can only be accomplished by knowing where the trucks are at the given time. GPS tracking ensures that the location of the trucks is always available.

GPS tracking and logistics are integrated into unique system. The logistics company or department can accurately know, by using tracking devices, where trucks and/or products on the trucks are by simply clicking a mouse. The rapid and accurate delivery of goods or product ensures that production schedules are always on time.

Global **S**ystem for **M**obile communications (GSM) is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for the second generation (2G) digital cellular networks. Developed as a replacement for the first generation (1G) analog cellular networks, the GSM standard originally described a digital, circuit switched network optimized for full duplex voice telephony. A very important feature of a wireless system is handover. Handover process enables cellular system to transfer an active from one cell to another (S and Kumar, 2009). It is very important from logistics point of view because it directly affects the signal range. Basically, the main reason of emphasizing GSM is maintaining the connections between subjects in logistics processes.

Fig. 1 shows some examples of implementation of ICT in logistics.

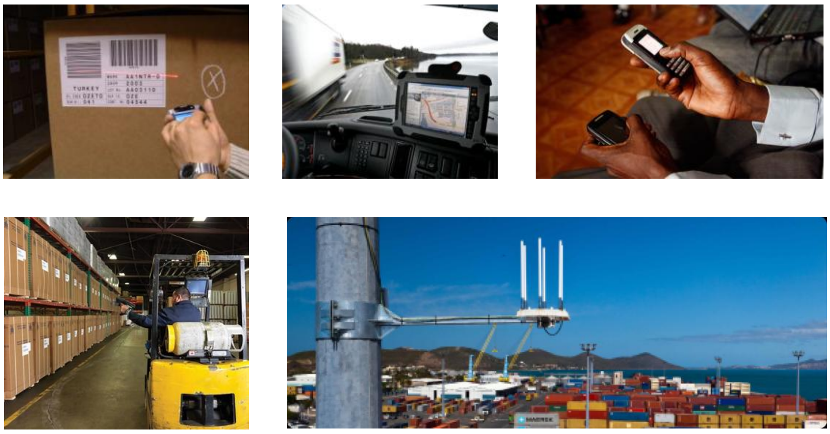

Fig. 1.
Implementation of ICT in logistics

There are many illustrations which can be presented on this subject. Fig. 1 demonstrates only one application for each technology. Increasing efficiency in warehousing (barcode, RFID), tracking (GPS) and establishing a reliable wireless network (GSM, Wi-Fi) is the main objective in the process of integration of ICT and logistics. Pace with the expansion of ICT, logistics systems are becoming more advanced and complex.

4. Wireless technologies and frequency spectrum

This Section is analyzed to provide a clear answer how a different type of wireless technologies improves and reshapes logistics systems and it this Section has objective to emphasize the frequency bands of wireless technologies, with particular focus on Wireless Fidelity (Wi-Fi).

Wi-Fi refers to wireless technology that allows an electronic device to transmit data wirelessly (using radio-waves) over a computer network. Devices that can use Wi-Fi (e.g. personal computers, smartphones, digital audio player etc.) can connect to a network resource such as the Internet, over a wireless network access point. Such an access point has a range of about 20 meters indoors and a greater range outdoors (Roshan and Leary, 2003).

Having a reliable Wi-Fi network can be very useful for logistics companies. Speed and efficiency are especially important in logistics. New possibilities and directions of developing intelligent systems emerge, e.g. improved track inventory movement, a direct connection between the warehouse and transportation and the office that creates unique network with the available databases in company.

The advantages of using Wi-Fi in logistics companies are multiple. Logisticians always dispose with the latest information from the warehouse and transportation (incoming and outgoing goods) and easy monitor key processes and goods flows. It is no longer necessary to do a maintenance of the cables. Wireless networks cannot completely replace wired, primarily because of data transmission speed and data safety, but they offer something that cannot be achieved with wired networks. It is the mobility which provides customers with the ability to move with a devices through established computer network and at the same time to maintain a consistent network connection.

Review of ICT with wide frequency band and application in logistics is given in Tab. 1. Frequencies are defined for each technology in particular, but without explanation of signal transmission, in detail. Review of frequencies is important because of the completeness presentation of the technologies. In addition, frequency spectrum of these technologies is shown on Fig. 2.

Table 3
Review of ICT with wide frequency band and application in logistics

Technologies	Frequency	The main applications in logistics
RFID	13,5 MHz	For identifying objects
	400 MHz	For remote control for vehicles centre locking
	868 MHz, 915 MHz and 922 MHz	For active and passive RFID tags for logistics in Europe, United States and Australia, respectively
GSM	GSM 900 (Uplink: 890–915 MHz, Downlink: 935–960 MHz)	For speech and text messages between participants in the logistics processes
	GSM 1800 (Uplink:1710–1785 MHz, Downlink: 1805–1880 MHz)	
	GSM 1900 (Uplink: 1850–1910 MHz, Downlink: 1930–1990 MHz)	
Wi-Fi	2,4 GHz	For real-time visibility of key processes and goods flows and for precise information on incoming and outgoing goods
	5 GHz	
GPS	1575,42 MHz	For truck tracking
	1227.60 MHz	
	1381.05 MHz	
	1379.913 MHz	
	1176.45 MHz	

Specified RFID frequencies (Table 1) are not all the frequencies used by RFID devices. All of these technologies have very significant role in the warehouse and transportation management, making it more organized and operative.

Integration of wireless technologies and warehouse and transportation, connects warehouse and transportation workers to the warehouse and transportation management application and data servers (barcode and RFID). These devices help employees to identify where to pick, put away, move products, etc. The result is better control over the movement and storage of materials within the warehouse and transportation by maximizing the efficiency of the receipt and shipment of the products. The main goal is to optimize warehouse and transportation space and to know, at any time, where the products are stored. RFID has already become a promising technology and it can be widely used in the decision support systems.

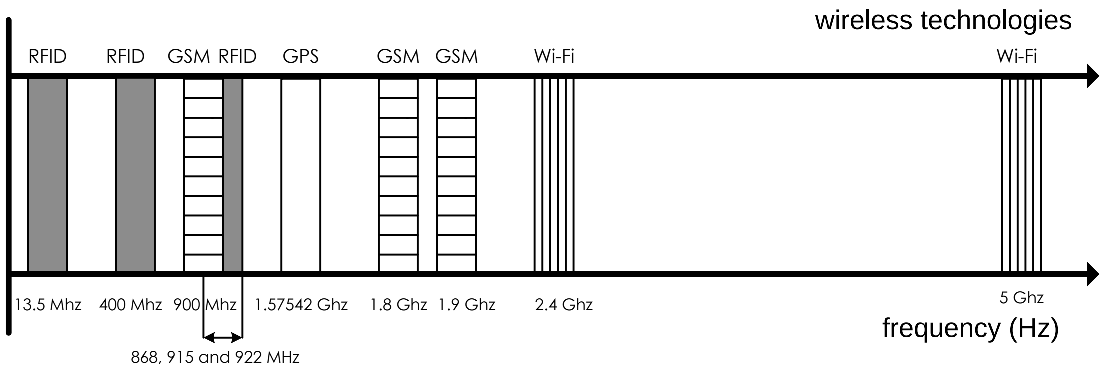

Fig. 2.
Frequency spectrum of analyzed wireless technologies

Some parts of frequency spectrum (Fig. 2) are too close to each other. Thus, it can cause deterioration and interference of signal if devices, which receive and transmit signal, are too close. Wi-Fi network, for example, use the “spread spectrum” modulation which propagates signal in a wide range of frequencies. Therefore, Wi-Fi allows multiple users to simultaneously share the same frequency band without mutual interference, and also provides much greater resistance to interference (Roshan and Leary, 2003).

Only some of the existing and used technologies are analyzed in this paper. If some other wireless technologies are considered, there would be a greater overlap in the spectrum. From the logistics aspect, the most important is that the ICT system can be implemented, and fully functional, into the logistics companies, allowing them to become ILS.

5. Intelligent logistics systems

ILS is new way of organizing logistics companies which are stimulated with lightning-speed development of ICT and growing competition in markets (Verdujin and Van de Loo, 2003). ICT has been used to control and monitor processes which make logistics activities more and more efficient. Very important aspect – planning is accomplished with implementation of ICT into logistics system. At present time, those who have information achieve strategic advantage over the competition.

Logistics companies were forced to change its traditional way for solving complex problems. During rapid progress in the development of ICT, customers changed their requirements. Companies are brought into position to optimise their efficiency of the production, warehousing, supply management, just-in-time concept etc. Individual companies could not cope with tough competition in the market and thus they emerge, creating new ways of doing business.

It has become apparent that factors, such as ICT, transshipment technology and the standardization of loading units play a crucial part in the development of new distribution networks (Verdujin and Van de Loo, 2003). ICT support becomes, more and more essential for the logistics control of networks in which several organizations participate. It is important to define that new concept of organization which is, in fact, a network.

ICT enable rapid collection, processing and distribution of information, and, as such, they become suitable for integration with the logistics companies, and thus, ILS, as new shape of integration, emerge. Development of ICT brings new technologies to life, and ILS integrates them into new structure. In this way, customers can be provided with new, more accurate and transparent, services. Just-in-time concept becomes adopted as a basic service. New trends are rising, new approaches of integration companies are developing. Time and space are becoming increasingly surmountable, with the goal of satisfying customers’ needs.

Fig. 3 shows integration of logistics companies ICT into global marketplace. Two logistics companies are considered in this example, but the number of companies that cooperate in real system is much greater. Nowadays, globalization is becoming more and more present in every field of business, as well as in logistics. Thus, external influences, such as global environment, markets and competition, are becoming increasingly dominant. As a result, many logistics companies incorporate ICT into their systems trying to make them more competitive and more efficient.

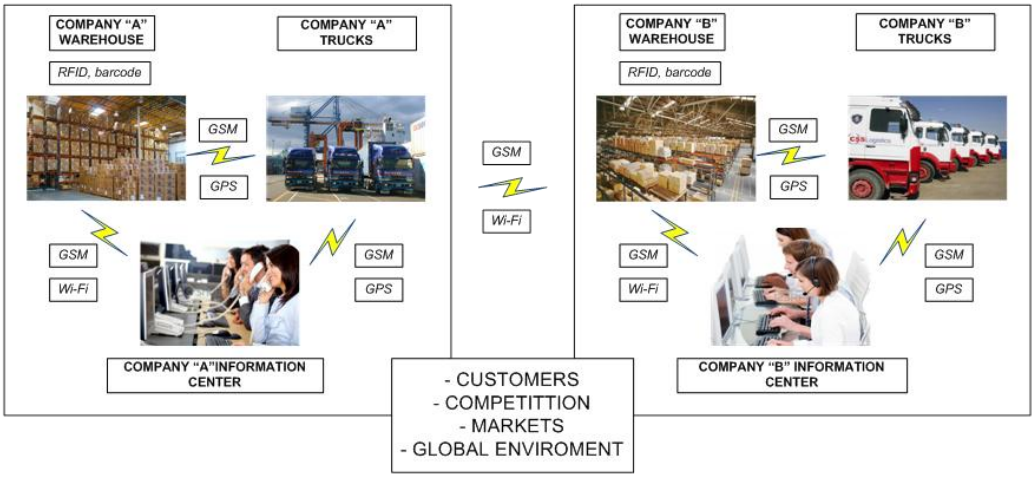

Fig. 3
Integration of logistics companies ICT into global marketplace

ILS has a great potential to reshape and improve logistics processes. Improvements can be noticed in a reduction of lead times, better utilisation of resources, less communication and administrative activities, improvement of service levels and service reliability and improved processes control and management (Verdujin and Van de Loo, 2003). These improvements modify logistics development radically, making it more efficient and transparent.

6. Final remarks and conclusion

In recent years concept of merging ICT and logistics has become more of an expectation of integration of two branches, than trend. Effective coordination of integration of ICT and logistics is essential for achieving the benefits of the companies in comparison with the competition. Global market forces and exposes all logistics companies to rivalry and market. It is most likely that in such struggles, companies that keep pace with technological advances will in the end emerge as winners. Also, besides the benefits in relation with the competition, ICT provides better cooperation with them. Globalisation becomes inevitable, and logistics companies that are isolated and are not ready for global cooperation are convicted to business failure. The integration of ICT and logistics, which is the basic idea for this paper, shows how ICT, logistics, market and global environment are permeated into ILS and connected, at some levels.

Future research can be extended to other technologies, in order to obtain a complete picture of the dependence and reliance of logistics companies on ICT. The dependence is unavoidable, and the only question is how much is it expressed? In this paper the focus is sited on wireless ICT. Some further research can incorporate other networks (wireless and wired) in ILS system described in this work, or they can be analyzed separately.

The conclusion of this paper is that function of logistics processes without ICT would be insufficient for operation of the logistics sector, even impossible. ICT provides strategic advantages in business for logistics companies. Providing such benefits only emphasizes the significance and importance of ICT, in general and it also expounds the described approach for analysis in this paper. The future of logistics is unpredictable, but it can be assumed that it is closely associated with the development of ICT sector.

Acknowledgements

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References

Amit, R. 2009. RFID: the next generation auto-id technology, *Microwave Journal* 52(3): 58-76.

Galo, O.; Manduchi, R. 2011. Reading 1D barcode with mobile phones using deformable templates, *IEEE Transaction on Pattern Analysis and Machine Intelligence* 33(9) 1834-1843.

Langley, J.; Holcomb, M. 1992. Creating logistics customer value, *Journal of Business Logistics* 13(2): 1-29.

Lewis, I.; Talalayevsky A. 1997. Logistics and information technology: a coordination perspective, *Journal of Business Logistics* 18(1): 141-157.

Lewis, I.; Talalayevsky A. 2000. Third-party logistics: leveraging information technology, *Journal of Business Logistics* 2(21): 173-185.

Organization for economic co-operation and development. 2002. Transport logistics, shared solutions to common challenges. Available from internet: <http://www.internationaltransportforum.org/pub/pdf/02LogisticsE.pdf

Roshan, P.; Leary, J. 2003. *802.11 Wireless LAN Fundamentals*. Cisco Press, Inc. USA. 312 p.

S, A.; Kumar, S. 2009. Handover in GSM networks, In *Proceedings of the 5th International Conference on MEMS NANO, and Smart Systems*, 142-145.

Verdujin, T.; Van de Loo, B. 2003. *Intelligent logistics concepts*, Eburon Publishers, Inc. Netherlands. 159 p.

Wei, W.; Baosheng, S.; Kefa, Z.; Jinlin, W. 2010. The use of GPS for the measurement of details in different areas, In *Proceedings of the 3th International Symposium on Electronic Commerce and Security*, 59-62.

CITY LOGISTICS TERMINAL LOCATION SELECTION USING COMBINED FUZZY AHP AND FUZZY TOPSIS ANALYSIS

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Abstract: City logistics terminal (CLT) location selection affects logistics costs, transportation routes, overall city traffic, planning and development of the city. When selecting CLT location, conflicting goals and interests of all stakeholders (residents, shippers and recipients, transport operators and municipal administration) have to be taken into account. A vast number of economical, infrastructural, socio-political, natural and ecological criteria arise from these different goals and interests, and it is necessary to include them in the CLT location selection process. Because of the restricted resources (time, costs, data bases), majority of these criteria are assessed with linguistic statements, which is not suitable for application of the conventional methods of multi-criteria decision making. Considering that, in this paper a fuzzy extensions of the conventional methods of multi-criteria decision making are used for CLT location selection. Fuzzy "analytical hierarchy process" (AHP) is applied to determine the relative weights of the evaluation criteria, and after that fuzzy "technique for order preference by similarity to ideal solution" (TOPSIS) is applied to rank the potential CLT locations. The usability of these methods is tested on the example of locating CLT in the city of Belgrade.

Keywords: city logistics terminal, location, fuzzy AHP, fuzzy TOPSIS.

1. Introduction

Designing an efficient logistics system implies analysis and planning of all elements that could have affect on its performances. Some of the key elements are logistic centers, and it is necessary to determine their number, roles in the logistic chains, structure of their functions and subsystems and their location. City is the place of the highest concentration of economical and social activities, and logistics is one extremely important activity for sustainability and economy of the city. Continuous growth of congestion and number of freight vehicles, air pollution and other bad influences on the environment and inefficient land use in urban environment, have influenced the development of alternative logistics solutions for eliminating freight transport problems in the city. One of the solutions is introduction of the city logistics terminals – CLT (Kayicki, 2010). Urban logistics centers for different users have been proposed for the first time in Japan to help alleviate traffic congestion, environment, energy and labor costs (Taniguchi, et al., 1999). The optimal city terminal location selection is one of the key elements of the efficient logistics systems of a city, and as such, the problem that has been discussed in this paper.

All city functions and structures (consignors, recipients, transport operators, logistics providers, residents, city administration) have interests in efficient and effective realization of the logistics activities, especially of freight transport, in the city (Zečević, et al., 2002; Taniguchi and Thompson, 2003). They all have one common objective: attractive city by economic, social, traffic, ecological, cultural and all other criteria. However, individual objectives are in conflict, and making changes that could be positive from the point of view of one group, can cause a lot of negative effects for others. The efficiency improvement, for example, can be in conflict with the environmental objectives (Zečević and Tadić, 2006). Conflict objectives are also present in determination of the CLT location, and this problem could be solved by defining a great number of criteria which will take into account all needs and interests of all stakeholders. However, traditional optimizing models cannot adequately deal with a great number of criteria, and classical methods of multi-criteria analysis are not able to take into account vague and ambiguous nature of human thinking. Due to the described reason, certain problems could be solved with multi-criteria methods in fuzzy environment.

Through the literature survey, the combination of fuzzy AHP and fuzzy TOPSIS methods for solving certain complex problems has been noticed (Sun, 2010; Chen and Yang, 2011; Choudhary and Shankar, 2012). This integrated approach has also been used for solving a problem of locating the CLT in this paper. Generally, methods of multi-criteria analysis have not been used to a great extent for logistics center location selection, and their application for solving this problem is even more uncommon. Contribution of this paper is the first application of integrated FAHP-FTOPSIS approach for CLT location selection.
The problem of selecting the location of urban logistics center has been described and the overview of methods developed and used for solving it, has been given in this paper. The methodology of solving the problem by applying FAHP-FTOPSIS method has been presented and its applicability has been demonstrated on CLT location selection in the city of Belgrade.

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2. Locating the city logistics terminal

The present problems of supplying the city with goods and extracting the materials from urban areas are being solved in accordance with the different levels of economic, cultural, technological and other aspects of social development. Delivery of goods is a prerequisite for the maintenance of urban life and business activities, aimed at realizing the wealth and development of urban areas. An efficient logistics system can play an important role in the competitiveness of urban areas and due to that logistics should be an integral part of the city's economy. Logistics systems support employment and generate income, but may also have negative effects on all the essential functions of the city.

Urban freight transport has continued growth, and the expectations are that this trend will continue in the future. Densely populated urban areas require delivery of large quantities of goods, which leads to launching a greater number of vehicles and the increased congestion on city streets. The reason for the increasing share of freight transport in the city are the trends in the production and distribution based on low inventories and precisely defined deliveries (JIT, Just In Time strategy), as well as the growing trend of e-commerce and home deliveries (B2C, Business to Customer). City logistics flows are characterized by partiality, spatial dispersion of generators, variety in the logistic chains structure, dynamics, stochastic etc. All this adversely affects the economy of the city, living conditions, mobility and environment.

The above-mentioned problems and complexity of logistics in urban areas, but also social, cultural, demographic characteristics of the city, architectural heritage, habits and perceptions of the population, have led to the development of different conceptions of city logistics. In a variety of different conceptual solutions, cooperative logistics systems and logistics centers are often apply as integrated. The concept is based on the direction of goods and transport flows of different providers toward the logistics center and consolidated shipment to the generators in the urban area. In this way, logistic centers are becoming the central element of the system for goods supplying and removal of waste materials. Depending on the size and characteristics of different cities, the number, size and location of logistics centers are different.

Logistics centers play an important role not only in the supply chain, but also in the planning of logistics and transportation in the city as a whole, and their location has a significant impact on the scheduling of transport flows on the city's traffic network. They are founded on the favorable traffic locations at the edge of the cities, or in the city area itself, and linking inbound and outbound flows and coordinate the flows of goods in the processes of supplying and extracting from the urban area. The planning of city logistics terminals requires the participation of various stakeholders: local authorities, potential operators, trade associations, local logistics companies, potential customers, etc. Without the participation of all interested groups the opportunity for success of the concept is significantly reduced, because only through active participation all requirements can be provided and compromise solutions adopted. Location of the city terminal in relation to the target market significantly affect traffic and the environment, as well as the economic parameters of the adopted concept of consolidation. Benefits of dislocating terminals in relation to the target zone of service and final delivery are reflected in the fact that heavy trucks that deliver goods to the terminal do not enter into the urban part of the city. However, if low capacity vehicles are being used for the consolidated distribution from the city terminals, number of their trips and traveled distances will increase. On the other hand, if the city terminal is located next to the area for which it provides services, that reduces distances traveled by environmentally friendly vehicles in the delivery, and therefore all the benefits of using these vehicles. Clearly, there is a need for careful balancing between these facts when making a decision about the location.

Taking into account the specificity of the problem, some authors have defined the specialized location models for locating a CLT. Taniguchi et al. (1999) have developed a mathematical model to determine the optimal size and location of a CLT, where they used queuing theory and nonlinear programming techniques to determine the best solution. Their model explicitly takes into account the traffic conditions on the network and has been successfully applied to an actual road network in the Kyoto-Osaka region of Japan. Yang et al. (2005) have determined the location and size of a CLT by applying genetic algorithms on the optimization model defined as a linear programming problem, which took into account shipping and delivery costs to and from CLT as well as the costs of operating the CLT itself. Guyon et al. (2012) solved the problem of locating a CLT for fast parcels delivery by developing mathematical integer linear programming model in which the global objective function consists of 8 economic, ecological and social optimization criteria. They tested the applicability of the model on the example of the city of Marseilles. Due to the existence of a large number of criteria, but also ambiguous and vague nature of human thought, the problems of CLT location selection can be solved with multi-criteria methods in fuzzy environment. Awasthi et al. (2011) proposed approach in which they quantified criteria values by applying the theory of fuzzy sets and then chose the best location for CLT by using fuzzy TOPSIS method. Kayikci (2010) defined a model for determining the location of intermodal terminals in an urban area, based on a combination of fuzzy AHP and artificial neural network (ANN) methods.

Ren et al. (2011) in order to determine the location of a CLT created mathematical models of single-factored fuzzy evaluation, single-stepped fuzzy evaluation and multi-step fuzzy evaluation and then solved the problem by using fuzzy comprehensive evaluation method. In this paper, the problem of locating a CLT is solved by using integrated fuzzy AHP - fuzzy TOPSIS method which is explained with more details below.

3. Fuzzy multi-criteria analysis

Many authors have solved some problems of multi-criteria decision-making by applying different methods in fuzzy environment. Onut and Soner (2008) have solved the problem of selecting the solid waste transshipment site, and Dagdeviren et al. (2009) the weapon selection problem, by using TOPSIS method in fuzzy environment for ranking the alternatives, while they determined the relative weights of criteria by applying a classical AHP method. Integrated fuzzy AHP and fuzzy TOPSIS method Sun (2010) have used for the analysis of company's business performances, Chen and Yung (2011) for suppliers selection, Rostamzadeh and Sofian (2011) for prioritizing the factors affecting the production system performances, Buyukozkan and Cifci (2012) for the analysis of electronic service quality in the health industry, Kutlu and Ekmekcioglu (2012) for analysis of the failure modes in business and manufacturing systems, Choudhary and Shankar (2012) for power plant location selection. In this study, the integrated FAHP-FTOPSIS approach is applied for solving the city logistics terminal location selection problem. Fuzzy set theory is a mathematical theory pioneered by Zadeh (1965), which is designed to model the vagueness or imprecision of human cognitive processes. The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set, that is a fuzzy set is defined by a membership function which defines a degree of membership of each element within a certain interval, which is usually [0, 1]. If the membership function value is zero, the element does not belong to the set, but if the value is one, the element belongs completely to the set. If the membership function value lies within the defined interval, the element has a certain degree of membership (it partially belongs to the fuzzy set) (Ayag, 2005).

3.1. Fuzzy analytical hierarchy process (FAHP)

AHP method developed by Saaty (1980) deals with the determination of the relative importance of criteria in multi-criteria decision making problems. The method makes it possible to simultaneously observe intangible qualitative criteria and tangible quantitative criteria (Badri, 2001). AHP method is based on three principles: the structure of the model, a comparative analysis of the criteria and alternatives, and synthesis of priorities. The first step in applying the method is the formation of the hierarchical structure of the problem being solved. AHP first decompose a complex multi-criteria decision making problem into a hierarchically arranged elements (objectives, criteria, alternatives). The hierarchy has at least three levels, final objective at the top, a certain number of criteria which determine the alternatives and the alternatives themselves at the bottom (Albayrak and Erensal, 2004). In general, according to the defined problem an analysis is performed to determine the relative weights of criteria at each hierarchical level and value of alternatives against the criteria. This analysis includes pair-wise comparison of all criteria in each hierarchical level as well as the pair-wise comparison of all alternatives against the criteria. In classical AHP method the pair-wise comparison is performed by applying the standardized nine-point scale (Saaty scale).

Although conventional AHP takes into account the qualitative criteria assessed by the opinion of decision-makers, it is not able to depict the ambiguity and vagueness of human thinking. Therefore, to solve the hierarchical fuzzy problems a fuzzy AHP method has been developed as a fuzzy expansion of AHP method. In this paper, fuzzy AHP was used to determine the relative weights of criteria, and not for ranking the alternatives. Authors who were using the integrated FAHP and FTOPSIS model for solving multi-criteria problems were solving FAHP in different ways. The first step is the same i.e. process begins with forming a matrix for pair-wise comparison of criteria. A linguistic scale shown in Table 1 which can be converted into triangular fuzzy numbers was used for comparison of criteria. For assessing the importance of one criterion against another the linguistic expressions are used and thus formed the matrix for comparison of criteria. The differences arise in the way of obtaining the final values of the relative weights of criteria.

Table 1
Definitions and membership functions of the fuzzy scale for the weights of criteria

Importance	Fuzzy number	Definition	Membership function
9	$\tilde{9}$	Absolutely preferable (AP)	(8, 9, 10)
7	$\tilde{7}$	Strongly preferable (SP)	(6, 7, 8)
5	$\tilde{5}$	Quite preferable (QP)	(4, 5, 6)
3	$\tilde{3}$	Moderately preferable (MP)	(2, 3, 4)
1	$\tilde{1}$	Equally important (EI)	(1, 1, 2)

Final values of criteria Sun (2010) calculates using the geometric mean technique (Hsieh, et al., 2004), Chang (1996) by using extent analysis method (Chen and Yang, 2011, Rostamzadeh and Sofian, 2011, Kutlu and Ekmekcioglu, 2012, Choudhary and Shankar, 2012), and Buyukozkan and Cifci (2012) by using a fuzzy eigenvalue (Ayag, 2005).

3.2. Fuzzy TOPSIS

TOPSIS, as one of the classical methods of multi-criteria decision making, was first developed by Hwang and Yoon (1981). It is based on the concept that it selects an alternative that has the least distance from the positive ideal solution (PIS) and the maximum distance from the negative ideal solution (NIS). Despite its popularity and simplicity in concept, this method is often criticized for its inability to adequately handle the uncertain and imprecise perception of decision makers. In the traditional formulation of the TOPSIS, personal judgments are represented with crisp values, but in many practical situations that is very difficult (Chan and Kumar, 2007). Decision makers usually feel more confident to give interval judgments rather than single numeric values. As some criteria are difficult to measure by crisp values, they are often neglected during the evaluation. Besides that, the methodology of classical TOPSIS method is established on mathematical models that are based on actual (crisp) values. Therefore, it is not able to take into account the ambiguity, uncertainty and vagueness in decision maker's thinking. The use of fuzzy set theory (Zadeh, 1965) allows the decision makers to incorporate unquantifiable, incomplete, non-obtainable and partially ignorant information into decision model (Kulak, et al., 2005). Many authors have used the fuzzy TOPSIS method for solving certain problems of multi-criteria decision making (Onut and Soner, 2008, Dagdeviren, et al., 2009, Chen and Yang, 2011, Rostamzadeh and Sofian, 2011, Buyukozkan and Cifci, 2012, Kutlu and Ekmekcioglu, 2012, Choudhary and Shankar, 2012) developed by Chen (2000).

Chen (2000) extends the TOPSIS in fuzzy environment by considering triangular fuzzy numbers for evaluating alternatives by criteria and defining crisp Euclidean distance between two fuzzy numbers. To evaluate alternatives linguistic assessments are used, which can be easily converted into fuzzy numbers, which are used in the further process of calculating (Onut and Soner, 2008, Kutlu and Ekmekcioglu, 2012) (Table 2).

Table 2
Definitions and membership functions of the fuzzy scale for the values of the alternatives

Linguistic expression	Fuzzy membership function
Very poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

After determining the weights of criteria and fuzzy values of alternatives against the criteria, fuzzy multi-criteria decision making problem can be expressed in matrix form. Matrix consists of a triangular fuzzy numbers $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ representing the value of the alternative A_i in relation to the criterion *j* (e.g. C_j). In order to transform the various criteria scales into a comparable scale it is necessary to perform normalization. The normalization formula for classical TOPSIS method is complicated, and therefore the linear scale transformation is used here. With this method the different ranges of triangular fuzzy numbers are reduced in the interval [0, 1] as follows (Eq. (1) and Eq. (2)):

$$\tilde{r} = \left(\frac{\tilde{a}_{ij}}{c_j^*}, \frac{\tilde{b}_{ij}}{c_j^*}, \frac{\tilde{c}_{ij}}{c_j^*} \right), \quad j \in B; \qquad c_j^* = \max_i c_{ij} \quad if \ j \in B; \tag{1}$$

$$\tilde{r} = \left(\frac{a_j^-}{c_{ij}}, \frac{b_j^-}{b_{ij}}, \frac{c_j^-}{a_{ij}} \right), \quad j \in C; \qquad a_j^- = \min_i a_{ij} \quad if \ j \in C. \tag{2}$$

where B and C are sets of benefit and cost criteria, respectively.
In this way normalized fuzzy decision matrix is formed, which can be written as:
$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}$, where $i = 1,2,...,m;$ and $j = 1,2,...,n,$ are indexes of alternatives and criteria, respectively.

Taking into account various importance of the criteria, a weighted normalized fuzzy decision matrix can be formed (Eq. (3)):

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n}, \quad i = 1,2,...,m; \ j = 1,2,...,n, \qquad \text{where} \quad \tilde{v}_{ij} = \tilde{r}_{ij} \otimes w_j(C_j) \tag{3}$$

where w_j denotes the weights of the criteria C_j .

Based on the weighted normalized fuzzy decision matrix, fuzzy positive ideal solution (*FPIS, A^**) and fuzzy negative ideal solution (*FNIS, A^-*) can be defined as:

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_n^*), \qquad \tilde{v}_j^* = (1,1,1), \ j = 1,2,...,n.$$

$$A^- = (\tilde{v}_1^-, v_2^-, ..., v_n^-), \qquad \tilde{v}_j^- = (0,0,0), \ j = 1,2,...,n.$$

The distance of each alternative from A^* and A^- can be calculated as (Eq. (4) and Eq.(5)):

$$d_i^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right), \quad i = 1,2,\ldots,m, \tag{4}$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right), \quad i = 1,2,\ldots,m, \tag{5}$$

where d (.,.) represents the distance between two fuzzy numbers which is calculated using the following formula (Eq. (6)):

$$d(\tilde{\rho},\tilde{\tau}) = \sqrt{\frac{1}{3}\left[(\rho_1-\tau_1)^2+(\rho_2-\tau_2)^2+(\rho_3-\tau_3)^2\right]} \tag{6}$$

where $\tilde{\rho}=(\rho_1,\rho_2,\rho_3)$ and $\tilde{\tau}=(\tau_1,\tau_2,\tau_3)$ are two triangular fuzzy numbers. Once the values $\tilde{d}_j^*$ and $\tilde{d}_j^-$ for each alternative are obtained, the closeness coefficient (*CC*) can be defined as follows (Eq. (7)):

$$CC_i = \frac{\tilde{d}_j^-}{\tilde{d}_j^* + \tilde{d}_j^-}, \quad i = 1,2,\ldots,m. \tag{7}$$

It is obvious that the alternative A_i is closer to (*FPIS*, A^*) and further from (*FNIS*, A^-) as the CC_i is approaching to 1.

Accordingly, on the basis of closeness coefficient to ideal solution, the order of alternatives may be determined and selected the best one from the feasible set.

4. Locating the city logistics terminal in Belgrade

Belgrade with two million inhabitants and an area of about 3200 km² is the administrative, cultural, educational, political and health center of the country. Like many cities in the world, Belgrade also lives with logistical problems. Emphasized development of housing in the outskirts and the concentration of business activity in the central area, are not timely followed by investments in the development of logistic, and above all transport system, which led to disproportion between transport need and ability to meet the requirements, with quality. In the practice, problems of logistics were discussed only in terms of transport, while the problems of other logistics subsystems (handling, storage, ordering, packaging) are completely ignored. Very valuable land, in the vicinity of the city center, which is equipped with old technology for storage and handling systems, runs a large number of vehicles and in many cases performs the logistics function for users who are not in the immediate area of the city of Belgrade (Tadić and Zečević, 2009).

In the transport policy of the city, little attention has been devoted to freight transport, and generally the problems of passenger transport and the congestion that it creates were solved. Beside the overcame concept of structuring, under-utilization of space and the outdated technology, lack of transfer sites and poor conditions for positioning of the unloading vehicles, disconnection of road, river and rail transport, transportation of hazardous materials through the central city zone, Belgrade is missing the logistics scenario that would be consistent with the city development concepts. City logistics is lacking of necessary degree of concentration and consolidation of flows and logistics service providers. Providers and users of logistics services are not waiting for accurate planning documents, but in accordance with the capabilities and requirements they are solving problems of location and construction of warehouses and other logistics systems. These systems are dislocated in a very disorganized way without concentration and consolidation of the flows that initiate.

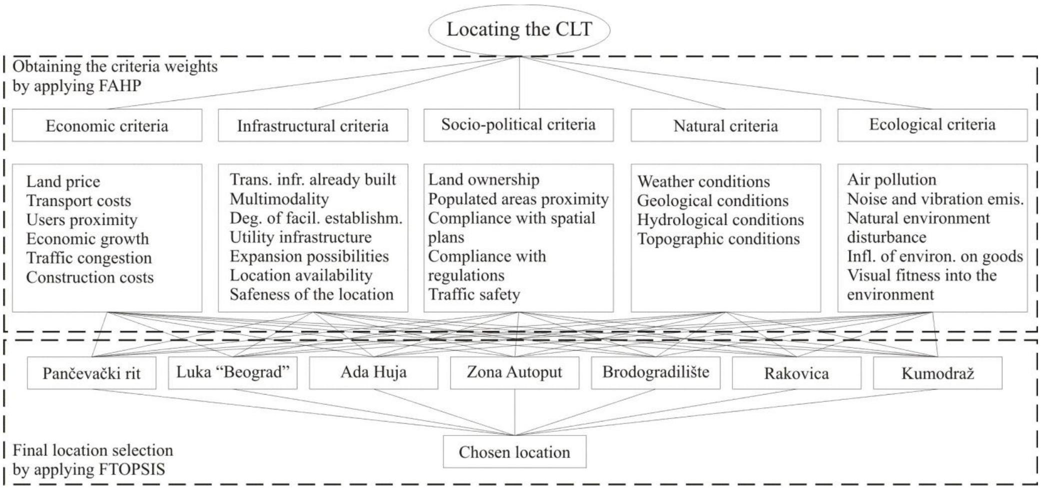

Fig. 1.
The structure of the problem of location selection using integrated FAHP-FTOPSIS approach

As noted above, one of the solutions to these problems would be construction of a logistics center for the reception of remote flows and consolidated deliveries to the generators in the city. Given the very significant role of the logistics center in the realization of logistics flows, but also in planning the logistics and transport system of the city, it is necessary to determine the optimal location for its construction. The first step of CLT location selection using integrated FAHP-FTOPSIS method is to define the hierarchical structure of the problem. For achieving the objective, the CLT location selection, five groups of criteria with multiple sub-criteria were defined on which the potential locations of CLT (alternatives) were evaluated (Fig. 1). Potential locations (Pančevački rit, Luka "Beograd", Ada Huja, Zona Autoput, Brodogradilište, Rakovica i Kumodraž) were defined by "Master plan of Belgrade 2021" as locations planned for the establishment of logistics facilities. The defined criteria for evaluation are based on the authors' experiences and literature review (Kayicki, 2010; Chen, 2001; Awasthi and Chauhan, 2012; Awasthi, et al., 2011; Anand, et al., 2012; da Silva Portugal, et al., 2011; Ertugrul and Karakasoglu, 2008; Ren, et al., 2011; Zečević, 2006; Tadić and Zečević, 2009; Vidović, et al., 2011).

Table 3
The criteria for evaluating potential locations for city logistics terminal

Criterion	Sub-criterion	Definition
Economic (K_1)	Land price (K_{11})	- Price of construction land on potential locations that depends on the zoning of the urban area defined by the city authorities
	Transport costs (K_{12})	- Costs of transporting goods from potential locations of the CLT to the cargo flows generators in the city
	Users proximity (K_{13})	- Distance of potential locations from the central city zones and zones with high density of generators
	Economic growth (K_{14})	- Degree of influence of the CLT on the development of infrastructure, job creation, and attraction of additional content and investments in the region of potential locations
	Traffic congestion (K_{15})	- The degree of traffic congestion increase (which generates costs for all stakeholders) in the surrounding of potential locations caused by establishment of the CLT
	Construction costs (K_{16})	- Cost of construction of facilities and infrastructure on the potential location
Infrastructural (K_2)	Transport infrastructure already built (K_{21})	- The level of establishment of transport infrastructure on the location (road access routes, railway tracks ...)
	Multimodality (K_{22})	- Connectivity of potential locations with multiple modes of transport
	Degree of facility establishment (K_{23})	- The presence and degree of development of equipment and facilities on the potential location that could be adapted for the required purpose
	Utility infrastructure (K_{24})	- The presence and degree of development of utility infrastructure (electricity, water, sewage) on the potential location
	Expansion possibilities (K_{25})	- The availability of land on the potential location for future development and expansion of the terminal
	Location availability (K_{26})	- Ability to access the site from different directions (access of goods, means of transport, workpeople)
	Safeness of the location (K_{27})	- The degree of site security (from theft, vandalism ...) depending on the part of the city where the potential location is sited and on the micro-location
Socio-political (K_3)	Land ownership (K_{31})	- The degree of resolved property rights over land on the potential location
	Populated areas proximity (K_{32})	- Distance of potential locations from residential areas and the attitude of the population in terms of establishing a CLT
	Compliance with spatial plans (K_{33})	- Compliance of potential locations with the plans of spatial planning and development, which are defined by the urban master plan
	Compliance with regulations (K_{34})	- The degree of compliance with the city government regulations in terms of building on the potential location and movement of transport vehicles in its surrounding
	Traffic safety (K_{35})	- Influence of the CLT development on the potential location on traffic safety
Natural (K_4)	Weather conditions (K_{41})	- Influence of meteorological conditions on the degree of attractiveness of the location (temperature, humidity, wind rose ...)
	Geological conditions (K_{42})	- Influence of geological conditions on the degree of attractiveness of the location (the structure and quality of the soil, landslides ...)
	Hydrological conditions (K_{43})	- Influence of hydrological conditions on the degree of attractiveness of the location (ground water, the risk of flooding ...)
	Topographic conditions (K_{44})	- Influence of topographic conditions on the degree of attractiveness of the location (ground slope, ...)
Ecological (K_5)	Air pollution (K_{51})	- The degree of increase in the concentration of harmful substances in the air due to the increased intensity of traffic flows and delays that would result from the construction of CLT on the potential location
	Noise and vibration emission (K_{52})	- The degree of increase in emission of noise and vibration due to the increased intensity of traffic flows and delays that would result from the construction of CLT on the potential location
	Natural environment disturbance (K_{53})	- The degree of influence of the goods (e.g. hazardous materials) and processes in the terminal on the destruction of the natural environment of potential locations
	Influences of environment on goods (K_{54})	- The degree of negative impact from the surrounding of the potential locations (landfills, industry) on the quality of the goods in the terminal
	Visual fitness into the environment (K_{55})	- The degree of visual compatibility of the CLT with the surrounding environment of the potential location

Selected criteria and sub-criteria (Table 3) include the requirements of all stakeholders in order to make a difference in the assessment of potential CLT locations. Thus, e.g. alternatives differ in relation to the construction land price or in relation to the transport costs from potential locations to the generators. Infrastructure criteria such as degree of transport and utility infrastructure development or connectivity with various modes of transport, but also natural criteria, such as geological, hydrological and topographical conditions of the site, affect the different level of attractiveness of potential locations. From the standpoint of environmental criteria, priority is given to locations whose activation would not lead to a significant increase in the traffic volume flows in the densely populated parts of the city and disruption of the natural environment.

In order to determine the relative weights, the comparison of criteria and sub-criteria has been made in terms of various stakeholders: investors, city government i.e. residents, and potential users of a CLT. Importance rates of the criteria (Table 4-9) are expressed by linguistic terms given in Table 1, and after that the linguistic assessment were converted into fuzzy numbers ($\tilde{a}_{ij}$ where $i=1,2,...,n$ and $j=1,2,...,n$ are criteria indexes). In this way, fuzzy decision matrixes were formed, and unified fuzzy values of the criteria importance are obtained by applying the technique of the geometric mean (Sun, 2010).

Table 4
Pair-wise comparison matrix of the set of basic criteria

	K_1	K_2	K_3	K_4	K_5
Economic (K_1)	-	MP, EI, MP	SP, - , SP	SP, - , -	AZ, - , SP
Infrastructural (K_2)	- , - , -	-	QP, - , QP	QP, - , -	SP, - , QP
Socio-political (K_3)	- , MP, -	- , MP, -	-	EI, - , -	MP, - , EI
Natural (K_4)	- , - , -	- , - , -	EI, - , -	-	MP, - , -
Ecological (K_5)	- , QP, -	- , QP , -	- , MP, EI	- , - , -	-

Table 5
Pair-wise comparison matrix of economic criteria

	K_{11}	K_{12}	K_{13}	K_{14}	K_{15}	K_{16}
Land price (K_{11})	-	- , - , -	- , - , -	MP, - , -	- , - , -	EI, - , -
Transport costs (K_{12})	SP, - , -	-	MP, - , MP	AP, - , SP	QP, - , QP	SP, - , -
Users proximity (K_{13})	QP, - , -	- , - , -	-	SP, - , QP	MP, - , MP	QP, - , -
Economic growth (K_{14})	- , - , -	- , - , -	- , - , -	-	- , MP, -	- , - , -
Traffic congestion (K_{15})	MP, - , -	- , - , -	- , - , -	QP, - , MP	-	MP, - , -
Construction costs (K_{16})	EI, - , -	- , - , -	- , - , -	MP, - , -	- , - , -	-

Table 6
Pair-wise comparison matrix of infrastructural criteria

	K_{21}	K_{22}	K_{23}	K_{24}	K_{25}	K_{26}	K_{27}
Transp. infra. already built (K_{21})	-	MP, - , -	QP, - , -	QP, MP, MP	SP, - , -	SP, - , -	AP, - , -
Multimodality (K_{22})	- , - , MP	-	MP, - , -	MP, - , QP	QP, - , -	QP, - , -	SP, - , -
Deg. of facility establishment (K_{23})	- , - , -	- , - , -	-	EI, - , -	MP, - , -	MP, - , -	QP, - , -
Utility infrastructure (K_{24})	- , - , -	- , - , -	EI, - , -	-	MP, - , -	MP, - , -	QP, - , -
Expansion possibilities (K_{25})	- , - , -	- , - , -	- , - , -	- , - , -	-	EI, - , -	MP, - , -
Location availability (K_{26})	- , - , -	- , - , -	- , - , -	- , - , -	EI, - , -	-	MP, - , -
Safeness of the location (K_{27})	- , - , -	- , - , -	- , - , -	- , - , -	- , - , -	- , - , -	-

Table 7
Pair-wise comparison matrix of socio-political criteria

	K_{31}	K_{32}	K_{33}	K_{34}	K_{35}
Land ownership (K_{31})	-	AP, - , -	SP, - , -	EI, - , -	QP, - , -
Populated areas proximity (K_{32})	- , SP, -	-	- , QP, -	- , QP, -	- , MP, -
Compliance with spatial plans (K_{33})	- , MP, -	MP, - , -	-	- , EI, -	- , - , -
Compliance with regulations (K_{34})	EI, MP, -	AP, - , -	SP, EI, -	-	QP, - , -
Traffic safety (K_{35})	- , QP, -	QP, - , -	MP, MP, -	- , MP, MP	-

Table 8 *Pair-wise comparison matrix of natural criteria*

	K_{41}	K_{42}	K_{43}	K_{44}
Weather conditions (K_{41})	-	- , - , -	- , - , -	MP, - , -
Geological conditions (K_{42})	MP, - , -	-	- , - , -	QP, - , -
Hydrological conditions (K_{43})	QP, - , -	MP, - , -	-	SP, - , -
Topographic conditions (K_{44})	- , - , -	- , - , -	- , - , -	-

Table 9 *Pair-wise comparison matrix of ecological criteria*

	K_{51}	K_{52}	K_{53}	K_{54}	K_{55}
Air pollution (K_{51})	-	MP, MP, MP	EI, QP, -	- , AP, -	QP, SP, -
Noise and vibration emission (K_{52})	- , - , -	-	- , EI, -	- , SP, -	MP, QP, -
Natural environment disturbance (K_{53})	EI, - , -	MP, EI , -	-	- , QP, -	QP, MP, -
Influences of environment on goods (K_{54})	QP, - , QP	SP, - , SP	QP, - , -	-	AP, - , -
Visual fitness into the environment (K_{55})	- , - , -	- , - , -	- , - , -	- , MP, -	-

In order to obtain the final weights of criteria for assessing the convenience of potential locations for establishing a CLT, three ways of solving the fuzzy AHP method are tested. This paper presents only the results obtained by using the fuzzy eigenvalues, the method proposed by Buyukozkan and Cifci (2012). For the problem defined in this paper, the extent analysis method (Chang, 1996) does not give acceptable results because in some cases overly favors or diminish the importance of certain criteria or sub-criteria. Weights of criteria obtained by geometric mean technique (Sun, 2010) and by using fuzzy eigenvalues are quite similar. Method of fuzzy eigenvalue was selected for calculation of criteria weighs because it includes the α-cut, as a level of experts' or decision-makers' confidence, and index of decision-makers' optimism μ in the analysis. In accordance, this method is described with more details below.

In general, after the formation of fuzzy decision matrix ($\tilde{A}$) a fuzzy eigenvalue ($\tilde{\lambda}$) of the matrix is being calculated. $\tilde{\lambda}$ is a fuzzy number which is a solution of the Eq. (8):

$$\tilde{A}\tilde{x} = \tilde{\lambda}\tilde{x} \tag{8}$$

whereby $\tilde{\lambda}_{\max}$ is the largest eigenvalue of the fuzzy matrix $\tilde{A}$, and $\tilde{x}$ is a non-zero $n \times 1$ fuzzy vector containing fuzzy number $\tilde{x}_i$.

When fuzzy multiplications and additions by using the arithmetic interval and *α-cut* is being done, equation $\tilde{A}\tilde{x} = \tilde{\lambda}\tilde{x}$ becomes equivalent to (Eq. (9)):

$$\left[a_{i1l}^{\alpha} x_{il}^{\alpha}, a_{i1u}^{\alpha} x_{1u}^{\alpha}\right] \oplus \ldots \oplus \left[a_{inl}^{\alpha} x_{nl}^{\alpha}, a_{inu}^{\alpha} x_{nu}^{\alpha}\right] = \left[\lambda x_{il}^{\alpha}, \lambda x_{iu}^{\alpha}\right] \tag{9}$$

where $\tilde{A} = \left[\tilde{a}_{ij}^{\alpha}\right]$, $\tilde{x}^{t} = \left(\tilde{x}_1, \ldots, \tilde{x}_n\right)$, $\tilde{a}_{ij}^{\alpha} = \left[a_{ijl}^{\alpha}, a_{iju}^{\alpha}\right]$, $\tilde{x}_{ij}^{\alpha} = \left[x_{il}^{\alpha}, x_{1u}^{\alpha}\right]$, $\tilde{\lambda}^{\alpha} = \left[\lambda_1^{\alpha}, \lambda_u^{\alpha}\right]$, for $0 < \alpha \le 1$ and all *i*, *j* where $i = 1,2,\ldots,n,\ j = 1,2,\ldots,n$.

The *α-cut* is known to incorporate the experts or decision-maker(s) confidence in terms of preferences of certain criteria. The degree of satisfaction of comparison matrix $\tilde{A}$ is estimated by the index of optimism μ. A larger value of the index μ indicates a higher degree of optimism. The index of optimism is a linear convex combination (Lee, 1999) defined as (Eq. (10)):

$$\tilde{a}_{ij}^{\alpha} = \mu a_{ijl}^{\alpha} + (1-\mu) a_{ijl}^{\alpha},\ \forall \alpha \in [0,1]. \tag{10}$$

When α value is fixed and when the index of optimism μ is set, a consistency ration (*CR*) for all pair-wise comparison matrixes is being calculated. The CR value should be less than 0,10 so the comparison would be acceptable. Otherwise, it is necessary to revise the pair-wise comparison of criteria.

In accordance with the previously described method, firstly the fuzzy criteria pair-wise comparison matrixes have been defuzzified using the equation (10) where the values $\alpha = 0{,}5$ and $\mu = 0{,}5$ were taken (Ayag, 2005, Buyukozkan and Cifci, 2012), and then the largest eigenvalues (λ_{max}) of the matrixes obtained in this way have been calculated. For all matrixes, CR values have been calculated in order to determine the extent to which the matrixes were randomly filled (Kutlu and Ekmekcioglu, 2012). Since all values were less than 0.1 it was noted that the comparison is acceptable.

Matrix equation in the form:

$AW = \lambda_{\max} W$, where W is the matrix of criteria weights being calculated,

is transformed into a system of linear equations, and final weights of criteria and sub-criteria obtained by solving it are shown in Table 10. Final values of criteria in the last level are obtained by multiplying the weights of those criteria and weights of criteria above them in the defined hierarchical structure.

For the purpose of final CLT location selection and application of FTOPSIS method, potential sites were evaluated by selected criteria (Table 11). Ratings of locations by quantitative criteria are numerical values and by qualitative criteria linguistic terms defined in Table 2.

Prices of construction land at potential locations are obtained depending on which of the four zones, defined by the urban master plan, the location is sited. Transport costs are a function of vehicle traveling times between the defined urban areas. These times were obtained on the basis of traffic distribution on the network by the principle of user equilibrium, in terms of loaded traffic network (Teodorović, 2009). However, calculation of transport costs, for the purpose of this study, did not take into account the time windows in which generators require delivery, routes and schedules of vehicle movements, and the impact of terminal construction on the increase in traffic density in the surrounding of potential locations. CLT construction costs on the potential location depends on renovation costs of existing facilities, on the cost of remediation of some adverse natural factors, on the shape and size of the plot, but the values shown in this paper were obtained from a review of case studies.

Table 10

Weights of criteria obtained by solving FAHP method

K1						**K2**							
0,352						0,214							
K11	**K12**	**K13**	**K14**	**K15**	**K16**	**K21**	**K22**	**K23**	**K24**	**K25**	**K26**	**K27**	
0,07	0,45	0,25	0,05	0,12	0,06	0,36	0,30	0,11	0,11	0,05	0,05	0,02	
0,023	0,159	0,088	0,017	0,042	0,022	0,076	0,065	0,023	0,024	0,010	0,010	0,005	
K3					**K4**				**K5**				
0,147					0,112				0,175				
K31	**K32**	**K33**	**K34**	**K35**	**K41**	**K42**	**K43**	**K44**	**K51**	**K52**	**K53**	**K54**	**K55**
0,23	0,22	0,10	0,24	0,21	0,12	0,26	0,56	0,06	0,29	0,17	0,18	0,30	0,07
0,033	0,032	0,015	0,035	0,031	0,013	0,030	0,063	0,006	0,050	0,029	0,031	0,053	0,013

Table 11

Evaluation of potential locations in relation to the defined criteria

	K_{11}	K_{12}	K_{13}	K_{14}	K_{15}	K_{16}	K_{21}	K_{22}	K_{23}	K_{24}	K_{25}	K_{26}	K_{27}	K_{31}	K_{32}	K_{33}	K_{34}	K_{35}
Pančevački rit	135	1800	MG	G	MP	85	P	G	P	P	G	MP	F	P	MG	F	MD	F
Luka "Beograd"	1200	1300	VG	F	VP	63	G	VG	VG	VG	VP	MG	G	VP	VP	G	MP	P
Ada Huja	550	1150	G	G	P	75	MP	G	F	MG	F	F	MG	MP	F	G	F	F
Zona Autoput	250	1400	MP	VG	VG	62	G	MG	MG	MP	VG	G	G	VG	VG	VG	VG	VG
Brodogradilište	400	1600	F	MG	MP	66	F	F	F	F	MP	F	MG	G	MP	F	F	MG
Rakovica	120	1500	P	P	G	60	MP	P	MP	G	P	MP	P	F	P	MP	F	MP
Kumodraž	130	1650	MP	MP	MG	60	P	P	VP	F	MP	MG	MP	F	MP	P	MP	F

	K_{41}	K_{42}	K_{43}	K_{44}	K_{51}	K_{52}	K_{53}	K_{54}	K_{55}
Pančevački rit	VP	VP	P	MG	MG	F	P	MP	P
Luka "Beograd"	P	F	F	F	VP	VP	MP	F	F
Ada Huja	P	P	VP	F	F	MP	P	P	VP
Zona Autoput	G	G	MG	G	VG	VG	G	G	VG
Brodogradilište	MP	MP	P	MG	F	MP	MG	F	F
Rakovica	MG	G	G	P	MP	P	MP	F	G
Kumodraž	MG	G	G	P	MP	P	F	MG	MG

Linguistic terms were converted into fuzzy numbers, and then using equation (1) fuzzy values were normalized. Multiplying by the obtained relative weights of criteria, normalized weighted fuzzy values are obtained. A fuzzy positive ideal solution (*FPIS*, A^*) and fuzzy negative ideal solution (*FNIS*, A^-) are defined. Fuzzy positive ideal solution is determined by the highest fuzzy values appearing in evaluations of criteria and sub-criteria, while all values in the fuzzy negative ideal solution are equal to zero.

Distances of all alternatives from positive and negative ideal solution are calculated using the equations (4) and (5), and afterwards, the values of closeness coefficients (CC_i) for all potential locations are calculated using the equation (7).

These values and the final ranking of potential locations for establishing a CLT in Belgrade are shown in Table 12. Solution to the problem of locating the CLT in Belgrade, by using fuzzy TOPSIS method, is the location of "Zona Autoput".

Table 12
The distances of alternatives from FPIS and FNIS and final ranking of alternatives obtained by using a FTOPSIS

	d_i^*	d_i^-	CC_i	**Rank**
Pančevački rit	0,547	0,499	0,477	6
Luka "Beograd"	0,447	0,585	0,567	2
Ada Huja	0,493	0,551	0,528	3
Zona Autoput	0,234	0,803	0,774	1
Brodogradilište	0,508	0,537	0,514	4
Rakovica	0,531	0,516	0,493	5
Kumodraž	0,538	0,508	0,486	7

Ranking of potential locations with fuzzy TOPSIS method has also been done for weights of criteria evaluated by investors, the city government and residents and potential users of a CLT. Comparative review of the order of potential locations for every interest group is given in Fig. 2. Location "Zona Autoput", which was the best in the final ranking with a combined score of weights of criteria and sub-criteria, is also the best potential location for investors and the city.

From the standpoint of potential users this location is in the third place, but with the value of CC_i that is very close to the value for "Luka Beograd" (which is the first) and "Ada Huja" (which is the second). For investors, the best locations are the ones that generate the lowest costs and with well-developed infrastructure, while the city government gives advantage to the locations whose activation would have the least consequences on human health and the environment, i.e. the locations that comply with city plans and regulations. From the standpoint of users, the preference has those locations that are closer to areas with a high density of flow generators and locations that can easily be connected with the different modes of transport.

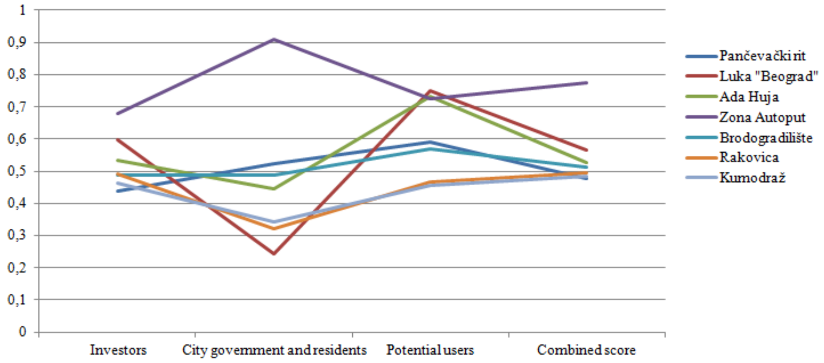

Fig. 2.
Comparative review of the alternatives ranking obtained by the fuzzy TOPSIS method

5. Sensitivity analysis of the obtained solution

As the relative weights of the criteria, by which the CLT' potential locations were evaluated, have largely been dependent on subjective evaluations of decision-makers, it is necessary to check the stability of the final order of alternatives. This can be done by conducting a sensitivity analysis, i.e. observing the effects of changing the values of criteria weights on the final order of the alternatives. If the order of the alternatives is very sensitive to even small changes in criteria weights, it is necessary to carefully review the weight values.

Sensitivity analysis can be realized in several ways. Onut and Soner (2008) and Choudhary and Shankar (2012) analyzed the sensitivity of the results by substituting the weights between all pairs of criteria. In this paper, a sensitivity analysis was performed by creating scenarios in which the values of the relative weights of criteria were increased by a certain percentage (Buyukozkan and Cifci, 2012; Ayag and Ozdemir, 2009; Chang, et al., 2007; Wu, et al., 2007). Five scenarios were created in which the weights of economic, infrastructural, socio-political, natural and environmental criteria were increased by 25%, afterwards the ranking by fuzzy TOPSIS method was carried out (the relative weights of other criteria were reduced so that the sum gives 100%). Based on the results of the sensitivity analysis (Fig. 3), it can be stated that the obtained order of potential locations for establishing a CLT is stable, because changes in the values of criteria weights does not significantly change the order of alternatives.

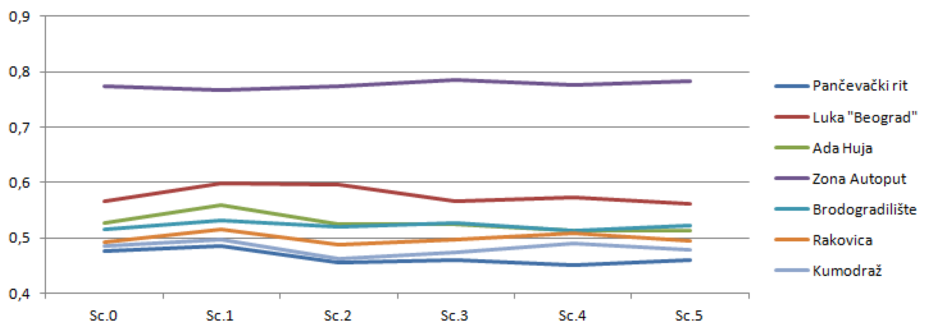

Fig. 3.
The results of the sensitivity analysis of the obtained solution

6. Conclusion

The aim of this paper was to harmonize the different requirements and objectives of the stakeholders and to rank the potential locations for establishing a city logistics terminal by using the hybrid multi-criteria technique which combines fuzzy AHP and fuzzy TOPSIS methods. The structure of the problem was defined, and afterwards the usability of the proposed methodology was demonstrated by solving the case study of selecting the location of the CLT in the city of Belgrade.

For solving the problem of CLT location selection, in this paper was for the first time used integrated FAHP-FTOPSIS method which allows consideration of the large number of quantitative and qualitative criteria and adequately takes into account the vagueness and ambiguity of human thinking. It is also pointed out that the application of different procedures for solving the fuzzy AHP method can result in obtaining the different values of criteria. Final weight values of criteria, for ranking the CLT potential locations in Belgrade, were obtained by fuzzy AHP method solved using the largest eigenvalue technique, which takes into account the level of decision-makers' confidence (parameter α) and the index of optimism (parameter μ). Further research could move in the direction of application of some other fuzzy multi-criteria decision making methods, such as fuzzy ELECTRE, fuzzy PROMETHEE, fuzzy VICOR, and of course the method which combines the ANP (Analytic Network Process) as an upgrade to the AHP and TOPSIS method in the fuzzy environment.

References

Albayrak, E.; Erensal, Y.C. 2004. Using analytic hierarchy process (AHP) to improve human performance. An application of multiple criteria decision making problem. *Journal of Intelligent Manufacturing,* 15(4): 491-503.

Anand, N.; Yang, M.; van Duin, J.H.R.; Tavasszy, L. 2012. GenCLOn: An ontology for city logistics. *Expert Systems with Applications,* 39(15): 11944–11960.

Awasthi, A.; Chauhan, S.S. 2012. A hybrid approach integrating Affinity Diagram, AHP and fuzzy TOPSIS for sustainable city logistics planning. *Applied Mathematical Modelling,* 36(2): 573-584.

Awasthi, A.; Chauhan, S.S.; Goyal, S.K. 2011. A multi-criteria decision making approach for location planning for urban distribution centers under uncertainty. *Mathematical and Computer Modelling,* 53(1-2): 98-109.

Ayag, Z.; Ozdemir, R.G. 2009. A hybrid approach to concept selection through fuzzy analytic network process. *Computers and Industrial Engineering,* 56(1): 368-379.

Ayag, Z. 2005. A fuzzy AHP-based simulation approach to concept evaluation in a NPD environment. *IIE Transactions,* 37(9): 827-842.

Badri, M.A. 2001. A combined AHP-GP model for quality control systems. *International Journal of Production Economics,* 72(1): 27-40.

Buyukozkan, G.; Cifci, G. 2012. A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry. *Expert Systems with Applications,* 39(3): 2341-2354.

Chan, F.T.S.; Kumar, N. 2007. Global supplier development considering risk factors using fuzzy extended AHP-based approach. *OMEGA,* 35(4): 417-431.

Chang, C.W.; Wu, C.R.; Lin, C.T.; Chen, H.C. 2007. An application of AHP and sensitivity analysis for selecting the best slicing machine. *Computers and Industrial Engineering,* 52(3): 296-307.

Chang, D.Y. 1996. Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research,* 95(3): 649-655.

Chen, Z.; Yang, W. 2011. An MAGDM based on constrained FAHP and FTOPSIS and its application to supplier selection. *Mathematical and Computer Modelling,* 54(11-12): 2802-2815.

Chen, C. 2000. Extensions of the TOPSIS for group decision/making under fuzzy environment. *Fuzzy Sets and Systems,* Issue 114(1): 1-9.

Chen, C.T., 2001. A fuzzy approach to select the location of the distribution center. *Fuzzy Sets and Systems*, 118(1): 65-73.

Choudhary, D.; Shankar, R. 2012. An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India. *Energy*, 42(1): 1-12.

da Silva Portugal, L.; Margado, A.V.; Lima Junior, O. 2011. Location of cargo terminals in metropolitan areas of developing countries: the Brazilian case. *Journal of Transport Geography,* 19(4): 900–910.

Dagdeviren, M.; Yavuz, A.; Kilinc, N. 2009. Weapon selection using the AHP and TOPSIS methods under fuzzy environment. *Expert Systems with Applications,* 36(4): 8143-8151.

Ertugrul, I.; Karakasoglu, N. 2008. Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection. *International Journal of Advanced Manufacturing Technologies*, 39(7-8): 783–795.

Guyon, O.; Absi, N.; Feillet, D.; Garaix, T. 2012. A modeling approach for locating logistics platforms for fast parcels delivery in urban areas. In Proceedings of *The Sixth International Conference on City Logistics*. Procedia Social and Behavioral Sciences 39, 360 – 368

Hsieh, T.Y.; Lu, S.T.; Tzeng, G.H. 2004. Fuzzy MCDM approach for planning and design tenders selection in public office buildings. *International Journal of Project Management,* 22(7): 573-584.

Hwang, C.L.; Yoon, K. 1981. *Multiple attributes decision making methods and applications.* Berlin, Springer. 259 p.

Kayicki, Y. 2010. A conceptual model for intermodal freight logistics centre location decisions. *Procedia - Social and Behavioral Sciences*, 2(3): 6297–6311.

Kulak, O.; Durmusoglu, B.; Kahraman, C. 2005. Fuzzy multi/attribute equipment selection based on information axiom. *Journal of Materials Processing Technology,* 169(3): 337-345.

Kutlu, A.C.; Ekmekcioglu M. 2012. Fuzzy failure modes and effects analysis by using fuzzy TOPSIS/based fuzzy AHP. *Expert Systems with Applications,* Issue 39(1): 61-67.

Lee, A. R., 1999. *Application of modified fuzzy AHP method to analyze bolting sequence of structural joints.* UMI Dissertation Service, A Bell and Howell Company.

Negoita, C.V. 1985. *Expert systems and fuzzy systems.* Menlo Park, CA, Benjamin/Cummings. 190 p.

Onut, S.; Soner, S. 2008. Transshipment site selection using AHP and TOPSIS approaches under fuzzy environment. *Waste Management,* 28(9): 1552-1559.

Ren, Y.; Xing, T.; Chen, X.; Chai, X. 2011. *Fuzzy Comprehensive Evaluation of Location Plan of City Distribution Center.* Singapore, Elsevier.

Rostamzadeh, R.; Sofian, S. 2011. Prioritizing effective 7Ms to improve production systems performance using fuzzy AHP and fuzzy TOPSIS (case study). *Expert Systems with Applications,* 38(5): 5166-5177.

Saaty, T.L. 1980. *The analytic hierarchy process.* New York, McGraw-Hill.

Sun, C. 2010. A performance evaluation model bz integrating fuzzy AHP and fuzzy TOPSIS methods. *Expert Systems with Applications,* 37(12): 7745-7754.

Tadić, S.; Zečević, S. 2009. Izbor optimalnog scenarija razvoja logističkog sistema, In *Proceedings of SYM-OP-IS 2009*, Ivanjica, 333-336

Taniguchi, E.; Noritake, M.; Yamada, T.; Izumitani, T. 1999. Optimal size and location planning of public logistics terminals. *Transportation Research Part E,* 35(3): 207-222.

Taniguchi E.; Thompson R.G. 2003. *Innovations in freight transport*, WIT Press, The University of Melbourne, Australia. 216 p.

Teodorović, D. 2009. Transportne mreže. Beograd: Saobraćajni fakultet Univerziteta u Beogradu

Vidović, M.; Zečević, S.; Kilibarda, M. Vlajić, J.; Bjelić, N.; Tadić, S. 2011. The p-hub Model with Hub-catchment Areas, Existing Hubs, and Simulation: A Case Study of Serbian Intermodal Terminals, *Networks and Spatial Economics*, 11(2): 295-314

Wu, C.R.; Lin, C.T.; Chen, H.C. 2007. Optimal selection of location for Taiwanese hospitals to ensure a competitive advantage by using the analytic hierarchy process and sensitivity analysis. *Building and Environment,* 42(3): 1431-1444.

Yang Z.; Song X.; Liu C. 2005. Optimizing the scale and spatial location of city logistics terminals. *Journal of the Eastern Asia Society for Transportation Studies*, 6: 2937 – 2946

Zadeh, L.A., 1965. Fuzzy set. *Information and Control,* 8(3): 338-353.

Zečević, S.; Kilibarda, M.; Radivojević, L.; Tadić, S. 2002. City logističke koncepcije. In *Prilog unapređenju teorije i prakse planiranja i implementacije*, Institut za arhitekturu i urbanizam Srbije: 251-259

Zečević, S.; Tadić, S. 2006. *City logistika.* Saobraćajni fakultet Univerziteta u Beogradu, Srbija. 190 p.

Zečević, S. 2006. *Robni terminali i robno-transportni centri.* Saobraćajni fakultet Univerziteta u Beogradu, Srbija. 284 p.

Zimmermann, H.J. 1985. *Fuzzy set theory and its applications.* Boston, MA, Kluwer.

Master Plan of Belgrade 2021. Available from internet: <http://www.beograd.rs/documents/plan2021/01_gpb_1-5.pdf>.

Warehouse construction cost estimates. Available from internet: <http://www.reedconstructiondata.com/rsmeans/models/warehouse/>

LOGISTICS AS AN INSTRUMENT OF TRADE MARKETING

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Abstract: In the framework of the marketing mix, distributive marketing instrument has the basic task of allowing the consumer to purchase the product, in keeping with his wishes manifested through time and place of delivery. Logistics management is responsible for defining the optimum level of service offered to consumers with respect to the physical movement of goods. What this means is that the task of logistics today has become much more complex, since apart from being efficient, it must also meet marketing demands regarding the tailoring of services to individual consumers. Marketing-oriented logistics ensures delivery tailored to demands not only of a narrower consumer group, but of individual consumers. Integrated approach to supply chain management ensuring comprehensive control of products and services passing through the distribution channel is of special importance to commercial economic subjects. Economic development dynamics generates an array of new logistical concepts demanding that logistics, being an instrument of trade marketing, be sufficiently elastic to adjust itself to changes both on the market and in the domain of technological development, especially in the areas in which parts of consumer services are created.

Keywords: Consumer, Logistical Process, Logistics Marketing, Supply Chain, Trade Marketing

1. Introduction

The business foundation of any economic entity represents clearly articulated needs. Activation of goods and money in trade, as well as in other industries, seeking real needs which are regulated by purchasing power and demand and its activation alone is regulated by purchasing power. Physical gratification of total consumer needs to logistics and trading business entities decide to perform the operational logistics activities. Logistic activities of trading undertakings were pursued through the input (purchase) logistics and outbound logistics (consumers). Retailers have traditionally dealt Inbound Logistics because their liability was focused on the physical delivery of goods to their facilities. Constant changing paradigms, stronger competition and the application of new technology business retailers, logistics and marketing logistics appears in retail trade. This traditional logistics comes out of its narrow frame, and becomes an instrument not only for price competition but also a means of raising the quality of services to consumers especially as there is a tendency in the number of consumers who want a higher level of service. Service has become the basis for the creation of competitive advantage, since it allows an important advantage of the opportunity for differentiation of standard products as well as satisfying the specific needs of consumers. For the achievement of benefits and consumer goodwill, retailers must coordinate logistics with his other business functions, as consumers, as well as end users of the product, the only measure of success of all marketing activities undertaken.

Manufacturers of physical products and services have to decide on the logistics market - the best method of storage and transportation of products and services on the destination market, and coordinate activities of suppliers, purchasing agents, manufacturers, marketing professionals, channel members and customers. Improving the efficiency of logistics result of the progress of information technology (Kotler and Keller, 2007), as the quality of logistics services plays a very important role in the survival of the market and fight with their competitors.

Logistics management is responsible for defining the optimum level of service to consumers when it comes to the physical movement of products, because today has to meet logistics and marketing requirements to adapt services to individual consumers. This means that the behavior of consumers when buying is an impuls to the process of production and logistics (Segetlija, 2006).

Logistics support for the traditional marketing mix. It encompasses a variety of activities that generate specific marketing costs, but also increase the value of the bid. Customer service defines its effectiveness in the distribution channel as 98% of the warehouse means that the requested product immediately available to the buyer in 98% of applications. This high level of logistics services marketing managers set to further increase penetration and market share. Therefore, the task of logistics calculates costs caused by this level of service in order to assess consumer response to deficiencies identified inventory levels. Logistics is in fact regulated system composed of a range of logical and interconnected subsystems. Structure and elements of logistics, to observe and study the different aspects - financial, economic, market, etc., and is therefore still necessary problems of economics, trade undertaking or issues of trade and the flow of the business process, the process under the conditions of market economy, ie an economic system that is based on other grounds (Segetlija and Lamza-Maronić, 1996). For this purpose, we have used with the literature from countries with developed market economies as well as the results obtained by our own research.

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2. Tasks of Marketing Logistics

The concept of marketing logistics in its content develops in relation to other aspects of logistics because it is traditional support to the marketing mix. It encompasses a variety of activities that cause certain marketing costs, but also increase the value of deals which can be seen in Fig. 1 (Lambert and Sterling, 1978).

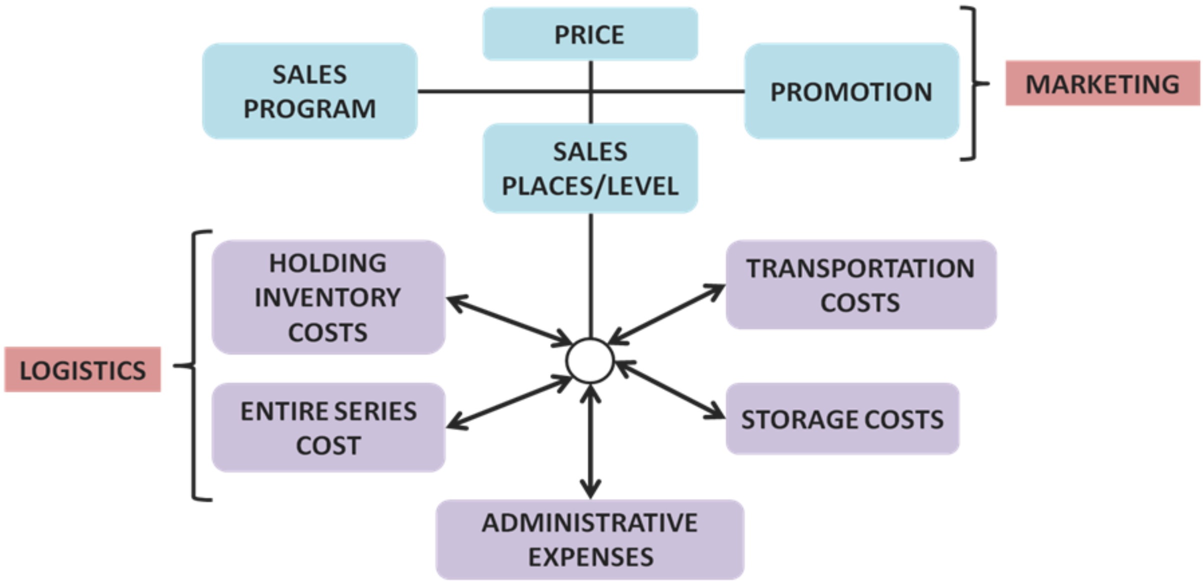

Fig. 1.
Costs and activities in the logistics system
Source: Made by Authors

Combining all of these activities is operationalized in the process of movement of finished products and information related to product placement. In these circumstances, the consumer is provided the desired product with minimal costs incurred in connection with bridging temporal and spatial differences between its production and consumption. The logistic function helps bridging spatial and temporal disparity so that the product will be in place at the time when consumers are looking for. Therefore it can be concluded that it is unlikely that many consumers have no need or desire to buy umbrellas VIS K & G in June, July or August, but the manufacturer will concentrate on production during the year and store umbrellas to readily meet increasing demand, which usually occurs in early fall (Grbac, 2007). This means that the orientation towards consumers must assume the position of the consumer, in order to supply the market could offer proper service system. Logistics is critical to maintain relationships with customers; leading industry players recognize and acknowledge the contribution of user services running logistics. In many cases, the logistics service is the primary deciding factor that influences their buying intentions. However, the logistics do not work in isolation. Logistics activities must be coordinated and complementary with other functional areas, particularly marketing. In order to maximize the potential of these two areas must work effectively together. Marketing to create demand, in order to cater for logistics and meet demand. It follows that the fundamental task of marketing logistics needs of consumers turn to an order convenient for delivery. The realization of the task indicates that the fundamental task of marketing logistics marketing. However, one should bear in mind that the dynamics of economic development may set new demands on the marketing logistics. This means that marketing logistics must be extremely flexible because it necessarily has to adapt to the changes in the market and in the area of technological development. Based on this, we can conclude that marketing logistics sea, among other things, to ensure optimal implementation and market demanding logistics system, both in terms of prices and the quality of individual and total logistics services. This will be realized overall marketing fundamental role in the economic entity, and that's good and successful integration of the production and consumption of the products, which affects their market development.

3. Meaning and positioning of logistics in trade

The purpose of logistics is constantly improving the flow of goods and information through a business entity, or in the entire supply chain. As the fundamental objectives can be set (Segetlija, 2006): reduce inventory, shorten the time (e.g., on the order of customers), etc. Today, more single economic entity that is engaged in the production and / or trade cannot be successful if your work is not regarded as a distribution business. Also the long term will not survive another economic operators with second-or delayed distribution structure or marketing logistics or marketing talent.

Therefore, it is its positioning within the store vital because only ensure its full implementation and includes all activities aimed at lifting the efficiency and effectiveness of trade and its entire system that is focused on customers and processes.

Large supplies, transportation costs and other logistical costs caused by the desire of management to store adequate logistics rationalization realize substantial savings, and thus achieving better business and financial results. Availability stocks will not always be a sufficient reason to make a purchase, but it is completely certain that the lack of supplies can often be a sufficient reason to change the place of purchase. Trade and logistics management must coordinate value of savings and sometimes excessively high service requests by customers. This means that logistics remains to be one of the underutilized areas for adding value to trade offers. Adding value through logistics ensures successful anticipation of the needs and desires of consumers and the development of such a business system that allows you to meet the needs and desires at the lowest cost. Therefore, the faster must end business process of procurement, production, realization and collection, and therefore just logistics is gaining importance and is equated with the other functions in the economic entity, So, I realized that the logistics can not only deplete reserves of rationalization, but to achieve and competitive advantages due to growing demand for shorter delivery deadlines, better flexibility, range, etc (Segetlija, 2006).

Control of management processes include planning, organization and control procedures for the target routing chain to create value with respect to quality, time, cost, and customer satisfaction (Gaitanides, et al., 1994). Optimal combination is achieved unhindered circulation of consumers as well as the maximum volume of sales per unit of retail space. Therefore, the obligation to coordinate store management functions, areas of action, decision-making and certain executives. So, logistically outputs should provide a competitive advantage in the market with more efficient to attract consumers, and thereby simultaneously creating additional time and space value to increase profits and increased capital values. Therefore, the goal of logistics as a marketing tool to increase the profitability of the trade that is based on customer satisfaction and integrating marketing efforts aimed at lifting the level of service to consumers. This means that the logistics marketing offensive weapon, or a field of potential competitive advantage in the marketplace. All this points to the maximum correlation marketing logistic functions, and this connection can be seen through the dimension of creating logistics value in trade economic entity. Such a strategy becomes a separate set of activities organized to give a specific combination of values of a selected group of consumers (Porter, 1985).

4. Logistics process - adding value

Successful economic operators develop superior management capabilities fundamental processes, giving them considerable acuteness of Competition, where they are viewed and further from their value chain, observed in the value chains of its suppliers, distributors and, ultimately, customers and consumers. Specifically, once the suppliers and distributors regarded as sources of costs, but they are now carefully selected according to the principles of partnership. We would argue that the main goal of efficient management of logistics processes achieving consumer satisfaction, which is achieved by creating and providing added value to the consumer, which will be considered to be higher than the amount paid for it, or greater than the value of their pungent amount offered competitors. An important source for obtaining a relatively long-term competitive advantage early in this century is becoming more value-added delivery to consumers. It is acquired by discovering new ways out to meet demanding customer value. Economic operators must learn extensively about your market and target consumers. A good number of businesses who are trying to gain a competitive advantage in the market, based on the assessment of what makes the offer of competitive businesses and trying to do something better than that. The innovation of placing emphasis on the value of the innovation, because without it, there is no improvement value for consumers that can be supplied by added value. Because of logistics functions including integration of multiple products in bulk, storing and making available to consumers, and often shapes the program offers in smaller units and a form placed on retail shelves. So, it is a transportation, warehouse, and making contact with consumers (Grbac, 2007). Logistics adding value (Fig. 2) is through successfully meeting the needs and desires of consumers and at the lowest cost.

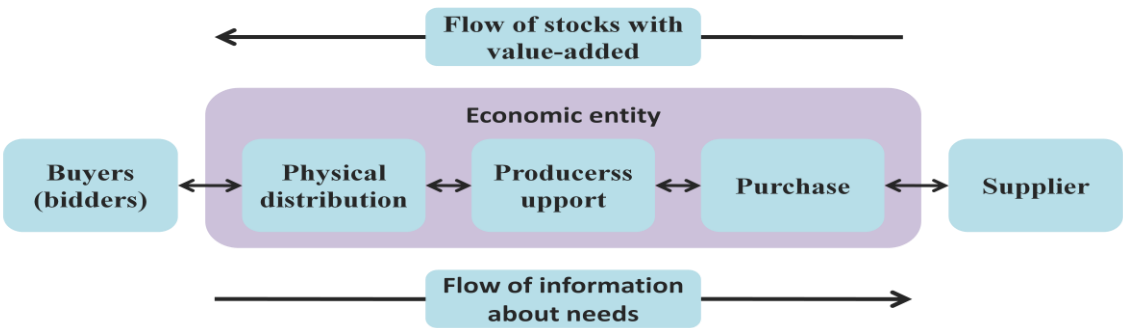

Fig. 2.
Value-adding chain in logistics
Source: Bowersox and Cooper (1992)

Adding value in the logistics channel involves optimization of the process and the establishment of efficient functioning of the logistics chain, which is achieved by running-in operations. The very effectiveness of the adjustment is accomplished by introducing new activities in the various steps of the process of logistics. Management value chain radically changes the organizational processes and the way in which the work is performed, and eliminates all activities that do not add value.

Tendencies that marked the end of the twentieth century in the distribution channels is making alliances between manufacturers and retailers. Commercial entities such as Dillard’s (department stores), Kroger (supermarket), K-Mart (discount houses) and Target (discount houses a full-service) established alliances with manufacturers, with the idea that a shared crispum costs and upgrading the performance. This implies a common measurement techniques and efforts in sharing information, and it's all focused on linking logistics efficiency and marketing effectiveness. Thus, for example, Wal-Mart announced that it has invested $ 600 million in information technology, which will allow access to POS data from a selected group of 2,000 suppliers (Borersox and Frayer, 1999). This activity has resulted in a better prediction of requests for products and services because of closer ties with customers and consumers and so the Wal-Mart and Warner-Lambert's Consumer Group collaborated on improvements to forecasting requirements for the product and the mutual efforts of partners increased sales of Wal-Mart for 6,5 million U.S. dollars (Robbins and DeCenzo, 2004). Also, the dynamic and competitive environment is facing the modern global corporation, requiring new solutions. Knowing about the dominance of the market-value of a consumer's economic subjects took the experiment with a new business model, or to the strategic design of how the economic operator is planning to benefit from its wide array of strategies, processes and activities. For example, IKEA, furniture manufacturer, has been transformed from a small Swedish manufacturer by postal orders in the world's largest furniture retailer, and design a new value chain. For consumers, it offers well-designed products at very low prices in exchange for those willing to take on certain tasks that have traditionally been in charge of manufacturers and retailers, such as delivery, installation, etc. (Robbins and DeCenzo, 2004).

Good value chain is the sequence in which participants work towards the principles of teamwork, where each adds some value, such as, for example, faster assembly, accurate information or to purchase a better response to consumer products or services. What is a better cooperation between the various stakeholders chain, better solutions to consumers. When the value to consumers when they are created and their needs and desires are met, everyone in the chain of benefit. For example, the Iomega Corporation, a manufacturer of storage devices for PC, manage the value chain begins to improved relationships with internal suppliers, and extends to external suppliers, customers and consumers. As the experience of the company with the management of the value chain strengthens and progresses, so increases their connection with consumers, which is finally paid to all partners in the value chain (Robbins and DeCenzo, 2004).

Special dimension to overcome inter-organizational boundaries is optimizing the total cost of the system. Functional intermediaries in this process is not cost efficient or not added to the otherwise overall value of the service consumer, a burden that other participants in the chain should be identified and removed.

However, apart from manufacturing operations, productivity can be increased and the rationalization of many other processes in companies. For example, the realization once received orders had already been operating a strategic character, and once with the delivery of the product could be delayed, without fear that they will lose existing customers, because the competition was of low intensity. In contrast, in the modern economy prompt delivery of products and services is one of the important elements of the overall productivity and competitiveness. Exact delivery includes horizontal integration and uninterrupted flow of information and material inputs and finished goods between supplier - manufacturer - distributor - customer / consumer. This is an integrated logistics process-driven sophisticated management techniques that today are constantly developing.

From this we can conclude that adding value includes all activities, functions and business processes that take place during the design and development, manufacturing, sales, distribution, and (after) sales service and support to consumers because the whole logistics process must ensure and generate added value for each participant in the process, which is a fundamental prerequisite of business success. Besides the possibility of creating new value-added, marketing logistics probably offers the greatest opportunities to improve profitability in companies.

5. Modern logistics concepts

From the previous argument we conclude that logistics plays an important role in the formulation and implementation of services to consumers. Rising levels of service and adding value to the logistics service have contributed to many modern logistics concepts.

The concept of supply chain began to develop significantly in late 80-ies of the last century. There is no universally accepted definition of the supply chain, as well as many other concepts. Many supply chain used as a synonym for logistics, although the logistics of one of his constituents.

One definition of the supply chain says it's integration of business processes from end user through original suppliers that provides products, services and information that create added value for customers (Lambert, et al., 1998). The main objective of the supply chain is actually achieving extraordinary speeds in the realization of the needs of consumers, because the restrictions caused by the consumer, which means that there is a change in the needs, wishes and expectations of consumers.

Synchronization of what real consumers want with what retailers really cannot easily deliver and requires a systematic approach to defining the organization's quality and logistics concept.

Today, supply chain and his organization represent areas of opportunities to create competitive advantages and, therefore, holds strategic tool for positioning the business entity in the market. There are many examples of businesses that are just high-quality supply chain management could significantly improve its market position and to move away from the competition. Many senior decision-makers now recognize that the supply chain is making a key contribution to operational excellence. It has been documented many times, most recently in an international research team, which included researchers from Accenture, the business school INSEAD and Stanford University (INSEAD). The results from this effort indicate that the supply chain is very important or critical to almost 90% of the population research manager. By supporting these statements, almost the same percentage has increased investment in the supply chain in recent years (Anderson, et al., 2003). Therefore, supply chain refers to the manipulation of materials and processing of the classical economy where profits gained by lowering costs. Value chain is, however, a process in which the individual stages of production or service adds value by means of, for example, knowledge, innovation, design, quality and small improvement of the working environment and the employment service process.

This study classifies different approaches to economic entities in the supply chain intervals since 1995 to 1997 and since 1998 to 2000 year. The study included 636 businesses from 24 industries, and tried to determine whether a supply chain to influence the success of the undertaking. Interviews were conducted with employees and consulted industry analysts, academic experts and the like, and the results were compared with earlier surveys and studies Accenture,

INSEAD and Stanford University. The studies were four main findings emerged, including (D'Avanzo, et al., 2003):

1. Senior managers at leading business entities in the supply chain viewed as a critical driver of shareholder value and competitive differentiation (acknowledging this perspective, research shows a strong relationship between superior supply chain performance and financial success);
2. Leading economic operators supply chain incorporate into their business strategies and attention to the design of integrated operational model;
3. Leading industry players in the supply chain innovations built into their operating models, with particular emphasis on outsourcing, internal / external integration and customization supply and demand and
4. Leading industry players in the supply chain are working towards its strategy and capabilities and are constantly adapting to the changing needs of the market (easily implementable design processes that meet stringent performance standards).

Way of managing supply chain shows the fundamental difference between those who create their own through the chain's competitive advantage and those that do not. If the supply chain begin to deal with when something goes wrong, then your competitive advantage we will create in the management chain, because we have to actively pursue it before and seen it as an opportunity to improve business. So, those who care about the effectiveness and efficiency of intensive thinking about the structure of the supply chain and the organization, they collect more information from the environment, to carefully analyze this information and based on them make better decisions more quickly respond to the constant changes in the market and the environment, accompanied their performance and continuously improve operations regarding the creation of new organizational forms, methods and procedures. Global trends and creating strong trading partnerships accelerate the development process within the supply chain as a competitive local and global distribution channels require that all parties affected by the goods and services in accordance with the requirements of consumers. In order for the buyer or consumer, have added value products and services should be available when they wanted. This means that establishes a continuous process where goods and services are continually flowing through the channel, because if there is a delay in the delivery channel system breaks down, suffering the additional costs (Bloomberg, et al., 2006).

Therefore, we can conclude that the management of physical distribution business fields with the greatest opportunities for potential savings in operating expenses (Drucker, 1962). Furthermore, Coyle, Bardi and Langley (1996) placed in the context of the broader concept of supply chain management and sales and show that they are successful logisticians to identify potential opportunities for savings in logistical costs (efficiency in operations), or those who aspire to better serve the consumer setting (effectiveness in business).

3. Conclusion

Logistics as a marketing instrument to trade increasingly focused on creating value for customers, while marketing concern, develops, cultivates and supplies customers with better products and services. Consumers are better informed and organized and are seeking full value for their money as a new logistics concept and allows. Innovations in logistics allow members of logistic chains big savings and a noticeable increase in the quality of service to customers and consumers. So logistics is an activity that affects more firmly linking trade and consumers. This means that the sale of products depends not only on consumers but also on the mediators (distributor or retail chain), and because each of them has to have an interest - the value added to the segment and in the successful sale of the product to the consumer.

That is why the concept of modern logistics as important in industry and trade, because it is interested in closer interconnection of physical and information flows to optimize the logistics of forming a process that will result in increasing their competitiveness, reduce costs and increase the quality of services that meet the demands of consumers. The basic principle is that the companies are developing the ability to learn about the market, which leads to the learning experience and makes the assumption of competitive advantage in the marketplace. Innovation will continue to be the most important way to create a competitive advantage.

References

Anderson, D.L.; Copacino, W.C.; Lee, H.L.; Starr, E.C. 2003. Creating and Sustaining the High-Performance Business: Research and Insights on the Role of Supply Chain Mastery, Available on Internet: <http:// www.accenture.com>

Bloomberg, D.J.; Lemay, S.; Hahha J.B. 2006. *Logistika*, MATE d.o.o. Zagreb

Borersox, J.D.; Frayer, J.D. 1999. Marketing and Logistics, in Tompkins, A. J. and Harmeling, D. *Distribution Management Handbook*, NewYork: McGraw Hill Inc.

Bowersox, J.D.; Cooper, M.B. 1992. Marketing Channel Managemet, New York: McGraw Hill.

Coyle, J.J.; Bardi, E.J.; Langley Jr. C.J. 1996. *The Management of Business Logistics*, USA: West Publishing Co.

D'Avanzo, R.; Lewinski, H.; Van, W.; Luk, N. 2003. The link between supply chain and financial performance, *Supply Chain Management Review*, November/December

Drucker, P. 1962. The economy´s dark continent, *Fortune*, 4.

Grbac,B. 2007. Načela marketinga, Solutio d.o.o. Rijeka.

Gaitanides, M.; Sholz, R.; Vrohlings, A. 1994. Prozessmanagement – Grundlagen und Zielsätzungen, in Gaitanides, M. Hrsg: *Proessmanagement*, München-Wien: Carl Hanser Verlag.

Kotler, P.; Keller, K.L. 2007. *Upravljanje marketingom*, 12. Izdanje, Mate d.o.o. Zagreb.

Lambert, D.M.; Stock, J.R. Ellram, L.M. 1998. *Fundamentals of Logistics Management*, McGraw Hill, Singapore.

Lambert, M.D.; Sterling, J.U. 1978. *Customer Service* in Tompkins, A.J., Harmelink, D.: *Distribution Management Handbook*, McGraw Hill, New York.

Porter, M.E. 1985. Competitive Advantage Creating and Sustaining Superior Preformance, New York: Free Press. Available from Internet: <http://www.insead.edu>

Robbins, P.S.; DeCenzo, A.D. 2004. *Fundamentals of Management – Essential Concepts and Applications*, Pearson Prentice Hall, New Jersey.

Segetlija, Z. 2006. *Distribucija*, Ekonomski fakultet u Osijeku, Osijek.

Segetlija, Z. 2006. *Trgovinsko poslovanje*, Ekonomski fakultet u Osijeku, Osijek.

Segetlija, Z.; Lamza-Maronić, M. 1996. *Marketing trgovine*, Ekonomski fakultet u Osijeku, Osijek.

Session 7: Transport Policy

SUSTAINABLE DEVELOPMENT OF TRANSPORT MARKET INSTITUTIONS FOR SMALL COUNTRIES

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Abstract: Creation of a unique European transport market requires establishment and strengthening of institutions which govern the market and develop governing mechanisms. This process in Europe takes place independently for each transport mode, with different rates and solutions. In the railway sector, along with railway infrastructure market opening, it is required to establish more institutions. One can distinguish between institutions which directly govern relations between market participants (Regulatory Body, Safety Authority, Licencing Body and Investigation Body) and institutions which grant various approvals for products of railway market (Notify Body and Designated Body). EU legislation defines roles, competence and functions of these institutions, but not their models. Likewise in the railway transport, there are several institutions in the road transport which govern the road transport market. Small countries face the issues of resources, efficiency and possibilities to establish large number of transport market institutions. Is the number of institutions required sustainable for small countries? What models are sustainable under current circumstances and how to develop them? What approach to develop for finding a solution to this problem? These are some of the issues discussed in this paper which gives Serbia as an example of a small country. The main issue raised in the paper is whether the required number of institutions is sustainable under the changes present circumstances with requirements set out in the EU legislation.

Keywords: Transport policy, Institutions, Transport market regulation, Small countries, Serbia

1. Introduction

The key transport policy determinant of the European Union (EU), and thereby of the whole Europe, is the preference for an open and free transport market for all transport modes. The process of creating a free market, however, does is neither simultaneous nor tailored to each transport mode. Inland waterways and air transport in Europe may be regarded as open markets, road transport as well, with smaller or higher limitations depending on whether a country is an EU member state or not, while railway transport is only in the initial stage of market opening (European Union, 2010). In Europe, each of the above markets developed independently from one another. Consequently, requirements for institutions to govern these markets were developed in different ways. What is the status quo for these institutions today? This paper focuses on issues of market institutions in road and railway transport as competitive modes of inland transport.

From the very beginning of common market policy in the EU, it has been clear that a common system of strict market regulations could not be the crux of a single market. On the contrary, the common market principle could only consist of a liberalized market structure that allows for an unrestricted movement of people, goods, services and capital amongst all member countries (OECD, 1997). The 1957 Treaty of Rome that established the European Economic Community stated that a common transport policy had to be achieved by December 1969. Because member states made little progress toward this principle during the 1960s and 1970s, the European Parliament brought legal action against the European Council, and in 1985 the European Court of Justice decided that member states had to enact legislation in order to achieve free transport. This initiated a period of liberalization. The process started in 1985 with the road sector and, except for some minor changes for inland waterways, it has left the railway sector basically unchanged until the early 2000s.

The form and speed of the deregulation process in the road transport was affected by desire to eliminate government discrimination based on nationality of the freight transport provider (Lafontaine and Malaguzzi, 2005). This rendered the process gradual, having been completed, or at least mostly completed, only at the end of the 1990s. Liberalisation process was followed by harmonisation of social, road safety, environmental, fiscal and technical regulations, as well as harmonisation of requirements to access the market and admission to the occupation of road haulage operator. Outside the EU, although most regulations in the said spheres were harmonized, access to international market is limited, i.e. it is authorized under bilateral agreements or under European Conference of Ministers of Transport (ECMT) quota arrangements.

During this same time period, there were few changes in the regulation of other modes of international transport in the EU. Rail freight transport which remained fairly heavily regulated though legislation enacted in the 1990s set the ground rules for a slow liberalization to occur in the rail freight industry starting in March 2003. The first concrete activity aimed at rail freight transport market opening was the enactment of Council Directive 91/440/EEC (1991). Ever since its establishment in the early 19th century, the railway market was organised as a monopoly. There are several requirements for its opening, the following two being the key ones. The first is the incumbant restructuring. The second is establishment and full capacity engagement of institutions governing the market.

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One can distinguish between institutions which directly govern relations between market participants (Regulatory Body, Safety Authority, Licencing Body and Investigation Body) and institutions which grant various permits for products of the railway industry (Notify Body and Designated Body). EU legislation defines roles, competence, limits, procedures and functions of these bodies, but not models of their organization. At this development stage of the EU and the legislation governing this sphere, there is still considerable freedom, or vagueness, with regard to independence of these institutions, their mutual relations, as well as relations to other railway sector and state institutions.

The process of forming the above institutions of the railway market in EU countries, development of their functions and competence is in the initial stage. Many countries have not yet founded all the institutions, while the whole process is characterized by frequent changes and vagaries. Legal actions were brought with the European Court of Justice against even 10 out of 25 EU countries with railways because of delays in the market opening process. This process requires considerable engagement of government resources and funds. Moreover, if one considers the current economic crisis, requirements to reduce budget deficits and to reduce state administration, as generally trending in Europe, then, the issue of forming four new institutions for the railway sector is even more aggravated. The process is highly correlated to the restructuring processes of the railway sector and especially of the incumbants. Some experience is gained in establishing these institutions, as well as the so-called best practice that can be taken as models. However, it is up to each country to find its own models for both processes of restructuring and forming the railway market institutions.

Unlike railway transport legislation, EU road transport legislation does not regulate the issues of forming specific institutions. Instead of explicitly prescribed obligations to designate specific institutions, road transport legislation prescribes only certain obligations of competent bodies in member states. It is either governed to designate a body which shall have specific tasks or there are certain limitations imposed in cases of transfer of powers. Thus, for example, Regulation (EC) No 1071/2009 (2009) defines the need to have a "national, regional or local authority in a Member State which, for the purpose of authorising the pursuit of the occupation of road transport operator, verifies whether an undertaking satisfies the conditions laid down in this Regulation, and which is empowered to grant, suspend or withdraw an authorisation to pursue the occupation of road transport operator", and it also defines the obligation of a member state to ensure establishment of a national electronic register of road transport undertakings and to ensure that all the data contained in the national electronic register is kept up to date and is accurate. Another example is the Directive 1999/62/EC (1999) which governs that a member state shall set the amount of the external-cost charge for the use of certain infrastructures for heavy goods vehicles. If "Member State designates an authority for this purpose, the authority shall be legally and financially independent from the organisation in charge of managing or collecting part or all of the charge". Hereby, it is implicitly required to constitute specific institutional capacities.

The paper provides an overview of required market institution in the railway and road transport according to the EU legislation. The paper draws attention to sustainability of EU model solutions and provides guidelines and criteria for developing models for these institutions in Serbia as an example of a small country.

2. Overview of Railway and Road Transport Market Institutions

This chapter provides an overview of institutions which regulate coming into/out of the market and relations between market participants. For railway transport, this implies description of requirements defined in the EU legislation for Regulatory Body, Safety Authority and Investigation Body, as well as their mutual relations. For road transport, there are no strict rules set out in that respect, therefore, each state has its own institution models. This requires a different approach when defining institution models and consequently when comparing these institutions, as well. The chapter gives an overview of bodies required in the railway transport, while for the road transport; only forms appearing in this sector are mentioned. Such an approach and methods are required due to completely different developments of these two transport modes in Europe which consequently resulted in separate transport setups. Namely, unlike in the railway transport, a single company has never held national monopoly in the road transport. This is exactly the reason why the approach to the railway transport had to include stricter legal forms and solutions in terms of railway market institutions.

Regulatory Body (RB) is an independent state authority which shall regulate the market by preventing discrimination and unfair behavior of certain participants in the railway market and to ensure transparency of the different processes, as well as equal treatment for all participants. RB shall be independent regarding its organization, funding decisions, legal structure and decision making related to the different actors in the market: infrastructure manager and railway undertakings.

Safety Authority (SA) is an independent state authority, respectively a national authority responsible for railway safety and interoperability issues in accordance with the Directive 2004/49/EC (2004). This authority can be integrated into a Ministry in charge of transport and shall be independent regarding its organization, legal structure and decision making related to any railway undertaking, infrastructure manager, applicant or supplier.

Investigation Body (IB) is a permanent body investigating accidents and incidents with the objective to improve the safety system and to prevent accidents by the necessary modifications of regulations. That body needs to have at least one employee capable of exercising the function of investigator in charge in case of an accident or incident. IB shall be independent concerning its organization, legal structure and decision making related to any infrastructure manager, railway undertaking or any party whose interests could be in conflict with the tasks of the investigation body (which means that it shall be established outside of ministry of transport). Besides that, IB shall be independent from safety authority and regulatory body.

Licensing Body (LB) is a body which issues licenses to railway undertakings and infrastructure managers. The only requirement which shall be met by a LB concerns its position and organization: it shall be independent from those who submit application for licenses. LB can also be an ad hoc body whose members meet if necessary, that is, when a license application has been submitted.

The above authorities are in the road transport implemented through various institutions. Most often, one or more sectors of the ministry in charge of transport or its executive agencies constitute the institutional framework, while powers are delegated to either public authority or government agency. There are cases when some tasks are also performed by non-profit organizations or associations, as well cases of entrusting task to companies from the private sector.

3. Road and Railway Transport Market Institutions in Serbia

Nowadays, there are four institutions operating in the road transport sector in Serbia, viz: the Ministry in charge of transport, the Road Traffic Safety Agency, co. Roads of Serbia and co. Corridors of Serbia. Current participants in the railway sector are: the Ministry in charge of transport, Serbian Railways JSC, being the infrastructure manager and railway undertaking in passenger and freight transport, Directorate for Railways, several companies for railway infrastructure and vehicle overhaul and the railway industry. There are 5 more registered railway companies to which access to public railway infrastructure was not yet provided.

Formally, the Ministry in charge of transport has all the auhtorities (the Law on Ministries). Nevertheless, it does not have, nor it ever had (especially for the railway transport), all the functions and resources developed pursuant to the above law. The Ministry essentially deals with investment issues and transport policy. For that purpose, the Ministry deploys legislative tools and inspections.

The Road Traffic Safety Agency is a body of the Government of the Republic of Serbia which was founded to perform developmental, expert and regulatory tasks in the railway safety sphere. Almost a year passed from the date when the Agency was founded in late 2009 until it actually started the operation, yet, not all of its functions have been established. Public enterprises "Roads of Serbia" and "Corridors of Serbia" are in charge of maintenance, protection, use, developing and managing the state roads, and they act as employers in respective highway constructions. The remaining functions, regulatory and licensing, are within the competence of the Ministry in charge of transport. Due to institutional capacities available to the Ministry, the majority is used for the tasks of administrating the quota permits for road transport market access. New draft laws related to passenger and freight road transport anticipate an agency for road transport to be formed to operate the activities of granting licenses to transport operators, and the complete administrative workload related to permits allocated to transport operators. Data of the competent Ministry (2011) shows that in the Republic of Serbia there are 1,000 companies registered for international road transport and 300 companies for international passenger traffic which own around 10,500 vehicles. In this respect, substantial activities of the Ministry in charge of transport were directed towards bilateral negotiations with other countries and towards providing a sufficient number of international transport permits.

Directorate for Railways is a special body of the Government of the Republic of Serbia in charge of licensing, railway safety, market regulation and other specialized activities. However, currently valid law still anticipates neither power to regulate the market nor most other functions related to safety and especially to interoperability, as governed by EU regulations, while Investigation Body is not even formed yet.

Due to the transit nature of the railway network and maintaining its competitiveness, it is imperative that the railway market be open, all railway market institutions (Regulatory Body, Safety Authority, Licencing Body and Investigation Body) be established and set up and their corresponding legal authorities defined. The main problem is to define the form for each of the institutions listed (legal form and position of these bodies, financing methods, independence from other participants) and their internal organizations. Thereat, one should bear in mind that even some combinations are possible when it comes to consolidating the functions of these bodies into a single institution with certain limitations imposed by the EU directives. All the above increases the number of models possible for these bodies, and an issue rises what are the criteria to apply when finding a solution. Moreover, it is required to decide whether a final solution is to be sought in the current development and restructuring phase or a development scenario is to be foreseen until a more permanent solution is reached, as well as what this depends on.

Although competent institutions already exist in the road transport, requirements arising mostly from the process of harmonizing the legislation and from the changed roles of the state administration in modern conditions generate a need to organize the institutions in a different manner. Thus, the above mentioned Road Traffic Safety Agency was formed, and it is also proposed to form others as well, as it is required to have an institutional setting which reacts faster to both global (international) and local (national) changes, as wells as to changes in the transport market. Re-examination of the existing institutions and forming new ones have to be considered as a whole and evaluated according to criteria to be defined in line with the conditions in small countries.

Solutions for such problems considerably depend on the initial (existing) situation in both road and railway sector in one country. The following are the characteristics of road/railway sectors in Serbia with regard to the problem observed: networks with heavy transit traffic, restructuring process either in the early stages (the railway sector) or just recently completed (the road sector) with privatisation of road maintenance companies, major problems and unproductiveness of business performance for all activities in both systems, lack of knowledge and limited human resources to be recruited for specific profiles in the above institutions, etc. Moreover, one has to consider external factors that influence generation and selection of models and scenarios at decision-making moments. This is at the moment influenced by the following factors: strong public pressure against forming new government bodies, especially agencies, massive budget deficit, uncertainty with regard to Government's problem solving in the public sector and notably in the railway sector, uncertain dynamics of Serbia's European integration etc.

4. Sustainability Analysis of Regulatory Framework for Small Countries and Serbia

The paper provides guidelines to build regulatory institutions for road and railway transport in Serbia as based on past assessments of Serbia's transport system (DB International, 2012; Italferr et al., 2010; Booz Allan Hamilton, 2005; EAR, 2006) and forecasts how the current situation and circumstances will further develop. First, it is required to identify international, interior (national) and internal (in the transport sector) changes in Serbia as compared to the time when EU directives defining transport market regulatory bodies were drafted and issued. The changes identified have to be taken into consideration when a defining development strategy for transport market regulatory institutions. The fact that market institution requirements for some transport modes developed independently have to be given special consideration.

Development of transport market institution has to be sustainable in new circumstances. What does sustainable development of regulatory bodies in the transport market imply? Today, there are many variations of the definition of sustainable development, as each country is defining the specific scope of what sustainable development encompasses with regards to its unique geographical, political, social, cultural, and economic conditions. Despite these specific interpretations, however, the concept of sustainable development is globally accepted as harmonized development and equilibrium between the economic, social, and ecological sector within a society.

Projections and further narrowing down of the sustainable development concept to regulatory bodies of the transport market puts a question what concept of their capacity development is sustainable in relation to the situation and possibilities in a country.

The process of projecting requirements for the institutions mentioned lasted for a longer period of time. As a consequence, the unity of required capacities and possibilities of smaller countries was overlooked. The EU legislation does not give models partly for these reasons, this is rather delegated to each country. The problem is that the whole EU concept with regard to transport sector institutions was not developed at once; it was actually upgraded gradually over time. Therefore, both requirements and limitations have to be reconsidered with regard to independence, relations and capacities of institutions. It is particularly required to examine institution models, the development of which has started in some countries.

How to describe and quantify key parameters and changes that took place from the moment when the EU legislation defining regulatory bodies was enacted? The structure of key changes in relation to the problem set may be defined as follows: changes at the international level which appear as global trends, changes within the country under observation and changes in the transport sector of the country under observation (Abbas, 2004). Reference period for recording these changes starts from the point when legislation defining transport market regulatory bodies was enacted. For the railway sector this period encompasses 2001-2004, i.e. from the Directive 2001/14/EC (2001) which refers to regulatory body and licensing body to the Directive 2004/49/EC (2004) which refers to safety authority and investigation body. For the road sector, this is the period from 2009 to 2011, when the Regulation (EC) No 1071/2009 (2009) and the Regulation (EC) No 1072/2009 (2009) were passed until they were fully implemented.

International changes related to the problem observed:

- World economy recession, which started with 2008 financial crisis and continued with new crisis impact in 2012;
- Budget crisis in most EU and non-EU countries;
- Further drop of railway share in the transport market;
- Railway sector restructuring in Europe decelarated in comparison to the projected dynamics;
- Further growth of incumbant debts;
- World wide concerns on environment and sustainability issues
- Globalization of trade involving the international agreement of the WTO, namely the Generale Agreement on Tariff and Trade and the General Agreement on Tariff and Services which affects services including the transport sector.

Changes within Serbia:

- Interminable, severe budget crisis since 2008;
- Contunuous deferal of public sector restructuring and within it, the transport sector in particular;
- Manpower surplus in state bodies which has to be eliminated;
- Odium towards independent regulatory bodies built with the public;
- Reorientation and shift from a centrally planned economy towards market economy with present tendency towards export economy;
- Deregulation of all public companies and privatization of several companies and formations of the Serbian stock market;
- Incentives to domestic and foreign private sectors and their contribution to Serbian economy development.

Changes within the transport sector in Serbia:

- Lack of knowledge and human resources in the sphere of transport market regulation;
- Ill-devised structure and lack of qualified manpower for the future modified role of the ministry in charge of transport;
- Restructuring of the incumbant is constantly being postponed;
- Institutional restructuring of the Ministry resposible for transport and changing roles;
- Increasing involvement of the private sector;
- Safety issues high on the agenda due to the potential accidents that attract public and mass media attention.

As based on the as-is analysis of regulatory bodies, EU legislative requirements and changes that took place upon the adoption thereof, it can be concluded that Serbia is at the beginning of establishing and operating the transport sector regulatory bodies under ultimately unfavourable circumstances. The following are the key limiting or guiding factors: huge budget deficit, manpower surplus in state administration, restructuring of the public transport sector is not completed, poor employee structure in the transport sector along with lack of knowledge.

Under such circumstances, solutions should be sought in models that consolidate regulatory activities within one transport mode as well as several transport modes. At the same time, there are more limitations in financial, legal and functional independence relations between existing institutions.

5. Criteria for Building Inland Transport Market Institutions

The main dilemma which decision-makers face in such problems is whether to instantly seek a final solution for all institutions pursuant to the current EU requirements or to anticipate an appropriate development scenario for them. The main motive behind choosing a development scenario is the wish to have organisational forms and capacities in specific time periods more tailored to the actual circumstances with all the advantages and disadvantages alongside. Bearing in mind the above mentioned, when generating models and development scenarios for specific bodies/institutions, or for all of them in general, it is required to lay down criteria for defining capacities, legal norms and forms of inland transport institutions (road, railway and inland waterway) as a single environment. In other words, if road and railway transport and institutions regulating these markets constitute a single environment, then also, a single model should exist, meaning the whole problem has to be uniformly addressed, on the same principles and criteria. Target function is the solution with least costs to the budget and tax payers and with institutions which are efficient if compared to corresponding market size and development.

The above setup applies to all countries, particularly to small countries with insufficient resources. Bearing all the above in mind, the following criteria were defined to be considered when solving the problem set for Serbia exemplifying a small country and all its circumstances:

Criterion no. 1: Degree of market openness. The highest correlation exists between institution capacities and the degree to which the market is open. Model variants for organisation and capacity of the institutions have to be in correlation with the degree of railway/road market openness.

Criterion no. 2: Dynamics of EU integrations. Model variants have to be in correlation with Serbia's integration process into the EU. EU requirements for forms and especially for independence of the above institutions are known to differ according to the stages of EU accession for candidate countries (viz: candidate country status not granted, candidate country status without negotiations, candidate country status with negotiations) with EU influence growing as the integration process unfolds.

Criterion no. 3: Prospects of model implementation vs. current Serbian legislation. It is required to analyze possibilities to implement each of the models proposed in relation to the current Serbian legislation. Possibilities to implement the model of institution which enjoys a state administration body status should be separately analyzed and evaluated due to higher limitations in founding thereof and decision making.

Criterion no. 4: Criterion of institution independence. EU regulations require certain independence minimum for each of the institutions observed. Financing methods, position of a body in relation to other institutions and the founder thereof can be used to evaluate a model pursuant to this criterion, as well as the competence to adopt (and sign) decisions in model variants with two or more bodies included in a single institution. Therefore, for given solutions, it is required to anticipate who shall sign decisions in line with current regulations in Serbia.

Criterion no. 5: Current state of market institutions and consequent limitations. When developing models of organisation for specific institutions, numerous limitations emerge from the initial (current) situation. Therefore, one has to analyze possibilities and difficulties of shifting from the current institutional form, their capacities and resources, towards the proposed organisation models.

Criterion no. 6: Future European legislative solutions expected in this sphere. Proposed models have to be harmonized and to follow the guidelines and requirements for these institutions which are expected in new EU directives. Each of the model variants proposed has to be assessed by a comparative analysis against the requirements in the proposal, both in relation to position and independence and in relation to its competence.

Criterion no. 7: Model flexibility. It is required to anticipate and evaluate flexibility of each of the models in terms of shifting towards a new organisational form. Regulations in the EU and Serbia for this sphere are frequently amended, and this will continue in the future as well, because these processes are insecure to a considerable degree. This should be borne in mind when generating a model and possibilities to transform each model into a new form pursuant to amended (or expected) EU regulative requirements should be assessed.

Criterion no. 8: Model implementation costs. It is required to make cost estimates for implementation (founding and operation) of institutions for each model. Such estimate can be made by comparing models without calculating absolute cost amounts.

6. Conclusion

Creation of a unique European transport market requires building and strengthening of institutions which regulate the transport market and development of mechanisms to regulate it. In Europe, this process has been and is still unfolding independently for each transport mode, with different institutional requirements and with different dynamics and solutions in that respect. The process of projecting the requirements for the above institutions took place in various periods for each of the transport modes and with longer duration. In addition, the society and conditions when transport market institutions were regulated differ from the present situation. As a consequence, the unity of required capacities and possibilities of small countries was neglected. Therefore, in small European countries and in changed circumstances, it is now required to reconsider the sustainability of the commenced model for building transport market institutions and which is characterized by independent development of institutions per transport modes.

Bearing in mind the changes which took place in the meantime, from the time when the relevant legislation was enacted (international changes as global trends, domestic changes within a country and changes in the transport sector of the country observed), when finding a solution to the problem set, one has to start from defining criteria for an overall solution for transport market system seen as a whole. The paper defines criteria for Serbia as an example of a small country which has, more or less, just started developing its transport market institutions. The current transport sector characteristics were thereat taken into account (market participants, network and market sizes, network operation degree, Serbian economic prospects, European integration dynamics, etc.) and EU directive requirements.

The following seven criteria for developing a single model for Serbian transport market institutions were defined, whereat capacities, legal forms, independence and funding thereof has to be correlated with the following: market openness degree, dynamics of Serbia's integration into the EU, possibilities to implement the model compared against the current Serbian legislation, with (minimal) institutional independence requirements from the EU regulations, with the current state of market institutions and limitations arising therefrom, with the future European legislative solutions expected for this sphere, model-flexibility-to-changes requirement and least possible implementation costs.

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References

Abbas, K. 2004. Assessment of national transport sector in Egypt: A basis for developing a skeleton strategic plan. Paper No 38, In *Proceedings of the 10th WCTR 2004*, Istanbul, Turkey.

Council Directive 91/440/EEC of 29 July 1991 on the development of the Community’s railways. 1991. *Official Journal of the European Union* L 305: 25–28

Hamilton, B.A. 2005. *Institutional study of ZTP Belgrade*. Booz Allan Hamilton. London, March 2004-June 2005, Belgrade, Serbia.

DB International. 2012. *Development of the rail regulator in Serbia* – EBRD Contract No: C22288/GER2-2010-08-05 Reviewed and analyzed of Serbia rail market, catchments area, stakeholders activities and legislation. Development of regulation functions for Rail regulator, EBRD, DB International, Belgrade.

Directive 1999/62/EC of the European Parliament and of the Council of 17 June 1999 on the charging of heavy goods vehicles for the use of certain infrastructures. 1999. *Official Journal of the European Union* L 187: 42–50

Directive 2004/49/EC of the European Parliament and of the Council of 29 April 2004 on safety on the Community's railways and amending Council Directive 95/18/EC on the licensing of railway undertakings and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification (Railway Safety Directive). 2004. *Official Journal of the European Union* L 164: 44–113

Directive 2001/14/EC of the European Parliament and of the Council of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification. 2001. *Official Journal of the European Union* L 75: 29–46

Directive 2004/49/EC of the European Parliament and of the Council of 29 April 2004 on safety on the Community's railways and amending Council Directive 95/18/EC on the licensing of railway undertakings and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification (Railway Safety Directive) 2004. *Official Journal of the European Union* L 164: 44–113
EAR. 2006. *Institutional Capacity Building Project in Transport Sector in Serbia*, EuropeAid/117701/d/sv/yu, Contract N0 04/SER01/07/005, An EU-funded project managed by the European Agency for Reconstruction, Belgrade 2005/2006

European Union. 2010. *Treaty establishing the transport community*. Brussels.

Italferr et al. 2010. *General Master Plan for Transport in Serbia*, Italferr – Italia, Witteveen Bos – Netherlands, NEA – Netherlands, Insitute for Research and Design in Commerce & Industry – Belgrade, Ref. EuropeAid/125976/ D/SER/YU, Belgrade, 2008/09.

Lafontaine, F.; Malaguzzi V.L. 2005. The Deregulation of International Trucking in the European Union: Form and Effect. Sloan 2005 Annual Industry Studies Meeting, 14-16 December 2005, Boston, Available from internet: <http://web.mit.edu/ipc/sloan05/index.html>.

OECD. 1997. Liberalisation and structural reform in the freight transport sector in Europe. Available from internet: <http://www.oecd.org/trade/environmentandtrade/2387068.pdf>.

Regulation (EC) No 1071/2009 of the European Parliament and of the Council of 21 October 2009 establishing common rules concerning the conditions to be complied with to pursue the occupation of road transport operator and repealing Council Directive 96/26/EC. 2009. *Official Journal of the European Union* L 300: 51–71

Regulation (EC) No 1072/2009 of the European Parliament and of the Council of 21 October 2009 on common rules for access to the international road haulage market. 2009. *Official Journal of the European Union* L 300: 72–87

The Republic of Serbia, Ministry of Infrastructure and Energy. 2011. Report 2008-2011. Available from Internet: http://www.mie.gov.rs/?lang=en

CHOICE OF AN OPTIMAL MANAGEMENT STRATEGY OF TRANSPORT DEMAND USING MULTI-CRITERIA ANALYSIS - CITY OF ZAGREB CASE STUDY

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Abstract: After initial enthusiasm by motor vehicles, society is lately increasingly noticing their shortcomings. Traffic problems caused by excessive use of cars, still represent a very serious and widespread problem, particularly in cities. Public opinion expresses dissatisfaction with the quality of the environment and traffic conditions. As the most important demand, the demand for human health stands out in the first place, and, consequently, the demand for sustainable transport development. The fact that the EU is involved in solving traffic problems my means of various directives and scientific research projects, points out the seriousness of the problem. Two solutions which are mainly used for solving traffic problems in cities are the construction or extension of existing transport infrastructure and traffic demand management (TDM). Traffic demand management is a new paradigm, which aims at reducing or transforming of traffic demand through reduction of unnecessary drives by cars and improvement of more efficient, healthier and, above all, cleaner forms of public and non-motorized transport. There is a whole range of methods for traffic demand management, such as Park & Ride system, carpooling, car sharing, priority for the vehicles with specified number of passenger – HOV, teleworking, congestion charging, charging for use of road infrastructure, bicycling infrastructure improvement, etc.

The topic of the work focuses on the choice of optimal traffic demand management strategies in the City of Zagreb using multi-criteria analysis.

Keywords: transport demand management, multi criteria analysis, City of Zagreb

1. Introduction

Since in the city the places of work, residence and other activities are usually situated at different locations, there is an increasing need for mobility of the population. Increased mobility and inadequate traffic capacity (insufficient infrastructure and means of transport) lead to a series of negative consequences which are being felt in large cities. Unfortunately, the city of Zagreb follows the negative trends of contemporary European cities in the development of the transport system (there are more cars in the city center, the traffic jams are greater, as well as noise and pollution), causing lower quality of life in the city centers. Finding new solutions in transport planning and management, traffic problems can be alleviated or completely eliminated. The ultimate goal of traffic planning and management is sustainable mobility and transport development of such transport concepts, which will not have adverse effects on humans in the future.

In the continuation of this paper, the optimal strategy of traffic demand management in the city of Zagreb will be selected using multi-criteria analysis Analytic Hierarchy Process (AHP).

2. Review and characteristics of transport demand management strategies

Transport demand management (TDM) is a concept to promote sustainable transport and manage the demand for car use by changing travelers' attitudes and behaviour. As appropriate name for traffic demand management, the most commonly used in terms in literature are the English terms "Transportation Demand Management" or "Travel Demand Management" (TDM), and names such as "Mobility Management" (MM) and "Congestion Management" (CM) (VTPI, 2010; FFP, 1999). At the core of Transport demand management are "soft" measures like information and communication, organising services and coordinating activities of different partners. "Soft" measures most often enhance the effectiveness of "hard" measures within urban transport (e.g., new tram lines, new roads and new bike lanes). Transport demand management measures (in comparison to "hard" measures) do not necessarily require large financial investments and may have a high benefit-cost ratio (Baasch et al.; Kaiser and Scholl, 2011).

Transport demand management aims at reducing and reshaping transport demand by reducing the unnecessary driving of passengers' cars, as well as at an improvement of efficiency, health and, above all, introduction of cleaner forms of public transportation.

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The Table 1 presents some transport demand management strategies.

Table 1
Transport demand management strategies

Strategy
Alternating directions of travel lanes
Alternate work schedule
Flextime
Compressed work week
Telecommuting
Congestion charging
Road pricing
Walking
Bicycling
Car sharing
Ride sharing (carpooling)
Vanpooling
Transit
Traffic Calming
Ramp metering
Park & Ride
Kiss & Ride
HOV, HOT
Express bus service
Intelligent Transportation System (ITS)
Use of mass public transport
Land use and zoning

Which of the transport demand management strategies is going to be used depends on the community, demographic, geographic, and political conditions. If possible, it is best to use a combination of different strategies. Combined effect of different transport demand management strategies has a greater synergistic effect than the sum of the effects of individual strategies. Individual strategies have a modest effect in terms of travel efficiency improvement.

Today systematic transport demand management represents a socially responsible and environmentally conscious behavior, and it is reflected in:

- the reduction of the number of vehicles on roads
- the reduction of the emissions of harmful gases
- the reduction of the level of environmental pollution
- increasing the fuel efficiency
- the reduction of noise
- prioritizing local public transport compared to individual transport
- the reduction of congestions
- the increase of the traffic flow
- significant savings for road users

3. Choice of an optimal transport demand management strategy using multi-criteria analysis

Analytical Hierarchy Process (AHP) is one of the most popular and in recent years the most commonly used method for multi-criteria decision making (Forman and Selly, 2002; Saaty, 1980). This method is intended for solving decision problems that involve multiple alternatives and a number of criteria. In decision making, multiple decision makers may be involved. Since the AHP method proved relatively successful in solving complex problems, a software package Expert Choice 11 (EC11) (Expert Choice) has been developed for its application. It has given a significant impetus to the development and the application of decision support systems and expert systems for solving problems of multi-attribute decision-making.

It is a robust application designed for desktop computers, which allows priority sorting and alternatives prioritizing, and reliable decision-making about the alternatives for achieving the desired goals. Expert Choice software package can integrate data from Microsoft Excel, Microsoft Project and Oracle databases. It is useful for "what-if" scenario in strategic planning. Hierarchical model of AHP methods for the improvement of traffic mobility management in the cities is shown in Fig. 1.

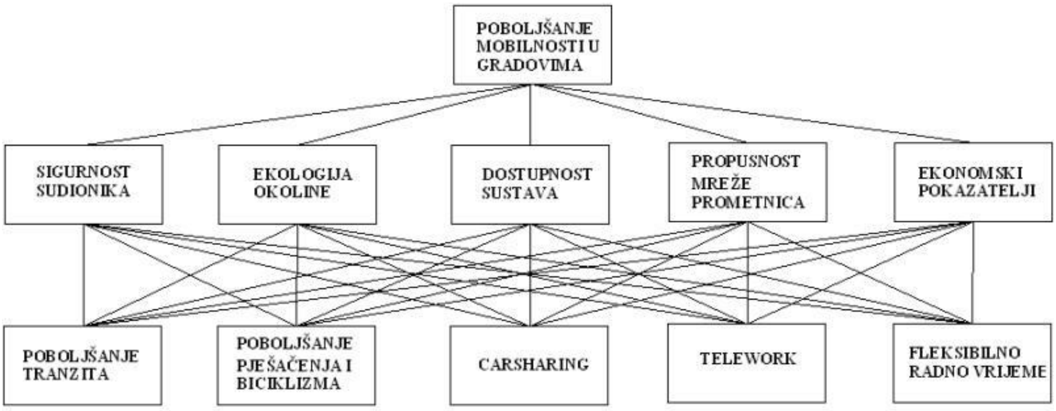

Fig. 1.
Model of the multiple criteria decision making for improved traffic mobility management in the cities

Basically, it is a hierarchical structure, having the goal at the very top, and below it are the criteria and the sub-criteria. On the lower level of the hierarchical structures, there are the alternatives. In the model of the multiple criteria decision-making, which aims to improve mobility in the city of Zagreb, the criteria are: safety of participants, ecology, system availability, road network bandwidth and economic indicators. The following strategies have been offered as the alternatives: transit improvement, walking and bicycling improvement, carsharing, teleworking and flexible working hours.

Structuring the problem and comparing alternatives and criteria in pairs can be done in several ways using Expert Choice software. Fig. 2 shows the basic structural model for the improvement of the mobility in the city of Zagreb in the program Expert Choice window.

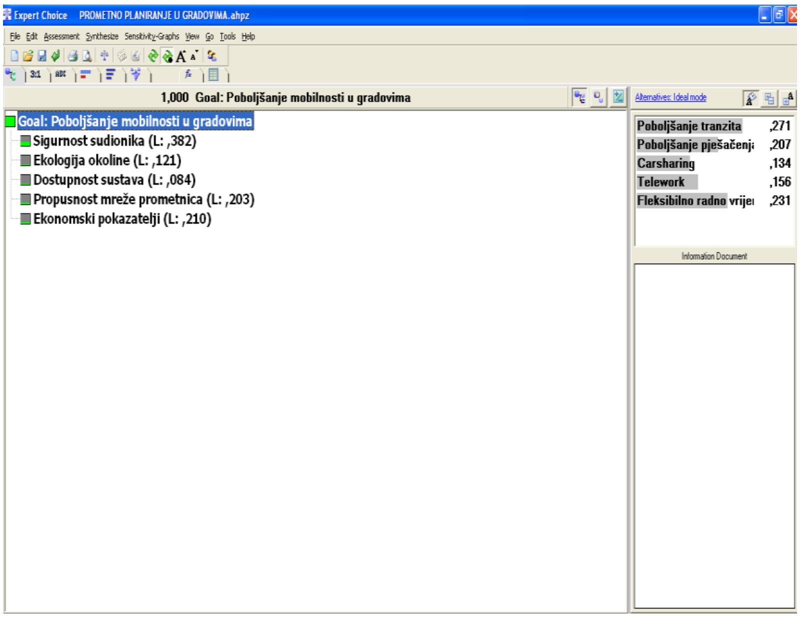

Fig. 2.
The goal, criteria and alternatives in Model View window, Expert Choice program

After defining the alternatives and determining the criteria, it is necessary to determine the importance of the criteria and their impact on the alternatives. At each level of the hierarchical structure, the elements of the structure are compared to one another in pairs, with the decision-makers' preference expressed according to an appropriate scale (Saaty-scale of the relative importance), having 5 degrees and 4 are sub-degrees of verbally described intensity and with corresponding numerical values for them, in the range 1-9.

Based on the assessment of the relative importance of the elements of the appropriate level of the hierarchical problem structure using the appropriate mathematical models, the local priority (weight) criteria, sub-criteria and alternatives are calculated and after that synthesized into the overall priorities of the alternatives.

Fig. 3 shows the comparison of the relative importance of alternative "Transit Improvement" compared to the alternative "Walking and Cycling Improvement" with respect to the criterion of "Participants Safety". Comparing the remaining pairs of alternatives has been conducted in the same way.

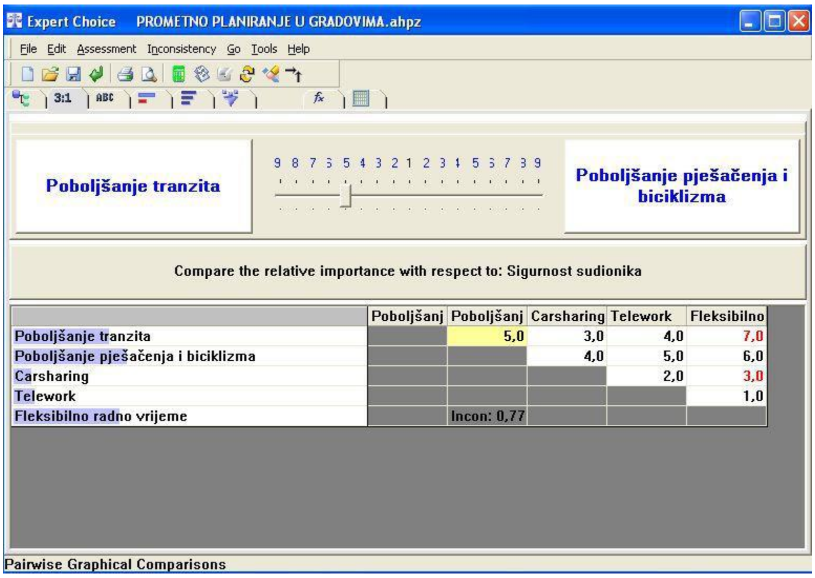

Fig. 3.
Procedure of pairwise comparison of the alternatives (PAIRWISE)

After determining the criteria, defining the alternatives, and setting up all the necessary weight, the sensitivity analysis is performed in order to determine the final optimal alternative. Results of the analysis are illustrated by the graphs: Dynamic, Performance, Gradient and Head-to-head.

Fig. 4 presents dynamic graphic display (*Dynamic)* of alternatives priority order depending on alternative weight of each criterion.

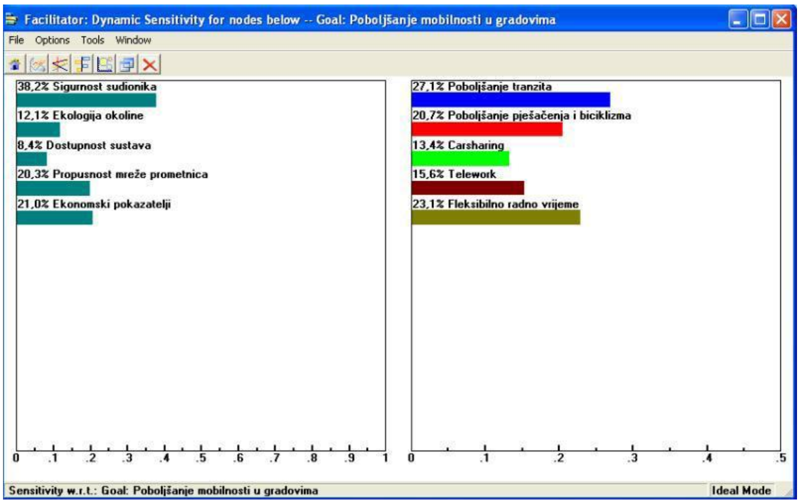

Fig. 4.
Graphical display of the importance of the criteria (left) for alternatives priority (right)

Fig. 5 *Performance sensitivity* displays the impact of certain criteria weight to the individual or the current overall alternatives order. Individual alternatives ranking is a change of priorities of an alternative under the influence of a criterion weight, and overall alternatives order represents an order of the alternatives affected by the weights of all the criteria.

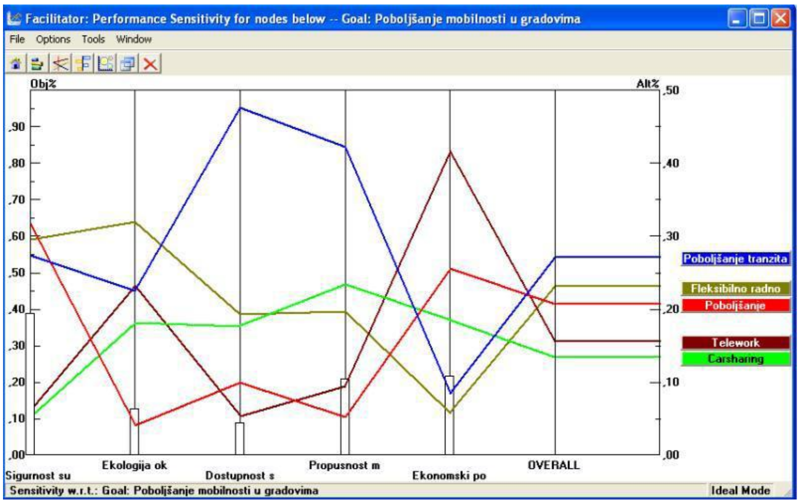

Fig. 5.
Performance – graphical display of the criteria impact on the alternatives and their overall priority

Weight of each criterion is shown on the left y-axis, the effect of all the criteria and alternatives ranking are shown on the right y-axis of the graph, and the x-axis shows the criteria. From the graph in Fig. 5 it is evident that the best solution to improve mobility in the city is an alternative *"Transit Improvement"*. The greatest impact on the choice of this alternative had the following criteria: system availability, capacity and safety of the participants, while the ecology criteria and the economic indicators had the smallest impact on its choice. The lowest ranked alternative for transport demand management is "Carsharing". The greatest impact on the selection of this alternative have the criteria permeability and ecology, and traffic safety has the lowest impact.

Changes in (gradient) weight of each criterion influence the priority order of each alternative as a strategy for traffic management. The intensity of their impact is different for different alternatives. The graph *Gradient* Sensitivity in Fig. 6 shows the impact on the choice of a particular alternative of the criteria *"Roads network bandwidth*," with the weight of 20%. Having compared the "*Teleworking*" and "*Carsharing*" alternatives on the graph, it can be seen that the "*Teleworking*" alternative has an advantage over the alternatives "*Carsharing*." Providing a greater weight to the "*Roads network bandwidth*" criterion changes the ratio in favor of "*Carsharing*." Weight change of the criteria "*Roads network bandwidth*", more or less, has a very little effect on the change of the priorities of some other alternative, such as "*Flexible working hours*."

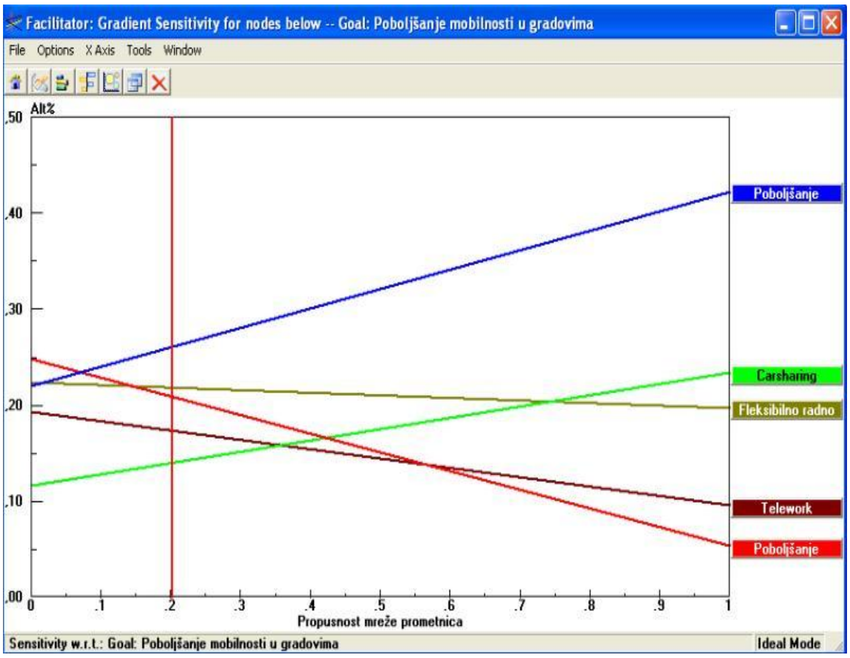

Fig. 6.
Preview of the sensitivity of the alternatives to a weight change of the "Roads network bandwidth" criterion

If we want to manage the transport demand in the city by increasing the network bandwidth capacity, it is necessary to improve transit in the first place, then introduce carsharing, followed by flexible working hours, teleworking, and ultimately improve the conditions for walking and cycling.

In Fig. 7 (Head to Head) rectangular surfaces show the relationship of the alternatives against the given criteria. If one alternative predominates, the rectangular surface will illustrate how better this alternative is.Have one alternative *"Carsharing"* and another alternative *"Walking and Cycling Improvement"*. The right side of the image shows that, according to the *"Safety of the Participants"* criterion, the *"Walking Improvement"* alternative is better than the alternative *"Carsharing"*, which is indicated by the rectangular area on the right. The ecology criterion, system availability and roads network bandwidth tend to follow the *"Carsharing"* alternative which is illustrated by rectangles on the side of the alternatives.

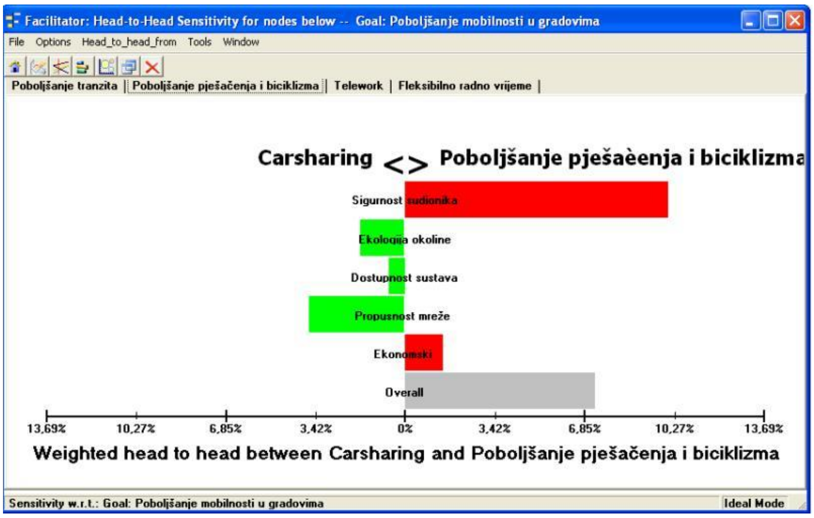

Fig. 7.
Parallel (head to head) graphical display of the two alternatives

The overall decision on the *"Carsharing"* and *"Walking Improvement"* alternatives tends to follow the *"Walking Improvement"* alternatives, which can be seen from the last rectangle “Overall” in Fig. 7.

AHP method is one of the popular methods also because of its ability to identify and analyze the inconsistencies of the decision-maker in the process of comparing the elements of the hierarchy (AHP; Saaty, 1980).

4. Discussion

Out of total of five criteria, which have been selected for this model, the utmost importance/weight was given to the criterion of the safety of the participants (38.2%), followed by the economic indicators (21%), road network bandwidth (20.3%), ecology (12.1%) and system availability (8.4%), as it is evident from Fig. 4. The greater the importance of the criterion, the greater impact it has on the final selection of an alternative. Evaluation of the importance of individual criteria was conducted by means of a survey among experts in the field of transport. According to Fig. 5, with regard to the "Safety of participants" criterion in the city of Zagreb, it would be ideal to encourage walking and biking in the first place, and in the last place car sharing is suggested as the worst choice. Taking into account the economic indicators, it would be best to introduce teleworking, then improve walking and biking, after that carsharing, then improve transit, and as the last alternative, to introduce flexible working hours. After the economic indicators, the road network bandwidth criterion follows. The best network bandwidth can be achieved by the improvement of transit, then by the introduction of car sharing, and flexible working hours, by teleworking and ultimately by walking and cycling improvement. Given the criteria ecology of the environment, it would be optimal to introduce flexible working hours, then teleworking, and then to improve transit and introduce carsharing. The smallest weight was given to the criterion of system availability. For an optimal implementation of this criterion, it would be best to improve transit, and in the last place to introduce teleworking. Namely, it has been shown that arriving to the destination safer, cheaper and faster is more important for the users (passengers) than the system accessibility.

Evaluating the transport demand management alternatives in the city of Zagreb, on the basis of the set criteria, it is possible to rank them in order to select the optimal strategy for traffic management in the city of Zagreb. In accordance with the established model, the priority in the city of Zagreb has the transit improvement alternative (27.1%), followed by flexible working hours (23.1%), walking and cycling (20.7%), teleworking (15.6%) and carsharing (13.4%) (Fig. 5).

For the full implementation of these strategies, it is necessary to provide a range of conditions, such as to construct the Park & Ride system close to the public transport station, modernize means of public transport (increase speed, comfort, frequency, reliability, security), improve passengers' awareness, give priority to public transport, introduce the use of "smart" cards, etc. Unfortunately, most of the strategies that contribute to sustainable urban mobility have not been applied in an appropriate manner in the city of Zagreb.

3. Conclusion

The destination of numerous car trips is the city center, which is spatially and in the sense of traffic mostly already built and defined. Large increase in the number of motor vehicles inevitably leads to the serious difficulties in the conduct of transport system throughout the city, especially in the historic center, having the streets which were originally built for pedestrians and carriages and which cannot withstand such pressure. The solution for traffic problems has lately been sought in transport demand management (TDM).

Individually, the intermodal transport or transit proved to be the best solution for transport demand management in the city of Zagreb. Since individual strategies have modest effects in terms of improving the efficiency of travel, it is best to use a combination of several different strategies. Simultaneous use of multiple different transport demand management strategies has a cumulative and synergistic effect (their overall effect is greater than the sum of their individual effects), so it is important to assess mobility programs as a package, rather than as individual strategies.

References

Baasch, S.; Bossaert, E.; Ljungberg, C.; Papadimitriou, S.; Papaioannou, P.; Posch, K.H.; Rye, T.; Welsch, J. Mobility Management: A Definition. Available from Internet: <http://www.epomm.eu/docs/mmtools/MMDefinition/MMDefinition_english.doc>

Belton, V.; Stewart, T. J. 2002. *Multi Criteria Decision Analysis – An Integrated Approach*, Kluwer: 151-159.

European projects in the Fourth Framework Programme, (4th RTD FP), 1999, MOSAIC (Mobility Strategy Applications In the Community) and MOMENTUM (Mobility Management for the Urban Environment), Rijswijk / Aachen. Available from internet: <http://www.gtkp.com/assets/uploads/20091117-102648-3156-Usermanual.pdf>

Expert Chioce software. Available from Internet: <http://www.expertchoice.com>

Experts Choice Inc. 1982-2004. Experts Choice, Arlington, VA, USA

Forman, E.H,; Selly, M.A. 2002. Decision By Objectives, How to Convince Others that You are right, World Scientific, New Yersey, London Singapore, Hong Kong, Available from internet: <http://mdm.gwu.edu/Forman/DBO.pdf>

Kaiser, A.; Scholl, G. 2011. Mobility Management, Institute for Ecological Economy Research (IÖW), Berlin. Available from Internet: <http://www.scp-knowledge.eu/sites/default/files/CORPUS%20WP%203%20KU%20Mobility%20Management%20Final%20version.pdf>

Matematički temelj AHP metode. Available from internet: <http://www.foi.hr/CMS_library/studiji/dodiplomski/IS/kolegiji/mzvo/MatematickiTemelj_AHPMetoda.pdf>

Saaty, T.L. 1980. *The Analytic Hierarchy Process*, McGraw Hill International. New York, USA

Šimunović, Lj.; Grgurević, I.; Pašagić Škrinjar, J. 2010. Selecting optimal pedestrian crossing using multi-criteria decision-making, *Promet - Traffic & Transportation* 22(2):105-116

US Department of Transportaion. 1993. *A Guidance Manual for Implementing Effective Employer-based Travel Demand Management Programs*, Washington, USA

US Department of Transportaion. 1993. *A Guidance Manual for Implementing Effective Employer-based Travel Demand Management Programs*. Federal Highway Administration. Washington, D.C.

Victoria Transport Policy Institute. 2010. Online TDM Encyclopedia, Victoria, Canada. Available from Internet: < http://www.vtpi.org> [Accessed 15 August 2012]

Višekriterijsko odlučivanje: AHP metoda. Available from Internet: <http://www.foi.hr/CMS_library/studiji/dodiplomski/IS/kolegiji/mzvo/ahp.pdf>

ASSESSMENT FOR POSSIBLE FUTURE ECA ADOPTION IN THE MEDITERRANEAN AREA (SHORT SEA SHIPPING VS. ROAD TRANSPORT)

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Abstract: In accordance to the Appendix III of MARPOL´s Annex VI, six criteria are proposed for emission control area (ECA) definition: a clear delineation of the proposed ECA; land and sea areas at risk; emission quantification and impact assessment; prevailing weather conditions; data on marine traffic; and land based measures concurrent with the ECA adoption. This paper carries out an scenario analysis 2012 onwards and until 2020, comparing both intra-European road transport and multimodal transport chains in the Mediterranean area. Thus assessing maritime transport's emissions and impacts in comparison with land based road transport. Therefore from the aforementioned six criteria this paper considers two: emission quantification and impact assessment; and land based measures concurrent with the ECA adoption.

Keywords: Short Sea Shipping transport, road transport, emission control areas, Mediterranean Sea, air pollution.

1. Introduction

There is a growing voice calling for an ECA in the Mediterranean claiming significant damages to the environment, crops and health produced by emissions from shipping both in Mediterranean Sea board countries as well as further in shore. The last ship emissions inventory for the Mediterranean developed by Entec UK limited in 2007 appointed that intra-European movements, i.e. Short Sea Shipping (SSS), contributed in 2005 significantly to emissions in the Mediterranean Sea, as 38% of the fuel consumed corresponded to intra-European movements (16% domestic and 22% between EU countries).

Building on the statistics of "*Maritime transport statistics – short sea shipping of goods*" published by the Eurostat, short sea shipping traffic volumes in the Mediterranean are already recovering from the downturn suffered due to the current economic crisis. Containerized and RoRo cargo which in 2010 represented 29,4% of the total short sea shipping volumes in the Mediterranean are emerging strong, registering highest traffics shares ever.

Table 1
Short sea shipping cargo volumes in the Mediterranean, 2005 – 2010

CARGO (Thousand tonnes)	2005		2006		2007		2008		2009		2010	
Liquid bulk goods	291.826	52,3%	287.750	51,0%	294.392	50,3%	293.462	49,8%	280.776	49,8%	276.919	48,6%
Dry bulk goods	90.518	16,2%	93.533	16,6%	92.124	15,8%	91.847	15,6%	101.578	18,0%	89.621	15,7%
Large containers	87.698	15,7%	91.626	16,2%	97.778	16,7%	102.646	17,4%	101.569	18,0%	104.444	18,3%
Ro-Ro (self-propelled units)	28.267	5,1%	30.024	5,3%	31.090	5,3%	35.124	6,0%	26.815	4,8%	40.331	7,1%
Ro-Ro (non-self-propelled units)	25.402	4,5%	25.764	4,6%	31.851	5,4%	23.102	3,9%	22.019	3,9%	22.529	4,0%
Other	34.807	6,2%	35.929	6,4%	37.659	6,4%	43.170	7,3%	30.945	5,5%	36.118	6,3%
TOTAL	558.518		564.626		584.894		589.351		563.702		569.962	

Source: Own, based in Eurostat

This papers objective is to assess the need to implement an ECA in the Mediterranean ensuring the competitiveness of SSS in comparison with road transport in terms of emissions and impacts of air pollutants (NOx, VOCs, $PM_{2,5}$, SO_2) and GHGs (CO_2). This means that only maritime alternatives competing with road transport are considered, which indeed are container and RoRo services. Results only reflect direct emissions, those arising during the actual transport. Indirect emissions occurring upstream and downstream the transport chain are not considered. Moreover both local and rural impacts caused by emissions to air are assessed.

Local impact estimation, needs of great emission site detail; therefore, a bottom-up approach has been chosen for the emissions' geographical characterization (Miola et al. 2010). On the other hand the rural impact is country specific, and therefore its quantification does not require that much and precise information.

Following the introduction section (section 1), this paper continues with the methodology (section 2) where the assumptions and calculations underlying the results are described. Following section 2, section 3 presents the baseline and future scenarios in which calculations are carried out.

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Once the methodology and scenarios are known, a case study is presented (section 4). Afterwards results are discussed (section 5) in order to finally present some conclusions (section 6).

2. Methodology

In a first instance the transport chains to be simulated need to be characterized, identifying parameters inherent to the route and fleets engaged. Second, both maritime and road transport policy contexts are studied and scenarios projected 2012 onwards and until 2020; in order to estimate emission factors according to the regulatory framework and fleets engaged. Finally once the emission inventory for the considered trade link has been carried out, the impact caused by the emissions is valuated according to the sensitiveness of the emission site.

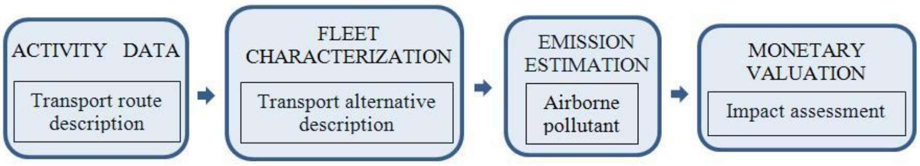


Fig. 1.
Calculation model breakdown
Source: Own

2.2. Main assumptions and methods

Tables 2 and 3 both the characterization and calculation procedures used for the environmental performance assessment of the considered transport chains. These tables gather emission and cost drivers together with main assumptions and methods used.

Table 2
Main assumptions and methods for the road transport model

ROAD TRANSPORT MODEL
Activity data: • Covered distance • Crossed countries • Affected inhabitants in the urban stage • Load factor • Route profile (flat, medium, highland) • Average speed
Fleet characterization: • Truck configuration: The articulated truck, i.e. a road tractor coupled to a semi-trailer, is considered representative of the truck fleet engaged in SSS services. A configuration responsible of the 73,9% of the total intra-European road freight transport in 2009 (Hill N. et al., 2011). • A review of allowed gross vehicle weights in articulated trucks within the EU27 is consulted (EU, 2011), identifying articulated trucks with maximum gross weights between 40 to 50 tonnes as the most representative category among the ones considered by the Tier 3 methodology. • Engine type: The fleet is considered to be evenly distributed along its eleven years of life cycle (Hill N. et al., 2011), what it means that for projecting purposes an annual replacement rate of 11,1% is assumed. Then depending on the scenario selected, 2012-2020, and taking into account the emission standards (Euro I-VI) enforcement dates, engine technologies present in the fleet are extrapolated.
Emission estimation: • Tier 3 methodology from the EMEP/EEA air pollutant emission inventory guidebook 2009. Technical report; No 9; 2009; Part B; chapter 1.A.3.b.
Impact valuation: • Local impact: Benefits Table Database: Estimates of the Marginal External Costs of Air Pollution in Europe (BETA), 2002. • Rural impact: Clean Air For Europe project (CAFE), 2005. • HICP regression model for external costs price update and projection, period 1990 – 2012.

Source: Own

Table 3
*Main assumptions and methods for the maritime transport model**

SSS TRANSPORT MODEL
Activity data: • Ship type • Sailing scenario (year + emission standard in force) • Covered distance • Sailing area (Mediterranean Sea, North East Atlantic, English Channel, North Sea or Baltic Sea) • Load factor (ship´s and average intermodal transport units (ITU) load factors) • Origin and destination ports details (country and inhabitants in port cities) for sensitivity assessment.
Fleet characterization: • Emission factors are engine type and power dependent, therefore these have to be identified for the considered ship types engaged in SSS services. In the marine industry diesel engines are the predominant form of power for both main and auxiliary engines, ME and AE from now on (Trozzi C. et al., 2010). Diesel engines, depending on their rated speed, are categorised into slow (up to 300 rpm), medium (300-900 rpm) and high (more than 900 rpm) speed diesel engines: SSD, MSD and HSD respectively. Moreover, emissions to air are also related to the fuel consumption or engine power; therefore besides the engine type, the average power for the different representative SSS ship types needs to be identified. • Emissions also depend on ship service speed and engine load factors in each of the sailing phases (at sea, manoeuvring and at berth). The ship service speed, determining the time spent at sea and hence total emissions, is the average value obtained from the SSS fleet survey. Engine load factors are directly obtained from the study carried out by Entec for the European Commission regarding emissions from ships associated with ship movements between ports in the European Community (Whall C. et al., 2002). • At sea, manoeuvring and at berth times are either estimated using the average service speed or taken from previous studies such as Whall C. et al. 2002, Whall C. et al. 2010 and Usabiaga et al. 2011. These data are necessary as emissions will be proportional to them. • The capacity tab together with the covered distance will enable the model to produce results (emissions or impacts) in transport work units (per tonne kilometre). Results in transport work units will enable the comparison between various transport alternatives. Capacities are given in units (TEUs or line meters) inherent to the ship type being considered.
Emission estimation: • Tier 3 methodology from the EMEP/EEA air pollutant emission inventory guidebook 2009. Technical report; No 9; 2009; Part B; chapter 1.A.3.d.
Impact valuation: • Local impact: Benefits Table Database: Estimates of the Marginal External Costs of Air Pollution in Europe (BETA); 2002. • Rural impact: Clean Air For Europe project (CAFE); 2005. • HICP regression model for external costs price update and projection, period 1990 – 2012.

**Assumptions and methods for the road transport leg in the multimodal transport chain are those presented in table 2.*
Source: Own

3. Scenarios

3.1. Emission standards

In the last two decades road transport has improved significantly its environmental performance regarding emissions to air (CO, NOx, HC and PM), Table 4. A set of emission standards known as the Euro standards have been progressively introduced since 1993. The next and more stringent standard, so called Euro VI, will be implemented by the end of 2013 reducing even more road transport's emissions to air. Moreover road transport has also improved in sulphur emissions to air by limiting the sulphur content on diesel fuels (Directive 2009/30/EC and Directive 98/70/EC). Currently and since 2009 the limit is in 10 ppm which is considered to be effectively "zero" content. With regards to CO2 emissions road has not achieved significant improvements as this GHG emission is proportional to the fuel consumption and the carbon content in the fuel and neither of these have been significantly reduced.

Table 4
Heavy duty vehicle emissions standards development

Euro Standards	Emissions to air			
	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Euro I (October 1993)	4,9	1,23	9	0,4
Euro II (October 1996)	4	1,1	7	0,15
Euro III (October 2001)	5,45	0,78	5	0,16
Euro IV (October 2006)	4	0,55	3,5	0,02
Euro V (October 2009)	4	0,55	2	0,02
Euro VI (December 2013)	4	0,16	0,4	0,01

*Euro I and II emissions standards are not directly comparable with those for Euro III or the later because of changes to the duty cycle used for each of these standards.
Source*: Own, based in directives 88/77/EC, 1999/96/EC, 2005/55/EC, 2005/78/EC and 2007/46/EC*

Unlike road transport, maritime transport has not been regulated with regards to emissions to the air until recently. Was the MARPOL 1973/1978 convention which through its Protocol of 1997 including the Annex VI introduced for the first time standards to prevent the air pollution from ships in May 2005. In this first version of the Annex VI a global sulphur cap limiting the sulphur content in the fuel to 4,5% was introduced. NOx emissions resulted also limited through the adoption of the NOx Technical Code (Tier I and Tier II standards), figure 10, and a more stringent SOx emission control area (ECA) was established in the Baltic Sea where the sulphur content in the fuel was limited to 1,5%. In July 2005 the MARPOL Annex VI resulted amended and new North Sea and English Channel SOx ECAs were introduced, although these were not fully enforced until November 2007. The last review of the MARPOL Annex VI took place in 2008 when a progressive reduction of SOx emissions from ships was planned and introduced to the annex: reducing the global sulphur cap to 3,5% by January 2012 and to 0,5% by 2020 subject to a previous feasibility review; and reducing the sulphur content in fuels used in SOx ECAs to 1% by July 2010 and to 0,1% by January 2015. Moreover same amendments also introduced new NOx emission limits for the so called Tier III engines, applicable to ships constructed after January 2016 and operating in NOx ECAs. Finally the revised Annex will also allow to designate ECAs for SOx, PM and NOx.

The regulatory framework established by the MARPOL Annex VI was transposed into EU law by Directive 2005/33/EC in July 2005. This directive known as the " Low Sulphur Fuel Directive" does not only transpose what Annex VI establishes, but complements it introducing more stringent limits for passenger ships (1,5% sulphur content limit in the fuel) and ships at port (0,1% sulphur content limit in the fuel).

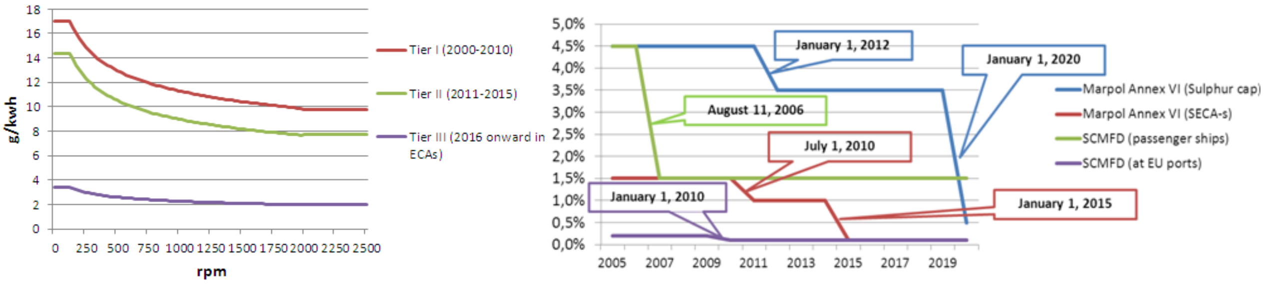


Fig. 2.
NOx Technical code and sulphur caps
Source: Own

3.1. Modelling current and future scenarios

According to current and future regulatory frameworks for road and maritime transport, the scenarios in table 5 and 6 were created for environmental performance assessment. These scenarios extend from 2012 (baseline year) until 2020 and include also specific scenarios representing ship types (passenger ships) and areas (SOx or/and NOx ECAs) in which due to their higher sensitiveness more stringent regulations are applied.

Table 5
Marine scenarios

Scenario	Year	Regulatory framework	Sulphur content in the fuel	NOx emission standard
2012 baseline	2012	MARPOL (Annex VI - Global sulphur cap)	3,50%	Tier 0 (52%)/Tier I (44%)/Tier II (4%)
2012 ROPAX	2012	Directive in Sulphur Content of Marine Fuels (DSCMF) - passenger ships	1,50%	Tier 0 (52%)/Tier I (44%)/Tier II (4%)
2012 SECA	2012	SOx ECA	1%	Tier 0 (52%)/Tier I (44%)/Tier II (4%)
2015 baseline	2015	MARPOL (Annex VI - Global sulphur cap)	3,50%	Tier 0 (40%)/Tier I (44%)/Tier II (16%)
2015 ROPAX	2015	DSCMF - passenger ships	1,50%	Tier 0 (40%)/Tier I (44%)/Tier II (16%)
2015 SECA	2015	SOx ECA	0,10%	Tier 0 (40%)/Tier I (44%)/Tier II (16%)
2016 baseline	2016	MARPOL (Annex VI - Global sulphur cap)	3,50%	Tier 0 (36%)/Tier I (44%)/Tier II (20%)
2016 ROPAX	2016	DSCMF - passenger ships	1,50%	Tier 0 (36%)/Tier I (44%)/Tier II (20%)
2016 SECA	2016	SOx ECA	0,10%	Tier 0 (36%)/Tier I (44%)/Tier II (20%)
2016 NECA	2016	NOx ECA	3,50%	Tier 0/I/II (0%)/Tier III (100%)
2016 SECA/NECA	2016	SOx and NOx ECA	0,10%	Tier 0/I/II (0%)/Tier III (100%)
2016 ROPAX/NECA	2016	DSCMF - passenger ships and NOx ECA	1,50%	Tier 0/I/II (0%)/Tier III (100%)
2020 baseline	2020	MARPOL (Annex VI - Global sulphur cap)	0,50%	Tier 0 (20%)/Tier I (44%)/Tier II (36%)
2020 SECA	2020	SOx ECA	0,10%	Tier 0 (20%)/Tier I (44%)/Tier II (36%)
2020 NECA	2020	NOx ECA	0,50%	Tier 0/I/II (0%)/Tier III (100%)
2020 SECA/NECA	2020	SOx and NOx ECA	0,10%	Tier 0/I/II (0%)/Tier III (100%)

Source: Own

Table 6
Road scenarios

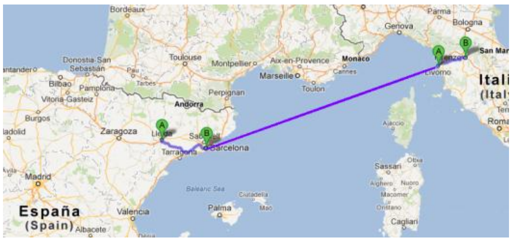
Scenario	Engine technology in the fleet
2012	Euro II (6,8%) Euro III (45,5%) Euro IV (27,3%) Euro V (20,5%)
2015	Euro III (25%) Euro IV (27,3%) Euro V (29,5%) Euro VI (18,2%)
2016	Euro III (15,9%) Euro IV (27,3%) Euro V (29,5%) Euro VI (27,3%)
2020	Euro IV (6,8%) Euro V (29,5%) Euro VI (63,6%)

Source: Own.

4. Case study

In this section the transport link between Lleida and Firenze is presented for analysis. Two transport alternatives are considered: an unimodal transport chain using only road transport and a multimodal transport chain combining road and maritime transport. The table below summarises the parameters inherent to each transport chain.

Table 7
Route parameters

UNIMODAL (road only)		MULTIMODAL (road +SSS)	
			
LOADED LEG			
ROAD		ROAD	
Origin:	Lleida	**Origin:**	Lleida
Destination:	Firenze	**Destination:**	Firenze
Loaded distance:	1239 km	**Loaded distance:**	267 km
Spain	315 km	**Pre Haulage:**	173 km
France	531 km	**Spain:**	173 km
Italy	393 km	**Post Haulage:**	94 km
TOTAL DISTANCE:	1239 km	**Italy:**	94 km
		SSS	
		Sea distance:	380 nm
		Port of origin:	Barcelona
		Port of destination:	Livorno
		TOTAL DISTANCE:	971 km

Source: Own.

Moreover only considering ship types competing for cargo with road transport, the ship types listed in the table below are used for calculation purposes. These ship particulars correspond to real ships considered representative of each type and range of sizes. This data derives from a comprehensive review of the Lineport Database (years 2010 and 2011), made available by the Valenciaport Foundation, and a complementary research task carried out consulting the Seaweb ships database.

Table 8
SSS fleet characteristics

	Container ships (LOA<155)	Container ships (LOA≥155)	Car Carrier (LOA<155)	Car Carrier (LOA≥155)
Length Over All	129,6	216,9	126,9	176,7
Breadth	20,9	32,2	18,8	31,1
Draft	7,4	12,25	6,2	8,8
GT	7545	30166	11591	38651
DWT	8168	35082	4442	12292
ME type	MSD	SSD	MSD	SSD
ME power	7000	31920	9840	11060
AE type	MSD/HSD	MSD/HSD	MSD/HSD	MSD/HSD
AE power	1540	7022	2952	3318
Average service speed	15,9	22,4	20	20,5
Capacity (TEU-s)	698	2833	na	na
Capacity (line meters)	na	na	448	3600
Capacity (trailers or CEU-s)	na	na	107	867
Capacity per TEU (tm)	21,5	21,5	na	na
Capacity per trailer(tm)	na	na	na	na
Total capacity (tm)*	8168	35082	107	867

*The unit for total capacity is CEU for car carriers

	Ro-Ro MSD	Ro-Ro SSD	Ro-Pax ships	Con-Ro
Length Over All	141,3	200,9	199	165,8
Breadth	21	26,5	26,6	23,4
Draft	6	7,5	6,4	7,3
GT	15222	32647	25518	15586
DWT	4695	10773	7500	11407
ME type	MSD	SSD	MSD	MSD
ME power	12960	20070	25200	15000
AE type	MSD/HSD	MSD/HSD	MSD/HSD	MSD/HSD
AE power	3888	6021	8820	4500
Average service speed	18,5	22,3	24	20
Capacity (TEU-s)	na	na	na	484
Capacity (line meters)	1500	3810	2600	2155
Capacity (trailers or CEU-s)	100	254	173	143
Capacity per TEU (tm)	na	na	na	21,5
Capacity per trailer(tm)	26,0	26,0	26,0	26,0
Total capacity (tm)	2600	6604	4498	11407

Source: Own.

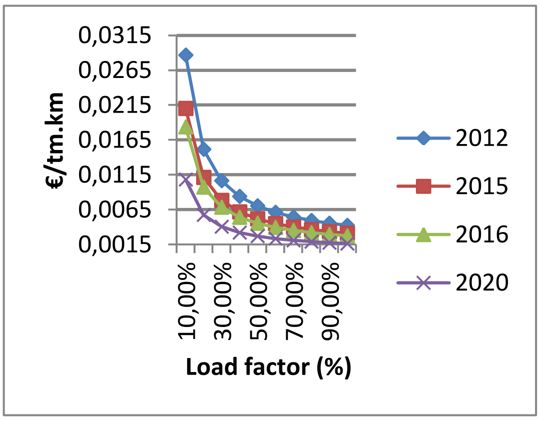
5. Results discussion

The results given in this section correspond to the trade link between Lleida (Spain) and Firenze (Italy). Table 9 presents the results for the road only transport alternative, linking the environmental performance of the transport alternative and the ITUs load factor. Main assumptions with regards to the type of ITU, empty distance, etc. are also listed. For comparison purposes results given in figure 3 correspond to a 60% load factor of the ITU, the rest of the assumptions are coincident for both transport alternatives.

Table 9
Road transport performance

UNIMODAL OPTION (road only)	
ITU	Semi-trailer
Empty trip distance (km)	100
Urban segment	10%
Rural segment	15%
Highway segment	75%
Urban (km/h)	40
Rural (km/h)	65
Highway (km/h)	80

Source: Own.



Looking into figure 3 the environmental performance of multimodal transport chains, combining road and maritime means of transportation, may also be called into question. For instance the environmental performance of transport chains using RoPax and RoRo ships expressed in €/tm.km is far more damaging than that of road transport. However those transport chains combining road transport with ConRo and container ships, perform better than road transport solely.

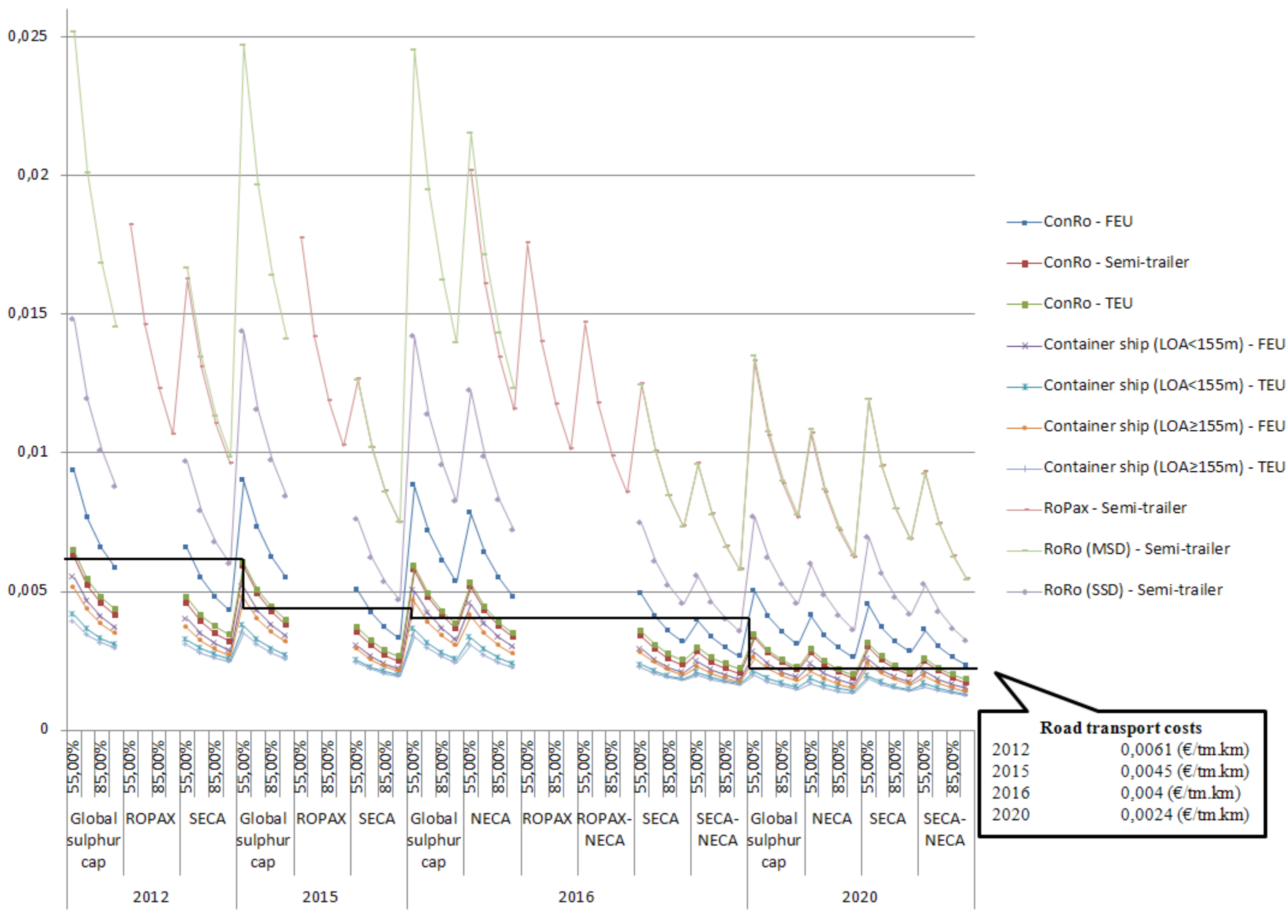


Fig. 3.
Multimodal and unimodal transport chains environmental performances comparison
Source: Own

6. Conclusions

Obtained results demonstrate that especially in certain types of maritime transport, improvement is needed to compete in environmental terms when talking about air pollutants and GHGs emissions and their impacts. However results are given in €/tm.km and thus do not represent the geographical characteristics of each trade link, where often the detouring between road only and multimodal alternatives is significant, especially in the Mediterranean. This benefits multimodal transport chains crossing seas, instead of land based alternatives going all the way around the Tyrrhenian, Aegean and other Mediterranean seas. Moreover not only the mean of transport, as the ship type, is a decisive variable: factors such as the load factor and ITU make all the difference between unimodal and multimodal transport chains.

Finally if similar environmental performances are going to be demanded to road and maritime transport in Europe, it is necessary, as in the North and Baltic seas, to implement more stringent measures also in the Mediterranean. Otherwise in the years to come, road transport will displace maritime transport regarding environmental friendliness. Although maritime transport will always have a competitive advantage in comparison with land based transports due to the Mediterranean geography and the consequent detouring between land and maritime transport alternatives.

In this respect an ECA proposal by a Mediterranean country is all the more essential keeping in in mind that since its proposal, around five years are needed until its adoption. On the contrary by 2017 road transport will have swept away maritime transport.

References

Meech, R. 2008. *Designation of the Mediterranean Sea as a SOx Emission Control Area (SECA) under MARPOL Annex VI.* SAFEMED project, task 3.7.

Wall, C. 2007. *Ships Emissions Inventory – Mediterranean Sea.* Entec UK limited.

Eurostat. 2012. Maritime transport statistics – short sea shipping of goods. Available from internet: <http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Maritime_transport_statistics_-_short_sea_shipping_of_goods>.

Miola, A.; Ciuffo, B.; Giovine, E.; Marra, M. 2010. *Regulating Air Emissions from Ships. The State of Art on Methodologies, Technologies and Policy Options*. JRC Reference Reports, European Union. 68 p.

Hill, N.; Finnegan, S.; Norris, J.; Brannigan, C.; Wynn, D.; Baker, H.; Skinner, I. 2011. *Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy.* AEA Technology. 290 p.

European Union, 2011. *EU transport in figures. Statistical pocketbook 2011*. 22 p.

Holland, M.; Watkiss, P., 2002. *Benefits Table Database: Estimates of the Marginal External Costs of Air Pollution in Europe (BETA).* AEA Technology, NETCEN.

Holland M. et al. 2005. *The Clean Air for Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality.* AEA Technology.

European Commission. 2009. Directive 2009/30/EC of the European parliament and of the council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC, *Official Journal of the European Union* L140: 88-103.

European Commission. 1998. Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC. *Official Journal of the European Union* L 350: 58-68.

International Maritime Organization (IMO). 2009. *Revised MARPOL Annex VI – Regulations for the prevention of air pollution from ships and NOx Technical Code*. London. 34 p.

European Commission, 2005. Directive 2005/33/EC of the European parliament and of the council amending Directive 1999/32/EC, *Official Journal of the European Union* L 191: 59-69.

Trozzi C. et al. 2010. *Update of Emission Estimate Methodology for Maritime Navigation*. Techne Consulting srl.

Whall, C.; Cooper, D.; Archer, K.; Twigger, L.; Thurston, N.; Ockwell, D.; McIntyre, A.; Ritchie, A. 2002. *Quantification of emissions from ships associated with ship movements between ports in the European Community*. Entec UK limited. 21 p.

Usabiaga, J.J.; Castells i Sanabra, M; Martínez de Osés, F.J. 2011. Port-city closeness and turnaround time critical for Short Sea Shipping sustainable performance. *International Journal for Traffic and Transport Engineering* 1(3): 168-179.

Whall C.; Scarbrough, T.; Stavrakaki, A.; Green, C.; Squire, J.; Noden, R. 2010. *UK Ship emissions inventory*. Entec UK limited. 152 p.

OPPORTUNITIES FOR PUBLIC-PRIVATE PARTNERSHIPS FOR URBAN TRANSPORT PROJECTS IN SERBIA

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Abstract: The paper deals with the main issues of public-private partnerships (PPP) for urban transport projects. The role of government is necessary for successful transport projects, and therefore for urban transport projects as well. The question is not whether the government should intervene, but what that role should be, i.e. what is the best way that (national and local) government can strengthen its role by using new possibilities. This is of special importance for countries in transition, such as Serbia, because they need to attract foreign direct investments (FDI) and transport projects that need vast resources where PPPs can be an attractive vehicle for mobilizing FDI. The evolution of PPP initiatives took place over the last decades and some lessons should be learned. They are related to methodological issues, risk sharing, procurement methods, relationships between public and private sectors, the design of adequate regulatory and legal systems etc. Special attention is given to some opportunities for PPP for urban transport projects in Serbia. Experience of other countries of Southeastern Europe in this area could be instructive and helpful. PPP as a relatively new source for financing infrastructure projects may be of greater importance in Serbia in the coming years. Better knowledge of the potential of PPP with the building of monitoring mechanisms, legislative regulation and risk sharing can contribute to the creation of conditions for attracting new foreign investment to Serbia through urban transport projects.

Keywords: public-private partnerships, urban transport projects, foreign investments, Serbia.

1. Introduction

Since the last two decades of the last century the idea and practice of supplementing infrastructure investment with finance from the private sector through the model known as public-private partnerships (PPPs) has been developed. The application of this model is more widespread in the US, Australia, Canada and the member countries of the EU than in the less developed countries or the countries in transition. The traditional methods of finance are well known so that the introduction of new approaches always arise pragmatic and intellectual skepticism. This is especially true where the state dominates and exercises a dominant influence. In countries like Serbia, this skepticism is even more present. Nevertheless, the Parliamnet of Serbia passed (on 22 November 2011) the Law on Public-Private Partnerships and Concessions which is supposed to encourage public –private partnerships and attract domestic and foreign investments and banks to take part in the financing of projects of public interest.The new Law introduces the possibilitiy of public-private partnerships,at the local government level and enables local authorities to implement such projects on their teritory without the inclusion of the state government, as the goal of the Law is to create long-term partnerships between the public and private sector (Republic of Serbia, 2011). The Law was passed as part of the process of the Serbian efforts to fulfill obligations stemming from the requirements of advancing to candidacy for memebership in the European Union.

2. Main characteristics of public-private partnerships (PPPs)

There is no single definition of PPPs. According to the International Monetary Fund PPPs are contract relationships within which the private sector undertakes to provide infrastructure and services which have been traditionally provided by public authorities. According to the World Bank, PPPs are projects which deal with investment and the providing of services (which have traditionally been provided by public authorities) in which the private sector bears a large segment of risk, while the public sector retains an important role in providing services and taking on a large part of significant risks of the project.

The guidelines of the European Commission for successful PPPs define it as a „partnership between the public and private sector with the goal of implementing projects or services traditionally provided by the public sector", these being characterized by a sharing of investment, risk, responsibility and profit among partners (European Commission, 2003). In the Green Paper of the European Commission PPPs are defined as partnerships of different forms of cooperation between the public and private sectors with the goal of ensuring the financing, building, restoration, management and upkeep of infrastructure or the provision of services (European Commission, 2004).

In other words, the goal of contracts of public-private partnerships is economic stimulus, accelerating development of infrastructure and public services in order to satisfy public needs which require cooperation between the public and private sector.

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According to the Law of the Republic of Serbia on PPPs and Concessions PPP represents long-term cooperation between public and private partners in order to provide for the financing, construction, reconstruction and management or upkeep of infrastructure and other construction of public interest and providing services which can be on a contractual or institutional basis (Republic of Serbia, 2011).

The European Investment Bank describes the main characteristics of PPPs as follows: (i) risk- sharing between public and private sectors; (ii) a long-term relationship between parties, and (iii) public service and ultimate regulatory responsibility remaining in the public sector. The criteria for PPPs are projects that are : (i) economically viable for the public sector, (ii) financially viable for the private sector, (iii) have an appropriate risk and reward balance for the public and private sector, and (iv) where the public sector achieves value for many (The European Investment Bank, 2008).

PPPs describe a form of cooperation between the public authorities and economic operators. The primary aims of this cooperation are to fund, construct, renovate or operate an infrastructure or the provision of a service. PPPs are present in sectors such as transport, public health, education, national security, waste management, and water and energy distribution. At the European level, they help implement the European Initiative for Growth and trans-European transport networks (European Commission, 2004).

3. Types of PPPs

The two basic forms of PPPs according to the Green Paper of the European Commission are contractual and institutional. The Law of the Republic of Serbia on PPPs also assumes these two types. According to the contractual model of PPP, the partnership between the public and private partner is based solely on contractual relations. The contractual form can be of two basic types. The concessional type is one through which the private partner collects revenue from the final user while being monitored by the public partner. Another model is a private finance initiative (PFI). The institutional form of PPP incorporates the cooperation between the public and private partners through a special purpose vehicle (a special legal entity). This assumes the founding of a separate firm which is owned by both the public and private partner with the goal of providing a product or service in the public interest. Such a firm can be either established as a new entity or can be stem from a public firm by allowing a takeover by a private partner.

Aside of these basic models there exist other forms of PPPs, with the ultimate forms being public financing or privatization. International experience with PPPs recognizes a variety of models depending on the degree of involvement of the public and private sector in drawing up the project, construction, upkeep, financing and management, as well as, the allocation of risk in the provision of public service and the building of public infrastructure. Among them are: BOT (Build, Operate, Transfer), BTO (Build, Transfer, Operate), BOO (Build, Own, Operate), BBO (Buy, Build, Operate), PFI (Private Finance Initiative).

There is no specific legal framework for PPPs at European level. That is why the Green Paper seeks to examine whether the Treaty establishing the European Community (EC Treaty) and its secondary legislation is suitable and sufficient to cope with the particular challenges posed by PPPs. It should not come as a surprise that professionals complain about the lack of legal clarity in Community legislation, considering this as the primary reason for holding back the expansion of PPPs. To minimize these obstacles, the EC launched the Green Paper as public consultation on the best way to ensure the development of PPPs under conditions of effective competition and legal clarity. It asks a total of 22 questions which deal in particular with the following topics: (i) the framework of the procedures for selecting the private partner; (ii) the establishment of private initiative PPPs; (iii) the contractual framework and any changes made in the course of a PPP; (iv) sub-contracting; (v) the importance of effective competition in the case of institutionalized PPPs (European Commission, 2004).

By expanding the private sector role, the public sector is seeking to avail itself of the technological, managerial, and financial resources to leverage scarce public funds and expedite the delivery of a project and/or services in a more cost-effective manner and with reduced risk to the public agency sponsor. By sharing responsibility and resources for the delivery of a PPP project, both public and private sectors can share in the potential risks and rewards from the delivery of the facility or service relative to what they retain responsibility for (National Council for Public-Private Partnerships).

The European bank for reconstruction and development (EBRD) has supported a large number of PPP projects in the region of Southeastern Europe. The major ways of implementing them were: (i) financing, (ii) due dilligence and (iii) covering political risk. The EBRD supports PPP projects on a nationali and local level.There are some fundemental difficulties regarding a higher level of involvment of the EBRD in supporting PPPs in the region. Firstly, a clear poltical consensus along with realistic expectations regarding PPPs do not exist. Inadequate capacity of the public sector for complex PPP projects is another constraint. This affects long-term projects regarding the sharing of risk and the like. A special problem lies in the legal and regulatory environment, that is, the investment climate.In the countries of the region financial markets are underdeveloped and the currency in use is not the Euro.

Also, the public procurement procedures differ between countries and EU standards are not routinely applied due to the fact that these countries have not become full members of the EU yet.

The EBRD, European Invest Bank (EIB), World Bank will continue to have an important role in the development of transport, energy and local infrastructure in the countries of Southeastern Europe. How much this will be in the form of PPPs depends not only on these financial organizations but also on the governments of these countries , their economic policies as well as prevailing global market conditions. The financial and economic crisis from which the EU and the US are still recuperating will ceratinly affect the financial markets and the stimulii for investment in infrastructure. Furthermore, as before, it is expected that most of the investment goes into transport.

In the countries of Southeastern Europe PPPs are overwhelmingly present in the transport sector with over 50% of all PPPs. This share is consistent with the general trend present in other countries which also have the largest share of PPPs in the transport infrastructure sector. Out of a total of 25 PPPs in all sectors, the majority of them, around 50% belong to the transpost infrastructure sector. Road transport infrastructure projects have the largest share (Sredojević, 2010). Experience points to the fact that developed countries as well as developing countires have the highest need to apply the PPP concept primarily in the transport sector.

Although the presence of international financial institutions in the Western Balkans is most welcome, in the long-term every country should develop its own capacity for implementing and taking responsibility for PPPs. In order to succeed in this, developing local expertise in organizing, implementing procurement, negotiating with foreign companies and especially monitoring PPP projects are of primary importance.

4. PPPs in transport and urban transport

The lack of public funding sources for transportation and the burdens placed on current transportation infrastructure by a growing global economy has influenced transportation policymakers, especially in Western Europe, to develop and apply alternative ways to finance and deliver needed transportation infrastructure. A number of countries have turned to the private sector for relief in the form of PPPs. A wide variety of project financing and delivery approaches to access capital markets, implement new technology, and expedite project delivery, operations, and maintenance in a more cost-effective manner were created.

In the design and development of transport projects three major stakeholders are involved : (i) transport users who are part of the larger group of the society as a whole and of the taxpayers, (ii) the government (i.e., public sector), and (iii) private sponsors or providers to which other players like lenders, are related. The relationships among them are presented on Fig. 1. The Government makes possible the provision of a service to the users and receives in exchange the political support of the society and collects taxes. The Government regulates the actions of the sponsors and may provide capital and guarantees for the development and operation of the transport infrastructure. In exchange, the sponsors comply with the contract and agreed performance and assume certain risks. And the sponsors provide the infrastructure to the users with a given level of service and for it the users pay tolls or other charges. Finally, the sponsors receive loans from lenders and pay them according to a debt service payment schedule. Two circles of opposite directions are in action, and their respective elements must be properly compensated (Menendez, 1998).

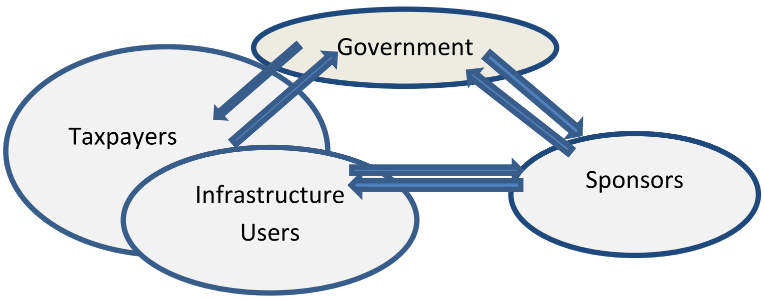

Fig. 1.
Stakeholders and Interactions
Source: Menendez, A, 1998.

Concession agreements typically involve the long-term lease of publicly financed transportation facilities, like toll roads or parking garages or rights over transit stations or highways, to a private sector concessionaire for a specified time period in return for the right to collect the revenues generated by the facility. During the concession period, the concessionaire may be responsible for financing, developing, and delivering the project, as well as facility operation, maintenance and preservation. Various categories of transportation PPP arrangements are described in more detail in Table 1. A hierarchy is shown of major types of PPPs, starting at the bottom with PPPs that have the least private sector role and ending on the top with PPPs with the greatest private sector role (Federal Highway Administration, 2007).

Table 1

Major Types of Transportation PPPs and Degree of Private Sector Responsibilities and Risk

Asset Sale	
Full Service Long-Term Concession or Lease	High
Multimodal Agreement (Public-Public Partnership)	
Joint Development Agreement (JDA - pre-development)	
Transit-Oriented Development (TOD - post-development)	
Build-Own-Operate (BOO)	
Build-Own-Operate-Transfer (BOOT)	
Build-Transfer-Operate (BTO)	
Build-Operate-Transfer (BOT)	
Design-Build-Finance-Operate (DBFO)	
Design-Build-Operate-Maintain (DBOM)	
Design-Build with Warranty (DB-W)	
Design-Build (DB)	
Construction Manager at Risk (CM@Risk)	
Contract Maintenance	
Fee-Based Contract Services	Low

Source: US Department of Transportation, 2007

Transportation projects differ in terms of the level of capital needed and the time frame of the project so that the risks which partners face also differ. Obviously, the largest infrastructural projects face the more numerous and higher risks (Table 2)

Table 2

Types of Risks Associated with Transportation Infrastructure Project PPP

Demand/volume	Compensation and termination clauses
Revenue	Changes of law
Environmental/archeological	Economic shifts
Regulatory/contractual	Currency/foreign exchange
Payment structure/mechanism	Taxation constraints
Transaction cost	Moral hazard
Construction cost	Loss of control of assets
Maintenance cost	Political stability
Life -cycle cost	Protectionism
Liability/latent defects	Public acceptance

Source: US Department of Transportation, 2007

Urban transportation projects generate multiple benefits ranging from pure private goods to public goods. The beneficiaries for each category are also different. There is a strong case for PPPs in capturing the value of urban transportation projects that accrues to all categories of beneficiaries. Public institutions need to develop innovative instruments that capture value from indirect and proximity beneficiaries so that urban transportation projects do not excessively rely on real-estate development for financing.

In the countries of Southeastern Europe it is necessary to upgrade education in the field of PPPs mostly in the field of development and control of the process of project financing. Aside of that, there is a lack of relevant information concerning future traffic flows in certain road segments, lack of forcasts on the future demand of the citizens and other infrastucture users as well as other factors affecting future demand.

5. PPPs in urban transport in Serbia

The first steps for introducing the private sector in urban transportation of passengers were undertaken in 1997 in Belgrade. The transport of passengers has a strong effect on the functioning of the city and for this reason is generally publicly financed. The process of privatization in the field of public urban transport was initiated because of lack of precise analysis on the effects that this has on the fulfillment of other important urban functions. Our research of these first privatizations regarding public urban transportation of passengers highlighted some of the important factors that need to be taken into account within the next steps of private provider entry (Petrović, et al., 2001).

Competition in urban transport is welcome, but the profit motive must be put under tight rules. Only a precise set of rules for the competitors in urban transport can bring desired social, economic and technological results. The model of the privatization of public urban transport in Beograd at the time was undertaken under the harsh constraints of lack of funds for the subsidy of operators. The effects of the model of privatization were analyzed from the aspects of: (a) city governance, (b) passengers, (c) operators and (d) bus producers.

The incorporation of private initiative in the domain of public urban transport in different ways is the practice in cities which have problems in meeting the necessary financial needs of public urban transport. In such circumstances the introduction of the private sector may be very efficient. Many public companies may find it desirable and efficient economically to lease or contract certain tasks to private enterprises. It is possible to privatize jobs and tasks such as the maintenance of vehicles, equipment and infrastructure, the sale of tickets and the like, but under the control of the public sector enterprise which sets the working conditions and the quality of service. In this case we were concerned with the privatization of certain tasks of public enterprises, but not the main jobs of organizing and executing public transport.

The renting out of certain bus routes to private operators is a possible solution and is a controversial model. Experience so far shows that such an approach may be useful only if the public company sets the parameters of service quality and controls its attainment. In 1997 the legal framework permitting the entrance of private companies into communal activities, including public urban transport, leads to the conclusion that there was an implicit "strategic decision" to privatize communal public enterprises. The public urban transport company of Beograd was not privatized according to the model of selling state capital. Instead of this, the entrance of private operators in the field of public urban bus transport was allowed (Petrović, et al., 2001).

In the past several years, Serbian municipalities have made the first tentative steps to introduce public-private partnerships to the provision of the local government services. A desperate need for new investments in traditionally neglected sectors like public transportation, district heating and natural gas supplies, and solid waste management has pushed municipal authorities in Serbia to enter into public-private partnerships and to open their doors for more innovative approaches to the traditional forms of public service delivery. However, the number of successful public-private projects in Serbia is still quite small relative to the substantial need for municipal infrastructure revitalization and an increase in the quality of services. During 2005 the city government of Belgrade recognized the possibility for the implementation of an integrated toll system for the city's public transportation system. The integrated toll system consolidated operations of the Public Utility Company (PUC) GSP and the private transportation companies and the use of single tickets and pre-paid passes by the citizens in both PUCs and private buses. The contract duration was 7 years (Pavlović-Križanić and Brdarević, 2011).

The analysis of this PPP shows that positive results were achieved. Firstly, the possibility for achieving benefits for both the city and the private partner was demonstrated. Secondly, private partners were selected by public competition and the content and form of tender documentation were prepared in accordance with the Law on Public Procurement of the Republic of Serbia. Thirdly, the private partner was obligated to invest in a rolling plant, according to the condition from the tender documentation (certain number and quality of vehicles). Fourthly, the revenue of the private partner was guaranteed and calculated on the basis of effective kilometers travelled and the contracted price of transportation delivered. The revenue was collected from the following resources: (1) from an integrated toll system (2) from the selling of the single tickets on the buses, and (3) from the city budget to complement a guaranteed level of revenue. Fifthly, risks were shared between the parties during the contract's lifetime. Furthermore, the contractual obligations of the private partner to finance procurement of a certain number and quality of vehicles and to provide public transportation of services across the city were defined. Further still, the carrying out of transportation public services was regulated by the contract and the public transportation department was obligated to perform the ongoing quality control of services delivered by private companies. Finally, contract termination in case of bad performance was used. All of these had the goal of delivering high quality services to the citizens of Belgrade (Pavlović-Križanić and Brdarević, 2011).

Another example of PPPs in urban transport was implemented in parking in the city of Kikinda. The municipality of Kikinda entered into a partnership with the private company “Parking System and Garage” Belgrade. The granting of the utility services operation contract was done in accordance with the Law on Utility Services, the Law on Public Procurement, and the municipal assembly’s decision on granting a contract for the operation of public parking services in the town. The duration of contract is 22 years.

It should be expected that the passing of the Law on PPPs and Concessions enhances the opportunities for PPPs in the urban transport sector in the fields in which it is already present such as public transportation and parking, as well as in larger projects such as the construction of transportation infrastructure.

6. Concluding remarks

In order to achieve more favorable conditions for PPPs, some problems need to be overcome. For example, it is debatable whether the principles of the Law on Public Procurement are applicable to PPPs which can be founded according to a law that does not lay down clear procedures for the choice of the private partner, that is in accordance with the Law on Public Enterprises and the legislation dealing with the fulfillment of contracts in areas designated as in the public interest. It is very common to have the public sector in PPPs provide basic equipment or real-estate as its initial investment into a PPP. The incoherence and dubious nature of legislation concerning government ownership or the ownership of local governments in many cases hinders the development of PPPs. The current legislation on government budgeting also slows down the progress in this area. Until very recently, the local authorities could not issue municipal bonds with the goal of financing PPPs. In practice it is common that various political party and individual interests at both the national and local level impede the speedier implementation of PPPs in (Savet stranih investitora, 2011).

Finally, last but not least, work needs to be done in the field of better information, training and education concerning tasks which involve PPPs as well as the highlighting of benefits that they bring for all those involved. This means creating a positive environment concerning the participation of the private sector in providing transport infrastructure and transportation services.

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References

European Commission. 2003. Guidelines for Successful Public – Private Partnerships, Available from Internet: <http://ec.europa.eu/regional_policy/sources/docgener/guides/ppp_en.pdf>.

European Commision. 2004. Green Paper on Public – Private Partnerships and Community Law on public contracts and concessions. Brussels, Belgium. Available from Internet: <http://europa.eu/legislation_summaries/internal_market/businesses/public_procurement/l22012_en.htm>.

Menendez, A. 1998. Constraints and Opportunities for PPP Transport Projects, Available from Internet: https://www.ppiaf.org/sites/ppiaf.org/files/documents/toolkit.

National Council for Public-Private Partnerships, Public Private Partnerships Defined, Available on internet: http://www.ncppp.org/howpart/index.shtml#define

Pavlović-Križanić. T.; Brdarević, Lj. 2011. *Public-Private Partnerships, Successes and Failures in Central and Southeastern Europe*, eds. Damjanović, D.; Pavlović-Križanić, T.; Peteri, G. Open Society Foundations, Budapest, Hungary: 174-176.

Petrović, J.; Glumac, S.; Vujačić, I.; Žeželj, S. 2001. Effects of privatization of public urban transport – the case of Beograd, In Proceedings of *the 7th International Conference on Urban Transport and the Environment for the 21st Century*, Wessex Institute of Technology, Lemnos, Greece: 259-267.

Republic of Serbia. 2011. *Law on Public-Private Partnership and Consessions*, Beograd.

Savet stranih investitora. 2011. *Bela knjiga – Predlozi za poboljšanje poslovnog okruženja u Srbiji*, ed. Crnobrnja, M. Beograd. 79-81.

Sredojević, G.S. 2010. *Javno-privatno partnerstvo*. Arhipelag & Institut ekonomskih nauka, Beograd: 163-166.

The European Investment Bank, 2008, Urban Transport, Funding and Financing solutions of the European Investment Bank, Available from Internet: http://www.sputnicproject.eu/meetings/3wgmeeting/Market%20Organisation/.

US Department of Transportation, Federal Highway Administration. 2007. *Case Studies of Transportation Public-Private Partnerships around the World*. 18 p.

DYNAMICS OF RAILWAY MARKET OPENING – CHOICE OF A POLICY

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Abstract: Opening of the railway market has no alternative for all European countries. Before the very opening of the market, it is necessary to take a number of independent and difficult decisions, namely, to find solutions with unpredictable results as far as dynamics and final models of realization of these solutions are concerned. The duration of the period preceding the beginning of activities on the opening of the market depends on interest and possibility to create a climate for opening of the market. The opening of the market can also be realized in phases until a completely free market can be established. In different phases, access to the market can be restricted (for example, only for national and regional railway undertakings). In order to achieve effectiveness and avoid unnecessary costs, all the activities shall be synchronized. This requires a clear state policy regarding the dynamics of the market opening process. It is possible to define several different policies, taking into account the existing characteristics of the railway sector in a certain country. The paper presents different possible policies of the railway market opening in Serbia and use of the ANP approach for the choice of the most appropriate policy.

Keywords: Policy, Railway market opening, Analytic Network Process, Serbia.

1. Introduction

The member states of the precursors to the European Union (EU) opted for an open and free transport market in the whole area, for all transport modes and in all segments of the market, by the Treaty of Rome in 1957. Railway reforms, which have been lasting for more than two decades, enable gradual opening of the railway market which has always been monopolistically organized. Although the opening of the railway market in the EU is generally being realized as a gradual process, in certain countries there are several alternatives regarding the dynamics of its realization. The process of the market opening can be realized more or less slowly or rapidly. Perception of dynamics of this process depends on the moment of decision making and realization. Thus, perception of dynamics of the market opening was not the same in the 90s as today.

Before the very opening of the market, it is necessary to make a number of independent and difficult decisions as a precondition of its liberalization. Many of the activities in this process take a lot of time and require more resources. Therefore, all the solutions, as well as decisions themselves, have a high proportion of uncertainty regarding their results, dynamics and final models. The most important decisions concern restructuring of the incumbent railway company, development of railway market institutions, subsidies and investment policy, railway infrastructure access charges, public service obligation, etc. Realization of each activity requires a certain time. Some of the activities are interdependent and, thus, they shall be coordinated. Therefore, target date and dynamics of the opening of the railway market shall be defined at the very beginning. Desired and realistic time limit for the opening of the market is essential for fixing time limits for all the necessary activities in this process.

Besides the dilemma regarding ”faster” or ”slower” opening of the market, there is also a doubt whether it would be useful to introduce different phases with restricted access to the market. For example, according to the draft “Agreement on Establishment of a Transport Community in the Western Balkans” (Treaty, EU 2010), railway market of the Western Balkans countries (Croatia, Serbia, Bosnia and Herzegovina, Montenegro, Macedonia and Albania) shall be opened through three phases until a completely free market can be established: the first concerns opening of the internal market (only for railway undertakings of the concerned country), then, opening of the market at the regional level (only for railway undertakings from the region) and, finally, complete opening of the market according to the EU legislation. Time limits for the different phases have not been fixed. Each country shall define its own time limits. Complete liberalization of the market of a candidate country shall be realized, at the latest, on the day of the accession to the EU.

What dynamics of market opening shall be adopted for a country in certain circumstances? Circumstances mean all important factors, such as economy requirements regarding quality of services and market, accounts and characteristics of railway infrastructure and railway undertaking, present and expected dynamics of restructuring process of the incumbent railway company, development of railway market institutions, subsidy and investment policy, dynamics of the EU integration process, projects of the other countries in the region for the future, etc.

On the other hand, in most railway markets there is still a "non ideal competition" and railways are still considered as a social transport mode. Such point of view slows down restructuring process and opening of the market. This affects the level of charges, subsidies, type of competition, structure of the market, specificities of demand, compliance with the EU strategy for development of transport, etc.

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Taking into account different circumstances, objectives to be achieved, competition on the market, etc, different variants of the railway market opening policy represent different ways of achieving balance among market development policy, policy of development of the railway sector and financing policy. It is a specific and difficult decision requiring research and modern decision making methods. In this paper, the ANP approach was applied as a support to the choice of the most appropriate policy for the opening of the railway market in Serbia.

2. Railway market opening in Serbia and surroundings

The main stakeholders on Serbian railway market are Ministry for Transport, Serbian Railways, Directorate for Railways, national operators (Kombinovani prevoz, ZGOP Novi Sad and TENT railway transport which are still not active on public railway lines) and railway industry.

Railway transport market in Serbia has not been opened yet. A part of the Serbian railway network belongs to the Corridor X having an important transit freight transport. It is surrounded by the networks of Hungary, Bulgaria, Romania, having an open market, and Croatia, Bosnia and Herzegovina, Macedonia and Montenegro, which do not have an open market. Serbia is in the process of accession to the EU (candidate status without the date of the beginning of negotiations).

On one hand, Serbian Railways are under constant pressure related to the opening of the market (both from the inside and from the outside) and, on the other hand, the railway system is extremely unproductive, namely, there is a small level of capacity utilization with high costs. The condition of existing system requires more intensive investments, both in order to maintain the network at the existing level and to improve the quality of services. What makes the situation even more difficult is the fact that a appropriate strategy of economy development has not been defined yet, that is, it is still not known which economy fields will be developed as a comparative advantage of Serbia. There is also a constant budget deficit.

Serbia belongs to the Southeastern Europe (Western Balkans + Romania, Bulgaria and Greece), in which, development of the railway market is in the initial phase and real opening of the market and introduction of competition is yet to come.

3. Railway market opening variants

Complexity and dynamics of the railway system in all the different aspects (technical, socioeconomic and environmental) and necessity of making connections between vertical and horizontal policy (different administration levels and interdependence with other systems), but also different intentions and interests (often confronted) of different stakeholders, has created the need for a strategic planning. In other words, it is necessary to carry out an analysis and define the elements of transport policy in order to cover different questions and create a policy to be followed through the years.

The process of strategic planning defines the content and form of strategy elements. Strategic planning of the railway system shall result in the appropriate policy of the market opening. Policy is here considered to be a methodical influence of the state and includes all governmental activities influencing economy and society. It represents directions of strategic *action* (in order to regulate the concerned field) adopted and monitored by the Government. It has *regulatory* or *management* functions.

Based on the previously defined concept of policy, as well as on discussions on the policy of market opening in the Introduction and situation in the railway sector in Serbia, the following 4 policy variants related to the opening of the railway market in Serbia have been defined:

- *Variant 1 – slow opening of the market (SOT).* According to this variant, the market will remain closed for a longer period of time, with the same market participants, while financial instruments (for example grants, debt cancelling, investments, PSO, charges, etc) will depend on the budget and needs of the monopolist. The aim of this policy is to protect the existing railway undertaking (there is no competition). It has been estimated that a longer period of time will be necessary to prepare the incumbent for competition and that, at the moment, the Government and competent authorities do not have enough capacity to restructure the railway sector.
- *Variant 2 – gradual opening of the market (POT).* This variant requires appropriate financial instruments in order to support opening of the market and enable market participants to be competitive where the incumbent railway undertaking is still dominant. The aim of this policy is to harmonize restructuring of the monopolistic national company with the opening of the market by improving the efficiency of the railway system. In other words, competition shall be introduced gradually which means that the existing national company will remain dominant railway undertaking but its efficiency will be gradually improved.

- *Variant 3 – rapid opening of the market (BOT).* This variant of the policy is based on the priority objective of Serbia, which is quick accession to the EU, and, in order to achieve this objective, the necessary requirements shall be fulfilled as soon as possible. This implies rapid opening of the market and providing efficient transport enabling a competitive economy. Making the existing RU competitive is less important than opening of the market, which means that the priority of this policy is to join the EU railway market.
- *Variant 4 – selling of the market (PT).* This implies selling the only freight railway undertaking which, in the situation where the market is monopolistic, means selling the whole market. Freight transport is the only one which is "interesting" at the private capital market, namely, this is the only activity of a railway company which can find a buyer. This policy is based on the opinion that there are no resources (financial, human, etc) which could recover the company from crisis and, therefore, it is necessary to find a strategic partner by selling profitable activities and solving most of the problems. Policy which consists of selling the market does not mean rapid opening of the market. That will depend on the situation in the freight company and possibility to sell the company to a strategic partner and thus make the sale successful.

4. Analytic Network Process and its implementation

Analytical Network Process (ANP), which is both a quantitative and qualitative approach, is a decision support system that evaluates different alternatives for a purpose by comparing them. This approach, which was developed by Saaty (1996), was successfully applied to many cases that required complex decision analyses.

The application of ANP in problem of strategy selection can be followed in papers of Maede and Sarkis (1998) for selecting a strategy for managing logistical chains, Ulutas (2005) for selection of the appropriate energy policy in Turkey and for selecting a knowledge management strategies (Wu and Lee, 2007; Sercuk, 2010). ANP was preferred because it disaggregates the problem to its parts; it examines the problem by considering the opinions of every different stockholder that gives different weights to different criteria and it is easy to use. Another advantage of the Analytical Network Process is that there is no need to openly establish a function (Zoffer el al., 2008).

ANP starts with disaggregation of a complex multi-purpose problem into a network which comprises specific clusters. In order to establish such a network structure, all of the elements of the system and the relationships between these should be observed.

4.1. Basic steps

The most important issue in the ANP is creation the network structure which describes dependency among /within sets of elements (clusters); because with this model, the main purpose is to measure the effect of the relative priority of the tangible and intangible elements. After the network model is established, the next stage is to determine the attributed weights to the elements within and among clusters. Pair-wise comparisons matrices are prepared. So the ANP prioritizes not only elements but also their groups or clusters as is often the case in the real world.

A network model example is seen in Fig. 1 and pair-wise comparison is given in Fig. 2. The importance of clusters C1–C3 is scaled with a value from 1 to 9, according to its effect on cluster C2. For example, in the matrix in Fig. 2, if C1 and C3 are equally important, $X_{c1c3} = 1$; if C1 is certainly more important than C3, $X_{c1c3} = 9$. In this situation, it is apparent that $X_{ii} = 1$ and $X_{ij} = 1/X_{ji}$. After the pair-wise comparison matrix is established, the eigen vectors of this matrix are founded by using the computer software name SuperDecision. These eigen vectors are used for determining the priority orders.

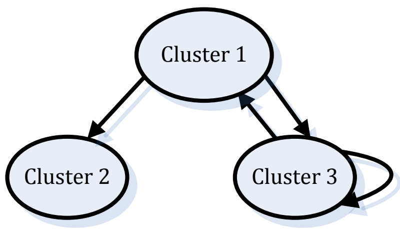

Fig. 1.
Network model example
Source: owner

	C1	C2	C3	
C1			X_{c1c3}	X_{c1}
C2	X_{c2c1}			X_{c2}
C3	X_{c3c1}		X_{c3c3}	X_{c3}

Fig. 2.
Pair-wise comparison matrix example
Source: owner

By utilizing the pair-wise comparison matrices that come back from the experts, supermatrix is founded. The priorities derived from the pair-wise comparisons are entered into the appropriate position in this supermatrix. This supermatrix has to be normalized using clusters weights.The SuperDecision software is used for this purpose and the priorities of the elements in the model are calculated. Thus, the importance or weights of the alternatives according to the target are found. These weights are then summed up separately for each alternative and the general weights of the alternatives are obtained. Then overall inconsistency indexes are calculated. If any inconsistency exists, the expert opinions should be reviewed and the inconsistencies should be cleared up.

4.2. Defining criteria

For this purpose, survey and in-depth interviews were used. Initially, interviews were conducted with a total of 20 experts on transportation, representatives of Ministry of Transport, Railway Directorate, Serbian Railways and transport planning in the universities. Their points of view about the most important factors to be taken into consideration were gathered. The final result is 7 criteria clustered under three different titles: market, financing policy and development of railway sector.

The selected criteria are as follows:

1. *Strategy of restructuring of the incumbent* – Policy variants related to the opening of the market shall correspond to the process of restructuring of the incumbent. This means that it is necessary analyze the convenience of the different implementation alternatives for the chosen strategy of restructuring of the incumbent or evaluate the possible dynamics of restructuring of the incumbent according to the above mentioned dynamics of the market opening.
2. *State policy regarding subsidies in the railway sector with the accent on the incumbent.* For rapid opening of the market, it is necessary to improve capacities of the RU in freight and passenger transport as soon as possible in order to ensure its competitiveness on the transport market, as well as to enable the infrastructure manger (IM) for doing business in a commercial way. First of all, this requires financial consolidation of the incumbent and paying its long and short term debts. Can the budget of the Government support quick and overall financial consolidation or does such an attempt require a longer period of time?
3. *Investment policy.* Technical improvement of the state owned railway undertaking up to the level of competitiveness in the open market, as well as improvement of the infrastructure performance which enables providing of competitive services.
4. *Dynamics of EU integrations*. In most cases, this was a crucial criterion for the last 12 countries which have entered the EU. Why? Because the expected and defined period of time necessary for the EU integrations, together with the existing situation, defines the variant of the market opening policy.
5. *Market requirements*. Growing economy requires railway undertakings providing quality services at low prices. In other words, it is necessary to have a strong transport market and competitive railway undertakings. Therefore, economic requirements can be of great importance for the dynamics of restructuring and opening of the market.
6. *Competitiveness of the network.* This criterion points out the influence of competitiveness of other networks and lines which may speed up opening of the market on the concerned network. In case of Serbia, opening of the bridge Vidin – Kalafat between Bulgaria and Romania on the corridor IV is reducing transit traffic through Serbia and thus requires rapid opening of the Serbian railway market. This criterion requires good knowledge of the railway network, infrastructure and railway undertakings in the region.
7. *Establishment of railway sector institutions required by the opening of the market*. The necessary capacities of railway regulatory bodies depend on the degree of openness of the market. Institutions can sometimes obstruct opening of the market. In other words, it is necessary to define the capacities of those institutions taking into account the degree of openness of the market and restructuring phases of the incumbent. Establishment of these institutions and development of all their functions require a certain time.

These 7 criteria were put on network structure as elements of clusters and following relationship was obtained (Fig. 3)

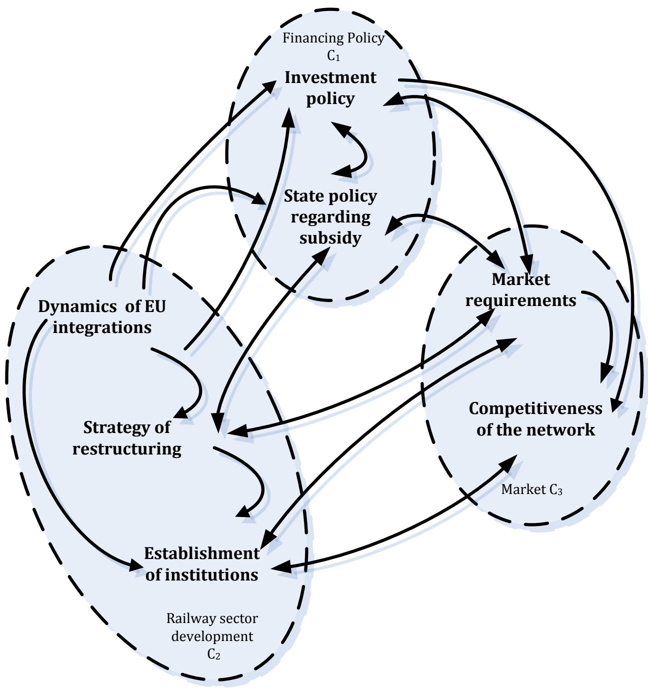

Fig. 3.
Criteria relationship in the clusters
Source: owner

4.3 Network structure

The alternatives are the cluster A and criteria perform clusters C_1, C_2 and C_3 that are related to the each other by casual relations (Fig. 4). Once the network model has been constructed, the elements in one cluster are evaluated according to their relative importance with respect to one element in the other clusters. The evaluations are made on a 1–9 scale (Saaty scale). The matrices are then evaluated using SuperDecision software and the global importance of the alternatives are calculated.

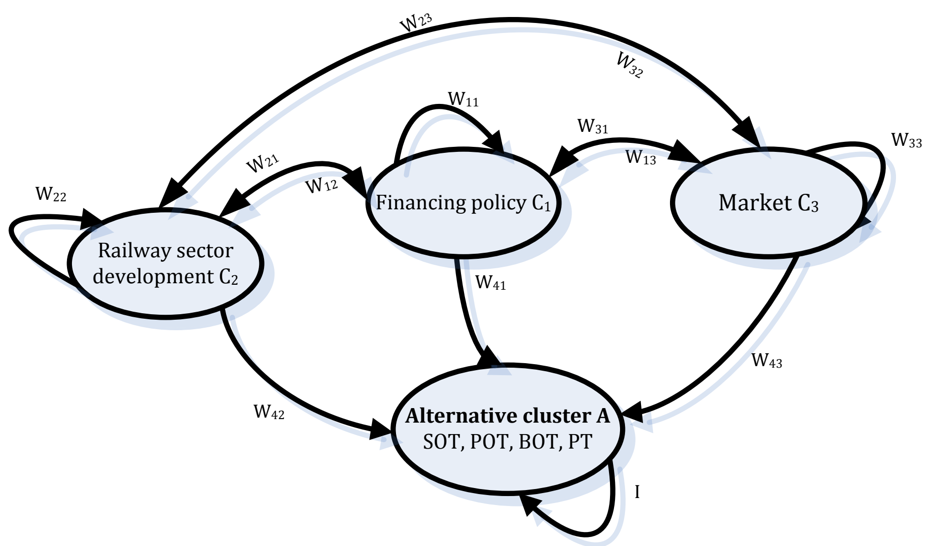

Fig. 4.
Railway opening market choosing
Source: owner

5. Results and discussion

After the evaluation of preferences among the different elements and once the priorities have been defined, limit supermatrix is calculated. The first column in the limit supermatrix (Table 1) represents final priority vector for all elements of the defined structure. The obtained priorities of policy variants related to the opening of the market are shown in the Table 2.

Table 1
Limit supermatrix

Limit supermatrix		Development of			Financing		Market	
		Development of new institution	Dinamic of EU integration	Strategy of restructuring	Investment policy	Subsidy strategy	Market requirement	Network competition
Alternatives	BOT	0.094	0.094	0.094	0.094	0.094	0.094	0.094
	POT	0.111	0.111	0.111	0.111	0.111	0.111	0.111
	PT	0.074	0.074	0.074	0.074	0.074	0.074	0.074
	SOT	0.071	0.071	0.071	0.071	0.071	0.071	0.071
Development of railway sector	Development of new institution	0.082	0.082	0.082	0.082	0.082	0.082	0.082
	Dinamic of EU integration	0.123	0.123	0.123	0.123	0.123	0.123	0.123
	Strategy of restructuring	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Financing policy	Investment policy	0.093	0.093	0.093	0.093	0.093	0.093	0.093
	Subsidy strategy	0.089	0.089	0.089	0.089	0.089	0.089	0.089
Market	Market requirement	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	Network competition	0.088	0.088	0.088	0.088	0.088	0.088	0.088

Table 2
Priority of the market opening policy variants

Name of alternative	**Graphic**	**Results (1)**	**(2)**	**(3)**
BOT		0.845	0.269	0.094
POT		1.000	0.318	0.111
PT		0.664	0.211	0.074
SOT		0.637	0.202	0.071

The ANP evaluation shows that with respect to the market, financing policy and development of railway sector, the highest relative importance is for the POT policy.

Priorities regarding criteria and analysis of individual influence of criteria show the following:

- ✓ Decision makers and experts consider in this moment criteria related to restructuring strategies of the incumbent and dynamics of Serbian accession to the EU as key elements (criteria) defining the dynamics of the opening of the Serbian railway market. A more detailed analysis of those two elements shows that, in case of Serbia, both processes are late. If we take into account that the objective is to choose a market opening policy, it is logical that those two criteria are the most important and that relations between those criteria are defined by the experts.
- ✓ If the railway sector and its participants are not competitive enough and the final date of the accession to the EU is close, then variants BOT or PT are more convenient than the variant POT. But, if the accession to the EU has not been planned in close future or if it is very uncertain, which is the case of Serbia, then the criterion related to the dynamics of the EU integrations does not change ranking of the alternatives, namely, the variant POT has the highest preference.

- ✓ If the neigburing railway markets have been opened or will be opened before the opening of the concerned market, and, if other parameters are more convenient (market institutions exist, improved performances and quality of infrastructure services, subsidies are still being allocated to IM and RU, etc), then the variant BOT has the highest preference.

5. Conclusion

Opening of the railway market has no alternative for all European countries. Before the very opening of the market, it is necessary to take a number of independent and difficult decisions, namely, to find solutions with unpredictable results as far as dynamics and final models of realization of these solutions are concerned.

It is imperative for decision-makers to devise, identify and recognize railway market opening criteria prior to define opening policy. In order to design a more effective decision making process, this study applies ANP approach for choosing the variant of railway market opening.

The model have shown that restructuring strategy of the incumbent is the most important criteria for opening the market. It is understandable that Serbian railway, where IM and RU are together, cannot be part of the competitive open market and be efficient too. Moreover, experts who participated in the work are highly valuated dynamic of EU integration which is capture by investment policy and policy for subsidy. The third concern is network competition. The lowest two criteria are development of new institution and market requirements.

As a result of the evaluations made to the elements listed under the clusters, it was observed that the gradual opening of the market (POT) is the most weighted as a variant for the opening of railway market in Serbia in this moment. In this paper, the interdependence among the criteria was analyzed by the author first, and was confirmed by the experts after a few rounds of revisions. Other method such as decision making trial and evaluation laboratory (DEMATEL) or interpretive structural modeling (ISM) may be used to facilitate the process. This can be our future research direction, and a more comprehensive model can be constructed.

Acknowledgements

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References

European Union. 2010. Treaty establishing the transport community, Brussels

Meade, L.; Sarkis, J. 1998. Strategic analysis of logistics and supply chain management systems using the analytical network process, *Transportation Research – Part E* 34(3): 201-215.

Saaty, T.L. 1996. *Decision making with Dependence and Feedback: The Analytic Network Process*, 1st ed., RWS Publications, Pittsburgh, PA, 352p

Selçuk, P. 2010. Use of analytic network process in selecting knowledge management strategies, *Management Research Review* 33(5): 452 – 471.

Ulutas, B.H. 2005. Determination of the appropriate energy policy of Turkey. *Energy* 30: 1146–1161.

Wei-Wen, W.; Yu-Ting, L. 2007. Selecting knowledge management strategies by using the analytic network process, *Expert Systems with Applications* 32(3): 841-847.

Zoffer J.; Bahurmoz, A.; Hamid, M.K.; Minutolo, M.; Saaty, T. 2008. Synthesis of Complex Criteria Decision Making: A Case towards a Consensus Agreement for A Middle East Conflict Resolution, *Group Decision Negotiations* 17: 363-385.

DECISION MAKING ON OPTIMAL ROAD SUBNETWORK

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Abstract: The paper introduces a family of subnetwork optimization problems as a part of network management theory. Three optimization problems are formulated and the solution methods are described. Five practical situations, when these solutions may be applied, are presented. Possibilities of future research are outlined as well.

Keywords: Transport network, subnetwork, cost, length, attractiveness, optimization

1. Introduction

This paper presents topics met during the last decade by the Research Group of Network Management and Optimization at the Faculty of Management of the University of Economics in Prague. The main purpose of the paper is to show how the transport network theory can help managers of public administration or of carriers in their decision making on the optimal subnetwork choice. Examples of the possible practical situations are mentioned in the chapter 2.

The problems, the paper deals with, belong to network economy theory. This scientific discipline contains several branches. They can be divided into two main directions: The first one focuses networks of mutually connected and interacting enterprises, as described e.g. in the books by Fiala (2008) or DeMan (2004). The second direction looks for economically optimal transport and telecommunication networks as described e.g. in the papers by Jun Xiao et al. (2008) and Shimoda (2000).

The later contains, among others, the family of network design problems, namely the ones looking for a subnetwork of the given network. Several papers deal with related topics, concerning a network, represented by a graph $G = (V, E, c)$ with $c(e) \geq 0$ expressing a general cost (e.g. passing time, length, building cost, toll etc.) of the edge $e \in E$. The paper by Eades et al. (1982) seeks the maximum planar subgraph of G. The papers by Cheriyan and Thurimella (2000) or by Gabow et al. (2005) seek a λ-edge connected spanning subgraph which minimizes costs of edges when the integer $\lambda > 0$ is given. Minimization of total edge costs is also the topic of the papers by Safari and Salavatipour (2008), Amini et al. (2009) and Vassilevska et al. (2006). Other papers deal with maximum cost subgraphs, namely Suzuki, A. Tokuyama, T. (2006) and Amini et al. (2009).

The problems studied in the present paper look for a subgraph, analogically as the items mentioned above. However, the constraint and objective functions are different. They are formulated precisely in the chapter 3.

Particular cases of the problems are met when the subgraph is linear, i.e. it forms a route. Note that it is not necessary that the route is a path in mathematical sense. It may happen that the route arrives to a vertex v, then it deviates to a vertex u, returns back to v and continues in its original direction.

2. Examples of Applications

In practice, it is quite often possible to meet managerial decision problems concerning the selection of optimal subnetwork of the given network. In the sequel, some typical ones are mentioned.

2.1. Rural Road Network

In the Czech Republic, one can see many regions with the average distance about 2 km between neighboring villages. There are direct roads from a village to other 3, 4 or 5 villages. Such a network is too large for the maintenance, especially in the winter time. The problem is to find a suitable subnetwork. It is necessary not to increase significantly the length of trips between villages.

2.2. New Urban Transport in Sprawl Zones

There are many sprawl zones around or within metropolitan areas. The zones are covered by networks of local roads, more or less suitable for the operation of buses, at least smaller.

The problem of public administration (and, maybe, together with carriers) is to choose a bus routes subnetwork of the given network. The problem has different variants, depending on whether the network is chosen freely, or whether there are predetermined vertices, such as railway station, subway station, etc.

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2.3. Urban Trolleybus or Tram Network

It happens that an existing bus network is to be partially transformed to a trolleybus (or a tram) network. The decision problem is to choose the corresponding subnetwork to be electrified.

2.4. Urban Bus Transport Intensification

It may happen that the bus transport system in a town is “extensive”, i.e. it consists of many routes with long headways, operating on very dense road network. Almost all streets are passed by a bus route, but the passengers there have to wait for the next connection for a long time. If one wants to intensify it without increasing of costs, the existing network must be reduced to a suitable subnetwork.

2.5. Leisure Non-Motorized Network

This problem is met when in a nature area there is a network of natural, soft (i.e. unhardened) surface and a trail subnetwork for hiking or leisure cycling is to be chosen. Afterwards, in case of hiking, the trails are marked and all places of impassability are eliminated. In the case of cycling, the trails are hardened, usually bituminized in width allowing two-way traffic.

3. Constraints and objectives

Suppose that a network $G = (V, E)$ and its subnetwork $G' = (V', E')$ are given, i.e. $V' \subset V$, $E' \subset E$. Then the following functions could be done:

q: $V \to \langle 0; \infty)$ where $q(v)$ denotes the passenger demand a hour in the edge v,
t: $E \to (0; \infty)$ where $t(e)$ denotes the duration of transit through the edge e,
d: $E \to (0; \infty)$ where $d(e)$ denotes the length of the edge e,
c: $E \to \langle 0; \infty)$ where $c(e)$ denotes the cost (maybe generalized) associated e.g. with the construction or maintenance of the edge e,
a: $V \cup E \to \langle 0; \infty)$ where $a(v)$ or $a(e)$ denote the tourist attractiveness of passing through the vertex v or through the edge e respectively.

Remark. If $r = v_0, e_1, v_1, e_2, v_2, ..., e_n, v_n$ is a route then r is said the route connecting v_0 and v_n and
$t(r) = t(e_1) + t(e_2) + ... + t(e_n)$ expresses the passing time of the route r,
$d(r) = d(e_1) + d(e_2) + ... + d(e_n)$ expresses the length of the route r,
$c(r) = c(e_1) + c(e_2) + ... + c(e_n)$ expresses the costs of the route r,
$a(r) = a(e_1) + a(v_1) + \rho a(e_2) + \rho a(v_2) + ... + + \rho a(e_2) + \rho a(v_n)$ expresses attractiveness of the route r, where the reduction factor $\rho = 1$ when corresponding vertex or edge is passed for the first time and $\rho < 1$ (e.g. $\rho = 0.2$) otherwise.

Remark. The minimal possible length of the route connecting two vertices v and w is the distance $d(v, w)$ of v and w. Obviously, the shortest route connecting two vertices $v \neq w$ is a path, because it certainly does not pass twice through any its vertex. As one will see, all problems presented in the sequel have their constraint and objectives formulated exclusively in terms of the functions q, t, d, c and a.

4. Selected problems

The following problems correspond to the examples mentioned in the chapter 2 (not one-to-one, of course).

4.1. The Cheapest Subnetwork with Limited Relative Extension of Distances

Suppose a network $G = (V, E, d)$ is given, together with a set $W \subset V \times V$ of important pairs and a number $\psi \in \langle 1; \infty)$ expressing the relative extension limit. **The problem** is to find a subnetwork $G' = (V', E', d')$ with the property that

$$d'(e) = d(e) \text{ for all } e \in E'$$

fulfilling the constraint

$$d'(v, w) \leq \psi * d(v, w) \text{ for all } v, w \in W$$

and minimizing the total length of E'

$$d(E') = \sum_{e \in E'} d(e) \rightarrow \min$$

Remark. It is shown in Czimerman et al. (2007) that in the particular case of $\psi = 1$ the problem is NP-hard and it would be very surprising if for $\psi > 1$ it is not.

Remark. The problem 4.1 corresponds to the examples 2.1 and 2.4.

Solution. The authors were quite successful in solving this problem optimally (in smaller instances) as by depth-first-search as by integer linear programming and (in greater instances) by an original heuristics. The paper describing these results will be completed soon.

4.2. The Cheapest Subnetwork with Limited Inaccessibility of Bus Service

Suppose a network $G = (V, E, d)$ is given, together with the inaccessibility limit $\lambda \in \langle 0; \infty)$ and the passenger demand $q(v)$ for each vertex $v \in V$. Let

$$Q = \sum_{v \in V} q(v)$$

denote the total number of passengers in the network and for $V' \subset V$

$$d(v, V') = \min_{w \in V'} d(v, w)$$

is the distance of a vertex $v \in V$ from the closest vertex $w \in V'$.

The problem is to find a bus service subnetwork $G' = (V', E', d')$ with the property that the mean walking distance to the next stop, expressing “inaccessibility”, should not exceed the limit, i.e.

$$\frac{1}{Q} \sum_{v \in V} q(v) d(v, V') \leq \lambda$$

and the costs ought to be minimal:

$$\sum_{v \in V} c(v) \rightarrow \min$$

Remark. The problem 4.2 corresponds to the examples 2.2 and 2.3. The resulting subnetwork G' is then the basis for the construction of bus/trolleybus routes. However, that is outside the scope of this paper. An exception is when G' is linear, i.e. when it represents a route itself.

Solution. For the case when it is requested that the subgraph G' should be linear, i.e. that it represents a route, the exact methods depth-search-first and integer linear programming are described in the paper by Černá et al. (2011), together with several heuristics. The general case may be solved by a modification of depth-first-search method and the heuristics.

4.3. The most Attractive Route for Cyclists or Hikers

Suppose a network $G = (V, E, d, c, a)$ is given, together with two important vertices $v \in V$, $w \in V$, the length limit $\lambda \in (0; \infty)$ and the cost limit $\gamma \in (0; \infty)$. **The problem** is to find a route $r = v_0, e_1, v_1, e_2, v_2, ..., e_n, v_n$ such that $v_0 = v$, $v_n = w$ meeting the constraints

$$c(r) \leq \gamma, \quad d(r) \leq \lambda$$

and maximizing the objective function

$$a(r) \rightarrow \max$$

Remark. The problem 4.3 corresponds to the example 2.5.

Solution. The depth-first-search method can be found in the paper by Černá and Černý (2012). The integer linear programming and heuristics are subject of research.

3. Conclusion

The paper presented practical situations when managers of public administration and of carriers are faced with a problem to find an optimal subnetwork of the given transport network. Three different optimization problems were formulated and possible methods for exact and heuristic solution are presented (if they are known). The open questions are outlined.

One can expect the following direction of the future research:

- exact and heuristic solution of the general case of the problem 4.2,
- direct imbracement of route design into the problem 4.2,
- integer linear programming and efficient heuristics for the problem 4.3 where one of the difficulties is in the attractiveness reduction when an edge or a vertex are passed for the second time.

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References

Amini, O.; Peleg, D.; Pérennes, S.; Sau, I.; Saurabh, S. 2008. *Degree-Constrained Subgraph Problems: Hardness and Approximation Results*. In: E. Bampis and M. Skutella (Eds.): *WAOA 2008, LNCS 5426*, Springer-Verlag Berlin Heidelberg 2009: 29–42.

Černá, A.; Černý, J. 2012. Note on Optimal Paths for Non-Motorized Transport on the Network. In *Proceedings of the Conference Mathematical Methods in Economics*, Karviná: 91-94.

Černá, A.; Černý, J.; Přibyl, V. 2011. Bus Route Design in Small Demand Areas. *Transport* 26(3): 248-254.

Cheriyan, J.; Thurimella, R. 2000. Approximating Minimum-Size k-Connected Spanning Subgraphs via Matching, *SIAM J. Comput.* 30(2): 528-560.

Czimerman, P.; Černá, A.; Černý, J.; Peško, Š. 2007. Network Reduction Problems. *Journal of Information , Control and Management Systems* 5(2), 139-147.

De Man, A.P. 2004. *The Network Economy: Strategy, Structure and Management*. Edw. Elgar, Cheltenham, GB. 190 p.

Eades, P.,; Foulds, L.R.; Giffin, J.W. 1982. An efficient Heuristic for Identifying a Maximum Weight Planar Subgraph. *Combinatorial Mathematics IX, Lecture Notes in Mathematics No. 952*, Springer-Verlag, Berlin 1982.

Fiala, P. 2008. *Network Economics* (in Czech) Professional Publishing, Praha. 324 p.

Gabow, H.N.; Goemans, M.X.; Tardos, E.; Williamson, D.P. 2005. Approximating the Smallest k-Edge Connected Spanning Subgraph by LP-Rounding. In *SODA '05 Proceedings of the sixteenth annual ACM-SIAM symposium on Discrete algorithms*. Society for Industrial and Applied Mathematics Philadelphia, PA, USA. 562-571.

Jun Xiao et al.2008. Comprehensive method on evaluation of distribution network planning. In *Proceedings of the DRPT 2008, Third International Conference on Electric Utility Deregulation and Restructuring and Power Technologies*. Nanjuing (China), April 2008. 1249-1254.

Safari, M.A.; Salavatipour, M.R. 2008. *A Constant Factor Approximation for Minimum λ-Edge-Connected k-Subgraph with Metric Costs*. In: A. Goel et al. (Eds.): *APPROX and RANDOM 2008, LNCS 5171*, Springer-Verlag Berlin Heidelberg, 233–246.

Shimoda, Y. 2000. Heat source network and heat transport. *District Heating & Cooling*. 41(3): 3-5.

Suzuki, A.; Tokuyama, T. 2006. Dense subgraph problem revisited. In *Proceedings of the Joint Workshop "New Horizons in Computing" and "Statistical Mechanical Approach to Probabilistic Information Processing"*,18-21 July, Sendai, Japan. 1-2

Vassilevska, V.; Williams, R.;Yuster, R. 2006. *Finding the Smallest H-Subgraph in Real Weighted Graphs and Related Problems.* In: M. Bugliesi et al. (Eds.): *ICALP 2006, Part I, LNCS 4051*, Springer-Verlag Berlin Heidelberg, 262–273.

Session 8: Transport and Environment

THE INFLUENCE OF THE FLOATING ICE ON SHIP PASSAGE ON THE RIVER DANUBE AND THE STRUGGLE WITH ICE DURING THE WINTER

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Abstract: State with river waterways must, to some extent during the winter, think about ice and the impact on navigation on the river. Since the Danube is international waterway and part of corridor VII, ice in winter requires special attention. This paper generally contains everything you need to know about ice on the Danube (what is ice, how it occurs, what types there are, when it happens, how long it lasts and terms of navigation during ice stagnation and ice floating). Furthermore is explained how to break the ice on the river Danube, types of icebreakers and ice-blasting method. The paper is based on the ice on the Danube, and explains how to fight against the ice. There is a conclusion at the end of the paper how to fight back in order to prevent tragic events and reduce property damage.

Keywords: ice on the river, navigation in ice conditions, fight against the ice

1. Introduction

Ice is important for the morphology of the river bed and for the living world in rivers: the icebergs carried by the water stream hit the river banks and destroy them; they narrow their profile and thus cause deepening of the bed or flooding in the valley. The ice stops traffic on navigable rivers; the icebergs threaten hydrotechnical plants and buildings, such as piers, coast forts, dikes, dams, rivers and so on. The icebergs created in different ways are particularly dangerous. At some places, discharging small icebergs for any reason causes them to stop and pile which forms ice surfaces that can over time increase the upstream flow. The formation of free space between ice and water surface can be formed, as the water levels and temperature decline, in which are drawn the newly emerging icebergs. Because the water is not able to spread throughout the iceberg it leads to the formation of thicker ice that can sometimes reach a height of 10 m.

For certain sectors of the river, the ice is formed by freezing water in this place and in this part of the river bed, which is usually wide, where the current is much slower, and the flow is peaceful which make it is easier to freeze.

When the water level rises and the ice is suppressed with the upstream parts of the ice mass, the icy surface also moves. This situation can be a threat to downstream settlements in case of direct impact of icebergs.

2. The ice on the Danube

Forming the ice barriers in area of Đerdapska klisura causes an increase in the upstream water level of the Danube, which is why there is always a danger of flooding. There are three stages of ice formation on the rivers:

- forming of ice - the first forms of ice on the river,
- frozening of the river – surface ice on the river, and all things associated with the process and
- disclosure of rivers - the melting of the ice cover and the movement of the icebergs.

The development of ice on the Danube is related to the low temperature, if we are not talking about the ice that comes from the upstream section in the form of icebergs.

Outbreaks and icing speed is different depending on the start time, duration and value of low temperature, water temperature, then the speed and composition of the water, rainfall, wind and various other factors. Because of the way of water movement in the river, all the water has a uniform temperature and the ice first forms on the surface. Timing of the ice and icing speed of the stream are different form stream to stream. On the basis of previous studies it is known that the ice on the rivers is formed in the following way: the appearance of ice crystals occurs only when water temperature is from -0.01 to -0.05°C. The first ice crystals appear on the surface of the river and have a form of needles and thin plates. Forming of ice is impossible if there are no crystallization nuclei in the water - these are the tiniest crystals of ice or snow, they fall to the surface of cold river water from the cold air.[2]

By combining ice crystals on the surface of the river, thin and translucent glassy ice is formed, which melts into the rapids where mixing of water, whose temperature is dropped below 0°C, is intensive. Vitreous ice is appeared again in downstream sectors where the water is moving at a slower pace.

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[2] When crossing the water from a liquid to a solid state, latent heat of crystallization is released, this goes into the air thanks to continuously stirred water mass.

The movement of ice on the river is called floating ice, a period of movement is called floating ice period, while the appearance of ice stagnation, ie. when the stream is frozen, is called stagnation ice, and its period is known as period of ice stagnation.

Given the way of the formation of ice, there are: river ice, deep ice, icebergs and vedrac.

a) RIVER ICE is the kind of ice that occurs after several days of snow when temperature of water is 0°C. It is first created on the river banks, the stones and earth are bound in snow water mass which is than converted into the icy crust on whose surface snow continues to fall, and thus create blocks of ice that hinder navigation.
b) DEEP ICE is formed on the bottom of river bed.
c) VEDRAC occurs at very low temperatures, the most peaceful streams or stagnant waters (effluents, closed ports, etc.).
d) ICEBERGS are formed on the surface of the river and on their way they encounter various obstacles (shallow water, bridges and other carriers) where they are usually stopped.

Icebergs (Fig. 1) collide with each other and they pile up in the constriction of the river bed from coast to coast. As the icebergs continue to pile up the increasing pressure, to which contributes the speed of the water, crawl underneath one another, creating physical barriers - barriers several meters high. Such a pile of ice regularly leads to upstream flooding and downstream water level falls, and only icebreaker ships can cut or break this kind of ice. In some severe cases it is necessery even blasting of ice.

Fig. 1
Piling up of icebergs

3. Information regarding the ice and the navigation

Data containing ice characteristics are regularly registered in the profiles of hydrological stations, with the additional data of the thickness of the ice sheet in areas of congestion of the icebergs. These data are periodically collected, depending on the needs and available funds for this kind of research.

Base of the data processing mode of ice on navigable waterways is the analysis of the current state of the database registered in the past. As part of this analysis the following basic characteristics of ice regime are:

- the earliest date for the appearance of ice and ice stagnation
- the latest and average data of ice break and release the river of ice,
- maximum possible and the average duration of the presence of ice in river,
- the actual maximum and average duration of ice stagnation and ice floating period and
- annual probability of occurrence of ice and ice stagnation.

If some changes in natural river regime wil occur, there is the need for forecasting of ice changes. This is based on data registered in the past, using complex hydraulic and statistical methods.

Operating hydrometeorogical bulletin is issued by the Republic Hydrometeorological Service of Serbia which shows weather conditions, forecasts and warnings. Bulletin gives the status of all the ice on the rivers with the level of defense against ice, which can be ordinary or extraordinary.
When there is ice on all our waterways, navigation is interrupted, and the boats are packed and secured in winter homes[5] and winter shelters[6].

Boat in the winter home or in the natural shelter, exposed to ice, should be protected so that the icy crust around the ship breaks or cuts in order to avoid squeezing hull. If the vessel is found in open places under the influence of ice that moves, it is certainly going to suffer great harm, even sinking.

[5] Winter home is part of the water area outside the fairway of ships. Its main purpose is to protect ships during the winter and ice. As a rule, winter home is furnished and ready for accepting a larger number of vessels and provides shelter and safe returns of ships. Our known winter ports are Baračka, Novi Sad, Ivanovo and Kiseljevo
[6] Winter shelter are a natural place protected from the ice in the river backwaters, around the corner, on the fairway and similar to this. Winter shelter, regardless of the protection provided, includes special security measures.

Interruption of navigation lasts from 15 December of the current year until 1 March of the following year. The actual interruption of navigation due to ice on the Danube lasts for 38 days, and navigation in ice conditions on the waterway is permitted only to those vessels that are built according to special conditions for navigation in ice.

A state of emergency in case of accumulation of ice on the Danube is declared when the ice takes 60% of water and on the other rivers after the movement of ice. The danger arises when it comes to moving ice and formation of ice barriers also known as plugs. Ice plugs must be mined in order to prevent upstream flooding.

Autonomous navigation is possible only if the ice is broken and crushed, if the state of the ice field is favorable, and if the hull is strengthened for navigation in ice cowered waters.
Basically, whenever it is possible, if the ice appears, navigation should be avoided, especially at night, in fog, bad weather and similar. If the movement of ice is anticipated, navigation should be postponed.

4. Icebreakers

Ships - icebreakers (Fig. 2) are designed to break the ice on the waterway to allow navigation to other ships and to prevent the accumulation of ice and ice barriers. The hull icebreaker is strengthened by additional ribs and thicker plating. Icebreaker bow is oblique, in order to climb on the ice, which is then broken by the mass of the ship. The sides, at the water line level, are wider than the other ships. At the bow and stern of each icebreaker special tanks are built in order to increase mass. The tanks on the bow are filled in order to increase the mass of an ice breaking ship and the tanks on the stern are filled only when they need to create a stern ties, in case the icebreaker bow remains on iceberg and it should be moved. Icebreakers can have devices that cause a rocking boat in order to increase ice breaking. Vibrations are generated with special vibrating devices.

Fig. 2.
Icebreaker ship "Čakor" Company "Dunav agregati" from Novi Sad

In order to facilitate navigation through the waterway which is completely covered by an ice crust, ice must be broken in a separate track, which is achieved by icebreakers or other continuous sailing of ships. Icebreaker breaks ice creating a track, as wide as the ship, it sails forward – breaking ice with bow. The maneuver is performed as the ship rushes into the ice field to the point when it can not normally go forward. After that it goes backwards, and then repeats the above navigation and so on. Thus created track allows navigation of ships with a width smaller than the width of an icebreaker or ships similar capacities to icebreakers.

However, most track width should be two to three widths of icebreaker hull or ships similar capacities to icebreakers. In this case, the ice-breaker after the creating the center track goes backwards and break the ice on the left and right sides of the central track extending at an angle from the 45°.

In order to create track wider than an icebreaker for two to three times, one to two extra icebreaker can be used. In order to create tracks in conditions when ice thickness does not exceed 40 cm other ships such as tractors and pushers can be used.

5. Ice blasting

Ice blasting is done on the basis of pre-existing water management plan and other organizations, which compiles the data blasting purposes, as well as the condition of ice on rivers and in some sectors.

Before proceeding to a method of ice blasting, it is necessary to know the purpose of blasting, which implies what we want to accomplish by blasting. Therefore, measures are elaborated to protect certain important buildings from running ice or stationary ice, to prevent the increase in water level upstream areas, to maintaine traffic or to prevent the accumulation of ice floes in certain sectors of rivers.

If the object must be protected, then mining should cover 5-10 km upstream and 2-3 km downstream from the protected object. In this case, two-stage of ice mining can be applied.

The first stage is lifting of ice during icebergs period. Depending on the thickness of the ice and applied method, explosive can be accommodated on the ice sheet, or beneath the ice.[7]

Ice Drilling method are well known, but in this case length shouldn't be less than 1,5m and width not less than 0,2m.[8]

Depending on the thickness of the ice, explosive can be thrown on the ice or it can be put in the holes beneath the ice. Explosive charges must be fixed on a pole or rope and dropped under the ice.

If we want to increase the width of the surface that should be free of ice, additional charges can be used.

The explosion formes a hole, diameter approximately 3-8 lowering depth (W) under the ice. The cracks are formed outside this diameter, and therefore the distance between the charges takes up to 5W. If the depth of the river at the site of the charge installation is less than the arithmetic depths, then it is placed so that the distance from the bottom of the river load is not less than 0,5m. In this case, the distance between charges is determined depending on the actual depth of the placement of explosives. In all cases - near bridge or object abutments, the distance fromt the object to the location of mining should be at least $a=10\times3\sqrt{G}$, where a is the charge distance from the support, poles, buildings, and G is loading weight (kg).

In front of the bridge, 100m upstream and downstream, as well as under the bridge, the entire width of the river should be kept free. If the ice is formed in front of and behind the bridge, and if all bridge openings aren't free of ice, then there is a danger that the navigable river bed will be narrowed, and that icebergs will pille up. Due to the sudden pressure of ice on the support poles, they can be damaged or even destroyed in some cases.

It is especially important to accurately and promptly take actions on mining, which always have to be done the opposite of the movement of river flow, so that the ice plate is broken before the upcoming waves of water and that the ice can go before the waves.

For the purpose of the swelling groove of the moving ice, related to the width of the river (40 to 70m width), holes are made through the ice at intervals of 10m to 15m. Holes diameters of 30 to 40 cm are sufficient for this type of mining.

If you need to perform blasting near or under artificial objects, then the charge must be placed at least 3m from the observed object. The distance between holes is 3m to 5m. Explosive charges must not be larger than 0.300 to 0.500 kg.

Nearby the foundations of buildings with trusses, mining operations are not performed, because the pressure is transmitted through the water beneath the building, which can result in separation of the structural supports and bearing. Sometimes, even with great care and use of low charge such damage can not be avoided.

Moving ice in most cases creates piling-up, especially if large blocks of ice move. Therefore, faster chopping is needed. Explosive charges are thrown on the ice or between moving bergs from the shore or from bridges in order to crush the ice.
In order to free icebound vessels it is necessery to create holes in the ice at a minimum distance of 3m.

6. Conclusion

The ice on the rivers is a major threat; it can cause great damage and be dangerous for safety of people. Ice on rivers should be studied and monitored, necessary information should be given timely to all users of rivers and a strategy should be created to fight ice on the rivers.

References:

Dukić, D.; Gavrilović, Lj.; 2008. *Hidrologija*, Zavod za udžbenike, drugo izdanje Beograd. 386 p.

Operativni hidrometeorološki bilten. 2012. RHMZ, Beograd. Available from Internet: <http://www.hidmet.gov.rs>

Petrović, I. 2000. *Mala enciklopedija plovidbe*. MP Futura, Petrovaradin. 285 p.

[7] For this it is best to use waterproof blasting explosives protected in polyurethane tubes, boxes, bottles, etc.
[8] The grooves in the ice can be made with breaking rods, ax, pickaxe, drill or external charges. In order to make an explosion hole in the ice, it is necessary to set the charge on the ice or in the grooves created. For example, to create hole for the blasting of the ice over 30 cm thick, small dents must be made before the blasting.

METEOROLOGICAL AND OCEANOGRAPHIC DATA ON SELECTED ROUTES ON THE ADRIATIC

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Abstract: When choosing the optimal route navigation, except for information about the ship and cargo, timetable, etc., are essential meteorological and oceanographic data. Sources of this information may be current synoptic data from terrestrial, coastal, ocean and marine stations and previous multi-year data from different sources. This paper will present a contemporary way of selecting the optimal routes using vessels of modern shipping system for weather forecasting and long-term ship meteorological data.

Keywords: meteorological and oceanographic data, weather forecasting, ship routes

1. Introduction

Planning a voyage by ship in the modern navigation is made on the basis of the regulations and maritime skills that include the execution of the ship voyage, from the port of departure to the destination port. Itinerary must comply with the positive maritime practices and in line with the international and regional regulations, the regulations from classification societies, the national regulations, and the rules and instructions of the company (Jašić, et al., 2011). Most maritime accidents occur due to increasing traffic density, especially in the channels and approaches to major ports, reduced visibility, due gale to hurricane wind, moderate to extremely severe sea states, strong sea currents, sea ice, etc. Meteorological and oceanographic information present a spatial and temporal framework in which all activities place at sea. The adequate and thorough planning of voyage, including preparing the ship and adequate preparation of ship routes can often be the key element between safe sailing and a disaster. The STCW convention requires that the upcoming ship voyage is planned in advance, taking into consideration all the information necessary to make a ship journey safe and also acceptable from an economic point of view (Dexter and Parker, 2009).

2. Sources and methods of data analysis

For making this study data were used on the heights of the waves of the windsea and swell from ship meteorological reports from quadrants 1°x1° through which vessels routes pass, and the selected meteorological stations.

The data on the amount of waves from ship meteorological reports are often visually estimated data on the height of wind waves from wind sea (h_w) and swell (h_{sw}) expressed in half-meters. In case you had only the height of the wind sea or swell the mean wave height is calculated according to the Eq. (1), where $\overline{h_s}$ - mean height of significant wave height h, and N-total number of significant wave height.

$$\overline{h_s} = \frac{\sum_{i=1}^{N} h}{N} \tag{1}$$

That is, if at the same time the height of the waves of the wind sea and swell, when the difference between the direction of wave seas and swell was up to 30 °, the mean total height of the waves $\overline{h_s}$ is calculated from the Eq. (2).

$$\overline{h_s} = \frac{\sum_{i}^{N} \sqrt{(h_w^2 + h_{sw}^2)}}{N} \tag{2}$$

However, the maximum wave height was calculated using the Eq. (3).

$$\overline{h_s} = \frac{\sum \max(h_v, h_s)}{N} \tag{3}$$

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To be able to make a joint analysis of the waves from the marine, coastal and island stations, all wave heights from ship meteorological reports were turned into the state of the sea by the sea state rankings of the World Meteorological Organization. A certain number of wave data from ship meteorological reports crossed the expected values, and are therefore excluded from further processing. It should be emphasized that many of the analysis have shown that observers on ships usually underestimate the lower wave heights and overestimate higher wave heights. Because of non-continuous work of stations, data on the state of the sea, with coastal and island weather stations are usually in terms during day-time.

Original wave data from weather stations waves were visually evaluated according to the sea state of the World Meteorological Organization (WMO), the synoptic term schedule of individual stations (Table 1).

Table 1
Scale sea state

Sea state	Height in meters	Descriptive
0	0	Calm (glassy)
1	0 - 0,1	Calm (rippled)
2	0,1 – 0,5	Smoot (wavelets)
3	0,5 - 1,25	Slight
4	1,25 - 2,5	Moderate
5	2,5 - 4	Rough
6	4 - 6	Very rough
7	6 - 9	High
8	9 - 14	Very high
9	more 14	Phenomenal

3. Display weather conditions in selected routes

Typical winds on the Adriatic are bora and sirocco throughout the year, and “maestral” (Etesian and sea breeze) usually from April to September. In the time from June to September bora intensity decreased significantly, especially in the coastal area. The consequences of the wind are wind waves, which on the Adriatic can cause waves to the maximum sea state 7, which exceeds the maximum height over 10 meters.

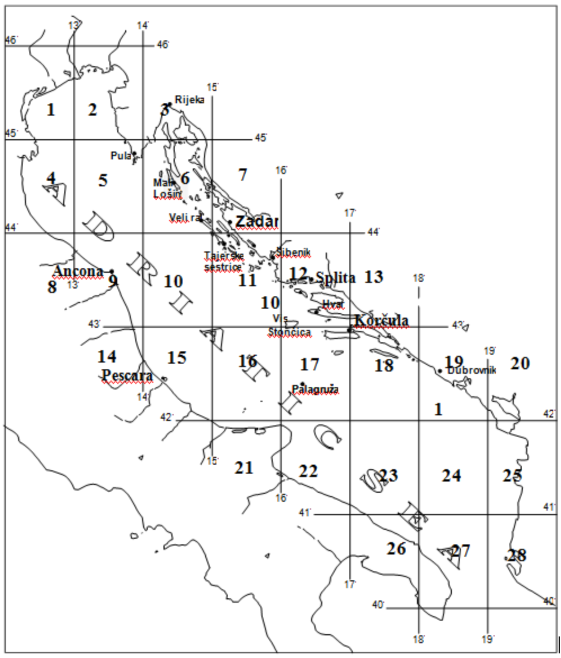

Fig. 1.
The division of the Adriatic Sea into squares (1°x1°) from 1 to 28

3.1. Navigation routes Split-Ancona-Zadar

For the analysis of the state of the sea on the route Split-Ancona-Zadar in the period from April to October ship data on the heights of wind sea and swell with the quadrant number 6, 7, 9, 10, 11 and 12 (1961-1990), (Fig. 1) sea state with synoptic stations Split-Marjan (1992-2001), Hvar (1999-2001) and Vela Sestrica and the lighthouse Stončica (island Vis) (Meteorological and Hydrological Service, Marine Meteorological Centre, 2002).

3.1.1. On navigation route Split-Ancona

The mean sea state on the route Split-Ancona (Table 2), is ranging from 1,4 (in August) to 1,9 (in April). The sea state is higher on the open sea than along the Adriatic coast. This is confirmed by the data from Stončica where the mean sea state ranges between 2, 2 (in April) and 1,6 (in May and August).

Table 2
The mean sea state according to ship reports (1961-1990) and reports from the stations Stončica, Hvar (1999-2001), Split-Marjan (1992-2001) and on the route Split-Ancona

	April	**May**	**June**	**July**	**August**	**September**	**October**
Quadrants: 9, 10, 11 and 12	1,9	1,5	1,4	1,2	1,5	1,5	1,8
Stončica	2,2	1,6	1,8	1,7	1,6	1,9	2,1
Hvar	2,0	1,6	1,7	1,6	1,3	1,7	1,7
Split-Marjan	1,6	1,4	1,4	1,4	1,3	1,5	1,6
SPLIT – ANCONA	1,9	1,5	1,6	1,5	1,4	1,6	1,8

The maximum sea state (Table 3) is in the range 5 - 7, usually with smaller states along the sea shore, and more in the open sea.

Table 3
Maximum sea state reports (1961-1990) and reports from the stations Stončica, Hvar (1999-2001), Split-Marjan (1992-2001) and on the route Split-Ancona

	April	**May**	**June**	**July**	**August**	**September**	**October**
Quadrants: 9, 10, 11 and 12	6	6	5	5	5	6	6
Stončica	7	5	5	7	5	4	5
Hvar	4	4	4	4	4	4	4
Split-Marjan	4	5	4	4	4	4	4
SPLIT - ANCONA	7	6	5	7	5	6	6

Intermediate state from ship reports and reports from the islands and coastal stations ranges from 1,3 to 1,8, while the maximum sea state, ranges from 5 to 7 (Table 4).

Table 4
Average and maximum sea state from ship reports (1961-1990) and reports from the islands and coastal stations (1992-2001), route Split-Ancona

	April	**May**	**June**	**July**	**August**	**September**	**October**
Average sea state	1,8	1,5	1,5	1,4	1,3	1,6	1,8
Maximum se state	7	6	5	7	6	6	6

On the ship route Split-Ancona, according to the ship meteorological reports (Table 5), the maximum wave heights range from 3,5 m (in July) to 5,5 m (April and October).

Table 5
The maximum wave height (m) according to the ship meteorological reports (1961-1990), the ship route Split-Ancona

Quadrants: 9, 10, 11 and 12	**April**	**May**	**June**	**July**	**August**	**September**	**October**
SPLIT - ANCONA	5,5	4,2	4,0	3,5	4,0	4,7	5,5

According to the reports from the ships (quadrants: 6, 7, 9 and 10) and the island's meteorological station Vela Sestrica (Table 6), medium sea state ranged from 1,3 (in July and August) to 1,8 (in October) according to the sea state from WMO scale.

Table 6
Intermediate state has to ship reports (1961-1990), and the island stations Sestrica Vela (1992-2001), the route Ancona - Zadar

	April	May	June	July	August	September	October
Quadrants: 6, 7, 9, 10	1,5	1,4	1,3	1,2	1,3	1,5	1,8
Vela Sestrica	1,7	1,4	1,5	1,4	1,3	1,6	1,8
ZADAR-ANCONA	1,6	1,4	1,4	1,3	1,3	1,6	1,8

According to the Table 7 the maximum sea state on navigation route Zadar-Ancona is in the range from 5 to 6.

Table 7
The maximum sea state by ship reports (1961-1990) and island stations Vela Sestrica (1992-2001), a ship route Zadar-Ancona

	April	May	June	July	August	September	October
Quadrants: 6, 7, 9, 10	5	5	5	6	6	6	5
Vela Sestrica	6	5	5	4	4	5	5
ZADAR-ANCONA	6	5	5	6	6	6	5

The maximum significant wave heights is in range from 3,0 m (in October) to 5,0 m (in April, July and August) at the route Zadar-Ancona (Table 8).

Table 8
The maximum wave height (m) according to ship meteorological reports (1961-1990), ship route Zadar-Ancona

Quadrants: 6, 7, 9, 10	April	May	June	July	August	September	October
ZADAR- ANCONA	5,0	3,0	4,0	5,0	5,0	4,7	3,6

The results of analysis of ship route Split - Ancona - Zadar show that the mean sea state (Table 8) in the period from April to October ranges from 1,3 (in July) to 1,8 (in April and October), and the maximum sea state (Table 9) is in the range from 5 (in June) to 7 (in April and July), according to the WMO scale of sea states.

3.1.2. Ship Route Split-Ancona

Table 10
The frequency (%) of sea states according to ship reports (1961-1990) and reports from the island and coastal stations (1992-2001)

Hvar (1999-2001), the ship route Split-Ancona-Zadar	Sea states according to WMO								
	0	1	2	3	4	5	6	7	Sum
Quadrants: 6, 7, 9 and 10,	21,71	0,05	47,33	12,84	16,35	1,45	0,27	0,00	100,0
Quadrants: 9, 10, 11 and 12	20,41	0,05	47,07	13,31	17,64	1,31	0,20	0,00	100,0
Stončica	6,24	31,46	35,95	20,55	5,22	0,53	0,01	0,04	100,0
Vela Sestrica	7,70	47,40	31,35	9,87	3,00	0,65	0,03	0,00	100,0
Split_Marjan	0,22	61,38	27,47	10,00	0,93	0,01	0,00	0,00	100,0
Hvar	0,50	45,32	38,94	14,55	0,69	0,00	0,00	0,00	100,0
Split – Ancona –Zadar	9,46	30,94	38,02	13,52	7,31	0,66	0,09	0,01	100,0

On the ship route Split - Ancona - Zadar sea state is usually 1 and 2 (68,96%), and a maximum of 7 (0,01%), while the calm appears in 9,46%, Silence on the ship meteorological reports, accounting for about 21,71% and 20,41%, depending on the area. Comparison of the actual mean (according to the reports of island and coastal stations: Stončica, Vela Sestrica, Hvar and Split-Marjan) and forecasted sea state according to the Marine meteorological reports of Maritime Meteorological Center of DHMZ in Split for the period 1992-2001, for the area of route Split-Ancona-Zadar is shown in Fig. 2.

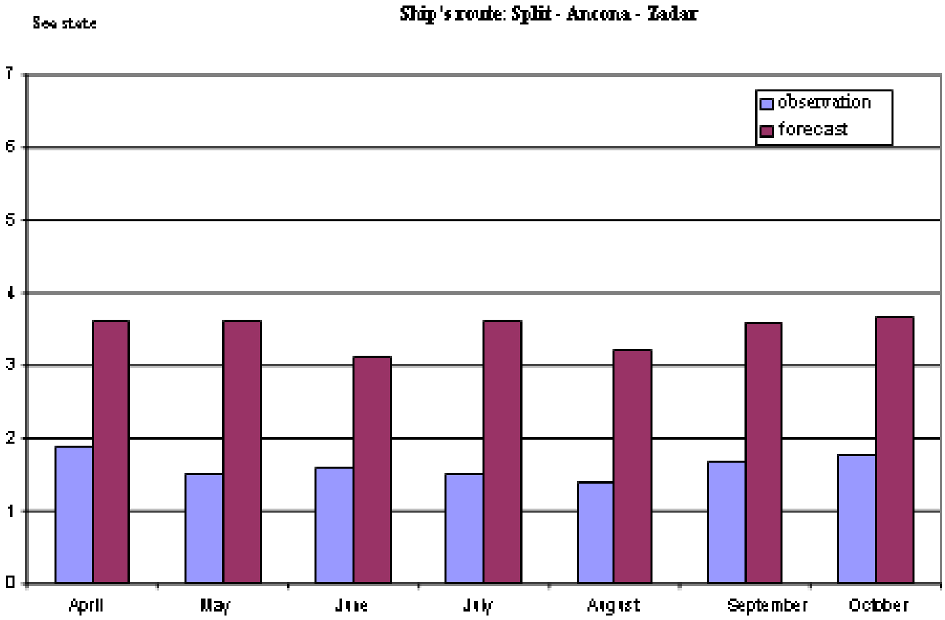

Fig. 2.
The mean and forecasted sea state by marine meteorological reports of Maritime Meteorological Center of Split (1992-2001), ship route Split-Ancona-Zadar

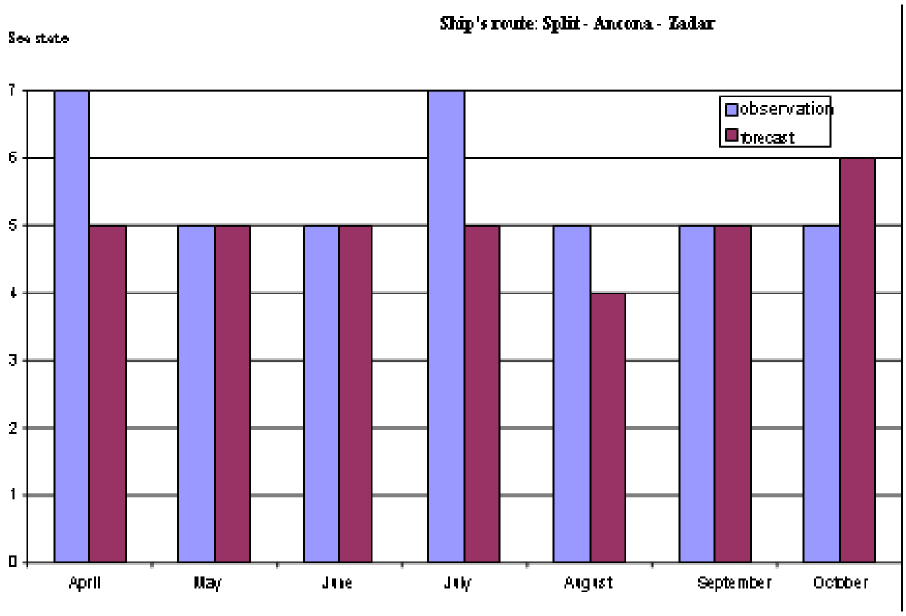

Fig. 3.
Maximum actual and forecasted sea state by maritime weather reports of Maritime Meteorological Center of DHMZ in Split (1992-2001), ship route Split - Ancona - Zadar

From comparison of the data on the mean real and forecasted sea conditions in Fig. 2, it can be concluded that the forecasted mean sea state is generally more than doubled than it has been recorded at the actual coastal and island stations at the same time. In contrast to the above, the maximum actual and forecasted sea state (Fig. 3) in the majority of cases is in good agreement. The largest differences exist in the forecasted sea state 6 and 7 in April and July. Comparison of the maximum actual sea state (according to reports of island and coastal stations) and forecasted sea state for this period is shown in Fig. 3.

3.2. Ship route between Vis and Korčula and Pescara

Data of wind speed and direction, wave height and its direction and visibility are based on marine meteorological measurements and observations with all the ships involved in the scheme of the WMO voluntary measurements and observations on ships (SDMOB), which sailed on the waters that affect navigation routes in the period 1961-1990. Data were first analyzed by quadrants. On the winds rose for the ship route between the island of Vis and Korčula on the east coast and Pescara on the west Adriatic coast there are three predominant wind directions (Table 11), with frequency of NW wind 21,58%, SE wind 11,82% and frequency of the NE wind is 6,22%, Silence occurs in 22,38% of cases (Meteorological and Hydrological Service, Marine Meteorological Centre, 1999).

Table 11
Frequency of wind direction and strength in % between the island of Vis and Korčula on the east coast and Pescara on the west coast of the Adriatic from June to September

	Calm	1-3 Bf	4-5 Bf	6-7 Bf	8-9 Bf	10-11 Bf	12 Bf	SUM
N		4,18	1,10	0,24				**5,52**
NNE		2,04	0,49	0,03	0,02			**2,58**
NE		4,90	1,11	0,21				**6,22**
ENE		0,87	0,13	0,03				**1,03**
E		3,58	0,48	0,06				**4,12**
ESE		2,07	0,73	0,10				**2,89**
SE		9,51	2,13	0,14	0,03			**11,82**
SSE		2,02	0,72	0,06				**2,80**
S		2,34	0,41	0,05				**2,80**
SSW		0,37	0,21	0,02				**0,59**
SW		1,35	0,22					**1,57**
WSW		0,52	0,10					**0,62**
W		3,72	0,25	0,06		0,02		**4,06**
WNW		3,26	0,80	0,06				**4,12**
NW		18,67	2,78	0,11	0,02			**21,58**
NNW		3,51	1,03	0,10				**4,64**
TIŠINA	22,38							**22,38**
SUM	**22,38**	**63,58**	**12,69**	**1,27**	**0,06**	**0,02**	**0,00**	**100,00**

Although in the Table 11 there is no wind frequency with strength of 12 Bf, however, climatologically and synoptic data show that in this period of bora and jugo winds, and during a storms along the coast in the afternoon and evening, the wind can have strength of 12 Bf, but periods with such strength are relatively short.

Analysis of wave data on the navigation route between the island of Vis and Korčula on the east coast and Pescara from June to September show that waves with a significant wave height can be > 3,5 m, in Table 4 shows that there may be a significant wave height > 4,0 m with frequency of 0,05% from the N and NNE direction.

Table 12a
The frequency of direction and significant wave height in % between the islands Vis and Korčula on the east coast and Pescara on the west coast of the Adriatic, from June to September

	0-0,1 m	0,2-1,5 m	1,6-2,0 m	2,1-3,0 m	3,1-3,5 m	3,6-4,0 m	>4,0 m	SUM
N	1,37	3,82	0,13	0,08			0,02	**5,42**
NNE	0,79	1,70	0,03	0,02			0,02	**2,55**
NE	1,57	4,70	0,12	0,02				**6,39**
ENE	0,38	0,68		0,02				**1,07**
E	1,45	2,64	0,02					**4,10**
ESE	0,59	2,04	0,05	0,07				**2,75**
SE	2,83	8,80	0,15	0,05				**11,83**
SSE	0,61	2,09	0,08					**2,78**
S	0,89	1,81	0,03					**2,74**
SSW	0,15	0,41						**0,56**
SW	0,58	1,02						**1,60**

Table 12b

The frequency of direction and significant wave height in % between the islands Vis and Korčula on the east coast and Pescara on the west coast of the Adriatic, from June to September (continued)

	0-0,1 m	0,2-1,5 m	1,6-2,0 m	2,1-3,0 m	3,1-3,5 m	3,6-4,0 m	>4,0 m	SUM
WSW	0,21	0,38						**0,59**
W	1,65	2,31	0,05	0,02				**4,02**
WNW	1,27	2,65	0,07					**3,99**
NW	6,67	14,85	0,10	0,03				**21,65**
NNW	1,25	3,11	0,07	0,03				**4,47**
TIŠINA	22,97							**22,99**
PROMJ,	0,36	0,13						**0,49**
SUM	**45,59**	**53,14**	**0,89**	**0,33**	**0,00**	**0,00**	**0,05**	**100,00**

The most common visibility on this route (Table 13) is between 1 and 10 km (56,63%), then a group of visibility of 20 km (40,89%), Visibility class 1-10 km is most common in the Split area (64,2%), Visibility of 50 km or more occurs in 2,34% of cases. The frequency of visibility from 50 m to 1 km is only 0,14%.

Table 13

The frequency of visibility in % between the island of Vis and Korčula on the east coast and Pescara on the west coast of the Adriatic, from June to September

<50 m	50 m- 1 km	>1 km -10 km	20 km	>=50 km
0,00	0,14	56,63	40,89	2,34

3.3. Modern systems for navigation planning

There are several kinds of marine systems to show weather and optimize navigation, and because of their number, only those among the best that have efficient functions are most commonly used on ships (Trošić, et al. 2012):

- BonVoyage System (BVS), Applied Weather Technology, USA, 2009 (www.awtworldwide.com)
- SPOS - „Master the weather", ver. 7, Meteo Consult, Nederland's, 2009 (www.spos.eu)
- Orion Pro, WNI Oceanroutes, Weathernews Americas Inc., SAD, 2003(www.oceanroutes.com)
- OCTOPUS, Amarcon BV, Nederland's, 2010 (www.amarcon.com).

Among them BonVoyage System stands out, which represents a powerful computing applications developed by the company Applied Weather Technology Inc. for the optimization of ocean navigation and increase of marine safety and ship performance, The application enables the simulation of navigation, ship speed reduction scheme under the influence of wind and waves, and behavior of the ship in the specific conditions of wind, waves and currents on navigation route. BonVoyage predicts ship speed over ground and arrival time, and calculates the courses and distances along the route.

The program shows weather and climatological data by which to navigate and help in the planning of navigation in accordance with specific requirements. BonVoyage can optimize the sailing route based on the latest forecasts and specific operational criteria such as the arrival of a certain time, save fuel, or sailing in the shortest time, avoiding certain restrictions and more. BVS can run on IBM compatible computers. Prognostic information from AWT's can be received via INMARSAT satellite system and e-mail. Time data are updated four times a day. Meteorologists review obtained meteorological and oceanographic data from various sources and institutions and include them in BonVoyage system BVS system allows display of air pressure, surface wind (10-min average wind speed and direction in the form of symbols at 10 m above sea level; heightmap at 500 mb, the wind waves, swell waves, significant wave height, information on tropical weather satellite images, the general current, specific currents, iceberg and pack ice, general currents, sea surface temperature, visibility, ice accumulation on the vessel and the type of weather from the various models and sources. BVS has built-in procedures for calculations: parametric rolling; synchronous rolling; high waves groups; broaching / surf riding Fig. 4.

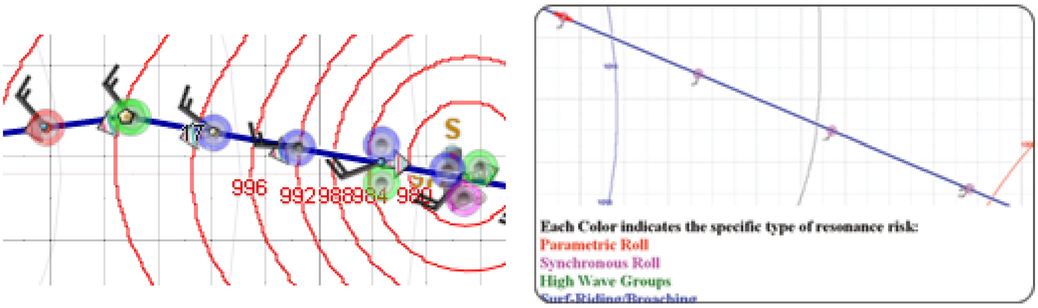

Fig. 4.
Potential areas that resonances on navigation route

4. Conclusion

During voyage planning it is necessary to have reliable and adequate meteorological and oceanographic data, climatologically and prognostic. Also, the choice of adequate vessels on certain routes and the season in which the vessel is to be used, it is necessary to dispose of high-quality information, in order to select an appropriate vessel. More reliable data increase the safety and efficiency of navigation. Integrated navigation systems with reliable systems for planning of maritime travel, with actual and forecast meteorological and oceanographic data, and forecasted and actual responses of the ship at rough sea, this provides an increase in the safety of crew and passengers, cargo and the environment.

References

Dexter, P.; Parker, F. 2009. Meteorology and marine transportation, *WMO Bulletin* 58(2): 111-117.

Jašić, D.; Belamarić, G.; Trošić, Ž. 2011. *Planning navigation voyage*. The University of Zadar, Croatia. 148 p.

Meteorological and Hydrological Service, Marine Meteorological Centre. 1999. *Maritime climate studies for navigation route between Long Island and Lošinj on the east coast and the west of Ancona on the Adriatic coast and the islands of Vis and Korčula on the east coast and the west coast of Pescara on the Adriatic coast.* Split, Croatia.

Meteorological and Hydrological Service, Marine Meteorological Centre. 2002. *Report on the state of the sea areas of navigation routes, Split-Ancona-Zadar; Pula-Venzia, April-October.* Split, Croatia.

Trošić, Ž.; Antonić, R.; Kos, S. 2012. Modern systems to increase safety and efficiency of marine vessels in heavy sea conditions,. In Proceedings of the *20th International symposium on electronics in transport*, M5.

SUSTAINABILITY WHEN DEVELOPING RETURN CENTERS

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Abstract: In its very beginnings sustainability was referred only as environmental issue. Supply chain strategies nowadays are green strategies, and the result of the need for a perfectly closed supply chains. Greening the supply chain is a tendency to minimize environmental impact of all activities in supply chain, and can be observed as a foundation for sustainable one. Reversing the supply chain includes activities based on tendency to capture value or to properly dispose goods that were returned to logistic distribution chain. Reverse logistics can provide improved customer satisfaction, raise level of environmental conscience and to keep profit inside company (by reducing costs). Reverse logistics activities are also implemented to keep up with new law regulations. When returning the products, company can implement a return centre, in a form of a new facility or a part of existing warehouse. Development of a return centre can result in optimized processes and can provide maximal possible value for each returned product.

Keywords: sustainable practices, distribution chains, reverse logistics, return centre

1. Introduction

In the area of product returns, one of the key elements of the chain are return centres that can be organized as separate elements or operate within the existing warehouse capacities. The return centres, that unify transport and logistics services, simplify the return procedure and the selection of channels in which the product will achieve the maximal possible value. Return centres organization must be proposed from the aspect of required storage capacity, acceptance, storage, classification and forwarding, must optimize the process for products in return, increase the level of customer satisfaction, and to reduce the amount of products unnecessary directed to landfills.

Every organized return centre must be in co ordinance with existing distribution chain and companies reverse logistics strategies. Before defining a reverse logistics chain company should track information about existing return. This information includes amounts and quality of product in return, disposition cycling time and level of consumer's satisfaction, reverse logistics channels and activities. To develop a return centre should be observed from product in return aspect (its specifications), but also from financial resources aspect. One cannot invest in infrastructure before defining needed activities and potential locations of return centre. Investing in a new return facility can provide unnecessary costs if reverse logistics strategies and activities are not well defined.

2. Sustainability as a foundation for reverse logistics concepts

Greening the supply chain is a tendency to minimize environmental impact of all activities in supply chain, when reversing it includes activities based on tendency to capture value or to properly dispose goods that entered again logistic distribution chain. Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Logistics sustainability is a goal that needs to be achieved. Not only as a business goal, is it a trend and a need because of (over) used resources and amount of everyday environmental impact that must be reduced. From the product return aspect sustainability can be partially achieved by reusing, reselling, recycling everyday products rather than disposing it.

Strategies of sustainable development are directed toward industry because of great impact caused by logistics party. Different authors implicated that reverse logistics is a foundation for construction of sustainable logistics, but it is only one aspect and congregation of processes that needs to be sustainably developed in a way to support it.

Today, every company should have at least some parts of their business "greened" because of several reasons. Not implementing the green logistics companies can affect their brand value, miss resources and paying penalties due to more rigorous regulations. There are numerous areas throughout the supply chain where sustainability can be implemented. Implementing sustainability requires a great deal of creativity; however, the benefits that can result are well worth the effort. (Dey, et al., 2010).

Foundation of sustainable logistics is green logistics that includes greening the processes of all parts of supply chain. Creation of sustainable processes inside manufacturing, manipulation, transport, packaging, etc. will ensure greening the supply chain. (Bajor, et al., 2012).

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3. Reverse logistics for products in return

Reverse logistics appears as a concept at the end of 80s of the last century and at the beginning of the 90s activities and flow of goods in return are beginning to be researched. Reverse logistics is defined as the movement of goods (raw materials, components or finished products) in reverse, from the final destination to the source, in order to facilitate the implementation of reverse logistics activities (processing, repair, remanufacturing, refurbishment, reprocessing, reuse, recycling or disposal). In addition to the movement of goods, to the reverse logistics belongs the management of return which means all processes regarding recovery or prevention of the formation of the goods in return, disposal at end of life, sales, etc. (McKinnon, et al., 2010).

In logistic systems two reverse logistics concept are considered, return of packaging and directing the products in return. In contrast to the distribution logistics, part of reverse logistics intended for directing products in return, is involved in evaluating and redistribution of single item and its current condition resulting in higher levels of complexity of managing reverse flow which beginning is usually created by the user (Rogers and Tibben – Lembke, 1998).

Proper selection of activities which are going to be implemented depends on the kind of products that the company offers, and on strategy that is set as the primary objective for company. Companies that are strategically focused on customer satisfaction, profit or monitoring the legal regulations will adjust the activities for products in return to its strategic goal. Any combination of reverse logistics activities should result in one or in businesses at the highest level of the organization reverse logistics, with all three business objectives. When a product is returned, it can be redistributed in order to achieve the highest possible value of the product in one of the channels of reverse logistics. Activities and reverse logistics channels are shown in Fig. 1.

Fig. 1.
Basic reverse logistic activities and channels
Source: Prepared by the authors

Location of product returns and unfolding of reverse logistics activities is a prerequisite for organizing the collection centre and it is needed to conduct research on the current location of return in order to determine the capability and manner of introduction. In medium developed logistics systems, such as in Croatia, uniform procedures for the return are not specific, and final costumer often return products to different locations, although the most common location of return is a point of purchase or retail level. At the retail level, 76% of respondents return the product, while 10% of respondents return a product to authorized service provider, as shown in the graph below. Final costumers find it logical to return the product to place of purchase, even though research has shown that from the point of return (retail level), 16.5% of the respondents were directed to return the product to another location. Directing users to perform return at another location, except that increases dissatisfaction of costumer with service users, it affects also the time of disposition. Final costumers, who had to return the product at another location other than dissatisfaction with the service, noted the lack of information about the ways, ie, the procedure in the case of a return. (Bajor, et al., 2012).

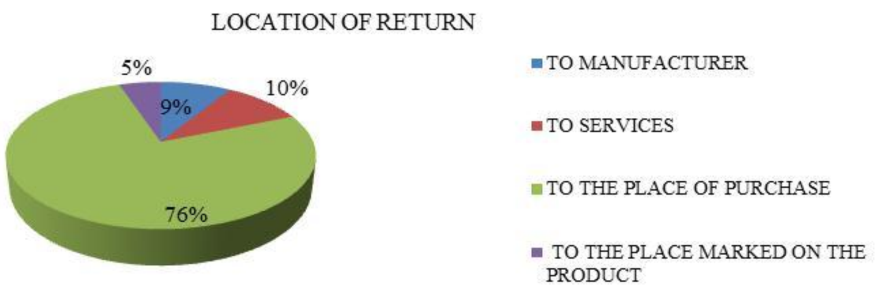

Fig. 2.
Study conducted on the location of product returns to Croatia
Source: Bajor, I., Babić, D., Ivaković, M.: Sustainability through greening and reversing the supply chain

4. Centralized return centres

Centralized return centres are advanced warehouses specifically modified to oblige the needs of the returned goods processes. These centralized return centres provide efficiently and expeditive performance for each returned product. Every product that is returned because of some reason is immediately directed in one of these centres. When entered the process this product is valued, directed to some of the activities if needed (packaging, refurbishment, etc.), processed and then shipped to the next destination. When constructed, CPC can provide benefits to the entire reverse logistics network from various sources like simplified store procedures, reduced store level costs, reduced shrinkage, reduced landfill, etc. (Rogers and Tibben – Lembke, 1998).

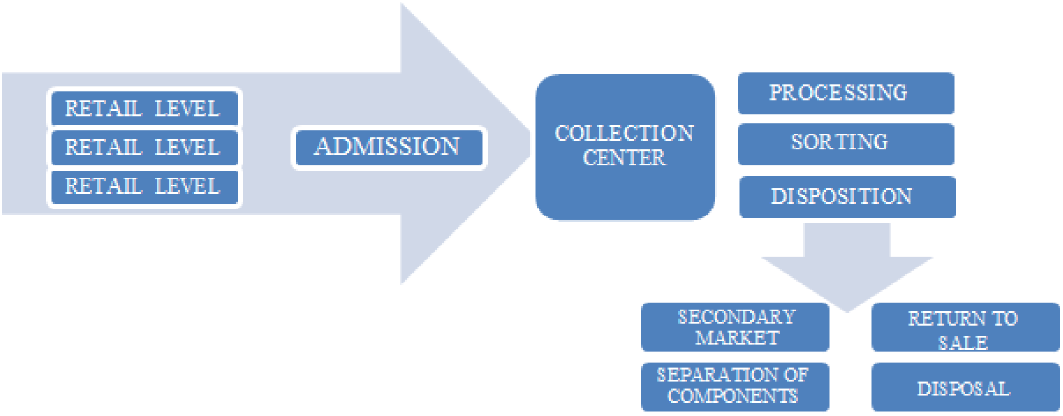

Fig. 3.
The concept of collection centres
Source: Prepared by the authors

One of the benefits that can affect at the quality of the reverse logistics system when CRC is established is knowledge. When working only in CRC employees have varieties of returned products to deal with, than they would ever experience at a retail store. Employees will in this way develop areas of expertise, which can greatly benefit the firm. Except of the educated personnel this centralized processing model will with unified procedures grant fewer errors. Many of the benefits appear to be due to the fact that this allowed the returns processing staff to focus solely on returns. Reverse logistics issues in Croatia are based on unorganized processes dedicated for handling returned goods from any point of supply chain. When returned product encounters established logistics system it is very often handled inappropriate and preceded to the distributers. (Rogić, et al., 2010). Collection centre in Croatia is not recorded, but the products are usually stored in a particular part of the distribution warehouse. In the warehouse activities are not carried out and sometimes product can be stored over a month until further guidance infrequently only to the landfill after a cursory evaluation of the non-educated employees. The results are presented in Fig. 4.

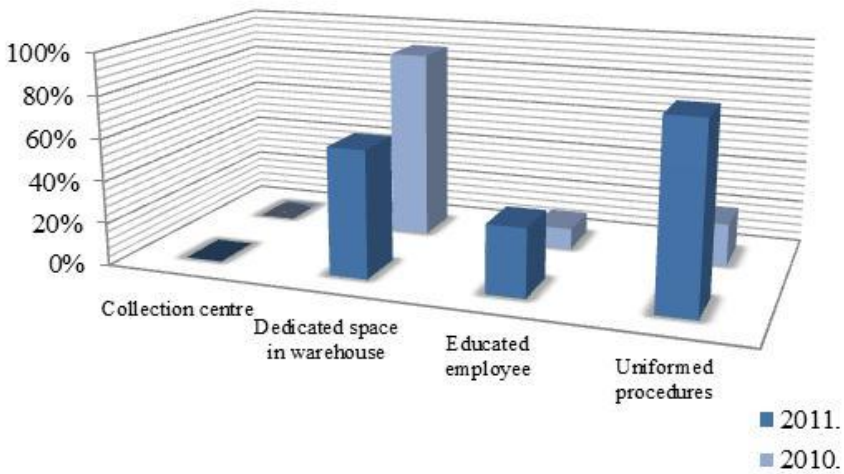

Fig. 4.
Conducted research in Croatia
Source: Prepared and adapted by the author

If companies want to improve an existing return system or certain activities, instead of the huge initial investment in building a collection centre, training of employees and changes in the business, the system can be improved in a way by using the services of external service providers, in the form of conducting certain activities (partial) or whole return system. With the application of this principle, companies can save up to 10% of their total costs.

5. Processing in the collection centres
In centralized systems with collection centres four basic processes designed for products in return are held:

Admission means that the company receives a report of damage by the final consumer, and then the product itself and the right to control and direct its future in return. Admission is carried out at the retail level or directly in a collection centre. If the reception is at the retail location, it also includes the transport process of the products in the return to a collection centre.

Processing products include checking documentation, fulfilment of the necessary documentation, obtainment of necessary information if the existing are insufficient, and further directing entity. When processing, the employees can make the decision to compensate the final costumer in the form of a new product or in refund. Processing of the products is very important for verifying the supporting documentation and collection of data relevant to the monitoring of trends and the amount of return. Verification of supporting documents is relevant to the justification of further guidance and input into the tool storage system (gate keeping).

Sorting is a process which involves the physical management of product in return. The process includes inspection, categorization of products in return and assignment of temporary storage location.

Disposition means the final process in a collection centre for products in return, where on the basis of processing (documentation) and sorting (inspection and classification) decisions is made about their future guidance. The product can be sent directly to the reverse logistics channels or certain activities can be carried out on them. Reverse logistics channels are organized different in different companies and their selection and choice of reverse logistics activities depends largely on the type of product in return and their potential for further guidance. In this process it is possible to return a product to sale, repack it, fix it, direct it to the secondary markets, delay it, etc.

Defining potential reverse logistics activities and channels in which products in return will be directed for achievement of the highest possible value, depends on the type of product recovery and state of goods.

The life cycle of the product is also conditional on the selection of the concept of return. From the standpoint of the level of value deterioration it is necessary to adapt the activities in a collection centre and return chain for the product in return. The products are divided into two basic categories, shown in Fig. 5. The first category consists of products with a high level of value loss per unit of time, such as computers, while the second consists of products with low value loss per unit of time. Product category with low loss values represents products such as refrigerators with a life expectancy in households with up to five years.

Products in return various categories are returned to the collection centre and it is necessary for them to provide a variety of activities and define the optimal concept of return, as shown in Fig. 6 which will be consistent with the achievement of the maximum possible added value. For products with high level of value deterioration is necessary to adapt all activities to reduce the time of disposition, whereas for products with low loss values is necessary that activities in a collection centre are efficient and not time limited.

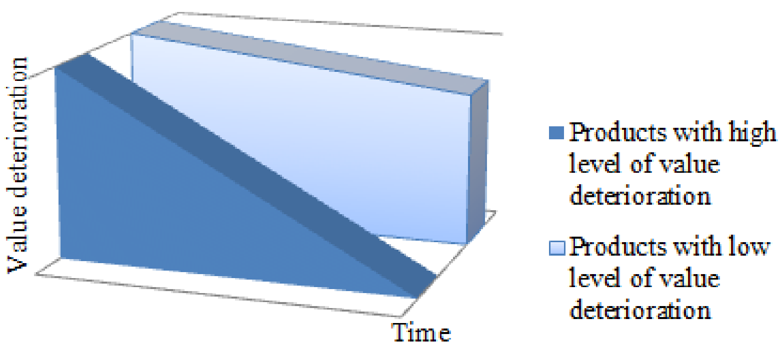

Fig 5.
Life cycle of two product categories
Source: Prepared and adapted by the author

Fig. 6.
Organization of reverse logistics activities to optimize the aspect of the product value deterioration
Source: Prepared and adapted by the author

The life cycle of the product complies with the accompanying warranty that usually guarantees the correctness of the product in its first stage of the life cycle, and the possibility of product failure is extremely small, i.e., it decreases from the moment of putting the product on the market. The level of possible malfunction of the product at the beginning of the first phase is high, then declines constantly in the second phase, and in the third phase is continuously growing.

The collection centre, the products in return are returned to the system at various stages of the life cycle, and it is necessary for all potential phases to allocate a possible channel and reverse logistics activities designed to achieve the maximum possible added values of product.

Product evaluation is performed by educated employee on whom further guidance to the activities and channels of reverse logistics in which the product in return achieve maximum possible value depends. Trained employees must know the specifications of potential products in return, and the value of product when placing it on the market, outlet, etc.

6. Conclusion

Because of the specificity of return systems for processing a single item, the aim is to harmonize the process that is more complex when the decision about the status of the product is made at the retail level due to the mixing of distribution and return processes, motivation and education level of the key personnel.

This harmonization is achieved by organizing a collection centre in which activities of reverse logistics will be carried out (it is possible to introduce and lock channels) for products in return. In systems, typical for Croatia, large quantities of completely non defective defectives products and products that because of the various reasons should not enter the system (insufficient documentation, return in the wrong system, etc.) come to entry points of return systems. In addition to large quantities of the product in the system, because of poor organization of flow and channels of reverse logistics and non-educated employees, the return of the product at the retail level increases the number of transport and handling processes, costs of company, reduces the possibility of reuse (product or its components) and affects the level of customer satisfaction due to the extension of disposition time.

If the investment in the organization collecting centre is considered unnecessary, the company may use the services of external providers. The advantages of using external service providers is the fact that they have developed a network for potential stock purchase that allows them to sell large quantities of goods and avoiding prolonged disposition time. Because of the basic activities, collection centres in the form of external service providers automate the processing, sorting and disposition, and track product bar codes in order to shorten the disposition time and track products in return.

Key elements of green and sustainable logistics include sources reduction/conservation (minimal use), recycling (reuse), substitution (use of environmentally friendly products) and proper disposal. Sustainability is possible if it is based on environmentally friendly concept that has the ability to upgrade. In addition to organizing sustainable business foundation, it is necessary to educate final costumers so they can be actively included in creation of long term environmentally friendly green logistics chain.

Organization of return centres as green processing points can result with benefits because a set of small movements will create and lead to major advantages providing safety for the environment and sustainable upgradable reverse chain.

References:

Bajor, I.; Babić, D.; Ivaković, M. 2012. Sustainability through greening and reversing the supply chain. Available from Internet: http://logi.upce.cz/issues/2012-02/bajor-babic-babic.pdf.

Bajor, I.; Jurčević, M.; Babić-Ivaković, M. 2010. Human Resources Management in Reverse Logistics Operations. In Proceedings of the *7th Russian Scientific and Technical Conference „Polytransport Systems“*. Novosibirsk, Siberian Transport University: 10 – 11.

Dey, A.; LaGuardia, P.; Srinivasan, M. 2011. Building sustainability in logistics operations: a research agenda. *Management Research Review*, 34(11): 1237 – 1259.

Ivaković, Č.; Bajor I.; Rožić T. 2010. The Concept of Disposition of Returned Goods in Reverse Logistics Channels. In Proceedings of the *13th International Conference on Transport Science: Maritime, Transport, and Logistics Science*, Portorož, Slovenia: 195-199.

McKinnon, A.; Cullinae S.; Browne, M.; Whiteing, A. *2010. Green Logistics: Improving the environmental sustainability of logistics.* The Chartered Institute of Logistics and Transport, Kogan Page. 384 p.

Rogers D.S.; Tibben – Lembke R.S. 1998. *Going Backwards: Reverse Logistics Trends and Practices*. Reverse Logistics Executive Council, Pittsburgh, USA. 280 p.

Rogić, K.; Bajor, I.; Rožić, T. 2010. Consumer as a Part of Reverse Logistics Chain, In *Annals of DAAAM for 2010 & Proceedings of 21st International DAAAM Symposium "Intelligent Manufacturing and Automotion: Focus on Interdisciplinary Solutions"*, Zadar, Croatia: 27-28.

Rogić, K.; Bajor, I.; Rožić, T. 2010. Reverse Logistics Operation as Element of Warehouse Management, In Proceedings of the *13th International Conference on Transport Science: Maritime, Transport, and Logistics Science*. Faculty of Maritime Studies and Transport, Portorož, Slovenia: 507-511.

Tuzkaya, G.; Gülsün, B. 2008. Evaluating Centralized Return Centres in a Reverse Logistics Network: An Integrated Fuzzy Multi-Criteria Decision Approach, *International Journal of Environmental Science and Technology*, 5(3): 339-352.

Wang, H.F., Gupta S.M. 2011. *Green Supply Chain Management: Product Life Cycle Approach*. McGraw Hill Companies. 384 p.

IMPACT OF WEATHER CONDITIONS ON THE CONSTRUCTION OF THE TERMINAL - MONTE CARLO SIMULATION

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Abstract: A simulation model is developed for the potential planned Patagonia and Tierra del Fuego terminals. The purpose is to identify the reliability and availability of the loading operation in the terminal. The harsh weather conditions, technical reliability and concurrent traffic prevent LNG (Liquefied natural gas) Carriers for approaching or loading. Probabilistic simulation method is created and Monte Carlo simulations carried for several cases where the production, number of jetties and terminal storage is varied. The results indicate the high importance of the weather restrictions and conclude for the recommendation of two loading jetties and larger volume of the storage capacity.

Keywords: terminal, weather conditions, technical reliability, simulations.

1. Introduction

The main result from study will be the quantified probability of failure of loading operation based in certain selected inputs of the system and probabilities of the weather and operability failures. Such a result is typically useful to decision-makers who can utilize the simulation results to support their decisions.

In order to support the decision making the information of potential unreliability in loading operation is important. There is not much practical experience of such operation which is planned for Patagonia and Tierra del Fuego, and therefore the study to estimate this issue has been requested. Finally, most of the new potential reserves that exist in Argentina are in the south of the country (in Patagonia and Tierra del Fuego), offshore, areas of difficult access requiring a large investment that Repsol YPF was neither interested in nor in a financial situation to make. Instead the company gave preference to utilizing its large reserves in Bolivia that were much easier to access.

It is possible to quantitatively represent uncertainties in simulations. Probabilistic simulation is the process of explicitly representing these uncertainties by specifying inputs as probability distributions. If the inputs describing a system are uncertain, the prediction of future performance is necessarily uncertain. That is, the result of any analysis based on inputs represented by probability distributions is itself a probability distribution. This type of the probabilistic simulation is often referred as Monte Carlo method and is selected to be used in this study.

2. Model of the Tierra del Fuego Complex

Considering this modelling work, different ways to improve the facility's availability could be proposed and tested using the model. The model will also be used to determine the effect of the offshore dredging and construction work during the LNG facility train developments. The main purpose of the availability study is to develop a computer model of the complete terminal complex to assess the overall availability of the loading and ship operations relating to it, and to assist in understanding the contribution of the different systems to the overall unavailability. The simulation for the Terminal includes the following units: LNG production facility, LNG terminal storage, loading jetty and arms, LNG tankers and icebreakers.

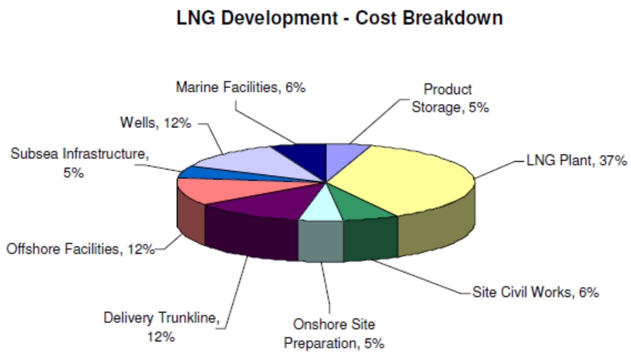

Fig. 1.
LNG Development Cost Breakdown

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The computer model was built using the software package Multiphysics, which is general purpose modelling software. The purpose built model was programmed for this study. The program predicts the performance of a system through application of a discrete event based system model that will simulate life-cycle scenarios of the terminal operation. The system must include the reliability of the units based on general historical data or the best judgement by the specialists. The operating policies are also built in to the model. The computer model can be run though a life-cycle of the terminal. Because the model includes events which are set by a random generator each run different result. Based on the Monte Carlo method the system must be run through a sufficient number of times in order to generate probability function. Typically more than 100 simulations are required.

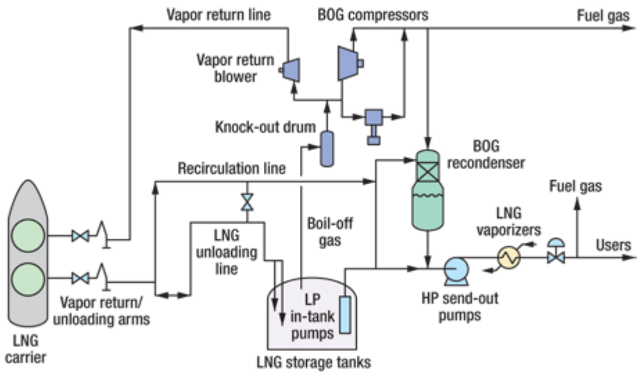

Fig. 2.
Designing the LNG terminal of the future
Source: 09-09_Lemmers_fig1.gif

Environmental and failure data contained within the model are described by different distribution functions, i. e. exponential, normal, triangular or rectangular. Where complex interactions between elements of the model are required, conditional logic is used to ensure a good representation of the planned real world operations (for example icebreaker support). In addition to the unscheduled events, all major known activities are included as scheduled events at the required frequency (in years) and duration (in hours). The known weather conditions, maintenance and production parameters which are changing annually are included in to the model as controlling elements.

3. Basic Mapping Project Assumptions

The main assumptions in the computer model are: Terminal life-cycle is 25 years, LNG facility input is 35 000m^3/day per single train, LNG storage tanks capacity 350 000 m^3, Number of loading jetties (1-3), LNG loading rate is 8 000 m^3/h, Berthing takes nominally 2-4 hours depending on the season, Approach will happen with the support from icebreaker tug boats (maximum of 25 nautical miles), LNG carriers is capable of handling all vapour during loading, Connection of the loading arms takes 3 hours, One line icebreaker is used at entrance, 4 tug boats in summer time and Dredging.

Items or operative functions or poor definition of environmental criteria which do not have a straight influence in the terminal are excluded from the model.

4. Weather related influence

4.1. Temperature

Air temperature is set to monthly average temperature and variation happens to be between minimum and maximum. Normal distribution is used.

Temperature is having effect on following events: loading arm connection time and berthing time.

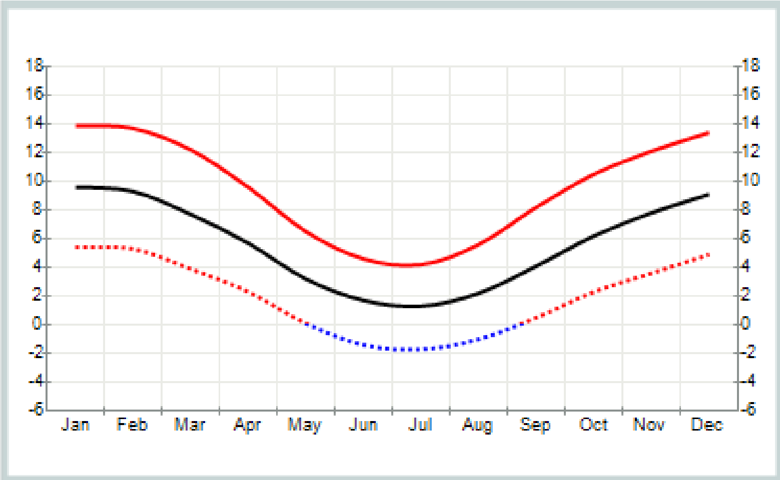

Fig. 3.
Average temperature per month
Source: WMO

	Temperature		
Months	**Normal**	**Warmest**	**Coldest**
January	9.6°C	13.9°C	5.4°C
February	9.3°C	13.7°C	5.3°C
March	7.7°C	12.2°C	3.9°C
April	5.7°C	9.6°C	2.3°C
May	3.2°C	6.5°C	0.1°C
June	1.7°C	4.6°C	-1.4°C
July	1.3°C	4.2°C	-1.7°C
August	2.2°C	5.6°C	-1.0°C
September	4.1°C	8.2°C	0.5°C
October	6.2°C	10.5°C	2.3°C
November	7.8°C	12.1°C	3.6°C
December	9.1°C	13.4°C	4.9°C

Fig. 4.
Tabular view for temperature and precipitation per month
Source: WMO

4.2. Wind speed

Wind information is available from Antarctica meteorological station and this data is used to represent Tierra del Fuego conditions in the terminal and offshore in the approach sea ways.

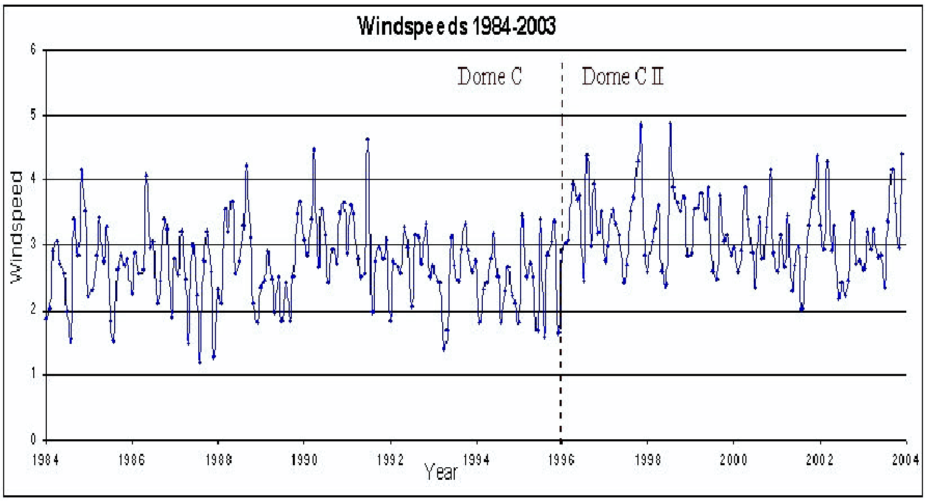

Fig. 5.
Monthly wind speed at Antarctica from the beginning of 1984 to the end of 2003
Source: http://www-luan.unice.fr/~aristidi/articles/aa_wind.pdf

Wind speed is having effect on following events delay in sea voyage limit approach when wind speed is more than 15 m/s.

Considering wind speed more than 12 m/s, it is expected to delay the sea voyage in approach channel by 20% due to more ice compression.

If wind speed is over 25 m/s, it is expected to delay sea voyage by 6 hours.

Taking in account wind speed is over 15 m/s, the approach into Tierra del Fuego is prohibited and LNG carrier must wait in the safe place outside the entrance channel. LNG carrier is also not allowed to leave the port.

4.3. Visibility under the fog impact

Table 1
Number of days with fog

MONTH	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average	2	3	3	5	5	7	9	7	7	4	3	3
Maximum	5	8	7	10	11	12	13	12	11	10	9	7
Heavy fog, average	1.0	1.0	1.0	1.0	2.0	2.5	3.3	2.3	1.8	1.1	1.0	1.0

Fog is having effect on following events if visibility less than 100m, limit approach and limit departure.
The duration of heavy fog is assumed to last also 1/3 of the average time shown in Table 1.

4.4. Rain/snow fall

No effect on the model.

4.5. Ice

Here is shown only summary of the most important values reflected in the simulation model. Ice conditions are varying a lot and are therefore have a strong effect on the transport and loading operability. Following unscheduled events may happen: delay in sea voyage, delay in approach and delay for icebreaker.

Table 2
Ice season

Freeze - up:	Average	Early November
	Earliest	Early October
	Latest	Late December
Break - up:	Average	Late May
	Earliest	Early April
	Latest	Late July

Delay in sea voyage is difficult to relate into known data of ice conditions and therefore we used a reference data from existing ships operating in same region. It should also be mentioned here that LNG carriers which operate today in ice free trades are able to follow their planned schedules very well. Following data is generated based on previous similar voyages data: average speed 10.35 kt, maximum average speed 11.45 kt, minimum average speed 9.64 kt and distribution type is rectangular. Speed must be changed to time and corresponding values based on 150 nautical miles ice distance are: deviation from average maximum 3.2 hours and deviation from average minimum 4.1 hours. Otherwise it is expected that there are suitable number of LNG carriers so that they are able to arrive with planned schedule towards the LNG terminal.

5. Probability of technical failures

Following probabilities can affect effective loading operation considering technical devices: Malfunction probability of loading arms (The repair time for loading arm malfunction is assumed to be 5 days.), Loading pumps or loading system (Malfunction probability for loading system is not considered.), LNG carrier off hire (Typical value for major accident for modern ships is 0.002 events/ship year. Additionally the availability rate for the LNG carrier is 99.8%. The off hire statistics from LNG carriers are not well published and it should be recommended to obtain relevant information from class societies) and other traffic is not included in the model.

6. Study cases, results and conclusions

Following cases were analysed in Table 3.

Table 3
Study case

Phase 1 production	1 loading jetty
	2 loading jetty
Phase 2 production	1 loading jetty
	2 loading jetty
	3 loading jetty
Phase 3 production	1 loading jetty
	2 loading jetty
	3 loading jetty

Source: According to authors analysis

6.1. Stability of the Monte Carlo simulation

The selection of the optimal LNG terminal site variant should start from an analysis of navigational risks on waterways leading to the examined LNG terminal variants. The navigational risk analysis aims at identifying the kinds of accidents that may happen to an LNG tanker proceeding along particular sections of the waterway leading to any of the terminal variant sites. The analysis of navigational risks in reference to LNG carriers allows to determine the following three types of waterway: open sea waterway (shipping routes); the prevailing risk is a collision of an LNG tanker with another vessel;coastal waterway; this is usually a fairway leading from an anchorage to entrance heads of the port, along which the prevailing risk is grounding in shallow water or on a slope of the fairway channel;waterway crossing port waters, where the vessel will be mainly manoeuvring while entering the port and approaching the terminal, turning and mooring; a risk involves LNG tanker's collision with a marine port structure, area bottom or another vessel or vessels berthing in the port.

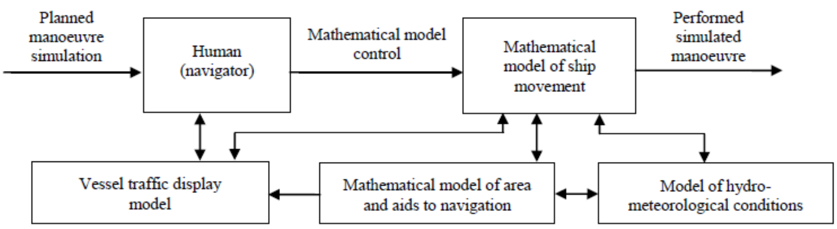

Fig. 6.
Non-autonomous simulation model of ship movement in restricted areas
Source: Gucma, S. 2011.

Taking in the account accumulated information's from the plots below from Phase 1 cases we can see that after 100 simulation runs the result of availability starts to stabilize. Plot line shows the cumulative average of the individual simulation cases. We can obtain it stabilizes after 50 simulation runs and therefore can conclude that 100 runs should be sufficient. Availability of Punta Arenas terminal will be expected to have a mean value of 83.2 %. Similar plot is shown also for Phase 3 simulation case.

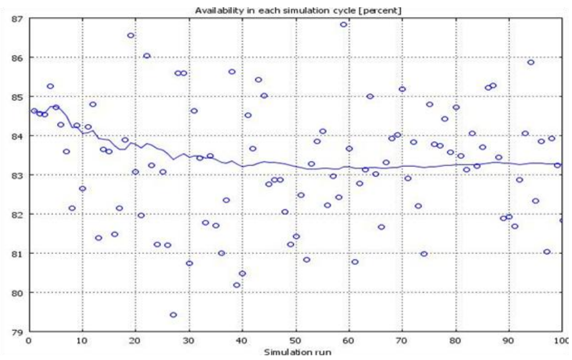

Fig. 7.
Result of MC-simulations of 100 times. Terminal availability percent (Phase 1).

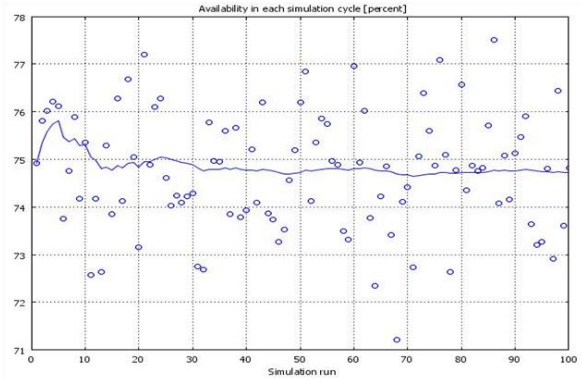

Fig. 8.
Result of MC-simulations of 100 times. Terminal availability percent (Phase 3)

6.2. Results for terminal availability and problems identified from simulations

This method was used in the process of designing the where the LNG terminal has been located. Two LNG tankers were used in test.

Methods in real time are also used to define the kinetic energy of gas carrier berthing for a selected set of cargo handling berth of the LNG terminal.

Availability is defined to be the relative time when weather, damage, delay or occupation of the entrance channel limits the approaching or loading operation.

Probability of overfill of storage tanks is the time when storage would exceed the given limit value (i.e. 350 000m^3).
In the below table the results from simulated cases are given.

Table 4
Availability percent and probability of overloading storage

CASE	Number of jetties	Availability Mean (min-max)	Limit of overfill	Probability of overfill (% of time)
Phase 1	1	82.5 % (79.0 – 86.0 %)	350 000 m^3	1.17 %
Phase 1	2	83.1 % (79.4 – 86.8 %)	350 000 m^3	0.06 %
Phase 2	1	77.9 % (74.0 – 86.8 %)	350 000 m^3	3.33 %
Phase 2	2	79.0 % (75.0 – 83.0 %)	350 000 m^3	1.26 %
Phase 2	3	79.0 % (75.0 – 83.0 %)	350 000 m^3	0.97 %
Phase 3	1	74.2 % (71.0 – 77.5 %)	350 000 m^3	8.19 %
Phase 3	2	74.5 % (71.0 – 78.0 %)	350 000 m^3	3.38 %
Phase 3	3	74.5 % (71.0 – 78.0 %)	350 000 m^3	2.23 %
Phase 3	1	74.0 % (71.0 – 77.0 %)	640 000 m^3	0.40 %
Phase 3	2	75.3 % (72.3 – 78.3 %)	640 000 m^3	0.06 %
Phase 3	3	75.0 % (72.0 – 78.0 %)	640 000 m^3	0.07 %

Source: According to authors analysis

Further analysis of the results will be required to evaluate the reasons and means of improvement. We also investigate how these values depend on the level of stochastic variability in the shipping model, the type of LNG carriers model used, the LNG throughput, and the type of inventory control policy employed.

6.3. Recommendation and Conclusion

Motivated by current developments in the LNG industry, a real option model for the strategic valuation of LNG storage has been developed. Unique to this model is the integration of models of natural gas liquefaction and LNG shipping, natural gas price evolution, and LNG inventory and sale into the wholesale spot market. This provides a heuristic strategic valuation of the real option to store LNG at terminal. This model is applied to real and estimated data.

The probability of terminal availability is dominated by the weather conditions. Therefore not much improvement has been observed by adding more loading arms or loading jetties. But clearly, the lower availability with increased production from Phase 1 to Phase 3 can be obtained. This is natural because the required loading frequency must increase.

The number of loading jetties, on the other hand, has a clear and positive influence on the probability of the overfilling the storage tanks.

The results of this study show the importance of the weather conditions, namely the ice, wind and fog. However, the reliability of the information used should crosscheck from various sources and more specific statistical data obtained. For example fog information did not give any data on limiting visibility and very rough estimation was made. Also the wind data available gives controversial information on the probability of high wind speeds over 14 m/s.

Based on this analysis it seems that two loading jetties would be best to install already in Phase 1 and thus gradually increase the storage capacity. 350 000 m3 capacity seems not to be sufficient for Phase 3 production and 640 000 m3 can be recommended, as well as two loading jetties.

References

Abadie, L.M.; Chamorro, J.M. 2009. Monte Carlo valuation of natural gas investments. *Review of Financial Economics* 18:10-22.

Aristidi, E.; Agabi, K.; Azouit, M.; Fossat, E.; Vernin, J.; Travouillon, T.; Lawrence, J.S.; Meyer, C.; Storey, J.W.V.; Halter, B.; Roth, W.L.; Walden, V. 2004. An analysis of temperatures and wind speeds above Dome C, Antarctica. Available from internet: <*http://www-luan.unice.fr/~aristidi/articles/aa_wind.pdf*>.

Gucma, S. 2011. Simulation methods in LNG terminal design. *Scientific Journals Maritime University of Szczecin* 25(97): 28–34.

Internet Services Group. 2007. National Weather Service. Available from internet: <http://weather.noaa.gov/weather/CL_cc.html>.

Jones, P.D.; Wigley, T.M.L.; Briffa, K.R. 1994. *Global and hemispheric temperature anomalies - land and marine instrumental records*. In Boden, T.A.; Kaiser, D.P.; Sepanski, R.J.; Stoss, F.W. (eds), Trends ’93; *A Compendium of Data on Global Change*, ORNL / CDIAC-65, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tn, pp. 603–608.

Jones, P.D. 1995. Recent variation in mean temperature and the diurnal temperature range in the Antarctic. *Geophys. Res. Lett*. 22(11): 1345–1348.

King, J.C. 1994. Recent climate variability in the vicinity of the Antarctic Peninsula. *International Journal of Climatology* (14): 357–369.

Lemmers, S.P.B., Vopak LNG Holding BV, Rotterdam, The Netherlands. 2009. Designing the LNG terminal of the future. Available from internet: <*09-09_Lemmers_fig1.gif*>.

Rosenbluth, B.; Fuenzalida, A.; Aceituno, P. 1997. Recent temperature variations in southern South America, *International Journal of Climatology* (17): 67–85.

Stanivuk, T.; Tokić, T. 2012. How to predict cargo handling times in sea port affected by weather conditions. In *Proceedings of the 14th International Conference on Operational Research*, 26-28.

USAGE OF BAYBURT STONE IN ROAD INFRASTRUCTURES AS A IMPROVEMENT MATERIAL

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Abstract: Subgrade is one of the most important factor which affects the operating time of highways. Subgrade of highways which are a part of freight transportation network exposes to more pressure. Therefore, stabilization of subgrades becomes more important for these highways. Usage of sustainable and eco friendly resources produce economic and effective solutions for stabilization of highways. BS can be a good example of the solution which are mined in Bayburt city, the north-east of Turkey. Bayburt Stone (BS) is Eocene age and consist of zeolite minerals. Because of containing high value of amorphous silica, tuffic Bayburt stones have pozzolanic activity. Therefore, the stones have binding characteristics when they mix in lime. In this study, It is intended to show that BS waste which obtained from the stone quarries during the stone processing, can be used as a stabilizing material in subbase layers of highways. Within the scope of the study lime and lime – BS mixtures were used to improve clayey subbase layers. In the experimental studies, different amount of 0.2-80 µm diameter BS and lime mixtures were used and improvement results of lime, lime - BS mixtures were compared. The obtained stabilization materials were tested for clayey soils. In this context nonconfined compression test, shear box, XRD,XRF and Particle Sizer tests, standard compaction and soil classification tests (Liquid-Plastic Limit Test, Sieve Analysis, Hydrometer Analysis) were performed. As a result of study it was observe that the strength of samples which obtained from lime-BS increased remarkably and it's possible to make compaction with lower compaction energies.

Keywords: Stabilization, Bayburt Stone, Lime Stabilization

1. Introduction

Subsoil plays important role in building durable and safe roads. Because of geographical differences, mechanical properties of subsoil can change and it's possible to run across to insufficient sub-base soils along the route. In such cases soil stabilization is common site application in order to enhance soil properties. Soil stabilization can be classify into two main categories as mechanical and chemical stabilization. Mechanic stabilization includes methods change physical and hydraulic properties of soil with physical processes. Mechanical stabilization is performed by mixing two or more gradations to obtain required properties. The mixed material is filled to excavated place and compacted to required densities by conventional methods. As a result of mechanic stabilization soil density, soil strength, volumetric stability of soils increase and settlement values of soils decreases.

When the mechanical stabilization methods are not efficient, chemical stabilization methods are used. The chemical stabilization is performed via adding chemical material to the soil. As a result of adding chemicals, chemical reactions occurs in soil and mechanic properties of soil like internal friction angle, soil strength, permeability, etc. improves. Nowadays, cement, lime, bitumen, pozzolana, resin, polymer and some chemicals (sodium silicate, hydrofluoric acid, phosphate, etc.) are used as additive material in chemical stabilization applications because of environmental and economical constraints. Two important reactions occur in chemical stabilization. One of these is cation exchange and other is cementation (Mitchell, 1993). In order to start cation exchange reaction, organic chemicals and calcareous chemicals which involve inorganic cations are used. For cementation reactions Portland cement, lime, pozzolana, sodium silicate, phosphoric acid, sodium hydroxide, gypsum and bitumen emulsions are added to in sufficient soil. The factors like soil class, the aim of stabilization, coast and material supply play important role in determination of stabilizer (Çalık, 2011). Hydrated or unhydrated lime is used in lime stabilization which is one of the chemical stabilization methods. Althought the studies that show unhydrated lime stabilization displays better performance than hydrated lime stabilization, hydrated lime is used generally due to safety reasons. The insufficient soils ingredient like CH, CL, MH, ML-CL, SC, SM, SM-SC, GC, GM-GC, GM can be treated by using lime stabilization methods. This methodperforms efficient performance for clayey soils between 10-50 plasticity index values especially in silty-clays.However, lime stabilization performance decreases in soils that contain more than 5% organic matter and sandy soils.

Determination of optimum lime content plays important role in lime stabilization.pH values of lime-soil mixtures are used in order to determine optimum lime content. When adequate quantities of lime and water are added, the pH of the soil quickly increases to 12.4, which enables the clay particles to break down.

Silica and alumina are released and react with calcium from the lime to form calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates (CAH). CSH and CAH are cementitious products similar to those formed in Portland cement. They form the matrix that contributes to the strength of lime-stabilized soil layers.

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As this matrix forms, the soil is transformed from a sandy than granular material to a hard, relatively impermeable layer with significant load bearing capacity (National Lime Association, 2004).Cation change, flocculation, aggregation, cementation and carbonation occurs during the lime stabilization process (Fang, 1991).

In general, low-valent cations tent to substitute with high-valent cations in soil. After the lime addition to the soil, lime ionizes with the effect of pore water. Than calcium cation (Ca^{+2}) and hydroxide ion (OH^-) concentration increases in the environment. High-valent calcium ions stabilizes the negative charges of clay particle surfaces. Generally, cation exchange reactions are completed in an hour. Plasticity, workability, shrinkage-swelling characteristics of soil improves at the end of the reactions (Bell, 1996). At the end of increasing of calcium cations on the clay surfaces, flocculation and aggregation reactions starts. The effect of cation exchange and attraction causes clay particles to become close to each other, forming flocs; this process is called flocculation (Al-Rawas etc.,2005). After the flocculation and aggregation remarkable changes occurs in effective grain size and micro structure of clay minerals (İpek, 1998).

All types of soils have their own lime saturation degrees. The lime added up to degree of lime saturation meets a need of enough lime for cation change, flocculation, aggregation reactions. Greater amount of lime addition than lime saturation degree is required to start cementation reactions. Excessive lime, meets the need of lime in cementation reactions rather than improve plasticity, shrinkage-swelling, workability characteristics of soil (Al-Rawas, 2002; Mathew and Rao, 1997).The cementation reactions occur between silicate, aluminate and calcium ions which come from soil and lime.After these reactions, high-strength matters are obtained (Nalbantoğlu and Tuncer, 2001).During the pozzolanic reactions chemical equations are given below. (C:CaO, S:SiO_2, A:Al_2O_3, H:H_2O)

$$Ca^{+2} + 2(\mathrm{OH})^- + SiO_2 \rightarrow CSH \quad (1)$$

$$Ca^{+2} + 2(\mathrm{OH})^- + \mathrm{Al_2O_3} \rightarrow CAH \quad (2)$$

$$Ca^{+2} + 2(\mathrm{OH})^- + SiO_2 + \mathrm{Al_2O_3} \rightarrow CASH \quad (3)$$

In some cases lime reacts with carbon diokside and at the end of the reaction calcium carbonate occurs. This reaction called carbonation and as a result of this reaction low-strength product (calcium carbonate) occurs. Besides low-strength calcium carbonate reduces lime amount of soil and prevents pozzolanic reactions (Çalık, 2011). If insufficient soil does not contain SiO_2, Al_2O_3, Fe_2O_3, natural pozzolans (volcanic slag, volcanic tuff etc.)or artificial pozzolans (fly ash of F type, blast furnace slag, silica fume) are added to soil in order to increase efficiency of lime (Atanur, 1973).Pozzolanic materials does not show binding material property alone but they react with binding materials that contain calcium hydroxide at appropriate water content and normal environmental temperatures . Lime stabilization may not be efficient in nonplastic and low plasticity soils. In such cases insufficient soils stabilizes with lime and pozzolan mixtures. Pozzolans are divided into two category according to their formation types: artificial pozzolans and natural pozzolans. Natural pozzolans contain large quantities of silicate and they are used after milling process. In lime stabilization, natural pozzolans are used without any processes or pre-treatement processes. For example, most of the natural pozzolans formed by volcanic eruption like volcanic glass, volcanic tuff, pumice are used directly in stabilization and some pozzolans like clays, silts, diatomites that contain at least 25% SiO_2 are used after heat treatement (700^{o}C-900^{o}C). There is no remarkable chemical differences between natural pozzolans and artificial pozzolans. Obtainment procedure is the biggest difference between artificial and natural pozzolans. Artificial pozzolans are made from industrial wastes and they are not found in nature. Fly ash, silica fume, micro-silica, coal bottom ash, rice husk ash etc. can be instance of articicial pozzolans (Çalık, 2011). A lot of researcher has worked on analyzing the reaction between lime and clay as a soil stabilization material up to now. Eades and Grim (1966) examined unconfined pressure values of samples which have different lime content and determined between 200% to 1000% arise in unconfined pressure values depending on the amount of lime content.Croft (1967) found that the addition of lime significantly reduces the swelling potential, liquid limit, plasticity index and maximum dry density of the soil, and increases its optimum water content, shrinkage limit and strength. Another study was done by Tüylüce (2010) about marine clay, which is found under the marine structure's base and obtainable by scanning. Based on the strength increases in soil-lime mixtures, it was seen that, marine clays can be used as filling material by stabilization with hydrated or quick lime. Miller and Azad (2000) used furnace slag which obtained from cement factories in soil stabilization. They found that mechanical properties of soils were improved with increasement of furnace slug. Jha and Gill (2006) studied the effect of rice husk ash-lime mixtures in soil stabilization. They found that compaction parameters, strength and durability values of stabilized soil was improved using rice husk ash with lime. Çalık (2011) used perlite as a pozzolanic additive in stabilization of insufficient soils and stated that engineering properties like workability, plasticity, permeability, compressibility, strength and durability of weak soil improved after perlite-lime mixtures stabilization.

In this research, we studied the effect of mixed lime and Bayburt Stone (BS) for improvement stabilization characteristics of high plasticity soil. Within the scope of the study lime and lime – BS mixtures were used to improve clayey subbase layers. In the experimental studies, different amount of 0.2-80 μm diameter BS and lime mixtures were used, and obtained results of lime, lime+BS mixtures were compared.

The existing stabilization materials were tested for clayey soils. In this context nonconfined compression test, shear box, XRD, XRF, standard compaction and soil classification tests (Liquid-Plastic Limit Test, Sieve Analysis, Hydrometer Analysis) were performed.

2. Materials and Methods

2.1. Materials

Bayburt is a city located near the Çoruh River in the North-East of Turkey. Due to the it's geological structure, various mineral deposits located in Bayburt. Bayburt tuff and tuffites known as BS mines is located around Bayburt.It has an important role on economy of the Bayburt city. As a result of researchesin 2005, total of 2.535.700 tons proved reserve were determined in Toptepe, Sırataşlar, Gevenli, Konakdağ ve Gümüşdamla locations. In general, white, yellow and green tuffs are named as BS and they contains compounds like SiO_2, Al_2O_3, Fe_2O_3.Chemical properties of BS are given in the Table 1. In this table, observed that the loss on ignition value high than expected because of $CaCO_3$ exist in Bayburt stone. CO_2 amount of materials can be determined by Loss on ignition method. So it known that this is attributed of $CaCO_3$ in materials.

Table 1 *Chemical properties of BS*

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Total Alkaline	Total	Loss on ignition
Ratio (%)	68,92	11,96	0,34	3,85	1,29	0,21	0,23	2,38	1,80	99,31	10,13

XRD analyses of the BS are given in the Figure 1. From the XRD results of Bayburt Stone it was determined that clinoptilolite, heulandite, orthoclase, quartz are main minerals that BS contain. From the XRF and XRD test results it is seen that BS contains high amount of SiO_2 and Al_2O_3 that play important role in pozzolanic reactions. Sieve analyze which has done laser particle sizer shows that 90% residue below sieve of the 64.74 μm size and 10% residue below sieve of the 1.89 μm size. 50% of the BS was residue below sieve of the 16.07 μm size. Density of the BS using in this study is 1.67 g/cm^3.

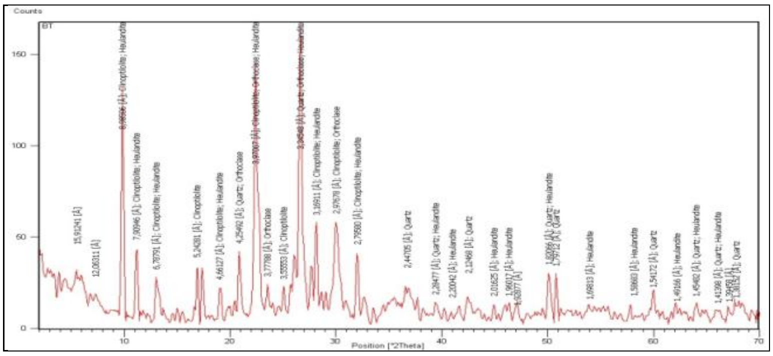

Fig. 1.
XRD results of Bayburt Stone

At the beginning of the study properties of soil was determined. Within this scope, soil classification (Liquid-Plastic Limit Test, Sieve Analysis, and Hydrometer Analysis) and compaction tests were performed. After these tests, soil class is determined as CH according to the Unified Soil Classification System (USCS) and compaction parameters, Atterberg limits and soil unit weight is shown in the Table 2.

Table 2
Results of Soil Classification and compaction tests.

Soil Classification Tests Results	Soil Class (USCS)	CH (High Plasticity Clay)
	Unit Weight of Particle (kN/m3)	25.52
	Liquid Limit (%)	50.00
	Plastic Limit (%)	30.00
	Plasticity	20.00
Compaction Test Results	Maximum Dry Unit Weight (kN/m3)	14.22
	Optimum Water Content (%)	19.50

Results of laser particle sizer and X-ray Diffraction (XRD) tests are shown at Figure 2 and Figure 3. Laser particle sizer test are performed at laboratories of Gazi University Faculty of Technology, X-ray Diffraction (XRD) tests are performed at Mineral Research & Exploration General Directorate (MTA). According to the laser particle sizer test results, it is determined that: grain size of the soil which passes through the sieve #200, changes between 0,05μm and 80μm. Moreover, from the XRD results it was determined that Kaoline, montmorillonite, calcite are the main minerals of tested soil.

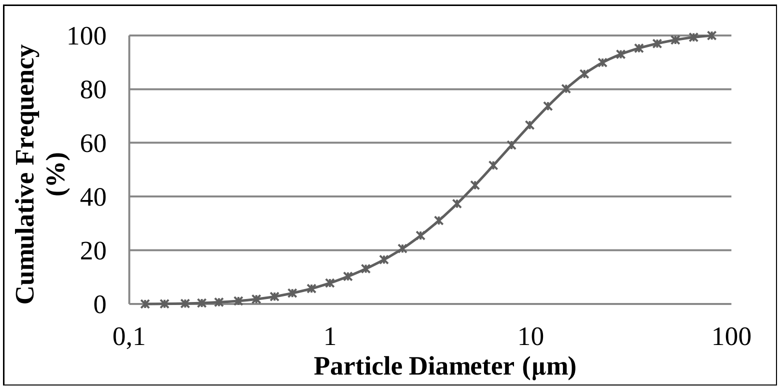

Fig. 2.
Result of particle sizer test of tested soil.

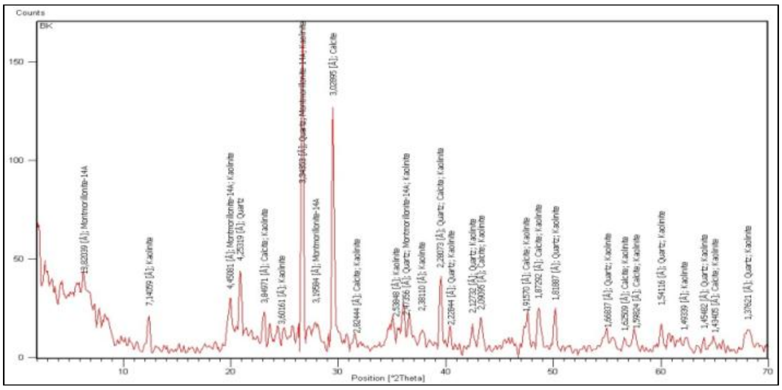

Fig. 3.
XRD results of tested soil

2.2. Preparation and testing of samples

Eades and Grim pH test was performed, in order to determine optimum lime ratio. Aim of pH test is, to produce a pH of 12.4 or equal to the pH of lime itself. The Optimum lime content shall be determined corresponding to the maximum pH of lime-soil mixture (Office of Geotechnical Engineering, 2008). At the beginning of pH test, lime-soil solutions were prepared with different lime content (%3, %4, %5, %6, %7, %8, and % 9). After curing period that took an hour pH values of mixture were determined. As a result of pH test optimum lime content determined as 5%. Result of pH test results are given in Table 3.

Table 3
Unconfined pressure strength of samples

Lime Content (%)	pH Values
3	11.9
4	12.2
5	12.5
6	12.3
7	12.3
8	12.5
9	12.4

Due to determine unconfined compressive strength and shear strength values, samples were prepared with using the same processes. Firstly, 3.5–4 kilograms of soil were put in to a metal basin. Then, this soil was put in a ventilated oven at 120°C, along 24 hours for drying.

Optimum percentage of lime (5%) was mixed with the dry soil in a basin. Determined ratio of BS (5%, 10%, 20% and 30%, these are showed in table L+BS5,L+BS10, L+BS20 and L+BS30) was added into mixture. After preparing the mixture of soil lime and BS, weigh of mixture was determined. Optimum content of water (19.5%) kept fix in conducted all sample preparation. The water was sprayed to the mixture and the mixture was mixing at the same time for diffusing the water homogenously. At the end, mixture compacted in standard compaction mould with standard compaction energy. Samples were taken from compacted mixtures in order to determine unconfined compressive strength and shear strength. While unconfined pressure and shear strength values of soil-lime mixture were determining, these processes were applied, too. All samples were cured along 7 days. After curing, shear box and unconfined pressure tests were performed.

3. Results and Discussion

In order to examine the effects of lime and BS on soil stabilization, unconfined pressure and shear strength values of the soil were determined. For this purpose the soil was compacted at standard proctor energy and optimum water content in compaction mould. After compaction, five samples were taken from the compacted soil with standard sampler due to determine approximate unconfined strength. Moreover, two samples were taken from compacted soil for shear strength. All the samples were cured along seven days. Result of shear box and unconfined pressure tests are given at Table 4. 2 values except of average value determined by unconfined pressure strength test is not incorporated at calculation of average value because of not homogenous values.

Results of unconfined pressure and shear strength tests show that soil-lime mixtures have nearly % 45 higher unconfined pressure values and nearly two times more shear strength values than soil's values. Moreover, soil-lime-BS mixtures have higher unconfined pressure and shear strength values than soil's values, too. As an important result is soil-lime-%10 BS mixtures (L+BS10) have the highest values. Therefore, it is determined that, optimum BS ratio is between %5 and %10 or %10 and %20 for soil-lime mixtures. Tests are continuing for determining the optimum BS ratio.

Table 4
Unconfined pressure strength and shear strength test results of lime- BS mixtures

Statistics	Soil		L+BS0 (Control)		L+BS5		L+BS10		L+BS20		L+BS30	
n	3		3		3		5		3		4	
Max. value (kPa)	878.58		1227.79		1656.05		2084.13		1258.19		1297.12	
Min. value (kPa)	669.30		1037.54		1517.68		1729.50		1046.37		1089.00	
Average (kPa)	786.91		1141.16		1605.02		1921.16		1154.44		1193.23	
Std. deviation	107.03		78.59		76.00		161.34		105.98		110.47	
	Shear strength test values											
Axial Load (kPa)	11.72	19.71	13.32	24.51	12.96	23.1	13.96	28.02	12.07	22.2	14.21	24.02
Shear Strength (kPa)	109.83	137.10	307.14	565.80	432.76	660.97	553.29	596.44	510	544.07	457.2	561.33

3. Conclusion

In this study lime and lime – BS mixtures were used to improve clayey subbase layers. In the experimental studies, different amount of 0.2-80 μm diameter BS and lime mixtures were used and improvement results of lime, lime - BS mixtures were compared. As a result:

- With lime stabilization unconfined pressure straingth of samples 150,99 % increased and shear strengths of soil samples increased approximately300 % .
- As a result of stabilization with lime-%5 BS mixtures it was determined that unconfined pressure strength of soil 212,10 % increased and shear strengths of soil samples increased approximately 450 %.
- After stabilization with lime- 10 % BS mixtures, it was determined that unconfined pressure strength of soil 286,31 % increased and shear strengths of soil samples increased approximately 460 %.
- With lime- 20 % BS mixtures 172% strength development and approximately 440 % shear strength increasement was observed
- After stabilization with Lime – 30% BS mixtures it was determined that unconfined pressure strength of soil 186,08 % increased and shear strengths of soil samples increased approximately 390 %.

References

Al-Rawas, A.A.; Hago,A.W.; Al-Sarmi, H. 2005. Effect of Lime ,Cement and Sarooj (Artificial Pozzolan) on the Swelling Potential of an Expansive Soil form Oman. *Building and Environment*40,681-687.

Al-Rawas,A.A.; Nelson,J.D.; Al-shab, T.B.; Al-Siyabi, H.2002. A Comparative Evaluation of Various Addiditives Used in the Stabilization of Expansive Soils. *Geotechnical Testing Journal.* 25,2,199-209.

Atanur,A. 1973. Kireç Stabillizasyonu ve YolYapımındaki Tatbikatı. Karayolları Genel Müdürlüğü Matbaası. Ankara. 11 p.

Bell, F.G. 1996. Lime Stabilization of Clay Minerals and Soils. *Enginnering Geology 42,223-237.*

Croft, J.B. 1967. The İnfluence Of Soil Mineralogical Composition On Cement Stabilization. *Geotechnique*, vol. 17, London, England. p. 119–135.

Çalık.Ü. 2011. Utilization of Perlite as a Pozzolanic Additive in Soil Stabilization With Lime. Phd. Thesis. Turkey.

Eades, J.L.; Grim, R.E. 1966. A quick test to determine lime requirements for lime stabilization, Bull. Highw. Res. Board, 61-72.

Fang, H.Y. 1991. Foundation Engineering Hand Book 2nd Edition. Van Nostrang Reinhold Publishing,London.

Füsun , T. 2010. Treatement of Marine Clays with Lime Stabilization, Master Thesis.Turkey.

Ipek, T.1998. Stabilization of Expansive Soils Using Lime,Cement and Fly Ash, Master Thesis.Turkey.

Jha, J; Gill, K.S.2006. Efect of Rice Hush on Lime Stabilization. *Journal of the Institution of Enginners.* 87,33-39.

Mathew, P.K:; Rao, S. N.1997. Effect of Lime on Cation Excahange Capacity of Marine Clay. *Journal of Geotechnical and Geoenvironmental Enginnering.*123,2,183-185.

Mitchell, J.K. 1993. Fundamentals of Soil Behviour. John Wiley&Sons Inc. New York 347 p.

Miller,G.; Azad, S. 2000. Influence of Soil Type on Stabilization with Cement Klin Dust. *Journal of Construction Build Materials.*14,2,89-97.

Nalbantoğlu, Z.; Tuncer, E.R. 2001. Compressibility and Hydrolic Conductivity of a Chemically Treated Expansive Clay. *Canadian Geotechnical Journal*. 38,154-160.

National Lime Association. 2004. Lime-Traeted Soil Constructure Manual. Bulletin 326.

Office of Geotechnical Engineering. 2008. Design Procedures for Soil Modification or Stabilization. Indiana 7 p.

Yılmaz, A.O; Alp,İ; Demir,C.; Arslan,M; Kolaylı,H. 2004. Bayburt Tüfünün (Bayburt Taşı) Fiziksel, Mekanik, Petrografik Özellikleri.

TRANSPORTATION AND ENVIRONMENTAL PROTECTION - CHALLENGE FOR THE FUTURE

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Abstract: Back in the 1977 Rodière wrote that the century of speed is the century of transportation. Along with positive characteristics, traffic has significantly contributed to the increase in local and global negative effects on the environment. Economic crisis in the world, as well as the high level of air pollution throughout the Planet have caused in some countries the beginning of production of means of transportation that will surely reduce the pollution of environment we live in. In the world, but also in our country a lot is spoken about hybrid cars as machines of our future. Besides, by giving certain tax reductions, subventions, the producers have made their product accessible to many inhabitants of Europe, as well as United States of America. In the paper some of the current regulation in the field of environmental protection along with the constant need for innovations is shown, with aim to reduce environmental pollution in our country.

Keywords: environment, vehicles, protection.

1. Introduction

Economic crisis in the world, as well as the high level of air pollution throughout the Planet have caused in some countries the beginning of production of means of transportation that will surely reduce the pollution of environment we live in.

For instance, Israel is a pioneer country in solar energy use. Solar plates are installed in solar farms and the whole process led to the improvement of the geopolitical position of the country. A large investment in the construction of solar system has been planned in Serbia as well and the resources would be provided from taxes. At the 27th of August 2012 the first solar plant of the power of 260 kilowatts was opened in Leskovac.

A lot has been achieved in the Scandinavian countries where electric vehicles develop velocity of about 80 km/hour with the longest distance of 4 hour without battery recharge. In Beijing, China, more than 1000 electric trucks are used by the communal services in order to reduce air pollution. In addition, China is believed to be a promised land for car manufacturers. And, while the „Car show 2012“ was canceled in our country, such show, held in Beijing[2] on April 27-May2, 2012, which is considered one of the most important planetary four-wheel events, was impressive having in mind that China is a global champion in vehicle sale.

2. What's new in the global car industry?

In the world, but also in our country a lot is spoken about hybrid cars as machines of our future. Besides, by giving certain tax reductions, subventions, the producers have made their product accessible to many inhabitants of Europe, as well as United States of America.

There has been a real revolution in the field of electric car production, especially in Germany which is the first in electric car use. The public has been informed that the scientists in several universities in that country are currently working on the construction of so-called "electric motorway" – a road with induction rechargers installed all along and electricity supply would be ensured for such cars. This is considered a completely safe system; however, it will take a while until its daily routine use. It is for that reason that many professionals[3] are putting their efforts to find a solution for a cordless car battery charger that would be built in cars, some of them trying to think how to place such chargers in the asphalt with the objective to realize a serial production of such cordless battery chargers. To that end, an interesting offer is that from the company „Folkswagen“ and the invitation made to buyers to place their suggestions and ideas for vehicles of the future.[4]

At the same time, the company "Smart" famous by the production of the small cars, launched its first battery operated bicycle[5]. The Smart's electric bike will be commercially available to the customers through selling salons in 17 countries (16 European countries and in Canada).

Other manufacturers ("Peugeot", "Opel", "Ford") are also planning to produce electric bicycles because they hope for enormous profits. In Europe last year 900.000 electric bicycles were sold, which is 28.6% more than in 2010.

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[2] More than 100 Chinese companies' exibited almost 500 models.
[3] Companies such as "Nisan", "Simens", "BMV", etc.
[4] Even the hover car, which has a very large manuevering capacity, was exibited.
[5] The manufacturers state that the price of this electric bike will be 2.849 euros.

According to the recent unofficial information, the German company “Opel” will relaunch its most luxurious car, that is a new “Omega”. That car, which production was stopped in 2003, will reappear sometime in 2014.

The company “Seat” designed and manufactured its first electric vehuicle in Spain, placing thus the foundation for electric mobility. In the next year, 2013, the company “Ferari” will initiate the production of a still un-named model[6] which will be its first petrol-electric-hybrid system in their offer.

In the Beijing fair, the famous “Lamborgini” introduced its new concept called “urus”[7], a name given after a bull species. Its serial production will start in 2016. The important thing is that it will have the least gas emission of all other cars of the same class and it will be manufactured based on the same platform used for manufacturing the models “Audi Q7” and “Porsche Cayenne”. It will have a harmonious measures irrespective of its 4.99-metre length, 1.99-metre width and as little as 1.66-metre height. In Italy, they plan to have the annual production of 3000 cars of this new model.

In the neighbouring Croatia, they plan to appear in the biggest car show in Great Britain with a sport electric car “Rimac concept one”. The company “Rimac” intends to manufacture only 88 car of this electric model.

In the Czech Republic, for example, according to the data obtained from the Automobile Manufacturer’s Association, the automobile production increased by 4.79% compared to the same period in 2011, which is considered the highest rise ever in production in the first half of the year. At the same time, the public was informed that the Czech car manufacturer TPCA, a joint-venture of the French “Peugeot-Citroen” and Japanese “Toyota” will lay off their employees (there were 2800 of them). “Peugeot-Citroen” also intends to cancel 8000 jobs in France.

In the last year, 2011, the Japanese car manufacturer “Toyota” (which over passed “General Motors” in 2008 and ruled the global automobile market), was hit by the devastating earthquake in Japan, as well as by the flood in Thailand, as well as by the recall of their vehicles from the American market. However, it returned to the top of the global automobile industry.

During the first six months of 2012, the sale of automobile in Russia was increased by 14%. The public was also informed that all local car models are among the first ten best-selling brands in the country.[8]

It is interesting that today at the time of advanced technology car producers also largely think about possibility to equip cars with constant connection to the global computer network. When shall we drive the car equipped with the link to Internet?

Considering that the company BMW became the official auto-moto sponsor of the Summer Olympic Games in London, the attention was drawn to the fact that BMW will supply vehicle with small CO2 emmission and, in addition to environment-friendly vehicles, this company will also supply motorbikes and bicycles. Therefore the effort was put to make the Olympic Games in London the most environment-friendly Games in modern history.

“Hybrid 414E” is the improved version of the model “Evora” by the “Lotus” company. In this car, the petrol engine serves only as the electricity generator for replenishing the drive battery, but the engine is started by electromotors. The most important advantage of this model is that carbon-dioxide emission is at the level of only 55 g/km.

The “Toyota” company joined in by considerable improvement of its model „Yaris“ at its manufacturing plant in the town Valencien in France, getting its business model close to the principle of sustainable production.[9]

There is a particularly interesting project that is a subject of interest for realization by a certain Endry Saul from the American state Meryland, which consist of making the hull of that „**greenest vehicle in the world**“ from the resin obtained from soybean. A lot was invested in the realization of that idea and the solution is certainly unique on the global level. It is called „Genovation G2“, and the manufacturer „Tate“ from India is ready to manufacture the cooling system for that unusual vehicle which will be offered only to the USA market.

The „European green cars“ project is an important initiative directed to further research related to electric and „hybrid“ vehicles, as well as to those using biofuel, hydrogen combustion cells, improvements of the internal combustion engine and of the logistics. Some of the designs were made at the Instutute of the Faculty of Transportation and Traffic Engineering at Belgrade University.

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[6] It will be the successor of a very limited series of the model “Enzo”.

[7] The wild predecessor of the local type of bulls; according to some data, it could grow considerably in width. Spanish corida bulls resemble a lot to that extinct species.

[8] The most popular car model „Lada kalina“, followed by „Lada priora“, and „Hyindai solaris“.

[9] In the period 2002 – 2007, the plant managed to reduce CO2 emission by 38% per produced car. The bottom line is that out of 9.5 kg of waste produced during manufacture of this car model 4.0 kg is directly recycled and the rest is used as alternative fuel in industrial processes.

The world competition for the car of the future, organized by Michelin[10], was closed on the last day of June this year. The applications from 70 countries arrived from all over the world, 132 in total, out of which 15 creations will be shortlisted. That was the 12th competition and the topic this year was the construction of the lightest car possible. The winner for the car of the future will be pronounced in January 2013 at the Detroit car show.

3. Serbian perspective

In the paper some of the current regulations in the field of environmental protection along with the constant need for innovations are shown, with aim to reduce environmental pollution in our country.

In 2004, in Serbia four laws in the field of environmental protection were adopted: Law on Environmental Protection, Law on Environmental Impact Assessment, Law on Integrated Protection and Control of Environmental Pollution and Law on Strategic Evaluation of Impact on Environment. *("Official Gazette of the Republic of Serbia", no. 135/04.)* These laws meant a lot in the sphere of protection of environment in Serbia.

According to the Law on Environmental Protection natural values are natural wealth which include air, water, land, forests, geological resources, flora and fauna. *(See: article 3. of the Law on Environmental Protection, "Official Gazette of the Republic of Serbia", no. 135/04.)* Management of natural values is achieved by planning of sustainable utilization and preservation of their quality and diversity, in accordance with conditions and environmental protection measures established by this and special law. *(Article 11, paragraph 1. of the Law on Environmental Protection.)* Natural values can be given for utilization in accordance with conditions and on the manner established by Law on environmental protection and special law.

Pollution represents big problem in Serbia too. About 32,000 cars were sold in our country in 2011. On our market so far can be found few models of hybrid automobiles of different producers. In our country the certain initiative to change the law and help the potential buyers of hybrid cars exists. There is also proposal that owners of these cars pay symbolic price for registration, with other reductions, like free parking, lower toll price and alike.

The Italian "Fiat" which manufactures the model "500 L" in Serbia is planning to go into the production of a new model "500 XL"[11] that is supposed to go into production from 2013.

Our country has a perfect geographical position, with road and railway corridor 10 and the Danube river, corridor 7, crossing. Considering that transportation is a significant drive force of economic development of each country and that the precondition for that is infrastructure provision, with passanger traffic being dominant in our country, it is necessary to point to the importance of the air and water traffic and their networking with the road and railway traffic. The question is whether the plans are being realized for the construction of the intermodal terminal at Batajnica which is a part of a large logistics center.

Related to this, it was planned that all documentation should be finished for the first intermodal terminal in Serbia by March this year, 2012. But, do we have the possibilities to be the logistic center of the region?

Having in mind environmental factors, the aim of the National Strategy of sustainable development (Official gazette, 2008) is to bring into balance three key factors that are three pillars of sustainable development: sustainable development of economics, economy and technology, sustainable development of society on the basis of social balance and protection of environment along with rational management with natural resources. Simultaneously, the aim of the strategy is to connect these three pillars in the totality supported by corresponding institutions.

The fifth part of the National Strategy of sustainable development (Official gazette, 2008) is dedicated to the issues of environmental protection and preservation of natural resources in the Republic of Serbia, as well as to the impacts of economic development on the environment. In that part the aims, measures and priorities connected with protection of natural resources (air, water, land, biodiversity, forests, mineral resources and renewable energy sources), protection from different factors of risk effects for the environment (climate changes and damage of ozone layer, waste, chemicals, accidents, ionizing and non- ionizing radiation, noise and natural disasters), protection from factors of risk for the environment effect in different economic sectors (industry, mining, energetic, agriculture, forestry, hunting and fishing, transportation and tourism), are given as well as introduction of cleaner production.

[10] A well-known tyre manufacturer.
[11] This „Fiat" model will be longer and will have seven seats.

4. Conclusion

Back in the 1977 Rodière wrote that the century of speed is the century of transportation. Along with positive characteristics, traffic has significantly contributed to the increase in local and global negative effects on the environment. Another priority is to combine different types of traffic and transportation in general and, for the transportation network to be well maintained, it is necessary to invest constantly in the traffic infrastructure. The named technological innovations will certainly contribute to the solution of many transportation problems. In the period from year 2008 till 2012 in Serbia 57 permits for utilization of renewable energy sources was issued (only 7% of permits was utilized).

A close multilateral cooperation is necessary, as well as that of the manufacturers in the EU countries. Indeed, innovation in the car industry is very important, in particular in the domain of hybrid, and electric, vehicle production by the companies all over the world. Looking forward to more creative solutions for vehicles of the future, the most important issue is, in addition to safety, and equipping them with the most modern technical achievements, to apply suitable technical solutions to reduce environment and our joint future pollution.

References

Auto world. 2012. *Politika,* May and August. Belgrade.

Official gazette. 2008. *National Strategy of sustainable development.*

Tomić-Petrović, N. 2011. *Law and ionizing radiation protection*, Foundation Andrejević, Library Educatio, Belgrade. 109 p.

Toyota European Sustainability Report. 2009. *Toyota Motor Europe NV/SA*, Brussels, Belgium.

ADRIATIC TRANSPORT CORRIDOR AS A FUNCTION OF SUSTAINABLE ECONOMIC DEVELOPMENT OF THE REGION

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Abstract: Market globalization and liberalization influence considerably on the world flow of goods, thus directly affecting the transport system, generating economic and transport growth. Economic development and investment capacities of a country determine the principle of inter-modality within the concept of transport network development and the possibilities of integration of both the Croatian transport system and the transport systems of neighboring countries into trans-European intermodal transport networks. Integrated and coordinated approach to redirecting traffic from road to energetically more efficient and more environmentally friendly means of transport implies a simultaneous development of land, port, rail and other transport infrastructure connecting ports with hinterland and other ports. There is undoubtedly a strong interactive influence between maritime traffic and the process of globalization and liberalization, with a positive effect on the ship transport cost reduction, thus increasing the significance of the flow of goods by sea for transport and economic development on the global, regional and local level. Maritime transport, as the cheapest of all means of transport, is the most important instrument of the globalization process, both for the quantities and the value of the transported goods. This article represents an overview of preliminary outcomes from ongoing research, resulting in the Adriatic Transport Corridor concept as a significant part of the intermodal transport corridor Baltic-Adriatic. Authors' research is directed towards defining strategic guidelines for the integration of intermodal transport system comparative advantages, important environment protection potentials, or ecological evaluation of the Adriatic transport waterway as a function of intermodal transport, as well as coordination with European transport network organizational concepts and achieving sustainable growth as the most important strategic challenge for Croatia. Owing to its compatibility with the environment, maritime transport is the least harmful to climate, thus gaining importance in the European intermodal transport system with a bright future ahead.

Key words: intermodal transport, transport networks, corridor Baltic-Adriatic, concept of the Adriatic Transport Corridor, sustainable development, ecological aspects.

1. Introduction

Market globalization and liberalization has a considerable influence on transport market and flow of goods. The European Commission has prepared general development guidelines, entitled Transport and Energy Infrastructure in South Eastern Europe, where they insist on a regional dimension and the establishment of connections within the region, encompassing Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia and Montenegro. Traffic and transport systems are mostly developed in the EU member countries, with road transport dominating in all countries. The need for sustainable development and environment protection, as well as traffic safety development, energy supply safety and applying alternative energy sources are emphasized as important goals. A series of applied measures are aimed at implementing an effective integrated intermodal transport system by sea, rail and inland waters, in opposition to the competitive road transport. The tendency of intermodal system is to achieve such a level of organizational and financial efficiency in transport system as to make it a logical choice of transport. Owing to that, the value of the results obtained through analysis of the said indicators demonstrates the purposefulness of their monitoring.

In the framework of thus defined scientific problem, the subject of the paper is to diagnose the principle of intermodality on scientific basis within the concept of transport network development, as well as emphasize the current transport development possibilities in Croatia in the framework of EU transport network, anticipating the flow of goods in the region as important accelerators of European and Croatian economic development. The goal of the research is to define the fundamental characteristics of development and integration of Croatian transport system into the trans-European transport network, considering the transport connection Scandinavia-Adriatic, environmental aspects and significance of the Baltic-Adriatic corridor and intermodal transport in the world trade of goods, increasing transport safety, transport market growth, development of Adriatic ports, especially Rijeka, and the Croatian transport infrastructure, cargo structure in sea transport and global changes in the world and EU economy reflecting on the changes in regional economy, including Croatian economy.

2. Development of the regional transport system

Transport systems in the region are unequally developed, along with different national economies, their policies, strategies and guidelines for planning infrastructural capital investments. Specialization in production, economy of scale and competition as basic market characteristics, are extremely important for continuous transport development.

Transport system development directly interacts with the development of economy, therefore it directly influences on the economic growth, the level of local, national and international mobility, and finally on the quality of life in the region.

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In that sense, it is necessary to take a holistic approach when planning transport system development, taking all means of transport into consideration. Such approach implies the coordination of strategies of different transport sub-sectors and their correspondence with the EU funds and other international financial institutions.

Croatia's location on important transport and transit corridors is extremely significant for establishing efficient connections between Western Europe and the Balkan, as well as between Central Europe, the Adriatic and the Mediterranean. The development and modernization of its transport sector is not only a prerequisite for its internal development, but also one of its potential comparative advantages. Pan-European transport corridors V, VII and X, pass through Croatia (Fig. 1), making its geographical location not only a comparative advantage, but also creating prerequisites for developing a transport network for Europe as a whole (TOP[2] 2007-2009).

3. Strategy of transport system development

Strategic planning of Croatian transport development should yield an overall economic growth and be dynamically adjusted to objective investment possibilities of the public sector, whereby the conceptual approach should not be nationally limited, but should be in the context of the development of the wider region. Strategic goals of Croatian transport development are integration into the trans-European transport network, environment protection, increasing transport safety, social cohesion and transport market strengthening.

Medium-term needs and goals estimate shows that the existing network of primary roads, seaports, motorways and air traffic is comparatively well developed, offering a good coverage of the area, while rail and inland waterways sub-sectors, whose shares in the transport market have plummeted, fall considerably behind in infrastructure restoration and modernization (TOP 2007-2009).

Important strategic goal of transport system development in Croatia is a systematic improvement of transport infrastructure through restoration, expansion and construction of new infrastructural objects (Fig. 2). This presupposes the modelling of a transport infrastructure modernization programme with financial instruments from national resources, as well as loans by international financial institutions and assistance through the EU pre-accession funds. In this sense, it is important to consider priorities, and make decisions through consensus according to the National Strategy of Transport Development, based on a strategic document (Official Gazette, 1999) from 1999 and the EU White Paper (EC, 2010) from 2001. Important priorities are reconstruction and restoration of railroad infrastructure, including telecommunications on pan-European corridors Vb, Vc and X, in order to enable a speed of 160 km/h, with a significantly increased passenger and cargo safety and necessary electrification and improvement of rail and port areas. Furthermore, completing and including road network on sections of pan-European corridors V_B, V_C, X and X_A, restoration and equipping airports, and the construction of passenger terminal at Zagreb Airport, as well as the restoration and modernization of seaports and inland waterways and ports located on pan-European corridors – Rijeka, Zadar, Split, Ploče, Dubrovnik, and Sisak, Slavonski Brod, Vukovar, Osijek. Realization of these strategic goals is a prerequisite for competitiveness on transport service market in accordance with the EU regulations and free transport market development.

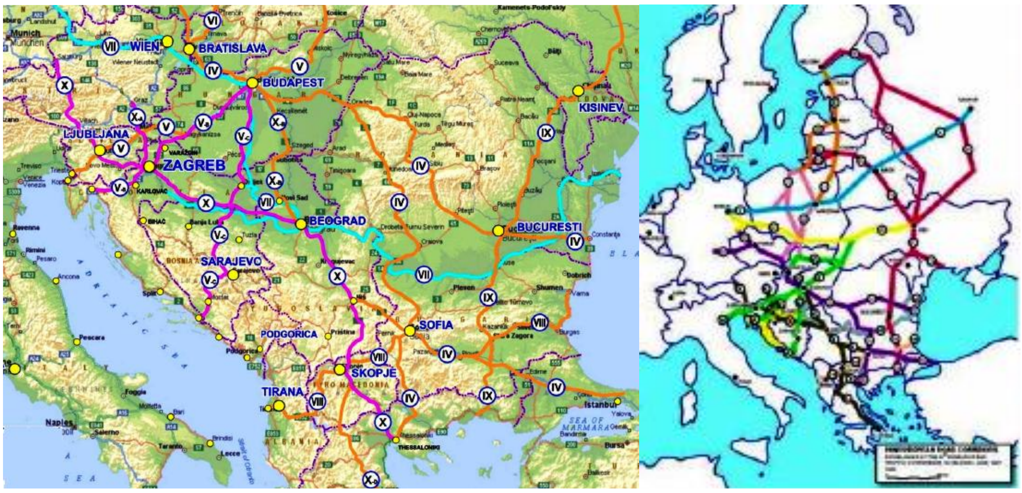

Fig. 1.
Pan-European corridor network
Source: Transport Operational Programme 2007-2009, Instrument for Pre-Accession Assistance 2007HR16IPO002

[2] TOP – Transport Operational Programme

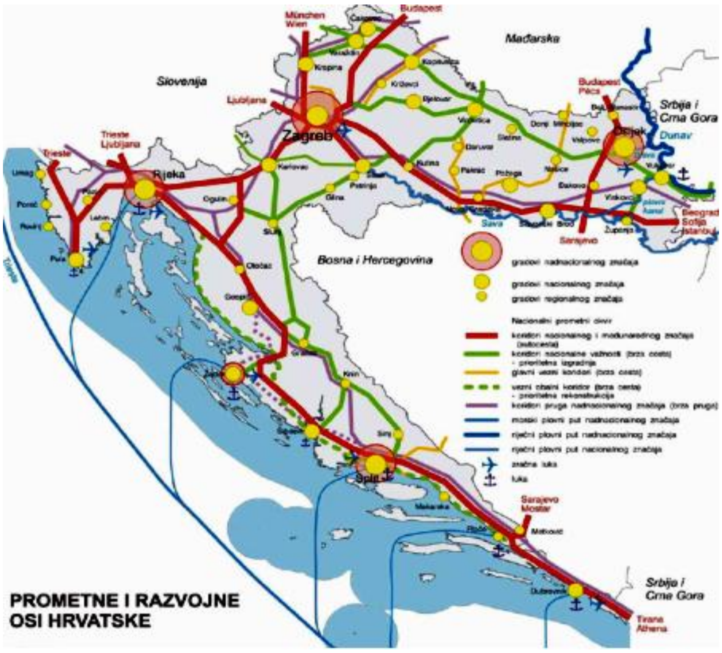

Fig. 2.
Transport and development axes in Croatia
Source: Transport Operational Programme 2007-2009, Instrument for Pre-Accession Assistance 2007HR16IPO002

4. EU guidelines

Regional transport organization SEETO - South East Europe Transport Observatory, issued a Memorandum of Understanding on the Development of the Core Regional Transport Network. The parties to the memorandum are Albania, Bosnia and Herzegovina, Montenegro, Croatia, Former Yugoslav Republic of Macedonia, Serbia, UN Mission on Kosovo and European Commission. SEETO was founded for promoting cooperation in the development of infrastructure of South East Europe Core Regional Network (SEETO, 2009).

In the framework of EU development strategy, the European Commission adopted a series of long-term development plans and projects (Freight Transport Logistics Action Plan, 2007) extremely important for the development of Croatian economy. The EU emphasizes the need for transport system development in Croatia in conformity with the development of trans-European network and South East Europe Core Regional Network, and welcomes the agreement made between Croatia and the European Commission about the future Trans-European Road Network (TEN-T) in accordance with the Decision no. 1692/96/EC, as amended, and about the priority project of European interest in the framework of the TEN-T network, which satisfies the standards prescribed for closing Chapter 21 of the Croatian pre-accession negotiations (2009). In that context, the Directive 2004/54/EC proscribes TEN-T as obligatory for all EU members since 19/11/2011. The European Commission designed the Freight Transport Logistic Action Plan which supports intermodal transport development as one of the major priorities of its transport policy, with defined outline and guidelines (Freight Logistics in Europe, 2006) which would ensure the modernization of European ports, thus raising the level of sea transport competitiveness, attracting investors and analyzing progress in sustainable mobility development. Larger investment project into the infrastructure on the Corridor X railroad, co-financed through Phare project and ISPA programme, focuses on the rehabilitation of eastern Slavonian, 34.5km-long railroad from Vinkovci to Tovarnik on the borderline with Serbia, thus opening the way for future investments into the transport sector in the framework of TOP for the period of 2007-2009 (IPA programme). Activities in ISPA project include investments of € 75,761 million with 38% IPA share. Furthermore, ISPA's "Preparation of Project List for IPA Programme – Transport" provides technical assistance for feasibility analysis of the entire remaining length of the Corridor X in Croatia. Precisely for that reason, after signing the pre-accession agreement, defining strategic guidelines for integration of intermodal transport system comparative advantages, harmonizing with the organizational concepts of the European transport network, Croatia has an opportunity to rise on the transport market and enable the integration of its transport system into the European transport network.

5. Concept of regional intermodal network

5.1. Transport infrastructure

The modernization of the very heterogeneous transport infrastructure in Croatia may assist in creating an efficient means of transport, both environmentally friendly and commercially attractive. Certain projects financed by the EU (rehabilitation of the railroad Vinkovci – Tovarnik - state border is financed from ISPA programme) contribute to the modernization of the railroad sector. Transport infrastructure in Croatia also includes 8 seaports, two mainly for cargo and three mainly for passengers, 7 airports and 2 airfields, 804.1 kilometres of inland waterways with 4 river ports and 2 combined traffic terminals. A few pan-European corridors pass through Croatia (2 land corridors X/Xa and Vb/Vc and an inland waterway corridor–VII as well as "motorways of the sea"), (Strategic Coherence Framework 2007 - 2013).

Based on the mentioned facts, due to an obviously uneven level of development of different transport branches, the concept of inter-modality is emphasized as a significant transport and economic resource which incorporates all principles of European transport strategy and corresponding transport policy of integration, interoperability and sustainability. Providing the construction of a double-track electrified lowland railroad and the multipurpose canal Dunav – Sava, as well as development of port capacities (Vukovar, Osijek, Slavonski Brod and Sisak), with the appropriate development and specialization of seaport capacities (Rijeka, Ploče), this may be considered a priority infrastructural project in all aspects of regional development. Transport connection of the port of Rijeka with its hinterland – Slovenia, Austria and Hungary, and the port of Ploče with Bosnia and Herzegovina, Serbia, Montenegro and Hungary, attracts international transport flows. This especially relates to connection routes and good pan-European corridors junctions in the region, including the branches of TEN-T network. In that sense, according to the goals of the EU joint transport policy, the possibility of intermodal chain development, combining ecologically acceptable forms of inland waterway, rail and sea transport represents the most interesting option (Jolić, 2009). Geotraffic position and natural resources ensure extraordinary comparative advantages to Croatia in connecting pan-European corridors with the new priority project 21 of TEN-T network – motorway of the sea.

5.2. Concept of the Adriatic transport corridor in the framework of the Baltic-Adriatic corridor

The concept of traffic connection Baltic-Adriatic should reintegrate navigable waterways of the Danube river basin with a canal for connecting river basins. The construction of a canal from the Danube to the Elbe, the Oder and the Vistula shall enable the navigation of river and river-sea vessels to all North Sea and Baltic Seaports. The construction of the canal Vukovar – Šamac and the regulation of the river Sava to Sisak and Zagreb, as well as the river Kupa to Brod na Kupi and Tunnel Canal to Bakar shall provide the shortest possible navigable connection of the Danube area with the Adriatic (Brnjac, et al., 2006). The development of intermodal transport network and its connection with TEN-T corridors (Fig. 3) in land transport (road and railroad), inland waterways, seaports and airports are prerequisites for strengthening national economies.

The EU has corrected its long-term development strategy and adopted a new strategy Baltic-Adriatic with the port of Rijeka as the core intermodal centre and the main transport route which should ensure maximal adherence to the EU strategic interests. The EU directs 90% of foreign trade by sea, which is why the European Commission believes great savings can be achieved by the new, considerably shorter corridor passing through Croatia. This strategic interest of the EU should be recognized in Croatia and used as a great opportunity for economic recovery and development. In favour of that, the estimate of the European Commission shows that transport in the countries of the region (Croatia, Italy, Slovenia, Serbia, etc.) will grow by 50% until 2020. In a wider context, including the adopted development programme of TEN-T network and the Common Transport Policy programme, the emphasis of development was put on acknowledging environmental and safety aspects, the efficient management of transport routes by applying intelligent transport systems and the interoperability of transport branches and transport means. As Croatia is not a member of the EU, it still does not have access to the financial means from TEN-T programme. After entering the EU in July 2013, the financial means for investment into sea and intermodal transport system on the Adriatic will be available, enabling the integration of east Adriatic coast transport systems into EU development programmes. The European Commission expects Croatia to nominate its strategic transport project for Cohesion Funds, which should enable non-return usage of about € 3.5 billion, when Croatia becomes a full EU member.

Fig. 3.
Corridors V and X, Adriatic sea corridor, the potential corridor V of the North Adriatic Ports Association (NAPA) and the interconnection with TEN-T land network
Source: East Mediterranean Master Plan of the Motorways of the Sea, 2011, p. 2-117

5.3. Intermodal transport as the generator of transport and economic development of Croatia

Intermodal transport represents a strategic issue as it is of fundamental importance for the development of a sustainable transport system, whose basic goal is the creation of competitive alternatives to road transport, the reduction of bottlenecks and jams on roads, increasing safety and protection in traffic, and especially the reduction of the negative influence of traffic on the environment. Croatia, with its favourable geographical location, should intensify and integrate sea and inland waterway transport, along with the already well-built and developed road infrastructure and the development of railroad infrastructure, which is a prerequisite for the development of a sustainable transport system, as well as economy.

Compatibility and competitiveness of transport networks, as well as traffic safety and environment protection will be increased through integration of intermodal sea and inland waterway system into European transport network. Another important aspect lies in a form of inter-coastal transport connection, called Short Sea Shipping[3], which represents the main form of intermodal transport in Europe. The development of intermodal system, with the main centre in the port of Rijeka and the transport-logistic centre "Miklavlje" in Matulji near Rijeka, may enable the realization of important strategic goals in the function of economic recovery, progress and the possibility of solving economic crisis in Croatia.

Potential main strategic goals are (Miloš, 2010):

- Realizing >€ 8.5 billion of new foreign currency annually,
- Opening >90,000 of new production working places,
- Reducing import and increasing export by >35% compared to the current state,
- Raise GDP by 4.5-6% in relation to the current state,
- Raise GDP by >€ 15.000 per capita,
- Increase of dry cargo transport by 40 million tons annually until 2025,
- Increase of profit for the state budget and the budgets of local self-government units on main transport routes by >€ 3.5 billion annually,
- Reduction of foreign debt and return of foreign debt due instalments,
- Various other economic effects.

The significance of Rijeka port as an intermodal centre and junction between Croatia and the EU is reflected through the expected increase of its share in Croatian GDP until 2020, when the share would amount to as much as 12.7%, which is ten times more than today (Rijeka Port Authority, 2012). On the national level, it is estimated that GDP would grow by 4.5-6% in relation to the current condition.

On the basis of implemented development projects, the EU redefined pan-European corridors and gave up the strategy of connecting the North and the Black Sea through the corridor North Sea-Rhine-Maine-Danube-Black Sea, adopting a new strategy Baltic-Adriatic.

[3] Short Sea Shipping – transport of cargo and passengers between European and nearby non-European ports.

Analyzing the database and utilizing the most contemporary methods and technologies for estimating economic effects, the European Commission carried out a survey of the flow of goods and transport-industrial flows, through international projects IMONODE, NADOK-X, ECO4LOG, INTERIM. Imonode and Interreg IIIb projects establish the strategic justification of the integration of north Adriatic ports Rijeka, Kopar and Trieste into a system that would strengthen the European corridor V, directly integrating the junctions in Rijeka and Zagreb into it. In that sense, it is necessary to build a lowland two-track electrified railroad Rijeka-Kopar-Trieste, a railroad from Rijeka through Pivka to Austria, and along the Adriatic coast from north Italian ports to Greek ports with branches towards Zagreb and Hungary (Rijeka – Zagreb – Botovo), maximally 200 m above sea. This modern railroad would connect Croatia to the European railroad network thus making it a key factor for connecting the EU with the Adriatic-Mediterranean sea transport route, or overseas areas of Africa and Asia. Also, with this new railroad the EU is trying to integrate north Adriatic ports into the key intermodal centre, which would connect EU and Asia strategically through transportation routes (QUITS, 2010). On the basis of this strategic goal, the ports of Trieste, Rijeka, Venice, Ravenna and Kopar have founded the North Adriatic Ports Association (NAPA) in 2010. The EU evaluated the NAPA project "ITS Adriatic Multi-Port Gateway" as extremely significant for the potential of port infrastructure and European market services, whereby NAPA ports were granted financial means in the amount of € 1,442,500 in a public tender by the EU for co-financing development programmes within the TEN-T programme. Co-petitiveness (cooperation and competitiveness) shall in the future have a favourable effect on the creation of a unique information platform, which would manage services meant for the markets of the Far East, as well as central and Eastern Europe. The project will last 30 months, with the implementation deadline on June 30, 2013. NADOK-X project (Nord Adriatic Danube corridor ten) designs transport infrastructure for transport and industrial connection of the Adriatic with trans-European corridors X and VII, for modern transport of goods on the route Adriatic – Danube (Central and Eastern Europe). ECO4LOG project relates to logistic goods services in international public transportation as value added services or economic multipliers which bring enormous benefits to countries through which they pass, and there are as many as 6 international transport corridors passing through Croatia (Miloš, 2010). INTERIM project relates to modern intermodal transport system ensuring the share of sea, rail and river traffic of more than 85%, and 15% of road traffic, in order to achieve the 3E goal (Environment, Energy and Economy) (Rijeka Port Authority, 2011).

6. Conclusion

Strategic planning of intermodal transport corridor development on the Adriatic and Croatian mainland, as a part of the transport development of Croatia and the entire region, should be in the function of the overall economic development, dynamically adjusted to objective investment possibilities of the public sector, but also interests of foreign investors. Besides the current means from pre-accession EU funds, World Bank and European banks credits, the accession to the EU in July 2013 will enable the availability of financial means for the investment into sea and intermodal transport system on the Adriatic, thus enabling the inclusion of east Adriatic coast transport systems into EU development programmes.

The need for investment into the development of transport infrastructure and transhipment capacities of the main intermodal centre in the port of Rijeka, but also other Adriatic ports, with the goal of long-term realization of national strategic economic and transport interests, parallelly with satisfying the interests of the EU, is one of the most important national priorities. Considering the potential, the current transport system in the region is under-developed, characterized by development strategies of individual states and important ports. One of the key solutions of its adequate development is the integration of activities, strategies and resources of the ports in the region, as well as their joint presence on the market.

Owing to comparative advantages, competitiveness and compatibility of intermodal sea and inland waterway transport systems in integrated European transport networks, this transport system has a bright future ahead. Geostrategically and geographically well located, with all its natural resources and economic potentials, Croatia and the port of Rijeka may become a strategic transport-industrial corridor and intermodal centre, a junction between the EU and the great countries of Asia.

References:

Brnjac, N.; Jolić, N.; Jenić, V. 2006. Validation of Combined Transport Quality Criteria, *Journal of Traffic*, 18(4): 245-249.

Central national office for development strategy and EU funds coordination. 2007. *Strategy Coordination Framework 2007 – 2013*. Instrument for Pre-Accession Assistance.

Communication from the commission - Freight transport logistics action plan, COM/2007/0607 final.

Common position, Chapter 21: trans-European networks. 2009. In Proceedings of the *Conference on accession to the EU*. Bruxelles, Belgium.

East Mediterranean Master Plan of the Motorways of the Sea. 2009/2011.

Environment Management Systems,. 2004. *Support to Further Coordination of Croatian Legislation to the EU Legislation in the Area of Environment Protection*. CARDS Project.

European Commission. 2005. *Energy and Transport in Figures 2005*. European Commission Directorate-General for Energy and Transport in cooperation with Eurostat, Brussels.

European Commission. 2010. *White Paper "European Transport Policy for 2010: Time to Decide*, COM (01)370.

Jolić, N. 2009. *Integracija sustava intermodalnog vodnog prometa u europskoj transportnoj mreži*. Faculty of Transport and Traffic Sciences, University of Zagreb, Zagreb.

Matešić, M. 2009. Sustainable Development Principles in Croatian Strategic Documents, *Socijalna ekologija* 18(3-4): 323-339.

Miloš, I. 2010. Strateška prometna promišljanja razvoja Republike Hrvatske Available from Internet: <http://www.pomorskodobro.com/hr/projekti/156-strateska-prometna-promisljanja.html>.

Ministry of Sea, Transport and Infrastructure, Sea Traffic, Good and Ports Department. Available from Internet: <http://www.mmpi.hr/UserDocsFig.s/080908-babic1.pdf>

Official Gazette of the Republic of Croatia. 1999. *Strategy of Transport Development of the Republic of Croatia.* Official Gazette no. 139/99

Project IMONODE, INTERREG IIIb, Project head: Hellenic Institute of Transport, 2009. Available from Internet: <http://www.hit.certh.gr/imonode/project.php>

Ministry of Regional Development, Forestry and Water Management. 2010. *Republic of Croatia Regional Development Strategy, 2011–2013*, version 1.0.

Rijeka Port Authority. 2012. Available from Internet: <http://www.portauthority.hr/razvojni_projekti/EU_projekti.

Rijeka Port Authority, Available from Internet: <http://www.portauthority.hr/razvojni_projekti/EU_projekti>

Ministry of Sea, Tourism, Transport and Development. 2007. *Transport Operational Programme 2007-2009, Instrument for Pre-Accession Assistance*, 2007HR16IPO002. 120 p.

SEETO. 2009. Plan for core south east Europe regional transport network development VPD 2010-2014. Available from Internet: < http://www.artzu.hr/medunarodna-seeto.php>

Quality indicators for transport systems - QUITS, 2010. European Commission Transport RTD Programme.
Available from Internet: <http://www.cordis.lu/transport>

Session 9: Air Traffic Performance

A NEW APPROACH TO AN AUTOMATED AIR TRAFFIC CONTROL

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Abstract: In this paper, we identify areas of improvements of the Air Traffic Control System and propose modification of the concept of automation by using available technologies. With the modification we propose, the current Europe wide en route network structure can be modified in order to make routes more optimal. For this new route network structure, a new concept of automation will be used for managing with the air traffic. The first identified area of improvement is implementation of automation process that will enable decentralization of the Air Traffic Control functionality to each individual aircraft and this will be achieved through automated routing of the aircrafts and conflict detection and resolution (CD&R). The Flight Management System (FMS) at the aircraft will make decisions for the optimal flight route based on the sensor inputs and information on selection of the routes, next hope points and flight levels, all these received by ADS-B. The second area is processing the information about the deviation from the optimal route as in flight plan due to a traffic management (vectoring, level change) and taking it into consideration when further actions are undertaken. For each action a cost factor will be calculated from the fuel burned for that action. This factor will be used for selecting conflict resolution protocol. The proposed concept shall increase the capacity of the network, and enable more efficient, safe and more environmental friendly air traffic.

Keywords: Automated Air Traffic Control, ADS-B, efficient flight.

1. Introduction

The entire Airspace used for civil flights is segmented into elementary volumes defining elementary sectors with limited capacity in terms of serving finite number of aircrafts per hour. There is one airway[2] or more in each elementary sector that connects entry/exit points of that sector. In order to increase capacity more sectors will be required. Creation of new sectors cannot be extended unlimitedly. Safe en route traffic in core area of Europe is ensured by complex ground systems, procedures and skilled Air Traffic Controllers. Each of the three mentioned elements are in a closed loop permanently monitoring and managing safe air traffic. The safe air traffic requires conflict free traffic, and the term conflict free means aircraft to remain separated e.g. at least 5NM laterally and 1000ft vertically. Currently, Flight Management System installed in the modern aircraft calculates its lateral and vertical navigation and might be coupled with the autopilot and steering commands. It also holds flight plan which is entered by pilots prior to take-off. FMS uses different sensors to calculate aircraft position and to determine optimum speed and level for given conditions. In one typical scenario, aircraft follows its flight plan but also makes deviation by manual modification of the route made by pilots on their decision or on request by Air Traffic Controllers. Until now, only the Air Traffic Control Center has had the traffic information mainly obtained through the existing radar systems. Having the full traffic situation awareness, the Air Traffic Controllers are responsible for providing safe air traffic flow by permanently monitoring the traffic and giving clearances to the aircrafts for their routes. The current technologies provide sufficient information to the pilots and on board systems so they also can have sufficient information for the relevant traffic flow. The current centralized role of the Air Traffic Controllers can be transferred and distributed to the pilots and on board systems. Several recent papers have focused on automation of the Air Traffic Control, especially in solving CD&R and optimal routing but mainly in the terminal area. At present, both conflict resolution and optimal routing remain mostly disconnected as it is concluded in (Mishra and Pappas, 2002), the two areas of research as routing methods do not incorporate conflicts inherently in their problem formulation. In the paper, it is taken a step towards bringing optimal routing and conflict resolution closer together. In particular, the paper is inspired from routing methods in optical communication networks, where optical packets cannot be buffered and must therefore continuously move within the network without colliding. The optimization criterion based on a Floyd-Warshall shortest path algorithm is presented in (Riviere and Brisset, 2005). It gives the shortest path between every pair of points on the grid. The authors propose the criteria but also some limitations should be added in order to provide a route network which could be potentially valid in reality: a) the distance between two crossing points cannot be smaller than 100 kilometers in order for an aircraft to spend more time on a main trunk than in a crossing area; b) the shortest path cannot include an angle smaller than 90 degrees for making turns points feasible. As the criteria favor the main flows, some flows (which are mainly orthogonal to these major flows) with only a few airplanes a day may have awkward trajectories with turning angles impossible to manage in reality. The computational agents that can control simulated air traffic as an attractive complement to traditional human-in-the-loop simulation methods, and safety/risk assessment are proposed in (Callantine, 2005). In the paper authors have elaborated a case study in which computational models of Terminal-Area Air Traffic Controllers were evaluated against human performance on the same simulated traffic scenarios.

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[2] A control area or portion thereof established in the form of a corridor (ICAO Annex 11- Air Traffic Services)

2. Problem definition

The current technologies as technical enabler for safe Air Traffic Control provide more than sufficient information both to the pilots and to the airborne systems in order to support them in making decision on the most optimal route. Part of the current role of the Air Traffic Controllers can be transferred to the pilots and on board systems. Human monitored concept where all decisions would be made by on board systems and pilots is proposed and the Air Traffic Controllers shall only monitor the actions and serve as backup and last resort part of the system. In this paper, an algorithm that will enable automated route selection and safe separation from the other traffic performed only by airborne systems is proposed. The criterion for the selection of optimal route is cost based. The key parameter for cost calculation is quantity of fuel burned on route.

3. Concept description

For the initial concept definition only on en route traffic in Upper Area where aircrafts spend most of their flying time in level flight is in the focus. Finite part of the airspace with its entry and exit points is defined. The airspace is modeled with a graph model consisting of nodes that represent waypoints and links between nodes representing unidirectional airways with their distance, as shown in Fig. 1.

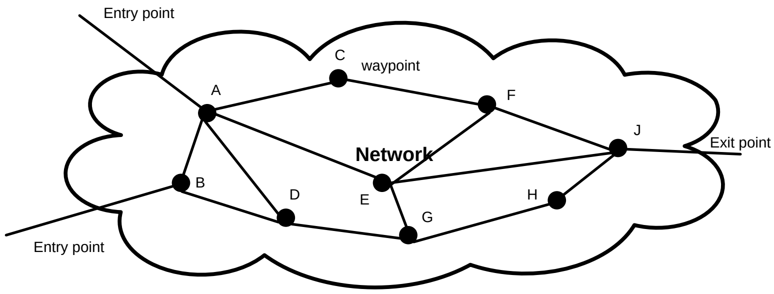

Fig. 1.
Graph model of the Airspace

For example, if an airplane at node A should fly to node J, the first task is to determine the “cheapest” available conflict free route. In the automation that we are proposing, each aircraft will have a route network map as predefined in their automation system. As a first step**,** the airplane should find available path from node A to node J. This could be performed using a popular Dijikstra (1959), the shortest path algorithm from the fifties, widely used in computer networks. Initially, the distance between nodes will be represented as a cost parameter of that link. Then the cost parameter could be slightly modified due to other factor like wind speed. Head wind will increase cost, while tail wind will decrease it. When the available route is found (e.g. A-E-J) then in the second step, the system will check for possible conflict situation during the timeline of the flight between the nodes. For that purpose ADS-B messages can be used. Each ADS-B equipped aircraft periodically broadcasts its identity, position, and Next Trajectory Change Point. The data obtained by ADS-B-in system will be kept in each aircraft as its own data record for the position of the neighboring traffic. That record will be regularly updated. Update rate could be 1 to 3 seconds. This will provide sufficient time for position calculation. This rate is improvement compared to the existing information obtained through secondary surveillance radar and tracker systems where typical refresh data rate is about 4 seconds. With simple calculation of the trajectories and with known present position, next position and speed, the system can easily check whether any conflicting traffic exists on the particular route in the determined timeframe. If the path is conflict free then this trajectory will be selected for the aircraft to fly from node A to node J and that information will be broadcasted so other aircrafts will update their own data record. If during the calculations in the second process a possible conflict is detected, then several options are available. Selecting the optimal option is determined by the “cost” of each action for the particular scenario. There are lots of papers describing different algorithms for conflict resolutions (Kuchar and Yang, 2000). For selecting the conflict resolution procedure in each particular case, we propose cost base criterion. Estimated cost is amount of fuel burned for applying conflict resolution procedure. For performing the cost calculation a Eurocontrol’s Base of Aircraft Data (BADA) tables are used. BADA provides characteristic aircraft performance data including typical climb and descent speeds and vertical speeds (climb rates) as well as cruise speeds for operations within the Air Traffic Control environment together with the amount of fuel burned for each phase of flight.

The data are organized in tables for many different aircraft types. For the purpose of possible conflict resolution, with simple calculation the required quantity of fuel can be obtained for the aircraft to:

- fly extra distance to the new temporary added node and vectoring it back to the initial route (Fig. 2); or
- change flight level; or
- fly longer route e.g. second or third the cheapest route found with Dijikstra shortest path algorithm during initial processing (A-C-E-F-J or A-D-G-H-J)

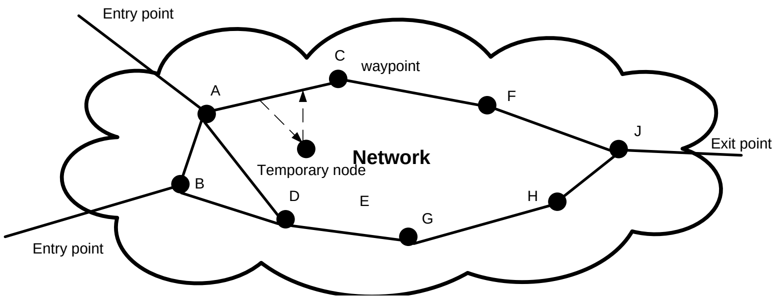

Fig. 2.
Adding temporary node for conflict resolution

The comparison between amounts of fuel required for flying extended track (in case of vectoring) or level change or for flying longer route will determine the preferable conflict resolution option.

4. Cost index calculation

It can be considered that the total cost per flight at a given range consists of a fixed cost, cost depending on flight time, and fuel cost (Eq. (1)):

$$\mathbf{C = C0 + CT \times t + CF \times WF} \tag{1}$$

in which:

C = total cost per flight
C0 = fixed cost
CT = time related cost
t = trip time
CF = fuel cost
WF = trip fuel

In the airline industry, Cost index is defined as a ratio of fuel costs to all time related operating costs for one flight (Eq. (2)).

$$\mathbf{CI} = f\,\{\mathbf{CT / CF}\} \tag{2}$$

Cost Index CI is the parameter which is used to choose the Mach / Altitude profile, and should, with available technology in correlation with the proposed concept, be used to solve for the route. It represents optimization parameter of the total trip cost by controlling both the fuel burned and the flight duration. The Cost Index method calculation is a good parameter to be used for path optimization (Le SelLier, 1999). For short or medium-haul flights (like most in Europe) distances are short enough to allow aircrafts to carry and burn enough fuel to fly at maximal Mach and shorten the flight time. This way they make CT much lower than CF. For long-haul flights a minimum burned fuel is an objective of the airliners so aircraft flies at such speed that will enable it to fly the longest distance. This makes CI minimal. For each flight airliners calculate CI for each particular flight for given conditions and that determines flight profile balancing the time cost with a fuel cost for minimal total cost of operation. FMS installed in modern aircrafts can calculate optimal flight profile based on input value for CI. Companies select typical values of 80 fuel saving long haul flights or 250 to 500 for short haul flights when time related cost are significant.

With the current air traffic management each individual air traffic unit/controller can modify aircraft trajectory and flight level. This will affect the optimal flight path, optimal flight level, speed or any combination of all of them. Any such action will change selected CI. Changing any of the flight parameters will prolong flight time (in case of new flight path longer than predicted) which will increase time related cost but also fuel related cost. Changing flight level, mostly will affect cost related to fuel. Increasing the speed above the optimal will increase fuel related cost. The information for such changes from the optimal flight route is not distributed to the other ATC units.

It can easily happen that one aircraft change route or flight level many times during its flight, so yo-yo effect will make the flying very inefficient. Within the automation we propose a counter and weighted factor number to be used. The counter will increment its value for each change from the optimal flight route. Weighted factor number will be derived as a percentage of extra fuel burned for the longer path or flight level change, compared with fuel needed for the optimum flight profile. For each deviation from initial flight path, a new CI will be calculated. This information can be used when conflict resolution algorithm is performed.

For the aircraft with lower counter values and lower weighted factor number, more "expensive" scenarios for resolution can be applied where for the aircrafts with higher counter values and/or higher weighted factor number, less demanding conflict resolution scenarios will be applied or different conflict resolution scenario will be applied e.g. other traffic will be re-routed. Counter value together with the weighted factor number will be distributed through the ADB-B messages to the neighboring aircraft, so each aircraft beside the position and next hope information for the neighboring traffic will hold information about "inefficiency" for each aircraft.

5. Operational consideration

For making fully operational concept, a modification to current ADS-B messages would be required in order to provide more information required for CD&R algorithms as well as for route reservation. For safety reasons additional information distribution chain shall be established. Possible solution could be inclusion of low orbit satellites or ADS-B IN ground station which will also receive ADS-B messages from the aircrafts and forward the received data to the ground station(s) where a local data base system will be maintained and regularly updated with the traffic information. The information from the data base then shall be transmitted and aircrafts can compare their local data base with the one transmitted from the ground stations.

6. Conclusion

The concept we are proposing extends the role of pilots and on board equipment. It enables delegating part of the Air Traffic Controllers role to the pilots and the on board systems at the aircrafts. Initially the concept would be applicable only on en route traffic where airplanes most of their time are in horizontal flight. A several different algorithms are utilized to enable full automation. For the most optimal route finding the Dijikstra shortest path algorithm is used and then conflict check algorithm is applied. If there is no conflict the selected route is reserved and if the possible conflict exists then conflict resolution algorithm is applied. The cheapest solution in terms of lowest quantity of fuel required for such a maneuver will be selected. The information about aircraft intention will be broadcasted and other participants will update their local data base for neighboring traffic. Position reports and next point information will be distributed by ADS-B. Some of the ADS-B messages would require modification or extension in order to make the concept feasible. A simulator that simulates described scenario is created in Matlab in order to test the robustness of the concept and to detect the possible weak points. Furthermore, distribution of the information for the flight deviation from the optimal flight route due to an air traffic control management will enable selection of the most optimal conflict resolution algorithms for making flights more efficient and environmentally friendlier.

References

Callantine, T.J. 2005. Computational Modeling of Air Traffic Control: Terminal Area Case Study. In Proceedings of the *IEEE International Conference on Systems, Man and Cybernetics Vol.* 3. San Jose State University/ NASA Ames Research Center Moffett Field: 2449-2454.

Dijikstra, E.W. 1959. A note on Two Problems in Connection with Graphs. *Numerische Mathematik* 1: 269-271.

Hwang, I.; Tomlin, J.C. 2002. *Protocol-based conflict resolution for air traffic control*. SUDAAR-762 Department of Aeronautics and Astronautics Stanford University, Stanford, CA 94305.

Kuchar, J.K.; Yang, L.C. 2000. A Review of Conflict Detection and Resolution Modeling Methods. *IEEE Transactions on Intelligent Transportation Systems*, 1(4): 179-189.

Le SelLier, F. 1999. *Discrete Real-Time Flight Optimization*. Master Thesis. Massachusetts Institute of Technology. 118 p.

Mishra, p.; Pappas, G.J. 2002. Flying Hot Potatoes. In Proceedings of the *American Control Conference*, Anchorage, AK.

Riviere, T.; Brisset, P. 2005. *Shortest path in planar graph and air route network*. Eurocontrol. 10 p.

Spath, O.; Eyferth, K. Conflict Resolution in En Route Traffic-A Draft Concept for an Assistance System Compatible with Solution of Air Traffic Controllers.Technical Univeristy of Berlin, Center for Human-machine systems. Available from Internet: <http://www.mmi-interaktiv.de/uploads/media/spaeth_01.pdf>

User Manual for the base of aircraft data (BADA) revision 3.9

MODEL FOR EVALUATING THE IMPACT OF AUTOMATION ON THE CAPACITY OF THE AIR TRAFFIC CONTROL SYSTEM

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Abstract: This paper evaluates the impact of the automation on the capacity of air traffic control, and thus the workload of air traffic controllers. The capacity of air traffic control system is defined by the operational units, and is expressed as the maximum number of users (aircraft) that can be accepted and served during a defined period of time under specified conditions. Workload of air traffic controllers is a limiting factor in determining the capacity of the air traffic control system and will remain such in spite of the introduction of automated air traffic control systems. The project of the Single European Sky provides modernization and replacement of existing air traffic control systems that use a system of physical forms to enter data about the flight of aircraft so called strip system. Highly automated air traffic control system does not require a system of physical forms, but the flight data is interactively entered and processed directly in the system by so called stripless system. The purpose of the introduction of automated systems is to increase the capacity of air traffic control systems by reducing controller workload. Using scientific research this paper elaborates the impact of automated systems on the workload of an air traffic controller. Measuring the impact of reducing the workload to increase airspace capacity and then taking these factors into consideration, model of optimal utilization of airspace will be developed. This paper presents review of the preliminary PhD research on influence of automation on air traffic controllers and their workload thus affecting air traffic control system capacity. Paper describes the first step in the evaluation of the introduction of new stripless system in the Croatia Control ltd. as an automation tool that affects the core business of the Air Traffic Control – providing safe and efficient separation of aircraft. The problem that this paper presents is the review of impact of automation on the capacity of the air control traffic system and thus on the workload of air traffic controller.

Keywords: automation, capacity of air traffic control, controller workload

1. Introduction

A steady growth of air traffic has accelerated rapidly particularly during the seventies, because of the deregulation of the global aviation market, (Law on the deregulation of U.S. airlines, 1978.) and the emergence of low cost airlines. Due to continuous growth of air traffic on air routes and aerodromes congestion and delays have emerged in air traffic system. Air traffic control is a complex "socio-technical" system in which humans and machines are connected through a variety of structures and processes. The purpose of air traffic control systems is to provide safe, efficient and economical services to all airspace users. The increasing number of different users has led to imbalance between demand and supply in the capacity of the air traffic control system, which results in increasing delays, causing increased costs to users, i.e. airlines. New projects, Single European Sky ATM Research - SESAR in Europe and the Next Generation Air Transportation System - NextGen in the U.S., propose the automation of air traffic control systems to increase capacity, efficiency, while maintaining or even increasing the existing level of safety.

The capacity of air traffic control system is defined by the operational units and expressed as the maximum number of users (aircraft) that can be accepted and served in a defined period under specified conditions (Janić, 2000). According to the EUROCONTROL the capacity is defined by a safe limit of the controller workload. Controller workload is a limiting factor in increasing the capacity of the air traffic control system and will remain such in spite of the introduction of automated air traffic control systems (Majumdar, 2003). The modernisation project of the Single European Sky - SESAR provides the modernization and replacement of existing air traffic control systems that use a system of physical form for entering data about the flight of aircraft so called strips system (SESAR Consortium, 2008). Highly automated air traffic control systems do not require such strips but the flight data are interactively entered into in the system. Automated systems use the following tools that reduce the workload of air traffic controllers and thus directly affect the increase the capacity of airspace:

- Conflict Detection Tools, the purpose of this tool is a warning air traffic controllers on the interactions that occur in the medium term (up to 20 minutes) that may require you to change flight path (vertical or lateral),
- System Supported Co-ordination – Sysco, this tool allows the electronic exchange and coordination about aircraft flight data through the system in real time,
- Monitoring Aids – MONA, this tool warns the controller when aircraft deviate from cleared route horizontally and vertically.

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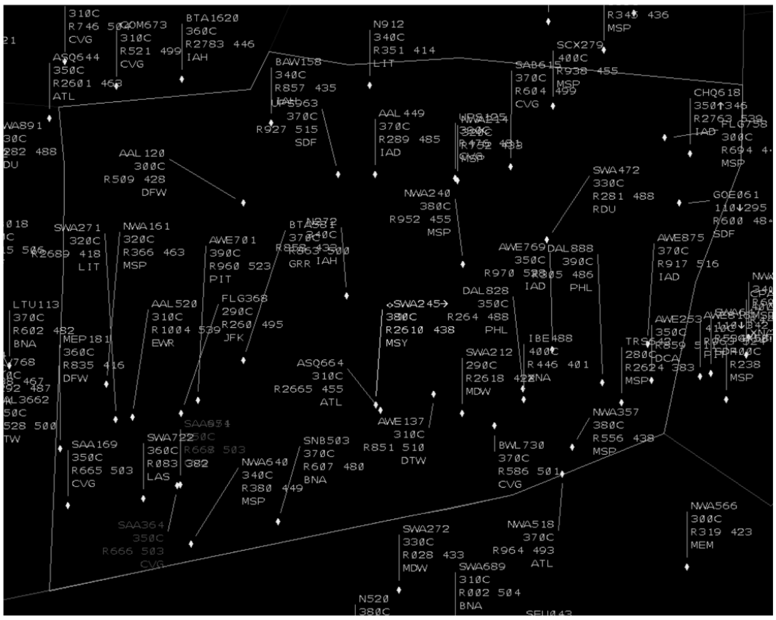

Fig. 1.
Traffic situation on a ATC controller display

The purpose of the introduction of automated systems is to increase the capacity of the air control system by reducing air traffic controller workload (Fig. 1). Existing non-automated systems require heavy controller workload in terms of verbal coordination, budget parameters, subjective estimation of the future position of aircraft, hand strip print forms about the flight and more.

Table 1
Automation Levels

Level	Human-machine cooperation
10 (high)	The computer decides everything, acts autonomously, ignoring the human.
9	Informs the human only if it, the computer, decides to.
8	Informs the human only if asked, or
7	Executes automatically, then necessarily informs the human, and
6	Allows the human a restricted time to veto before auto execution, or
5	Executes that suggestion if the human approves, or
4	Suggests one alternative
3	Narrows the selection down to a few, or
2	The computer offers a complete set of decision/action alternatives, or
1 (low)	The computer offers no assistance: human must take all decisions and actions.

2. Automation in Air Traffic Control

Variety meanings of term automation can be found in the world literature. It is the general view that automation leads to the technological change, where the general perception is that changes that automation brings would lead towards humans being replaced by machines. The US National Research Council, Panel on Human Factors in Air Traffic Control Automation provided more precise definition of automation in the context of ATM: *a device or system that accomplishes (partially or fully) a function that was previously carried out (partially or fully) by a human operator. (p. 243).*

Automation does not necessary means the change the allocation of functions between humans and machines. Change of colour on radar system display does not changes controllers tasks, while replacement of the paper flight progress strips with the electronic one presents automation because the tasks of air traffic controller has changed. Automation doest have to be applied fully across the whole ATC system it can be partially applied on different levels of the different systems.

The scale of ten levels of automation is usually applied, whereby the first level corresponds to complete absence of automation and complete execution of the functions by the human operator, and the tenth level of full automation or absence of human operators in the execution of some activities.

Application of appropriate levels of automation on air traffic control system is a complex problem due to the large number of different data and parameters that are required to a controller for a decision. There is no universal solution for the level of automation of the ATC systems, the automation must be adapted to the specific characteristics of the airspace (Wickens, 1997).

Automation in air traffic control system consists of three interrelated categories of activities of air traffic controllers (Wickens, 1998).

1) selection of appropriate decisions and actions,
2) collecting information necessary for the operation of air traffic controllers,
3) implementation of selected actions.

Using automation in air traffic control system changes the way of work of air traffic controllers, and thus the capacity the airspace. The capacity of air traffic control system is expressed as the maximum number of aircraft that can be accepted and served by the appropriate air traffic control unit for 60 minutes, according to certain conditions (Janić, 2000).

- a steady demand for service,
- different types of aircraft, jet propulsion and turbojet engines,
- characteristics of the management tasks of air traffic controllers that are transmitted via radiotelephony,
- layout of navigation aids / waypoints of area navigation
- equipment which are available to air traffic controllers upon which depends services that can be provided to users.

The fundamental problem that will be elaborated in the doctoral dissertation is the workload of air traffic controllers when using automated systems, and concrete and measurable contribution to increasing the capacity of airspace will be presented.

Factors that affect the controller’s workload, and are directly related to the capacity are:

- aircraft density (number of aircraft within a specified volume of airspace),
- the number and distance of crossing/merging points from sectorial boundaries,
- the minimum lateral distance between the nearest points on the air traffic routes,
- number of aircraft in vertical transition (climbing and descending),
- differences in the speeds of aircraft (airplanes equipped with turbo-propeller and turbo-jet engines),
- angle of approach between aircraft in a conflict situation,
- level of knowledge about the intentions of aircraft,
- coordination requirements (verbal coordination and / or coordination of the system),
- minimum separation standards to be applied between aircraft,
- the number and length of the air traffic routes within a specified volume of airspace,
- the number of entry-exit points to / from the airspace,
- volume of airspace (vertical and horizontal boundaries).

The workload of air traffic controllers can be measured directly or indirectly. Direct methods include measurements of various reactions of the human organism in terms of increased stress that is induced by increasing the workload of air traffic controllers.

Indirect methods of measurements include conducting surveys during and after the performance of duties in order of subjective assessment of workload of the controllers.

Automation of technological processes became a trend in the last 30 years. The role of operators is significantly altered by using automated systems. This is particularly evident in the air traffic control system in which the automated system doesn’t use physical forms paper strips that require additional engagement of the controller.

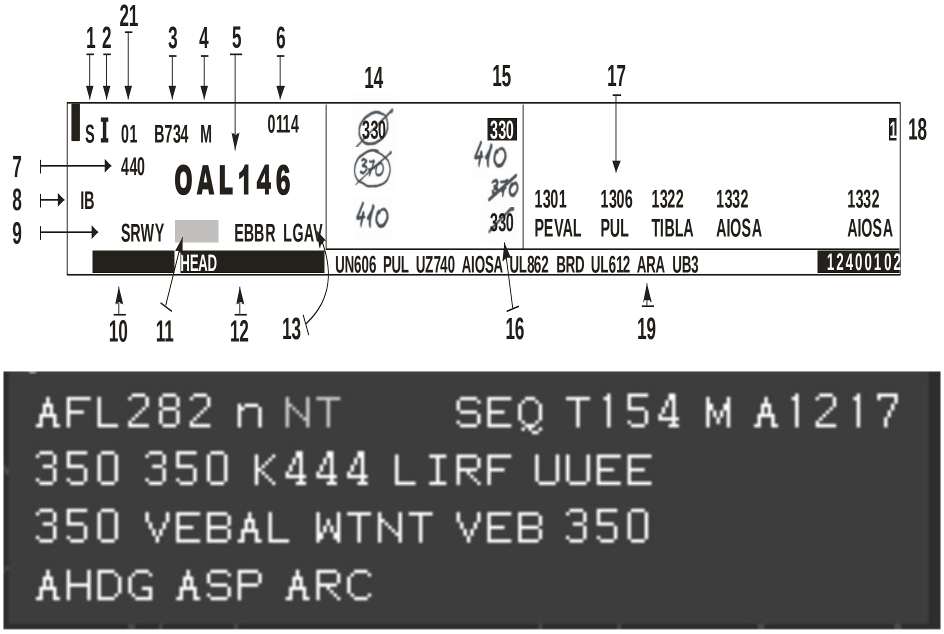

Fig. 2.
Paper flight progress strip vs. Electronic

It is therefore necessary to assess the impact of automated systems specifically designed for the Air Traffic Management - ATM on the air traffic controllers and capacity of airspace. This assessment is important for achieving the goals that are given by the EU's Council Decision endorsing the European Air Traffic Management Master Plan, 2009/320/EC. SESAR ATM. Master plan predicts a threefold increase in the capacity of air traffic control systems that will reduce delays on the ground and in the air, increase the safety factor by 10 times, reducing pollution of the environment that is caused by air traffic by 10% and reduce costs for the users of air traffic control systems by 50%.

3. Overview of previous research

In scientific literature there are different definitions of the workload of air traffic controllers. Majumdar (2003) in his paper described the workload as a mental and physical effort required to control air traffic. In a study of the European Agency for the Safety of Air Navigation EUROCONTROL (1999) according to the algorithm for determining the capacity, some 88 different tasks were used for identified for the ATCO workload. These tasks can be clustered as the flight data processing, communications with the pilots, and coordination with neighbouring air traffic control units. All of these tasks have a defined period of time measured in seconds and are added together. The controller overload occurs when all of these tasks together exceed the 70% of total time, which corresponds to 42 minutes of work for 60 minutes, when the overload occurs the controller cannot accept any more aircraft. We can convert the workload of 69% to 71% to number of airplanes that is necessary to assess the workload for each airspace, and then the capacity of airspace is 27-36 aircraft per hour.

Fig. 3.
ATC Centre that use strips

Workload of air traffic controllers is defined as the maximum bandwidth limitation, and that is the reference data for determining the capacity of air traffic control systems (Majumdar and Polak, 2001).

Wickens (1998) defined automation as the application of devices or systems for the realization of (partially or fully) a function or activity that were previously carried out (partially or fully) by human operators.

There are several reasons for the introduction of automation in air traffic control system, as well as the need to promote safety and system efficiency, and availability of new technologies to assist in the work of air traffic controllers (Fitts, 1951). Automation has multiple levels, which depend on the degree of participation of automation in the execution of a function or activity operators (air traffic controllers).

With the implementation of the automated system the concept and organization of a work of air traffic controllers significantly changes. An air traffic situation is presented visually, with the need to monitor, supervise and coordinate the large number of information about the systems itself and the air traffic. The scientific literature has not entirely covered topics about automation in air traffic control systems, but even in these works a proposed solution is often hardly enforceable and achievable in practice. Chaloulos, Crück, and Lygero (2010) propose a so called „Subliminal Control" concept. This concept foresees an automated system that works in parallel and independently of the air traffic control systems and is used to recognize potentially conflicting situations, up to 15 min before minimum separation occurs. An automated system is trying to solve those potentially conflicting situations by applying specially developed algorithms. The aircraft in conflicts are given instructions on adjusting the speed of flight. The predicted adjustment of the speed should be from -12% to +6% of the actual speed of flight. Correction in speed is not noticeable to the controller nor to pilots but is enough to ensure minimum required separation between aircraft. The concept resolves most conflicts within a defined volume of airspace, thus reducing the workload of a controller. "Subliminal Control" concept was conceived as a useful and easily enforceable way to increase system capacity of control of air traffic, but it is very difficult to implement. The existing system of controlling and management of aircraft (Flight Management System - FMS) requires pilots to confirm any change of speed, and thus proposed the concept of "Subliminal Control" is unenforceable from the pilots side. Also, changing the speed of the aircraft changes the cost factor, which shows the ratio of cost of time duration of flight and aircraft operating costs. By introducing the concept of 4 D flight path (4 D trajectories Business) any change of speed of the aircraft would disrupt the approved aircraft flight plan that is very precise and allow time tolerance of ± 30 s. By introducing the concept of "Subliminal Control", in which the automated system could seamlessly change the speed of flight of aircraft, the pilots and controllers perception of the aircraft position in space would be reduced. For the controllers, it would mean a loss of control over air traffic and it would limit the possibility of separation of aircraft that could be in a conflicting situation in the immediate future.
The time horizon of 15 minutes is too long, because most sectors in the Area Control Centres are of such size that modern jet aircraft pass them in the time interval from 12 to 15 minutes. This means that the automated system would have to issue instructions to aircraft for speed adjustments when they are in other sectors. As this is not allowed, this concept is not applicable in practice.

4. Methodology for analysis and evaluation of the effects of the automation in air traffic control system

Scientific research will be used to analyse the impact of automated systems on the workload of the air traffic controller. The impact of reducing the workload on the increase of airspace capacity will be measured, and the resulting data will be used to make a model of optimal utilization of airspace.

A comparative analysis between three different scenarios will be carried out in the development of the proposed model. Three different scenarios on the synthetic training device will be tested to evaluate existing and automated systems:

- no conflict of aircraft that are overflying,
- conflicts with only the aircraft in the horizontal plane (two dimensions), and
- conflicts of aircraft in space and time.

The scenarios will vary in complexity of the air traffic operations, and empirical and mathematical methods will be used in the development and creation of the parameters. Based on the performed analysis and the defined criteria of the level of complexity of each scenario, an assessment of the impact of automated systems on the increase of airspace capacity will be made.

The aim of the research is the valorisation of non-automated conventional air traffic control systems and the modern automated system. The identification of the different applicative system solutions, assessment of the impact on the workload of air traffic controllers and determine measurable value in increasing the capacity of air traffic control. This value can have a significant impact on defining the shape and size of individual sectors.
The basic hypnotise is that the automated systems in air traffic control, with proper application on the specific airspace, can increase airspace capacity by 10% up to 15%.

Arguments supporting the hypothesis:

- the usage of a modern automated air traffic control systems with tools which reduce the workload of the air traffic controller is directly connected with the increasing of airspace capacity,
- implementation of automation in air traffic control system affects the perception of air traffic controllers, and will be defined through an analysis model that will determine the level of reduced perception and its impact on the work of a controller,
- validation of the impact of automation will allow the definition of the capacity of the sector and the related sector configurations of airspace.

Using the scientific literature and the simulation at the synthetic training device the impact of automated systems on the workload of air traffic controllers will be determined and the value of increased capacity of air traffic control systems will be determined also. A comparative analysis on the simulator devices according to different scenarios will take place. Participants will first, on the simulator devices that use a physical form for entering data about the flight of the aircraft, „Rediffusion Simulation Ltd." (The Independent, Flexible Radar Skills Trainer FIRST), do a specially prepared exercise. There will be exercises with three different scenarios:

- no conflict of aircraft that are overflying,
- conflicts only with aircraft in the horizontal plane (two dimensions), and
- aircraft with conflicts in space and time.

The same exercises will be repeated on the simulator device for Thales ATM / Croatian Air Traffic Management System CroATMS. CroATMS is an automate simulator device that requires no physical form, but the flight data is interactively entered and processed directly in the system. CroATMS is a high fidelity simulation system which enables all functions of a working position and working procedures as in the operating environment.

Fig. 4.
Croatia Control ltd operations room

The introductory part of the dissertation will contain arguments and elaboration of scientific problems, objectives and expected results of research, review of previous research and applicable scientific methods, and structural description of the dissertation. Also, it will give an overview of the expected research results, expected scientific contributions in the field of Traffic and Transportation and the expected application of research results.

The second part of the thesis will describe the air traffic control system with a presentation of the current air traffic control systems. The first will provide insight into the system using physical forms for entering data about the flight of aircraft (strip system). Then automated system of air traffic control system will be presented. That system doesn't require a physical form, but the flight data is interactively inputted and processed directly in the system (stripless system). A descriptive method will be applied for the description of the automated system with a description of the tools that reduce the workload of air traffic controllers, thus directly affecting the increase in airspace capacity.

In the third part of the dissertation we will analyse the performance of air traffic control systems with focusing on key areas of performance that are defined in the legislation to create a single European sky. Key performance areas are: safety, environment, capacity and cost, and will further analyse the human factors.

The fourth part of the thesis will describe the operations of a controller in a conventional and automated system with special emphasis on activity of air traffic controllers, the workload of air traffic controllers, and the impact of workload on the capacity of air traffic.

Fifth part of the thesis will describe the methodology of conducting simulations under three different scenarios:

- no conflict of aircraft that are flying over,
- conflicts only with the aircraft in the horizontal plane (two dimensions),
- conflict with aircraft in space and time.

The scenarios will vary in complexity of air traffic operations, and in the developing and designing of parameters empirical and mathematical methods will be used. According to the resulting data, a model of optimum use of airspace for the selected traffic pattern will be made.

The final concluding part of the dissertation will present the results of scientific research in different parts of the dissertation, and will specify the specific proposals and assumptions, and confirm the hypothesis.

5. Conclusion

From the standpoint of scientific methodology and research, as a result of targeted research in the following doctoral dissertation, the following scientific contributions in the field of traffic and transport technology are expected:

- evaluation of existing automated air traffic control systems,
- the impact of advanced automated systems on the workload of air traffic controllers,
- proposed application solutions to reduce the workload in order to increase airspace capacity,
- identification and evaluation of application of advanced automated system solutions to the general perception of air traffic controllers in a defined airspace,
- development of the methodology for the selection of automated systems for traffic optimization and technological structure of the airspace.

It should be mentioned that this research will present significant contribution in the Croatia Control ltd. in terms of enhancing the overall performance of the Croatian ANSP, by identifying the influence of the new CroATMs system on its air traffic controllers.

References

Chaloulos, G.; Crück, E.; Lygero, J. 2010. A simulation based study of subliminal control for air traffic management, *Transportation Research Part C: Emerging Technologies*, 18(6): 963-974.

EUROCONTROL. 1999. *Link2000 +: Fast time simulation to assess the impact of data link on sector capacity*. Eurocontrol, Brussels, Belgium. 20 p.

Fitts, P.M. 1951. *Human Engineering for an effective air-navigation and traffic-control system*. Ohio State University Research Foundation. Columbus, Ohio, USA. 85 p.

Janić, M. 2000. *Air transport system analysis and modelling: capacity, quality of services and economics*. Gordon and Breach Science Publishers, New York, USA. 318 p.

Majumdar, A. 2003. *A Framework for Modelling the Capacity of Europe's Airspace Using a Model of Air Traffic Controller Workload* University of London Centre for Transport Studies Imperial College of Science, Technology and Medicine South Kensington, UK. 534 p.

Majumdar A.; Polak J.W. 2001. Estimating the Capacity of Europe's Airspace Using a Simulation Model of Air Traffic Controller Workload, *Transportation Research Record*, 1744/2001: 30-43.

SESAR Consortium. 2008. *SESAR Master Plan*. Brussels, Belgium. 123 p.

Wickens, C. 1997. *Automation in Flight to the Future: Human Factors in Air Traffic Control*. National Academies Press, Washington, USA. 384 p.

Wickens, C. 1998. *Automation issues in Air Traffic Management in: Future of Air Traffic Control: Human Operators and Automation*, National Academies Press, Washington, USA.

THE IMPACT OF AIRCRAFT OPERATIONAL FACTORS ON TURBOFAN ENGINE DIRECT MAINTENANCE COSTS

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Abstract: Turbofan engine shop maintenance costs can account for a third of aircraft total direct maintenance costs. This considerable amount raises the need to analyze primary engine maintenance cost drivers in order to achieve the lowest possible costs per engine flight hour. Main operational factors that affect time on-wing and their impact on engine maintenance costs are presented in this paper. For airlines, understanding both the on-wing and off-wing elements of engine maintenance cost is a key factor in successful business planning. The purpose of this paper is to identify and analyze the off-wing elements of engine maintenance cost including take-off thrust rating, applied take-off thrust derate, flight hour-to-cycle ratio, engine utilization, environmental conditions and to show the nature of their influence on engine direct maintenance costs. The estimation of the impact is based on turbofan engine data collected from different sources of information available to authors of this paper.

Keywords: turbofan engine, maintenance costs, thrust rating, utilization, operational severity.

1. Introduction

The maintenance of aircraft engines is preventive in nature (Seymour, 2011). The on-condition maintenance concept in today's use prescribes routine trend monitoring of key engine performance parameters such as rotor speed, Exhaust Gas Temperature (EGT), fuel flow and vibration along with inspecting the engine on a periodic basis in order to determine the appropriate moment when the engine should be removed from aircraft and overhauled in customized workshops (Ackert, 2011). The type of aircraft/engine operation will govern the extent and rate of engine deterioration and thus will have a large influence on engine maintenance costs. Different rates of engine deterioration will be reflected through different engine's on-wing lives between shop visits. A long experience in operating turbofan engines has shown that the cost of engine operation may be optimized by extending the time/cycles between shop visits. Thorough understanding of aircraft operational factors that drive engine maintenance costs is of main importance for airlines since these costs are a major part of an airline's total aircraft maintenance cost.

2. Engine Removal Reasons

Gas-turbine engine components degrade during operation, causing lower or higher level of engine performance deterioration, which can be detected through the application of engine condition monitoring program. During its entire service life, an engine will experience several shop visits. The rate of shop visit events will depend on the engine's utilization, maturity and operational severity. The operating experience indicates that the main causes of engine removals are the expiration of Life-Limited Parts (LLP) and the deterioration of Exhaust Gas Temperature Margin (EGTM). For example, LLP and performance (EGTM deterioration) drive more than 70% of mature CFM56-3 engine shop visits (Gruber et al., 2000). Other engine removal reasons include hardware deterioration, unscheduled events and maintenance convenience.

As illustrated in Fig. 1, the causes of engine removals depend heavily on the type of operation an engine is exposed to. Engines operating on short-haul operations experience higher removals due to EGT margin deterioration and LLP expiry. In contrast, engines operating on medium-to-long haul flights tend to have a higher percentage of removals due to hardware deterioration and EGT margin deterioration.

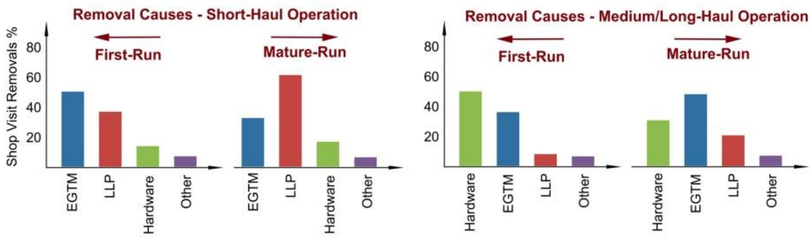

Fig. 1.
Engine removal causes
Source: (Ackert, 2011)

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2.1. Life-Limited Parts

Even though today's commercial jet engines as a whole are maintained on-condition, some of their critical components, that are mostly composed of disks, seals, shafts and spools, are still subjected to hard time limits. These components are commonly known as Life-Limited Parts and defined as those "*rotor and major static structural parts whose primary failure is likely to result in a hazardous engine effect*" (FAR, 2012). Being considered as "hard time" components, LLPs must be replaced after reaching the end of their permissible lives, specified by the number of Engine Flight Cycles (EFC) they are allowed to operate. Although some of the LLPs can be replaced on-wing, the replacement of the most number of LLPs requires engine removal from the aircraft, thereby bringing high shop visit costs that are primarily the result of large material expenses. Therefore, the engine's LLPs and their remaining life influence the timing of engine removals and removal intervals.

Each of the engine modules contains a certain number of LLPs. The life span of most LLPs usually varies between 15,000÷30,000EFC (Aircraft Commerce 34, 2004). For example, the CFM56-3 engine has 19 LLPs, as shown in Table 1. Three LLPs are installed in the Fan and Booster module with target lives of 30,000EFC. Five LLPs in the High Pressure Compressor (HPC) and four LLPs in the High Pressure Turbine (HPT) module have target lives of 20,000EFC. Seven LLPs installed in the Low Pressure Turbine (LPT) module have target lives of 25,000EFC. Some of the LLP part numbers, which are excluded from previous consideration, have shorter lives imposed on them by Airworthiness Directives (AD) or other technical issues (Ackert, 2011). Table 1 presents the analysis of the CFM56-3 LLP costs per EFC, using the Original Equipment Manufacturer (OEM) list prices dated from 2003. It should be emphasized that LLP list prices for the CFM56-3 have been escalating between 6÷7% annually, for the past ten years.

Table 1
Life limits and price list for CFM56-3 LLPs

No.	Module	LLP Description	List price [$]	Life limit [EFC]			Unit cost [$/EFC]		
				Cat A	Cat B	Cat C	Cat A	Cat B	Cat C
1	Fan & Booster	Booster Spool	113290	30000	30000	30000	3.78	3.78	3.78
2		Fan Disk	78250	30000	24900	20100	2.61	3.14	3.89
3		Fan Shaft	70850	30000	30000	30000	2.36	2.36	2.36
Fan & Booster Totals:			**262390**	**90000**	**84900**	**80100**	**8.75**	**9.28**	**10.03**
4	HPC	HPC Front Shaft	48710	20000	20000	20000	2.44	2.44	2.44
5		HPC Spool Stg. 1-2	77210	20000	20000	20000	3.86	3.86	3.86
6		HPC Disk Stg. 3	24120	20000	20000	20000	1.21	1.21	1.21
7		HPC Spool Stg. 4-9	173650	20000	20000	15800	8.68	8.68	10.99
8		HPC CDP Seal	34760	20000	18000	15000	1.74	1.93	2.32
HPC Totals:			**358450**	**100000**	**98000**	**90800**	**17.92**	**18.12**	**20.81**
9	HPT	HPT Front Shaft	60880	20000	17300	17000	3.04	3.52	3.58
10		HPT CDP Seal	64690	20000	15800	15100	3.23	4.09	4.28
11		HPT Rotor Disk	116140	20000	18500	16600	5.81	6.28	7.00
12		HPT Rear Shaft	47680	20000	20000	20000	2.38	2.38	2.38
HPT Totals:			**289390**	**80000**	**71600**	**68700**	**14.47**	**16.28**	**17.25**
13	LPT	LPT Disk Stg. 1	53970	25000	25000	25000	2.16	2.16	2.16
14		LPT Disk Stg. 2	61830	25000	25000	25000	2.47	2.47	2.47
15		LPT Disk Stg. 3	62420	25000	25000	25000	2.50	2.50	2.50
16		LPT Disk Stg. 4	53970	25000	25000	25000	2.16	2.16	2.16
17		LPT Conical Support	41880	25000	25000	25000	1.68	1.68	1.68
18		LPT Shaft	105470	30000	30000	30000	3.52	3.52	3.52
19		LPT Stub Shaft	35080	25000	25000	25000	1.40	1.40	1.40
LPT Totals:			**414620**	**180000**	**180000**	**180000**	**15.88**	**15.88**	**15.88**
TOTALS:			**1324850**	**450000**	**434500**	**419600**	**57.02**	**59.55**	**63.97**

Source: (Aircraft Commerce 33, 2004)

Differences in target lives among the LLPs installed in a specific engine are forcing the replacement of various LLPs at different shop visits. Furthermore, noticeable differences in LLP life limits within engine modules of the higher thrust-rated CFM56-3 variants (Cat B & C) require careful analysis of the LLP replacement schedules, in order to achieve desirable reductions in engine maintenance costs. Resulting from these variations, a small percentage of the remaining LLP lives are not consumed during the engine operation. That is why engine operators usually consider the replacement of LLPs to avoid limiting the succeeding on-wing intervals by leaving LLPs in the engine with lives shorter than possible intervals allowed by engine performance restoration (Aircraft Commerce 33, 2004).

The replacement of LLPs that have some portion of remaining lives may assist in recovering the cost of their scrappage by selling them on the used parts market. LLPs account for a large percentage of the overall engine maintenance costs, since the cost of full LLP replacement during engine's overhaul may as well exceed the cost of engine performance restoration.

2.2. EGT Margin

Degradation of a turbofan engine, which is mainly cased by compressor fouling, blade tip clearance increase due to wearing and erosion, seal leakage due to damage, and airfoil erosion, is reflected through the changes of efficiencies and flow capacities of its gas path components. The resulting engine performance deterioration increases the amount of fuel required to provide the same engine thrust, therefore leading to an increase in EGT.

The Exhaust Gas Temperature Margin is the difference between the maximum permitted EGT for an engine model (EGT red line), and the peak EGT, incurred during a take-off at maximum thrust at a referenced condition (Mungin and Maumy, 1988). Operating the engine below the EGT red line limit ensures that an engine stays on-wing without requiring maintenance actions. The deterioration of engine performance is reducing the EGTM due to increase of the EGT and causing the engine removal for performance restoration. Excluding other removal factors, an engine can remain in operation until its EGTM has reduced to zero (Ackert, 2011). Therefore, the EGTM is one of the most important engine parameters, whose monitoring is crucial for the evaluation of engine's overall health.

An engine's Time On-Wing (TOW) is largely dependant on the initial EGTM and the rate of EGTM deterioration. In general, higher rated engines have lower EGTM values. The initial EGTM values are the highest when the engines are new. EGTM can be recovered during shop visit to a level close to the levels of a new engine. The rate of EGTM deterioration is affected by several operational factors: takeoff thrust rating, applied takeoff thrust derate, flight length and type of an operating environment.

3. Engine Maintenance Cost Breakdown

Aircraft maintenance accounts for about 10% to 15% of the direct operating cost of an aircraft (Rupp, 2005), but this estimate is dependant on a number of parameters such as the aircraft model, the engine type and the nature of operation. Of this total aircraft maintenance cost, around 30% to 35% can be attributed to the cost of engine shop maintenance (Rupp, 2005). Although small at first sight, the percentage share of engine shop visit cost in total aircraft operating cost is very significant, considering that the cost of single shop visit may exceed $1 million (Aircraft Commerce 45, 2006).

Engine Direct Maintenance Costs (DMC) are those scheduled and unscheduled maintenance labor and material costs directly expended in performing maintenance on an engine (Poubeau, 1989). They can be further broken down into line and shop direct maintenance costs. Line maintenance of the installed aircraft engine is performed on-wing in compliance with the procedures and limits contained within the Aircraft Maintenance Manual (AMM). Regular line inspections and maintenance tasks ensure the continued operation of aircraft engines. On the other hand, engine shop maintenance is carried out off-wing in accordance with the Engine Shop Manual (ESM), when the engine has been removed from the aircraft and sent into airline's maintenance workshop for repair. The application of more strict ESM limits during the engine shop visit aims to restore the engine to an airworthy condition.

An engine's shop DMC, measured in $ per EFH, is the product of its Shop Visit Cost (SVC) and Shop Visit Rate (SVR). The SVR is a measure of an engine's average TOW that is calculated as the ratio of total number of shop visits to the total number of flight hours flown. Extending the interval between shop visits will lower the SVR and reduce the engine's shop DMC. On the other hand, the amount of work to be performed at shop visit generally increases as TOW increases, requiring higher levels of workscope and thus increasing SVC (Fig. 2). Finding the optimum on-wing interval that minimizes the engine's shop DMC depends on the operator's actual operation and cost assumptions.

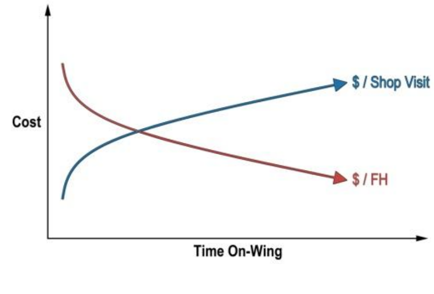

Fig. 2.
The impact of TOW on SVC and Shop DMC
Source: (Ackert, 2011)

An engine's SVC is usually regarded as a sum of the cost of module restoration and the cost of LLP replacement. The cost of engine shop visit will vary on the specific level of workscope for that particular shop visit. Workscope Planning Guide (WPG), written by engine manufacturers, contains the guidelines and recommendations that can be used to optimize the maintenance performed during each shop visit. WPG specifies three levels of workscopes for each engine module: minimum, performance and full workscope. Minimum workscope applies to the engines inducted into the shop with low time since last overhaul, possessing sufficient performance margins, which were removed for a known cause. Performance workscope is used for performance restoration of the engine modules. Full workscope refers to the combination of LLP replacement and performance restoration of an engine module, i.e. module overhaul. The level of workscope to be performed on an engine is dependent on the removal cause, time accumulated on the engine modules, observed hardware conditions, trend data at removal, and business goals.

The following is a discussion of the main operational parameters that affect the on-wing life of an engine.

4. Takeoff Thrust Rating

The levels of engine thrust, which meet the design limitations that are composed of pressure, temperature and rotational speed limits, are referred to as thrust ratings. Takeoff thrust rating is the highest level of available engine thrust that is based on a maximum allowable EGT at which the engine is allowed to operate for five minutes during the takeoff phase of flight. This approved thrust level is called maximum takeoff thrust and presents one of the certified thrust ratings for commercial civil aircraft engines quoted by the engine manufacturer for operational use. Engine manufacturers specify maximum allowable EGT for an engine model at a referenced condition, which is defined at sea level pressure altitude and at Outside Air Temperature (OAT) higher than the International Standard Atmosphere (ISA) condition. The OAT that defines a referenced condition is called the Corner Point (CP).

In general, assuming constant altitude and Mach number, for a given constant EGT, the engine thrust decreases with the increase of OAT (Fowler, 1989). However, in order to meet aircraft performance requirements, today's civil turbofan engine power management systems are designed to provide a constant level of thrust for a given pressure altitude, also known as flat-rated thrust, at OATs below the corner point (Fig. 3). As a result of flat rating concept, an engine's EGT will increase with the rise in OATs up to the CP. At OATs above the CP, engine becomes temperature limited and engine thrust must decrease in order to keep the EGT constant. For the CFM56-3 engines, the CP is at 30°C, and the gradient of the EGT increase in the flat-rated thrust region is 3.2°C for every 1°C rise in OAT (Aircraft Commerce 45, 2006).

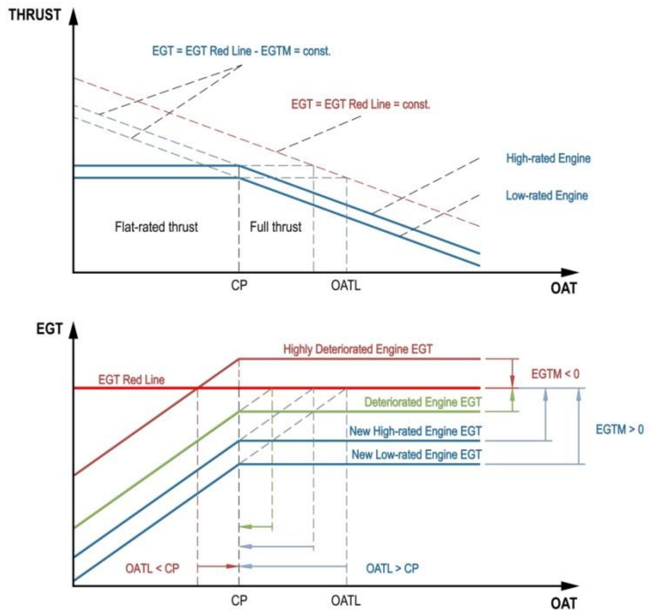

Fig. 3.
Flat rating concept and EGTM
Source: (Author, 2012)

The EGT would continue to increase at a constant rate with OAT if flate-rated thrust levels were maintained above the CP. The OAT at which EGT would reach the maximum allowable EGT is referred to as the Outside Air Temperature Limit (OATL), which is used as another indicator of engine's health. OATL presents the highest OAT at which an engine should deliver the full takeoff thrust without exceeding the EGT red line. However, engine deterioration causes the reduction of both EGTM and OATL, which may lead OATL to fall bellow the CP.

Operating the engine at maximum takeoff thrust may result in EGT exceedance if OATL is reduced below the CP. In addition, the negative EGTM will not necessarily lead to an EGT exceedance as long as the engine is operated at OATs lower than OATL. The AMM prescribes the operational EGT limits and EGT exceedance allowances along with the required maintenance actions depending on the number and the level of EGT exceedance.

The engine variant with higher takeoff thrust rating operates at higher exhaust gas temperatures and thus has a lower initial EGTM. In addition to low EGTM, operating the engine at high EGT increases the rate of EGTM deterioration because hot section life usage increases exponentially with increasing turbine metal temperature. For the same level of EGTM deterioration, an engine operated at a lower takeoff thrust rating can stay on-wing longer. Different deterioration rates for the CFM56-3 series of engines presented in Fig. 4 illustrate this fact. After the initial loss following the first 1,000-2,000EFC on-wing due to “running in“ of blade tip clearances, the rates of EGTM deterioration are reduced and remain approximately constant until the engine is scheduled for removal. As the engine ages the deterioration rates increase, shortening the intervals between shop visits, which stabilize at about 60% of the first on-wing life after reaching maturity (Beck, 2004).

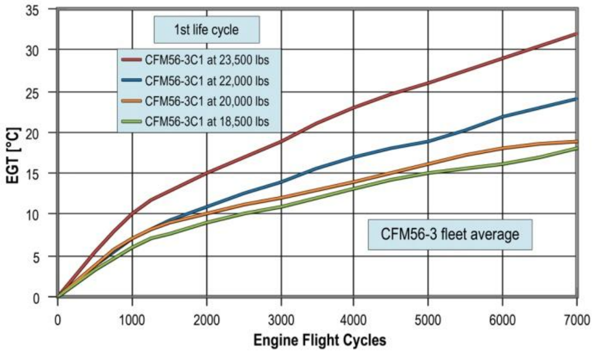

Fig. 4.
EGT deterioration
Source: (EGT margin, 2006)

The impact of engine thrust rating on shop DMC can be considered in two ways. Firstly, resulting from lower initial EGTM and higher EGTM deterioration rates, engines with higher takeoff thrust rating achieve shorter on-wing intervals, thereby increasing SVR, which directly affects the increase in engine shop DMC, primarily as a result of the increased performance workscopes. On the other side, the LLP cost per cycle is higher because of the stricter LLP target life limits within the higher thrust rating category. Taking into account such impact on shop DMC, the operators advise the application of reduced thrust takeoffs whenever possible, to prolong the service life of hot section components and to extend on-wing intervals. In addition, the engines that are capable of operating at different power ratings should be monitored for the number of operated cycles at each takeoff thrust rating category in order to determine the number of remaining cycles on LLPs and to plan the removals caused by LLP expiry.

5. Flight Length

The proportion of time an engine spends in a particular thrust setting in relation to the total flight time affects the severity of engine operation. On shorter flight lengths, a larger proportion of total flight time is spent using takeoff and climb thrust levels, an engine is operated at higher temperatures, pressures and speeds, resulting with higher rates of performance deterioration and thus higher maintenance costs per flight hour (Fig. 5). For example, one minute of takeoff has a responsibility of at least 45% on the engine maintenance cost (CFM, 2005).

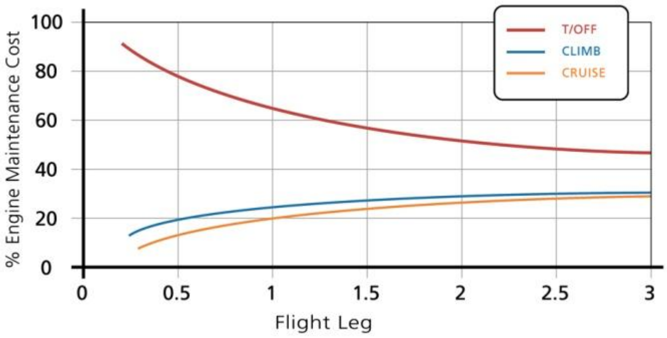

Fig. 5.
Thrust setting effect on engine maintenance cost
Source: (CFM Flight Operations Support, 2005)

The impact of time spent at takeoff thrust setting on engine DMC is significantly reduced on longer flight lengths, but remains somewhat higher than the impact of time spent at climb and cruise thrust settings. Consequently, the effect of longer flight lengths is less engine wear and tear per flight hour, leading to lower engine DMC because of the longer time between shop visits and the lower labor and material cost to restore engine to a specified condition. The general form of the flight length impact on engine DMC is presented in Fig. 6.

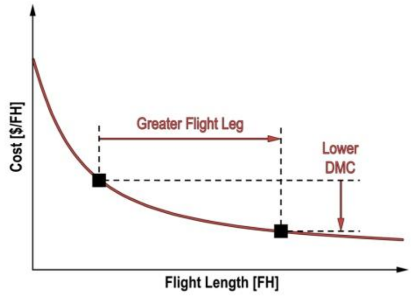

Fig. 6.
Flight length impact on engine DMC
Source: (Ackert, 2011)

Higher rates of EFC accumulation and EGTM deterioration that are experienced on shorter flight lengths are the main causes of higher engine DMC, where the cost of LLP replacement has the largest proportional share. Since LLP lives are limited in EFC, for the same annual utilization in EFH, the engines flown on longer routes will experience lower LLP costs per EFH because of the lower rate of EFC accumulation.

6. Reduced Takeoff Thrust

When the actual takeoff Gross Weight (GW) of an aircraft is below the maximum allowable GW for the actual OAT, the takeoff thrust required is lower than the maximum takeoff thrust available. This enables performing takeoffs at less than maximum takeoff thrust using the assumed temperature method, a derated thrust or a combination of both. When using assumed temperature method, the assumed temperature for which the actual GW would be equal to the maximum allowed GW is determined and entered in the Flight Management Computer (FMC) thus setting the reduced takeoff thrust level (Fig. 7). Since reduced thrust setting is not a limitation for the takeoff it enables the selection of full engine thrust at any time during the takeoff. The maximum allowable thrust reduction is 25% from the takeoff thrust rating according to the requirements.

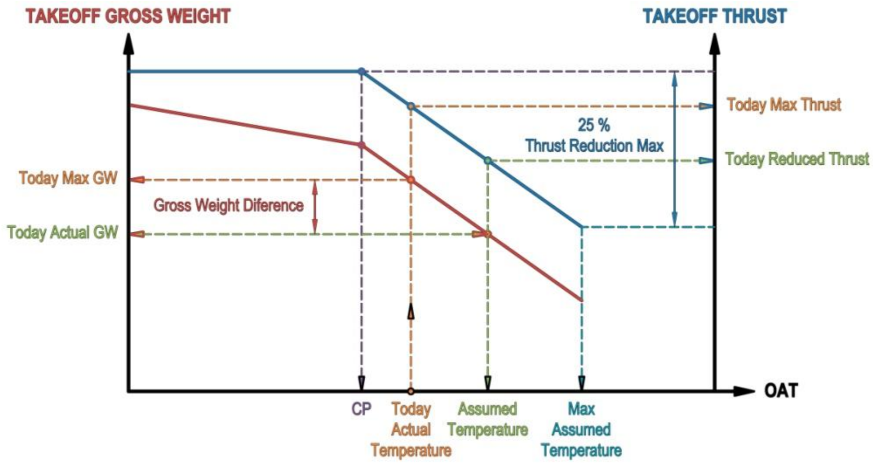

Fig. 7.
The assumed temperature method
Source: (Author, 2012)

On the other hand, derated takeoff thrust is set by selecting in the FMC an approved takeoff thrust rating that is lower than the maximum rated takeoff thrust. The derated thrust setting becomes an operating limitation for the takeoff. Sometimes derated thrust and reduced thrust can be used together, e.g., a derated thrust can be selected and thrust further reduced using the assumed temperature method. The application of the reduced thrust/derated takeoff helps lowering the engine operating temperatures, pressures and rotational speeds, resulting with reduced stress and wear, improved engine reliability, better EGTM retention, longer TOW and reduced engine DMC. The actual impact of the reduced thrust/derated takeoff on the engine DMC can be evaluated using the severity curves.

7. Operational Severity

Engine's internal temperature, internal pressure and rotational speeds determine the degree of operational severity. Operating the engine at more severe conditions is resulting with higher rate of performance deterioration and increased engine DMC. Aircraft operational factors that affect operational severity are flight length, effective derate, outside ambient temperature and type of operating environment. Effective derate is a sum of the partial takeoff, climb and cruise derates, including the effects of the flight length and the reduced thrust/derate operation during the takeoff, climb and cruise flight phases. On shorter flight lengths, the same operational takeoff derates carries a greater impact on the partial takeoff derates and consequently on the effective derates as indicated in the Fig. 8. Using the operational climb and cruise derates is weighted heavier on longer flight lengths, which reflects the previously discussed impact of the time spent in the corresponding thrust setting on the engine DMC.

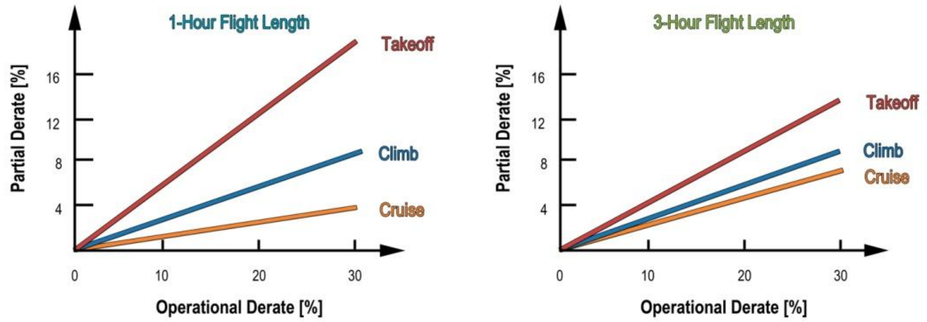

Fig. 8.
Partial derate vs. operational derate at different flight lengths
Source: (CFM Flight Operations Support, 2005)

The engine severity curves are used to determine the maintenance cost for specific flight conditions. Engine manufacturers develop severity curves applicable to different thrust ratings of the same engine family, due to a high degree of hardware commonality mutually shared. Some of the severity curves may include the impact of effective derate and others incorporate only operational derates, depending on the statistical data used for their development. Fig. 9 illustrates an example of the severity curves for the CFM56 family.

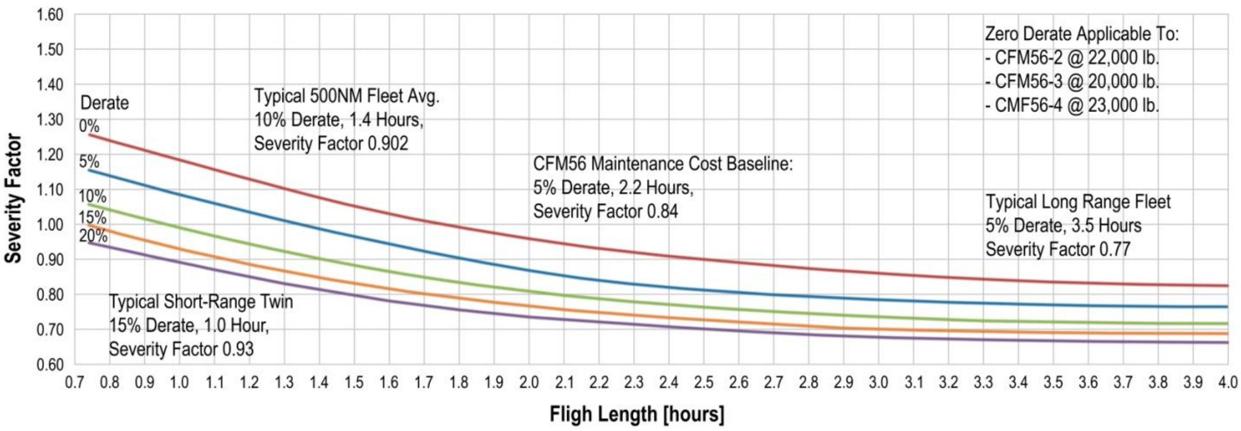

Fig. 9.
CFM56 maintenance cost baseline conditions & severity adjustments
Source: (Engine maintenance cost review for JAT, 1983)

The maintenance cost baseline condition for the CFM56 is defined at a 2.2 hour flight and at a 5% operational derate, corresponding to the severity factor of 0.84. Knowing the maintenance cost for the baseline condition, the maintenance cost for individual applications can be evaluated using the ratio of severity factors between the baseline condition and any other specific conditions. For example, the maintenance cost for typical short-range operation using 15% derate and one hour flight will be about 10% higher than the maintenance cost for baseline condition, as determined by the ratio of severity factors for these two conditions (Fig. 9).

Engine components are also affected by the environment in which they operate. Erosive and hot/dry environments increase the operational severity due to their negative effects on the engine components conditions. The impact of the operating environment can be included by using the enviromental coefficients (Ackert, 2011). More demanding operating conditions will accelerate engine aging process and lower the on-wing intervals between shop visits.

8. Conclusion

Extending the on-wing intervals is proven to reduce engine direct maintenance cost whose basic structure and share in total aircraft operating cost is presented in this paper. The consideration of engine removal causes distinguishes LLP expiry and EGTM deterioration as major removal drivers. Using the CFM56-3 engine as an example, an introduction to LLP management issues is provided by analyzing the LLP life limits and the cost of LLP replacement. The assessment of EGTM as one of the key engine's health parameters, whose impact on engine time on-wing is presented and explained in this paper is the first step in planning the incoming shop visit workscope. Controlling the type and extent of the workscope performed at shop visit is another area where the operators are best able to influence the time an engine remains on-wing. Certainly, the cost effective maintenance relies on the application of carefully developed engine condition monitoring program.

The analysis of aircraft operational factors can be used for prediction and evaluation of engine on-wing lives between shop visits. The application of reduced takeoff thrust or derated takeoff thrust may definitely provide significant cost savings. The evaluation of engine maintenance cost for the specific operating condition can be accomplished using the severity curves as explained. This paper is intended to provide qualitative information on main operational factors that affect time on-wing and to prepare the foundation for the planned development of a cost optimization model for turbofan engine maintenance management as a part of the ongoing research.

References

Ackert, S. 2011. Engine maintenance concepts for financiers. Available from internet: <http://www.scribd.com/doc/83845370/Engine-Mx-Concepts-for-Financiers-V2>.

Beck, A. 2004. Calculating maintenance reserves, *The Engine Yearbook*, 36-41.

CFM56-3B1/B2/C1. 2004. Maintenance cost analysis, *Aircraft Commerce*, 33: 27-34.

CFM Flight Operations Support. 2005. Available from internet: < http://www.smartcockpit.com/aircraft-ressources/CFM_Flight_Ops_Support_B737.html>.

FAR. 2012. Engine life-limited parts, Title 14, Part 33, Subpart E, Federal Aviation Administration.

Fowler, T.W. 1989. *Jet Engines and Propulsion Systems for Engineers*. GE Aircraft Engines, 516 p.

Gruber, P.; Fischer, B.; Segard, F.C. 2000. *Engine workscope management*, CFM International.
1983. *Engine maintenance cost review for JAT*, CFM International.

EGT margin. 2006. Available from internet: <http://www.smartcockpit.com/aircraft-ressources/EGT_Margin_by_CFM.html>.

LLP. 2004. management for short-haul engines, *Aircraft Commerce*, 34: 38-44.

Mungin, B.; Maumy, O. 1988. EGT margin A300/CF6-50C2, *FAST Airbus Magazine*, 9: 9-13.

Owner's & operator's guide: CFM56-3 series. 2006. *Aircraft Commerce*, 45: 10-31.

Poubeau, J.P. 1989. Direct maintenance costs, *FAST Airbus Magazine*, Special edition: 1-32.

Rupp, O. 2005. Engine maintenance costs, *The Engine Yearbook*, 20-25.

Seymour, P. 2011. An Introduction to Conducting Engine Maintenance, *AviTrader MRO*, April: 18-19.

SAFETY MANAGEMENT SYSTEM AS THE TOOL FOR AIRPORT BENCHMARKING PROCESS

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Abstract: The paper is based on the thesis which could be applicable to the benchmarking process at leading airports of South East Europe, and so visibly improve their business. The paper also shows how to carry out this process efficiently at the airport, which processes should be applied when benchmarking, and appropriate methodology. Special attention is given to the parameters necessary to carry out Benchmarking process. Airport Safety Management System has purpose to insure the certain level of safety for critical airport operations. Satisfactory level of safety cannot be achieved without proper level of quality. This fact will be used to determine how Safety Management System affects the benchmarking process at airports and how system components can help eliminate shortcomings of benchmarking analysis. Besides the safety management, attention will be given to the quality as the vision of the future and the quality systems, risk management and safety assurance. Most authors believe that we are living in the century of quality because it is a key concept to the success of many global companies, especially those involved in air traffic.

Keywords: benchmarking, safety, quality, implementation, analysis.

1. Introduction

Benchmarking is the process of comparing business processes and performance of one firm or industry with best practices, performances and business processes of other firms or industries. Dimensions typically measured are quality, time and cost. In the process of benchmarking, management identifies the best firms in their industry, or in another industry where similar processes exist, and compare the results and processes. A benefit of benchmarking is that a fact it can be a fairly straightforward means to identify performance deficiencies or exceptional performance, without detailed and complex examination of processes. Benchmarking has become an increasingly popular tool used in the management, regulation and review of both private and public organizations. Like many other industries within the transportation sector, the airport industry has used benchmarking in a number of different ways to assess and improve its performance.

In order to achieve its production objectives, the management of any aviation organization requires managing many business processes. Safety is one such business process. Safety Management is a core business function just as financial management, human resource management, etc. The Safety Management System (SMS) is a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures.

The question is, is it possible to use development and introduction of SMS at South East European (SEE) airports to inspire and implement benchmarking process at these airports.

2. Air traffic in Southeast Europe

The fragmentation of Yugoslavia and associated confrontations caused geopolitical and economic changes in the SEE region which resulted in reduction of air transport volumes. Mentioned trend remained until year 2000 when significant increase in traffic volumes was recorded. The high influence of passenger traffic growth in the region had the entrance of the Low Cost Carriers on the SEE market in 2003 resulting in increase of available destinations within the Europe from the regional airports. Impact of Low Cost carriers on the market is visible in traffic increase from 5.7 million in 2002 to 8 million in 2004. While connections with main European destinations are dominant and all the leading European carriers are already operating in the region, presently only 10% of all the SEE airlines' commercial activity is realized within SEE airport network.

Overall traffic carried on the SEE territory by regional airlines in year 2001 represents approximately 50% of passenger kilometers (PKM) carried by Yugoslavian JAT in 1989. Major SEE national airlines, Croatia Airlines and JAT Airways are still fully owned by the Government while Montenegro Airlines is privately owned but it has been granted a status of national flag carrier. Even though JAT Airways experienced difficulties in its privatization attempts, future privatizations in airline industry in the region are inevitable. In 2003 Kosovo Airlines was established by the United Nations Interim Administration Mission in Kosovo (under UNSCR 1244/99) and in 2006 it ceased operating flights and continued to work with other airline companies flying into Pristine.

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Among SEE airlines, Croatia Airlines strengthened its position as the busiest carrier in 2011 recording highest number of passengers (1.8 million) since it began operations in 1991. Comparing its performance in 2011 to 2010, passenger traffic increase of 15% and 5% increase of average cabin occupancy index (67%) can be noticed. Second highest performance recorded JAT Airways with 1.2 million passengers handled in 2011 and a recorded average cabin load factor of 70%, up 8 points on 2010. Apart from Croatia Airlines and JAT all the other SEE national carriers[2] (Albanian Airlines, BH Airlines and Montenegro Airlines) saw their passenger figures decline in 2011 compared to 2010.

International traffic in the SEE region is based on 17 airports which are a part of the SEETO[3] Comprehensive Network from which seven airports are situated in Croatia, two in Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro and Serbia and one airport in Albania and in Kosovo (under UNSCR 1244/99). The SEETO Comprehensive Network airports ownership structure differs significantly between Regional Participants. Airports situated in Bosnia and Herzegovina, Croatia[4], Montenegro and Serbia are under national control while in Albania, the former Yugoslav Republic of Macedonia and Kosovo (under UNSCR 1244/99) airports were given under concession to the private sector. All SEETO Comprehensive Network airports are equipped with one runway longer than 2,400 meters enabling commercial operations of narrow and wide body jets. The airports in Belgrade, Dubrovnik, Zagreb and Tivat operate on a runway longer than 3000 meters that enables landing and take-off of largest passenger aircrafts (B747, B777, A340), but airports taxiway systems, aprons, gates and passenger terminal areas preclude its usage.

Table 1
Basic technical characteristics of South East Europe airports

SEETO CN Airport	IATA level	Number of runways	Main runway length (m)	Number of passenger terminals	Passenger terminal area (m2)	Apron area (m2)
Tirana	n/a	1	2,750	1	13,000	55,500
Banja Luka	n/a	1	2,400	1	800	21,600
Sarajevo	2	1	2,600	1	46,000	8,000
Dubrovnik	1	1	3,300	1	15,000	110,500
Osijek	1	1	2,500	1	1,536	27,000
Pula	1	1	2,946	1	5,400	64,200
Rijeka	1	1	2,500	1	7,800	33,600
Split	2	1	2,550	1	10,800	50,000
Zadar	1	2	2,500	2	4,044	32,420
Zagreb	1	1	3,252	1	15,000	168,000
Ohrid	n/a	1	2,550	1	2,500	38,700
Skopje	2	1	2,950	1	40,000	77,220
Podgorica	1	1	2,500	1	5,500	33,220
Tivat	1	1	3,252	1	4,050	40,000
Belgrade	1	1	3,400	2	51,000	163,350
Nis	1	1	2,500	1	2,000	27,500
Pristina	n/a	1	2,500	1	3,938	46,020

Source: South East Europe Transport Observatory (SEETO) database

2.1. Traffic analysis at South East Europe airports for the period from 2000 to 2010

One of the highest air transport growth rates in Europe were recorded in the SEE region but the traffic volume figures in comparison with other European regions are low. In the last decade the SEE region recorded tremendous yearly growth rate in airport traffic volumes in some Regional Participants exciding 10%. Constant changes were noted in passenger traffic figures varying from - 49% in the Former Yugoslav Republic of Macedonia (2001) to 109.24% in Kosovo (under UNSCR 1244/99) (2002).

[2] MAT Macedonian Airlines is no longer flying and Kosovo Airlines does not exist anymore.
[3] South East Europe Transport Observatory (SEETO)
[4] In Croatia, ownership of all international airports is divided under national, local or regional government; Airport Zagreb is planned to be given under concession in the forthcoming period.

Table 2
South East Europeans airports passenger turnovers and indexes

Airport	2001	2005	2010	Index 05/01	Index 10/05	Index 10/01
Sarajevo	323,454	433,222	643,800	134	149	199
Dubrovnik	461,322	1,083,240	1,270,062	2439	117	2860
Osijek	NA	2,389	20,827	NA	872	NA
Pula	102,985	209,412	332,399	203	159	323
Rijeka	32,799	122,493	61,855	373	50	189
Split	568,625	934,049	1,219,737	164	131	215
Zadar	39,244	86,857	260,030	221	299	663
Zagreb	1,186,471	1,551,519	2,071,561	131	134	175
Ohrid	53,954	53,930	44,392	100	82	82
Skopje	495,204	521,339	681,080	105	131	138
Podgorica	NA	319,665	651,608	NA	204	NA
Tivat	354,666	377,013	541,836	106	144	153
Belgrade	1,497,519	2,032,357	2,698,730	136	133	180
Niš	NA	26,787	23,654	NA	88	NA
Pristina	403,408	930,346	1,305,532	231	140	324
Total	**5,519,651**	**8,684,618**	**11,827,103**	**170**	**136**	**232**

Source: South East Europe Transport Observatory (SEETO) database

By observing traffic performance of the SEETO Comprehensive Network airports in the last decade it can be noticed that the highest growth rates were recorded in the 2001 - 2005 period while in the period 2005 - 2010 the increase of passengers continues, but with a lower rate. Highest growth index was observed on airports with lower passenger traffic volumes (Zadar and Pula) while Belgrade Airport recorded highest passenger number increase from 2001 to 2010 (1.2 million passengers) remaining its leading position in the passenger traffic volumes among SEE airports.

The SEE airports do not fully use their favorable position on main traffic flows between Europe, Middle East and Africa which has repercussion on its low level of cargo traffic volumes. Cargo flows in 2010 in the SEE region were highest in Zagreb (9.386 tons) and second highest in Belgrade (7.427 tons) together accounting 60% of overall cargo traffic on the international SEE airports. Comparing cargo volumes in 2010 to 2009 rising trend was visible on Belgrade Airport (11%) while Zagreb Airport recorded cargo volume drop of 7%. Even though cargo traffic in the SEE region increased for 50% from year 2000 to 2010, traffic volumes are very low in European terms.

3. Airport benchmarking

Benchmarking is a management technique to improve business performance. It is used to compare productivity and efficiency, evaluate specific processes, policies and strategies and to assess overall organizational performance. Organizations need goals and targets for their management, their stakeholders and their employees: benchmarks are tools which show where the organization is meeting its objectives, and where it is not.

An example of collaborative benchmarking is the IATA Global Airport Monitor (now rebranded as AETRA and conducted in partnership with ACI), which benchmarks (passenger) customer satisfaction on a quarterly basis. Airports participate in the study on a voluntary basis; currently around 66 airports participate. In addition to assessing relative performance, the results of this benchmarking are also used for promotional purposes: Number 1 Airport in the World / North America / Europe, etc.

Similarly, Inter VISTAS Consulting Inc. conducts annual customer satisfaction benchmarking for a number of Canadian Airports Council small airports. The study benchmarks overall satisfaction with the airports as well as satisfaction with specific services – baggage delivery, ground transportation, retail, etc. The study also benchmarks other metrics such as average passenger spend rates and queue times.

Airport benchmarking is a component of an airport's strategic planning process. It is a statistical and accounting process that is used to monitor and compare airport economic, operational and service performance. Benchmarking assesses the implementation of an airport's strategic planning objectives to measure the performance of discrete airport functions and identifies best practices for possible incorporation into the organization's procedures to increase efficiency, quality and customer satisfaction. Thus benchmarking links day-to-day operations and management with an airport's short and long-term strategic initiatives and action plans.

There are two general types of benchmarking: partial, assessing and comparing individual processes/functions/services; and, holistic, creating a systematic approach for defining and assessing a critical set of processes/functions/services that, when taken together, indicate the relative performance of the total organization.

Within these general categories, as mentioned above, there are two predominant forms of benchmarking: internal, self-benchmarking within an organization which compares internal performance of processes/functions/services over time (time-series), and external, which compares performance across organizations with peers or in other industries (cross-sectional) at a single point in time and through time. The five basic steps of benchmarking are:

1 Deciding what to benchmark, bearing in mind that the parameters must lend themselves to quantification;
2 Deciding against whom to benchmark;
3 Analyzing data and identify key performance differentials;
4 Setting new performance goals;
5 Monitoring progress and communicate results to decision makers.

Table 3 presents a matrix of many of the key airport benchmarking areas produced for the North American AIM Benchmarking survey. This particular survey is among the most ambitious and complex in the marketplace and requires considerable resources to implement. Forty-five airports have committed to participating in the AIM survey, despite this resource requirement.

Table 3
Matrix of Key Airport Performance Benchmarking Areas

Traffic Activity • total passengers (originating and connecting) • total cargo (mail and freight) • total operations (commercial, commuter, GA and military)	**Airfield Aircraft, Terminal Passenger, and Landside Transportation Processing Efficiency (engineering measure of throughput and level of service)** • runway, taxiway, airfield design, layout and aircraft processing efficiency • airfield terminal area (ramp and gate areas) aircraft processing efficiency • terminal passenger flows and processing efficiency • terminal curb and landside processing efficiency
Physical Facilities • number of airports • land area, runways, taxiways, apron • terminals, concourses, gates • ticket counter, security, and baggage • parking spaces	
Aeronautical Charges – Airfield • landing & take-off fees • aircraft apron, parking and gate fees • aircraft environmental fees • aircraft fuelling fees and other ground handling fees	**Aeronautical Related Charges – Terminal** • ticket counter space • boarding gates and loading bridges • administrative office space • flight kitchens and services • baggage processing/handling • passenger lounges • FIS, BIDS and CUTE fees
Non-Aeronautical Concession Revenues – Terminal • retail/specialty retail • food/beverage • news/gifts • duty free/tax free • advertising • hotels	**Non-Aeronautical Concession Revenues – Landside** • parking • rental cars • taxis, buses, limos • rail and train stations • other commercial vehicles • hotels, conference centers, office buildings • shopping centers
Operating and Maintenance Costs • personnel costs (salaries & benefits) • soft costs/outsourcing • supplies and materials • repairs and maintenance • communications and utilities costs • law enforcement and fire fighting costs • other operating costs	**Other Financial** • other non-operating revenues • cash flow and liquidity • debt (bonds and loans) • return on equity and assets • EBITA and net profit • capital expenditures and costs (actual and projected)
Quality of Community Airline Service • number of airlines • airline routes and frequencies • aircraft types and fleet mix • airline competition and airfares	**Quality of Airport Facilities and Services (passenger satisfaction)** • quality of experience coming to airport • quality of passenger processing (check-in, gate, customs and immigration and security) • quality of airport commercial services • quality of airport physical facilities

Source: Ginn L: Airport Benchmarking to maximize efficiency

4. Methods of airport benchmarking

This chapter provides a brief introduction to the technical instruments which are used for measuring and comparing different companies/airports.

These methods can be roughly divided into the following categories:

- methods derived from econometrics and mathematical programming, e.g. stochastic frontier analysis;
- statistical measures and comparisons, e.g. comparison of passengers per employee, comparisons of user charges;
- qualitative measures and comparisons, e.g. questionnaires and surveys;
- expert assessments utilizing case study comparisons.

4.1. Econometrics and mathematical programming approaches

Broadly speaking there are three major approaches to estimating or measuring 'top down' performance and to formal estimation of cost functions: linear regression analysis (Ordinary or Corrected Least Squares), Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA).

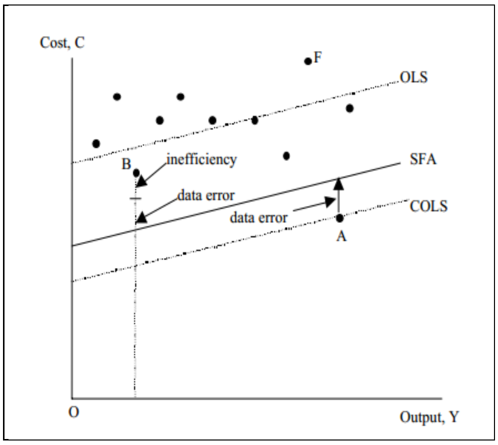

Fig. 1.
Ordinary least squares (OLS) analysis
CAA: The Use of Benchmarking in the Airport Reviews

The most basic approach is the ordinary least squares (OLS) analysis which fits a line of "best fit" to the observed data points such that the line minimizes the sum of the squared deviations of the data points from the fitted line (see Fig. 1). For example, in the simplest case of single input and single output, a (linear) line of the following form may be fitted to the observed data: $C = a + bY + v$, where the coefficients a and b determine the intercept and slope of the regression line in the (C, Y) space and v is the random error term. If C is the total cost incurred in producing the output Y, then coefficients a and b will represent the fixed and marginal costs in producing Y. The fitted straight line represents the costs that a firm of average efficiency would incur at each level of output. Firms above the fitted line (e.g. firm F) are said to be inefficient because they have costs in excess of those of an average firm with the same output level; firms below this line (e.g. firms A and B) by contrast are deemed efficient. The difference between the actual and the predicted costs is called the *residual*.

Stochastic frontier technique differs from the deterministic frontier approaches (e.g. COLS, DEA) in that it can accommodate both data "noise" and statistical tests. However, this is at the expense of requiring specification of a functional form of the underlying production technology and strong distributional assumptions on the error term. The main technical difference between SFA and simple regression analyses (e.g. OLS & COLS) is that SFA allows decomposition of the model residuals into a random but symmetrical component (v) and a one-sided error component ($u \leq 0$) that represents the "true" level of inefficiency: $C = a + bY + (v - u)$.

Fig. 2 below shows an example of an input minimization DEA model under the constant returns to scale (CRS) assumption. Point B' is the projected point of the target firm C on the frontier while firms A and E are referred to as the 'peers' of firm C. Intuitively, the DEA problem for the firm C is to seek to radially contract its input vector x_c as much as possible, while still remaining within the feasible production set. The radial contraction of the input vector produces a projected point B'(x_λ,y_λ) on the surface of this technology TT'. This projected point B' is a linear combination of the observed firms A and E. Similarly, G' is the projected point of firm F. The technical efficiency (TE) of firms C and F are then given by the ratios OB'/OC and OG'/OF respectively. Furthermore, if factor prices (PP') are known, one could also calculate the allocative (AE) and overall productive efficiency (PE) as OD/OB' and OD/OC respectively.

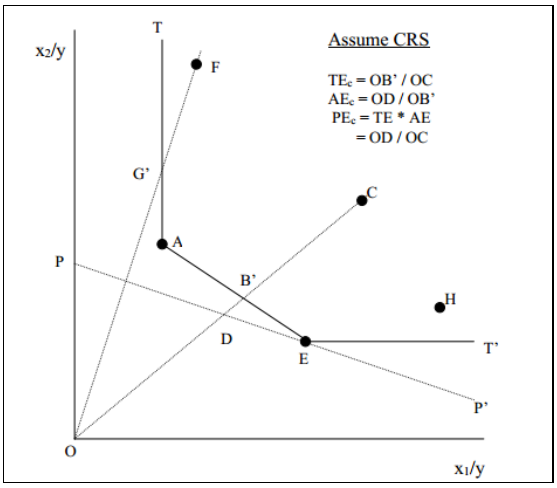

Fig. 2.
Input minimization DEA model
CAA: The Use of Benchmarking in the Airport Reviews

4.2. Partial statistical measures

These are less ambitious than full estimations of an airport cost function or overall efficiency. Instead they can act as indicators of performance in specific areas, such as unit costs in respect of particular services, or comparisons of costs of particular types of facilities. These kinds of measures must be handled with caution since good performance on one partial measure (for example a low number of security staff per passenger) may reflect under performance in another (for example the time taken for security processing of passengers).

These partial productivity measures have been criticized on the ground that they:
- do not reflect differences in factor prices;
- do not take into account of possible factor substitution in production;
- fail to take account of the differences in operating environments between firms;
- are unable to handle multiple outputs.

An alternative approach that can give an overall picture of performance is the index number technique such as Tornqvist Total Factor Productivity (TFP) and Malmquist Index (MI) measures (discussed later).

4.3. Qualitative measures

Qualitative comparisons (for example a high level of customer satisfaction in relation to airport cleanliness at one airport compared to another) must be treated cautiously since they may mask poor performance in other areas (for example a high cost of providing clean facilities). These types of measures and indicators are of greatest importance in assessing service quality.

4.4. Expert assessments and case study comparisons

This is a standard approach used by other regulators. It can be used to assess efficiency and performance, the scope for productivity gains, cost functions or incremental costs. Essentially regulators commission appropriate experts to undertake an expert assessment of one or other of these factors. This assessment is often likely to involve an element of benchmarking. Benchmarking in this area will often focus on appropriate case study comparisons.

5. Safety Management System as part of Benchmarking process

Safety Management System (SMS) is the formal, top-down business-like approach to managing safety risk. It includes systematic procedures, practices, and policies for the management of safety. Similar to other management functions, safety management requires planning, organizing, communicating and providing direction. A SMS provides a proactive, systematic, and integrated method of managing safety for airport operators. Essential to a SMS are formal safety risk management procedures that provide risk analysis and assessment.

Generally accepted industry standards and International Civil Aviation Organization (ICAO) guidance describe Safety Management Systems in terms of four distinct elements. They include:

- Safety Policy and Objectives,
- Safety Risk Management,
- Safety Assurance,
- Safety Promotion.

Management's commitment to safety should be formally expressed in a statement of the organization's safety policy. This policy should reflect the organization's safety philosophy and become the establishment of the SMS. Safety policy can be the result of benchmarking process, but also can be measure which aims to improve airport benchmarking.

Safety Risk Management (SRM) is a core of any Safety Management System. To be truly effective a SMS must have a formal risk assessment program that identifies and documents hazards on the airport. An SMS:

- Determines associated risk(s),
- Identifies the severity and probability of the occurring risk(s),
- Develops mitigation strategies as appropriate,
- Applies, tracks, and monitors the mitigation strategy,
- Assesses and modifies strategies as necessary.

SRM is a systematic, explicit, and comprehensive approach for managing safety risk at all levels throughout the airport processes. A comprehensive SMS using SRM will develop layers of safety built upon the measures taken to mitigate risk. These layers are examples of implemented protective measures such as vehicle driver's training programs, marking and lighting standards and reflective vests. An unsafe event can occur when gaps occur in the system's protective layers. These gaps are not static and may appear unexpectedly. In order for an incident or accident to take place there is normally a succession of gaps in a system that will line up and enable an event to occur.

SRM together with Safety Assurance can have a major impact on the implementation of benchmarking at airport. These two components of SMS are crucial for collecting parameters that relate to safety, quality and infrastructure of airport, and can play a major role in achieving benchmarking strategic goals.

Safety Assurance includes self-auditing, external auditing, and safety oversight. Safety oversight can be achieved through auditing and surveillance practices, given the diverse activities at commercial airports. In addition to the airport operator's existing responsibilities for self-inspection and correction of discrepancies, an effective airport SMS audit program should:

- Develop identified safety performance indicators and targets,
- Monitor adherence to safety policy through self-auditing,
- Allocate adequate resources for safety oversight,
- Solicit input through a non-punitive safety reporting system,
- Systematically review all available feedback from daily self-inspections, assessments, reports, safety risk analysis, and safety audits,
- Communicate findings to staff and implement agreed-upon mitigation strategies,
- Promote integration of a systems approach to safety into the overall operation of the airport.

Feedback is necessary to assess how well the SMS is working. This is achieved through safety oversight, performance monitoring, and continuous improvement processes. The SMS should include a visible non-punitive safety reporting system supported by management. The safety reporting system should permit feedback from personnel regarding hazards and safety-related concerns.

Safety auditing is a core safety management activity. Similar to financial audits, safety audits provide a means for systematically assessing how well the organization is meeting its safety objectives. Top Management may choose to have an external agency audit the system (e.g., by a consultant or another airport operator). The safety audit, together with other safety oversight activities, provides feedback to managers concerning the overall safety performance of the organization.

Safety performance monitoring validates the SMS, confirming the organization's safety objectives. Through regular review and evaluation, management can pursue continuous improvements in safety management and may revise safety objectives to ensure that the SMS remains effective and relevant to the organization's operation.

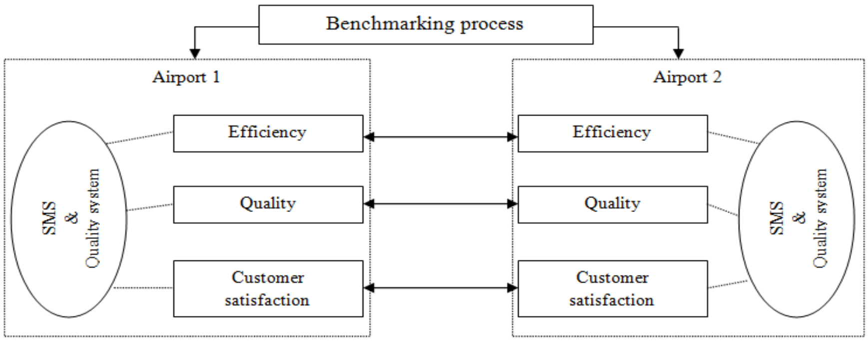

Fig. 3.
External benchmarking

To perform successful benchmarking process is critical to understand what processes are critical for successes. An airport provides services to airlines and passengers so the main activity of airport is handling aircraft, passengers and freight. SMS as the system collect information about safety performance of this operation's collecting crucial date about airport performance. From benchmarking perspective these are useful date about airport efficiency and quality service. On this way using SMS as benchmarking tool is solved one of main challenges in benchmarking airport performance, obtaining workable data.

Date collected through SRM and Safety Assurance represents good foundation for internal benchmarking. While for external benchmarking are necessary information from database of similar airports with similar SMS. This mean that is not possible simple use SMS dates for external benchmarking, but it is necessary to benchmark with airport of similar size, traffic indicators, ownership structure, etc. Even when airports are very similar data can be interpreted differently simply because different external influences, different SMS systems, etc. Fig. 4 shows relation between SMS and external benchmarking.

6. Conclusion

Airports of SEE participate in global air transport with a very small share (only 1.3%). In same time this airports has adequate infrastructure, sufficient capacity and are investing in modernization. This is the best indicator of the need to increase business efficiency. For the following reasons is considered that benchmarking process is suitable for increasing the efficiency of SEE airports: (1) benchmarking process is based on a comparison of the parameters. At U.S. and the EU airports this process has been already implemented long enough and there are international organizations, as well as sufficient sources and studies with which the airport of SEE could make comparisons; (2) SEE airports are similar by traffic demands, construction characteristics, ownership structure and stage of development. Because of these characteristics this airports are suitable for external benchmarking against each other; and (3) international airports including those of SEE are obliged to implement SMS and are developing quality management. These systems are based on the active collecting of dates that are useful for benchmarking and can greatly simplify the implementation of this process.

Through the SMS airports are building databases about efficiency and performance that resolve one of major benchmarking issues, obtaining workable database. Also, through development of SMS is possible to adjust the data to provide meaningful comparison in benchmarking process, especially when benchmarking process is used to compare performance of similar airports like those in SEE.

In same time introducing of benchmarking process encourage airports to implement and develop new systems such as SMS and quality systems. This is one of major benefits of benchmarking process; it helps introduce new ideas to an organization.

While benchmarking has many issues and limitations associated with it, it is certainly not without value. It is a useful tool to identify deficiencies and excellence in performance. It can spur competitive forces and shake up conventional thinking. SMS can serve as an effective benchmarking tool same as benchmarking can serve as an effective decision making tool, but decision makers must be aware of limitations of both SMS and the benchmarking analysis.

References

Bennett, D. 2007. *Introduction to Safety Management System*, U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular.

Buyukozkan, G. 2000. A cooperative approach for benchmarking process, Engineering Management Society, 2000. In *Proceedings of the 2000 IEEE*: 239 – 244.

Civil Aviation Authority. 2000. *The Use of Benchmarking in the Airport Reviews*, CAA Consultation Paper, London.

De Neufville, R.; Guzmán J.R. 1998. Benchmarking for Design of Major Airports Worldwide, *Journal of Transportation Engineering*, 124(4): 391-395.

Ginn, L. 2006. *Airport Benchmarking to maximize efficiency*, Airports Council International, ACI World Headquarters, Geneva 2006.

Kincaid, I.; Tretheway, M. 2006. Guidelines for Benchmarking Airports, GARS Workshop, In Proceedings of the *Hamburg Aviation Conference*, Hamburg, Germany.

Kincaid, I.; Tretheway, M. 2009. Methodology Choices for Benchmarking Airports, GARS Workshop, In Proceedings of the *Hamburg Aviation Conference*, Hamburg, Germany.

Maire, J.L.; Buyukozkan, G. 1997. Methods and Tools for First Five Steps of Benchmarking process, Innovation in Technology Management - The Key to Global Leadership. In Proceedings of the *PICMET '97: Portland International Conference on Management and Technology*.

Paljetak, J.; Šimecki, A.; Steiner, S. 2012. *Valorizacija prometa zračnih luka Jugoistočne Europe od 2000. do 2010. godine*, Hrvatska akademija znanosti i umjetnosti, Zagreb.

Steiner, S.; Tatalović, M.; Bajić, J. 2010. Competition and Cooperation on European Southeast Air Transport market, In Proceedings of the *7th International Conference "Economic integrations, competition and cooperation"*, Opatija, Croatia.

South East Europe Transport Observatory (SEETO) database. Available from Internet: <http://www.seetoint.org>.

PERFORMANCE BASED NAVIGATION IMPLEMENTATION IN CROATIAN AIRSPACE

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Abstract: Performance Based Navigation (PBN) is a term that has been recently introduced to cover a range of navigation requirements. It was adopted by ICAO to cover a several navigation specifications that already existed under common standards or common terms of reference. PBN was introduced because ICAO recognized the need to establish global standards which are complement to existing navigation systems, so the aircraft can fly from one region to another and be confident that their operating systems comply with the same standards anywhere. Harmonization of air navigation systems around the world is an important way to ensure that airspace is managed safety and efficiently. This is why the ICAO launched its PBN implementation plan along with the manual and the task force in late 2008 to help states to develop its common navigation concept. This paper will describe current process and future PBN implementation plan in Europe and in Croatia. The methodology and results of recent scientific research projects conducted by Department of Aeronautics at the Faculty of Traffic and Transportation Sciences at University of Zagreb will be also presented. Focus will be places on GNSS (Global Navigation Satellite System) navigation applications in terms of RNP approach procedures without the vertical guidance. The results from several flight trails will be presented to sustain the use of GNSS in non-precision approach procedures on airports without ground based navigation infrastructure.

Key words: Performance Based Navigation, Approach procedures, Area navigation.

1. Introduction

ICAO's Performance-based Navigation (PBN) Concept has replaced the RNP Concept and was introduced through publication of the ICAO PBN Manual (Doc 9613) in 2008. Performance Based Navigation (PBN) is an important concept because it makes the use of modern navigation tools. It allows aircrafts to use their advanced on-board navigation capabilities in order to fly the most direct and fuel efficient routes. It provides an alternative to conventional navigation methods which rely on ground-based navigation aids. These do not always support the most sufficient routes, and can be expensive to maintain. So, there are a lot of benefits of PBN as it can save fuel and emissions, and it can be used to introduce new routes that avoid areas of congestions, and different approaches and departure paths to and from busy airports.

Area Navigation (RNAV) is a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. Area navigation includes performance-based navigation as well as other RNAV operations that do not meet the definition of performance-based navigation. The concept of PBN relies on the use of an Area Navigation (RNAV) system. There are two core input components for the application of PBN: the navaid infrastructure, and navigation specification. A navigation specification is either an RNP specification or an RNAV specification. RNAV and RNP systems are fundamentally similar, the key difference between them is the requirement for on-board performance monitoring and alerting. An RNP specification includes a requirement for on-board self-contained performance monitoring and alerting, while an RNAV specification does not.

PBN challenges are *aircraft performance*, *airspace design and procedures* and *cultural change*.

- *Aircraft performance*: First the aircraft needs to comply with modern navigation capabilities. This means that aircraft must have the ability to fly accurately within a defined flight path, for example to within 1 or 2 NM accuracy. This is the Area Navigation or RNAV capability mentioned earlier. Then there is more precise Required Navigation Performance or RNP, and this includes performance monitoring and alerting capability on-board that means that pilot is alerted when navigation requirement is not met.
- *Airspace design and procedure*: There needs to be a published PBN route where the airspace is designed to support RNAV or RNP routes. There is also a need for procedures to be in place for new flight paths so the pilots and controllers are familiar with operations and to receive training in procedures needed to fly the routes.
- *Cultural change*: These involve changing the way we talk about navigation. This is happening thru modernization program like SESAR in Europe and NEXTGEN in US, both of which are starting to address airborne and ground infrastructure element together as a part of the whole airspace system modernization.

The release of ICAO PBN Manual marks the big step forward in publicizing these challenges. It includes global harmonized set of requirements and the whole combination of elements that make up the PBN concept. Manual contains navigation specifications for various navigation applications covering different phases of flight. These specifications define the RNAV system performance requirements in terms of accuracy, integrity, continuity of service

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The priority is to communicate these benefits to potential users and help them to understand the path of implementation in order to optimize the use of airspace.

2. ICAO PBN Implementation Strategy

Aviation is facing many challenges, starting from airspace congestions, fuel efficiency issues, growing environmental concerns, greater demands for safe accessibility to aerodromes, and currently big international programs such as SESAR and NextGen are addressing these matters. From the navigational point of view many of these challenges can be addressed by Area Navigation. However, the problem is that this far RNAV has been primarily a technological evolution that is not addressed regulatory aspects as ANSP, and interoperability requirements. Therefore there has been a lack of large scale global implementation of very useful technological innovation.

Area Navigation has been around for a long time (30 years ago). However, until now implementation of such advanced navigation methods has left behind, and is up to this day not much spread. Area Navigation is providing a lot of efficiency avoiding the need to fly from one navaid to another and provide more capabilities in direct routes.

It is important to emphasize that for the implementation in airspace, the PBN is only one of the elements to achieve the objectives for airspace. When designing the airspace, all the CNS/ATM features must be taken into account. So the PBN is really one of the pillars in the CNS/ATM and actually enables the airspace concept to be founded and to operate.

PBN is implemented in ECAC en-route and terminal airspace. The RNAV 5 (B-RNAV) in en-route airspace of Europe since 1998, that's across whole Europe continent, largely above FL95, and it's enabled the route structure optimization. Interestedly enough, what was introduced in 1998, is relayed on 1970 FMS. The RNAV1 or (Precision RNAV – P-RNAV) was also introduced, mainly in the Terminal airspace, but it is not mandatory in Europe. The route structure that was enabled by P-RNAV was impressive, because instead of STAR bursts at each VOR on the European continent with routes converging in and out of VORs, it was possible to introduce the system of parallel routes which unblocked chocked points and enabled the traffic to climb and descend much more liberally. B-RNAV is giving great benefits in Europe, it gave an increase in the capacity by 30%, but 30% of the aircraft had to be retrofitted, which is quite high number.

The next step is called the Advanced RNP and RNP Approach. There is a significant need to plan far ahead to reduce the need for a retrofit. Retrofits are costly, and the reality is that the older aircrafts are always in the fleet. For example, some 40% of aircraft operating in ECAC do not have GPS.

The next step into the future is Advanced RNP in all phases of flight. There is a strong case for Advanced RNP, traffic growth that is anticipated despite economic recession (2009-2015 between 25 to 35% traffic growth), a capacity increase of about 28-39%, the demand is less than a 1 minute en-route flight delay and intention is to reduce of current flight inefficiency of 2 km per year. There is also an increase in military airspace requirements, and there is more pressure on intense airspace usage. There is a need to progress the vertical and horizontal availability of airspace, and to address the en-route and TMA in a coherent manner.

In the Advanced RPN is included:

- improved track keeping (with the RNP functionality with its on-board monitoring and alerting)
- reduced route spacing (and for that we are talking about straight and turning routes with the reduced route spacing, FRT – Fixed Radius Transition, and RT – Radius to Fix functionality)
- parallel offsets
- RNP SIDs and STARs
- smaller/reduced holding areas
- (more) predictable turns
- improved 3D management and route 'tubes', to enable things like CDOs and CCOs (Continuous Climb Operations)

Advanced RNP is really going to cover all phases of flight (en-route, terminal, approach and departure). Initial ECAC estimate for an ECAC fleet is around € 3 billion. However, the benefits are also quite impressive: € ½ billion per year and that is just looking on en-route capacity and route savings (financial benefits of CDOs or CCOs or improved capacities in TMA – where the Advanced RNP will give enormous benefits excluded.

The next approach step is looking to be RNP Approach. With RNP Approach is looking to deliver improved access to airports, because here, of course, there is a better precision, both laterally and vertically. Next, reduced minima – it is all about getting DA/H lower, and improved safety such as providing a vertically guided approach with a stabilized approach and a standard crew operating procedures. Included in RNP APCH is actually coverage of the terminal, approach and missed approach and it covers LNAV (lateral navigation), LNAV/VNAV (lateral and vertical navigation), and LPV (localizer performance with vertical guidance).

Regarding the RNP Approach,

- the GNSS will be required, or GPS SBAS for LPV,
- an FMS with integrated air data system for LNAV/VNAV
- cockpit display requirements
- and in some cases there will be requirements for AP/FD coupling for LNAV/VNAV

But Advanced RNP aircraft would also be RNP APVH (LNAV) capable. In addition, some limited cost might be required to make Advanced RNP aircraft LNAV/VNAV or LPV capable. By including the RNP APCH (APV) criteria in Advanced RNP, one package can deliver the whole range of benefits. Advanced RNP and RNP APCH are of particular interest in Europe. The Advanced RNP anticipated having what is known as Scalable RNP. This means that the precision or the accuracy that will be required will change depending on the phase of flight. So it would step-down from 2 to 1 and 0.5 NM and then to 0.3 NM, and will also include the departure phase of flight. So the Europe is very much interested in the Advanced RNP and RNP Approach which to have a scalable kind of RNP.

The RNP Approach will provide increased safety and access. It's mentioned in the ICAO 36th Assembly Resolution as a recommendation that states should be prepare to achieve implementation of approach procedures with vertical guidance (APV – Baro-VNAV and/or SBAS) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones at 2010 and 2014. The ICAO PBN Manual classes these approaches as RNP approach (APCH) operations. The RNP APCH Navigation Specification currently covers RNAV (GNSS) NPA and APV Baro operations. In the near future it is expected to be extended to include APV SBAS. There is also an RNP AR APCH navigation specification which covers a different type of approach specifically for use in challenging obstacle environments or where tight separation requirements exist. They require a particular RNP approval for the aircraft, special crew training and usually Flight Operational Safety Assessment (FOSA). RNP Approaches (which are also called RNAV Approaches) are published on charts with the title RNAV (GNSS). These approach charts can have several descent minima depending on the kind of approach to be flown. RNAV (GNSS) non-precision approach (NPA) is an approach without vertical guidance flown to the LNAV MDA/H minima. Approach procedure with vertical guidance APV-Baro is a vertically guided approach that can be flown by modern aircraft with VNAV functionality using barometric input. It can be flown to the LNAV/VNAV DA/H minima. APV SBAS is supported by satellite based augmentation systems such as WAAS in the US and EGNOS in Europe to provide lateral and vertical guidance. The lateral guidance is equivalent to an ILS localizer and the vertical guidance is provided against a geometrical path in space rather than a barometric altitude. This kind of approach procedure has LPV DA/H minima (Fig. 1).

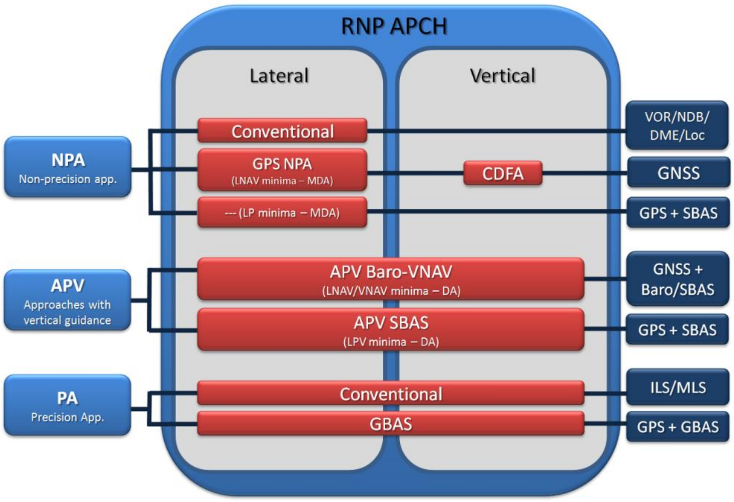

Fig. 1.
The types of RNP approaches

Regarding navaid infrastructure, the target is to have lowest cost as a means of meeting operational requirements safety. GNSS provides the user community with a navigation capability which is significantly more accurate than any ground-based navigation sensor. It also has the potential to support global operations through all phases of flight, unlike ground-based navigation facilities which are limited by line of sight. But, sole means GNSS isn't really possible at the moment, and the combination of Galileo and GPS would remove most, but not all, common mode failures. There are various reversion options in en-route and terminal: GNSS with on-board aiding (eg Inertial) or supported by independent surveillance and DME reversion. For options on the approach, the vulnerabilities are not readily overcome by on-board aiding and the long term maintenance of ILS is necessary.

3. RNP approach flight trails in Croatia

3.1. Motivation

In 2007 the original ICAO Resolution A36-23, required all member states need to implement APV at all instrument runway ends that serve aircraft with a mass of 5,700kg or more in line with the following deadlines: 30% by 2010; 70% by 2014; and 100% by 2016. However at the 37th ICAO assembly meeting in 2010, a new Resolution was passed. The change recognises the primary safety importance of having straight-in approaches at a wider range of smaller aerodromes. The resolution now allows for implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV only minima, for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; and implementation of *straight in* LNAV only procedures, as an exception to above, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft with a maximum certificated take-off mass of 5 700 kg or more suitably equipped for APV operations.

As a first step to APV procedures and its benefits (back-up to ILS approaches, low operational minima on non-ILS runways, and advanced arrival and approach procedures), an straight-in LNAV approaches were flown in Varaždin airport in 2011 onboard private operated Cirrus SR 20 aircraft and Cessna 172 aircraft equipped with stand-alone Garmin 496 and operated by Croatian Aviation Training Canter. The purpose of these approaches was to fly NDB-look-alike approach procedure published as RNAV (GNSS) NPA approach without vertical guidance to the LNAV MDA. Varaždin airport was chosen for the pre-demonstration flight since Croatian Aviation Training Canter is conducting one part of flight training operations from there. Also, Varaždin airport is small aerodrome located in North Croatia, and due to the limited approach capabilities (currently only visual approach) and type of traffic operating (mainly GA and business jets), this airport has effectively illustrated the potentials of RNP APCH operations to increase airport accessibility and safety of flight operations.

3.2. Flight trails in Varaždin airport

Flight procedures were designed as an extended traffic pattern for runway 16. Altitude at downwind leg was 2,000 ft, and aircraft descended to 1,500 ft on base leg. Final approach fix was created as a GNSS waypoint and aircraft was established on final approach course and speed. For that final approach segment, autopilot was engaged, coupled only with satellite navigation system (Garmin 1000). During flight trail on Cirrus aircraft VNAV function was used, and pilot manually maintained vertical profile according to glide slope indication. All flights were made in visual meteorological conditions (VMC) with ground visual references in all time. Total of three flights were made in this trail (Fig. 2).

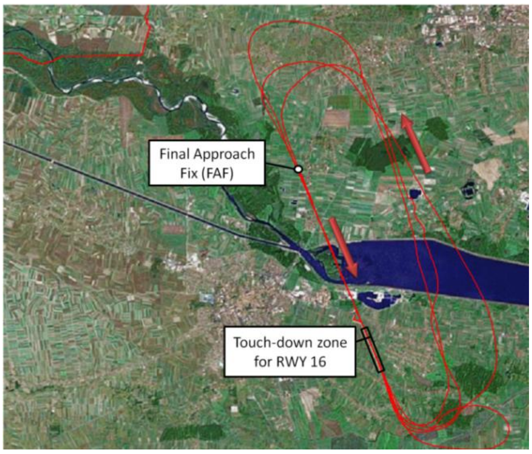

Fig. 2.
Flight tracks

After completion of each pattern, over runway 16 threshold aircraft initiated low approach procedure at 500 ft above ground level (AGL) and initiated climb for the next pattern. The primary objective of these flight trails was to establish lateral deviation from defined final approach course (160°) on three different approaches. From Final Approach Fix (FAF) to runway threshold in total distance of 5,2 km (9,6 NM) maximum deviation between three flight track was 40 meters at about 3 km from the runway threshold. Lateral navigation (LNAV) accuracy, or measured deviation from defined course, in final approach segment was less than 25 meters during these flight trails (Fig. 3). This means lateral misalignment of less than 0.05 NM, or approximately 1° to the left or right with respect to the final approach course.

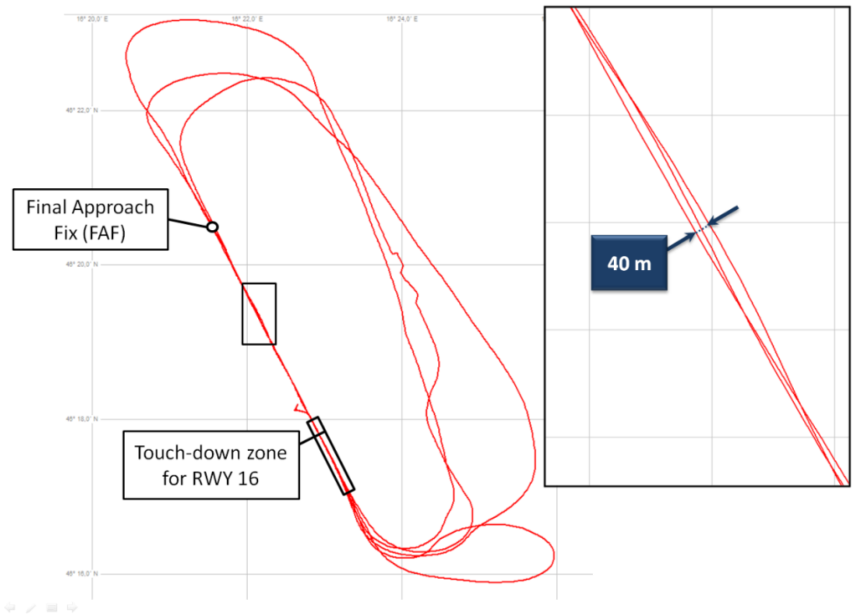

Fig. 3.
Analysis of flight tracks on final approach segment using GNSS

A secondary objective was to determine accuracy in vertical profile during final approach. Maximum deviation was 485 ft above defined glide path (Fig. 4.). These segments were flown manually with strong tail wind component (12 kts), without Baro-VNAV function, and result can be used only as information.

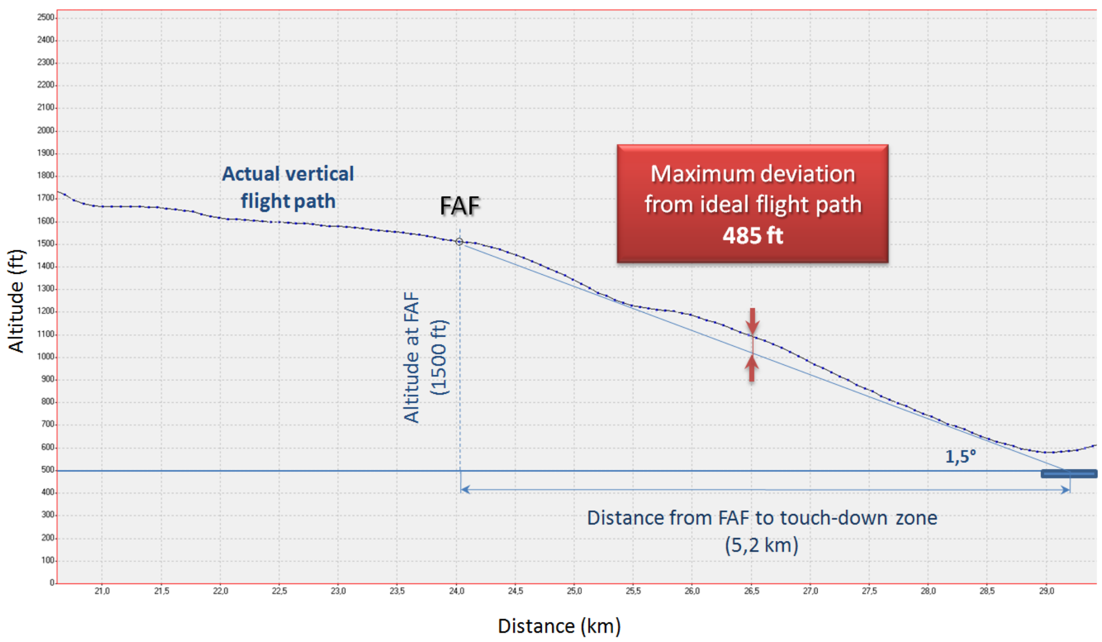

Fig. 4.
Vertical profile during descent on final approach phase

The flight trails showed that the horizontal accuracy (expressed in term of lateral Total System Errors) of the on-board navigation system was better than ± 0.3 NM for 95% of the flight time for the final approach segment, as required by AMC 20-27. It was also demonstrated that the Flight Technical Error was within ± 0.125 NM when approach was coupled to an autopilot. These accuracy requirements demonstrate that an RNAV system could be approved for RNAV approaches in accordance with 2D navigation criteria.

4. Preconditions for RNAV (GNSS) procedures development in Croatia

Croatian Civil Aviation Authority (CCAA) should initiate the actions necessary to introduce RNAV (GNSS) Instrument Approach operations for general aviation (GA) in Croatia under specified conditions, whose definition is also under their provision. It is reasonably to introduce first RNAV (GNSS) NPA for GA then in next phases RNAV (GNSS) APV operations for GA and commercial operators. The aircraft navigation system installation, based upon GNSS receiver equipment qualified to (E)TSO-C129a (certain classes only) or (E)TSO-C145 or (E)TSO-C146, must be approved for the purpose. However, at the moment initiative should consist of:

- CCAA should initiate request of design of RNAV (GNSS) Instrument Approach Procedure from the Crocontrol (national Air Navigation Services Provider) or another agency certified in procedure design, or strongly encourage Aerodrome Licence Holders to put these requests independently.
- Since any instrument approach procedure requires a survey to be carried out in accordance with appropriate CAA regulation, Aerodrome Licence Holders should initiate conduct of survey by certified companies, for intended type of operations. Availability of this information is fundamental to accurate and safe design of the procedures. No design task will be undertaken without survey data.
- The design task is subject to the quality management policy ensuring compliance to ISO 9001/2000 standards.
- In studying potential of the GPS for aeronautical use, CCAA through its Agencies should arrange and provide (acquire several years worth of GNSS Signal in Space -SiS data), since the accuracy and integrity of the GPS Signal in Space (SiS) are fundamental to the safety of a RNAV (GNSS) approach operation.
- SiS data collection should be arranged by using appropriate monitoring and acquisition system (GNSS receiver with data logger), and referenced in post-processing to available CROPOS (Croatian Positioning System) - a national network of reference GNSS stations of the Republic of Croatia, with purpose of quality assessment.
- After procedure design and its development, CCAA has to arrange and monitor a trial of GNSS (NPA or APV) Instrument Approach flights for GA aircraft at applicable aerodromes.
- Flight validation. Where such a check is required it will be the responsibility of the client (ALH). CAA will provide guidance on the requirements/objectives of the flight validation. If CAA staff is available it may be possible for them to attend this flight validation at the request of the client.
- Create the guidance for the training and operational use of GPS or Galileo in the flying of RNAV (GNSS) Instrument Approaches. Legislation should contain technical information on the function of GPS or Galileo, equipment and installation requirements, operations and training guidance material together with suggested training syllabus content and RTF Phraseology.

Any airport meeting the requirements and wishing to implement RNAV (GNSS) non-precision approach will also need to cooperate with the CCAA on the design of the approach, the development of a safety plan and, if the airfield was not part of the previous trial, a validation flight.

Basic requirements are:

- A CAA licence,
- A runway meeting the physical characteristics required for an instrument runway this covers the runway strip width, it’s clear and graded area, surface markings, holding points and lighting (if used at night),
- The runway is not required to have an instrument approach system already in place,
- An Air Traffic Control Service (not Flight Information Service or air-ground operator).

5. Conclusion

The PBN navigation specifications describe the required aircraft navigation performance in terms of accuracy, integrity, and continuity of function. Although the PBN specifications identify the navaid infrastructure and on-board systems that support each type of application, the performance requirements are focused on aircraft performance and not on navaids (signal in space) performance. Instrumental landing system (ILS) will remain the primary system for precision approach operations in the future. It currently provides a very efficient service for precision approach and landing operations.

However, ILS systems can only support straight-in approaches, limits the traffic handling capacity of runway due to sensitive areas protection and are facing problems in terms of multi path effects and radio spectrum constraints that are becoming progressively more critical. RNAV approaches based on the use of GNSS will be gradually implemented to replace existing conventional Non-Precision Approaches (NPA) or provide IFR approach procedures at airports where the ground infrastructure doesn't support conventional NPA procedures. This type of operations will provide improved accessibility and safety of operations and enable the rationalization of ground navigation infrastructure. RNAV approach procedures provide a safer operation to those airports (runways) which are not equipped with precision approach system. In the case of vertical navigation capability either by the integration of barometric vertical data or SBAS procedure (satellite based augmentation system), the minima can be low as 200 ft which is equivalent to ILS CAT I. In the frame of SESAR Programme, strategy and transition plans will be developed, taking into account the capabilities and vulnerabilities of GNSS and the requirements for the evolution of RNAV applications. These plans will provide a comprehensive rationale and guidance to States planning the transition to a total GNSS-based RNAV environment and the rationalization of ground Navaid infrastructure, in order that a coherent and coordinated transition can occur. It is important to highlight that the results of current research and development activities might demonstrate the feasibility of the use by State aircraft of precise GPS and Galileo services as equivalent means of compliance.

References:

EASA. 2009. AMC 20-27, Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV BARO-VNAV Operations (Annex III to ED Decision 2009/019/R of 16/12/2009.

Civil Aviation Publication (CAP) 773. 2007. Flying RNAV (GNSS) Non-Precision Approach in Private and General Aviation Aircraft, UK.

European Commission. 2008. Commission Regulation (EC) No. 859/2009 amending Council Regulation (EEC) No. 3922/91 as regards common technical requirements and administrative procedures applicable to commercial transportation by aeroplane, *Official Journal of the European Union*.

Eurocontrol. 1999. *RNAV application in terminal airspace – an ATC operational perspective*, Edition 2D.

Eurocontrol. 2008. *Policy on GNSS for Navigation Applications in the Civil Aviation Domain*, Steakholder Consultation Group, Action Paper SGC/8/AP10.

Eurocontrol. 2010. *Airspace Concept Handbook for the Implementation of performance Based Navigation (PBN)*, Edition 2.0.

Eurocontrol. 2011. *Local Single Sky Implementation Plan (LSSIP) Croatia - Years 2011 – 2015*, Level 1.

Farrell, J.; Barth, M. 1999. *The Global Positioning System and Inertial Navigation*, McGraw-Hill.

ICAO. 2008. Doc 9613 (PBN Manual) Third edition. *Volume I*: The performance Based Navigation Concept and Implementation Guidance; *Volume II*: Implementing RNAV and RNP.

ICAO. 2006. Doc 8168 Procedures for air navigation services aircraft operations. Volume II: Construction of visual and Instrument Flight Procedures.

ICAO. 2007. Doc. 9750/AN963. Global Air Navigation Plan, 3rd Edition.

Kayton, M.; Fried, W.R. 1997. *Avionics Navigation Systems*, 2nd Edition, John Wiley & Sons, Inc.

Murcia, J. et al. 2010. Operational Implementation of EGNOS and LPV Approaches in Aviation in Europe, *Proceedings of the 23rd International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS 2010)*, Portland, OR, September 2010: 1440-1448.

Navigation Applications and NAVAID. 2008. *Infrastructure Strategy for the ECAC Area up to 2020*, Navigation Sub-Group of the ANT, Eurocontrol.

Session 10: Transport Technology

ONE APPROACH TO EXPERIMENTAL AND NUMERICAL INVESTIGATION OF LONGITUDINALLY VENTILATED ROAD TUNNELS

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Abstract: Experimental instalation as well as experimental and numerical investigations of the road tunnel ventilation are presented. Since recently, two modern single tube two-way traffic road tunnels, 4.2 km and 1.4 km long, are in use in Montenegro. In order to analyse the flow of the first one in detail, the smaller scale model corresponding to a 400m length of real structure, has been constructed in the Laboratory of Faculty of Mechanical Engineering in Podgorica, Montenegro. It is equiped with a similar in geometry and function, scaled, ventilation system based on aircraft-modeling jet-fans powered by electric motors. The main tunnel tube is ventilated longitudinally, while the secondary (smaller evacuation tunnel) could be over-pressured with respect to the main tunnel, in the case of hypothetic accident situation. Cross passages connect the two tunnels. The ventilation efficiency, pressure drop, transient regime under changing air directions, are experimentaly and numericaly investigated. The obtained experimental and numerical results are compared.

Keywords: Tunnel, ventilation, tunnel flow transition

1. Introduction

Traffic road tunnels with a single tube for both-way traffic are currently the only ventilated traffic-tunnel type present in the country of Montenegro. Recently a modern 4.2km long single-tube two-way traffic road tunnel, named Sozina, has been inaugurated on the main road connecting the coast side with inland of Montenegro. For the purpose of passengers evacuation in case of fire accidents, a secondary smaller size tunnel tube has been constructed. The main tunnel is ventilated longitudinally. Secondary tunnel's ventilation, consisting of two fans blowing air towards the tunnel interior, provides it with an overpressure of air - with respect to the main tube, for accident scenarios. Cross-passages equiped with emergency exit doors connect the two tunnels. To allow for experimental investigations of this particular structure and ventilation-configuration system, a smaller scale model of both road and evacuation tunnels, corresponding to a 400 [m] length of real structure, has been constructed in the Laboratory of Mechanical Engineering Faculty in Podgorica, University of Montenegro. It is equiped with an equal scale, ventilation system based on aircraft-modeling jet-fans powered by AC electric motors. The model allows for experimental investigation of:

1. Validation of common design methodology of longitudinal tunnel ventilation required thrust,
2. Transient flow regimes with abrupt changes in the air flow direction,
3. Analysis of accident regimes of air flow in the connected-tunnels structure when one or several evacuation cross-passages are opened for air flow.

For the computational assesment of the 2. topic listed, a numerical model in form of a 1D differential equation of tunnel's air motion was performed. It's solution was carried trough a computer code and analysed in this paper. The model calculates the transient air-flow velocity in a single-tube tunnel, utilizing user-input data of the model structure and fan operation scheme.

These results are further used to supply a CFD code with boundary conditions in order to study in detail the various air flow regimes in the tunnels. The CFD computations of flow in the 3-dimensional model of laboratory model-tunnels is performed in ANSYS-FLUENT software.

2. Model tunnel layout

The model tunnel layout is presented in Fig. 1 and Fig. 2. Characteristic dimensions are given in Table 1. Model to real tunnel scale is approx. 1:19. The length of the real tunnel structure corresponding to this laboratory model would be approx. 400m. Roof of the main tunnel model is transparent for possible air flow visualization. Tunnel is equipped with six axial jet-fans, positioned in three batteries of two fans, see Fig. 1. Fans are spaced equally, in a distance of approx. 100 fan rotor diameters. Equal distance is available as entry and exit distance in the tunnel (without any fans present). Fans can be controlled simultaneously by one control unit or individually. Static thrust of the fans was measured in laboratory using a digital-scale measuring device prepared for this purpose.

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Evacuation tunnel model (Fig. 1) has an equal scale, but circular cross section, and equal length as the main traffic tunnel model. It is equipped with two fans, each positioned *0.5m* from the tunnel ends, and oriented to blow air towards the tunnel interior, in order to create overpressure of air in the evacuation tunnel. It is connected by evacuation passages ("EP") which are constructed of transparent tubes.

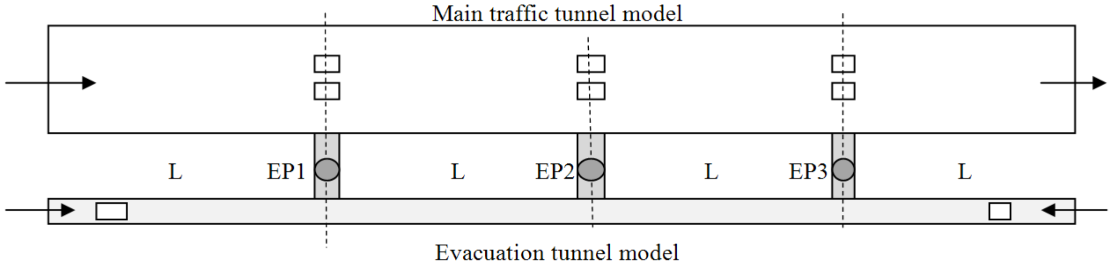


Fig. 1.
Scheme of the model installation

Table 1
Physical dimensions of the model tunnels

Traffic tunnel length	[m]	*20.55*
Road width (both lanes)	[m]	*0.47*
Traffic tunnel cross section	[m^2]	*0.147*
Traffic tunnel hydraulic diameter	[m]	*0.40*
Evacuation tunnel length	[m]	*20.55*
Evacuation tunnel hydr.diameter	[m]	*0.16*
Evacuation cross-passages hydraulic diam.	[m]	*0.067*

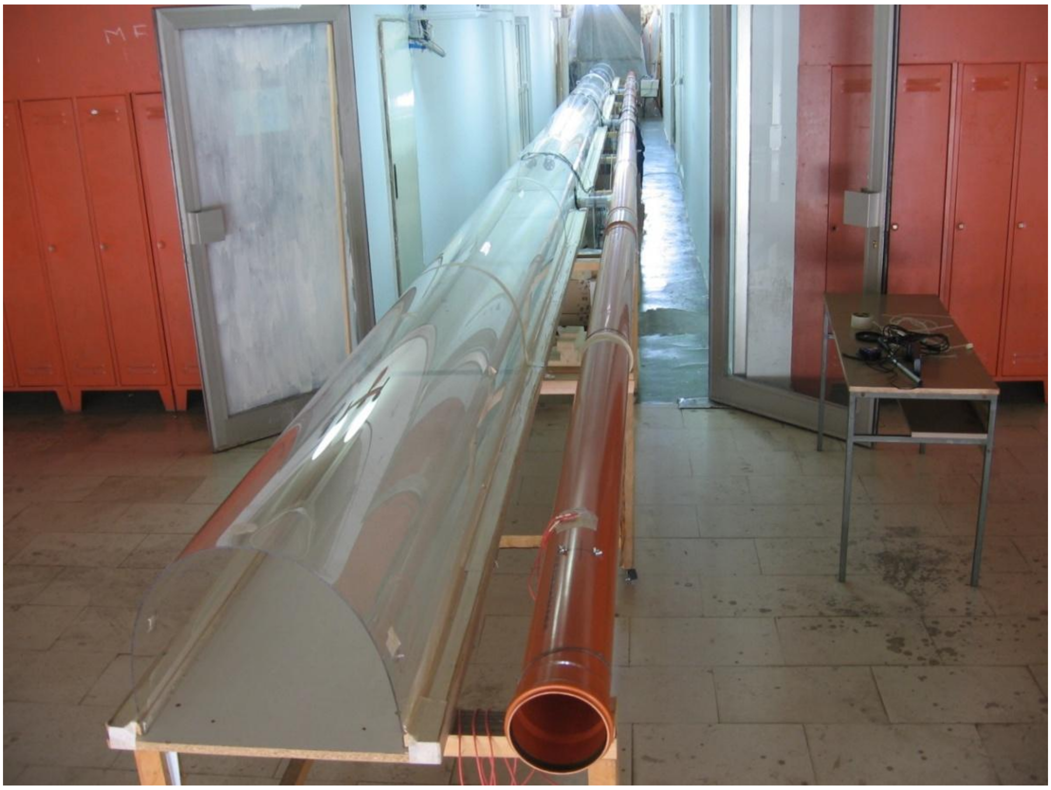
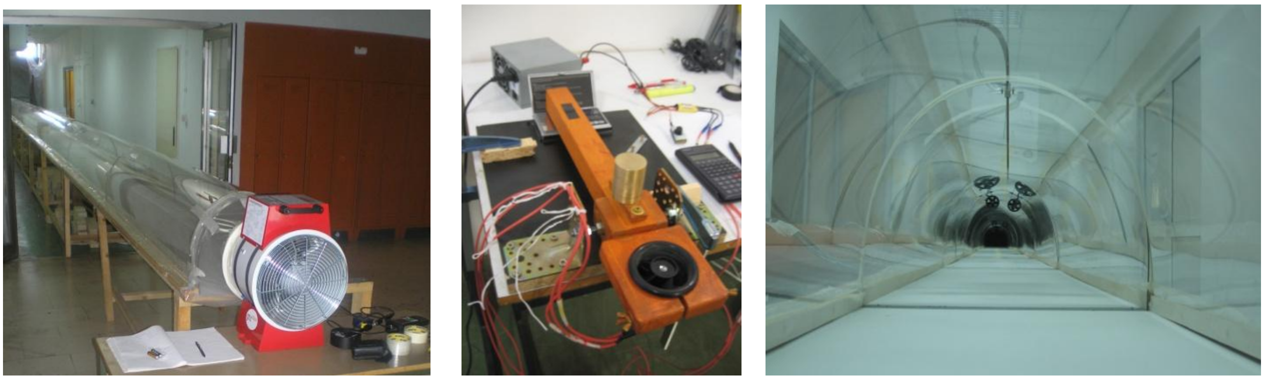


Fig. 2.
Laboratory installation of model tunnels

3. Hydraulic characteristics of the model tunnels

Experiments with air flow in the main and evacuation tunnel models were performed separately, to measure the hydraulic resistance characteristics of the tunnels: inlet pressure loss and friction pressure losses. For these experiments, air flow was induced using only one large jet fan, which was attached to the entry of the tunnel, Fig. 3 (a). Honeycomb material was used to cancel-out fan-swirl. Differential pressure transducer for gases was used for air pressure-drop measurements. For velocity measurements in stationary conditions, a commercial turbine-rotor type anemometer instrument and a Pitot tube were used. The turbine flow-meter was used by carefully uniformly scanning the exit cross-section area of the model tunnel where the flow exits the tunnel. Flow-meter's time-averaging function was used to take into account the actual velocity profile of flow. It is expected that the value obtained in this way reliably represents the true air flow rate in the tunnel.

Following that, experiments with tunnel's ventilation system induced flow were performed to generate flow conditions corresponding to a traffic tunnel. Turbine flow-meter was used to measure the mean air flow rate. Separate experiments were used to measure the fans static thrust characteristics, Fig. 3 (b). Based on these data, tunnel ventilation efficiency for the model tunnels could be estimated. For transient conditions experiments, a hot-wire anemometer probe with one sensor for one velocity component measurement was used, Fig. 3 (c).



(a) (b) (c)

Fig. 3.
Experiments on the laboratory model tunnels: ***(a)*** *Hydraulic resistances measurements,* ***(b)*** *Fan static thrust measurements,* ***(c)*** *Flow transition measurements*

The following results were obtained:

- Relative roughness of the main tunnel model: $\delta/D_H \approx 0.00035$
- Relative roughness of the evacuation tunnel model: $\delta/D_H \approx 0.00028$
- Inlet pressure loss coefficient: $\zeta_{IN} \approx 0.56$

Using a particular digital-scale device made for fan static thrust-force measurements, the following values of static thrust for the adopted main traffic-tunel model and evacuation tunnel-model ventilation systems, were measured:

- Main tunnel's ventilation total static thrust force:
  - at *50%* of full ventilation thrust: *14.42* [N]
  - at *70%* of full ventilation thrust: *17.78* [N]

- Evacuation tunel's single-fan static thrust:
  - at *50%* of full thrust: *2.16* [N]

The following values of ventilation efficiency, defined as ratio of the laboratory measured static fan thrust to the delivered thrust in the tunnel flow, were calculated based on the measured data:

- Ventilation efficiency - main tunnel model: $\eta \approx 0.53 - 0.65$
- Ventilation efficiency - evacuation tunnel model: $\eta \approx 0.62$

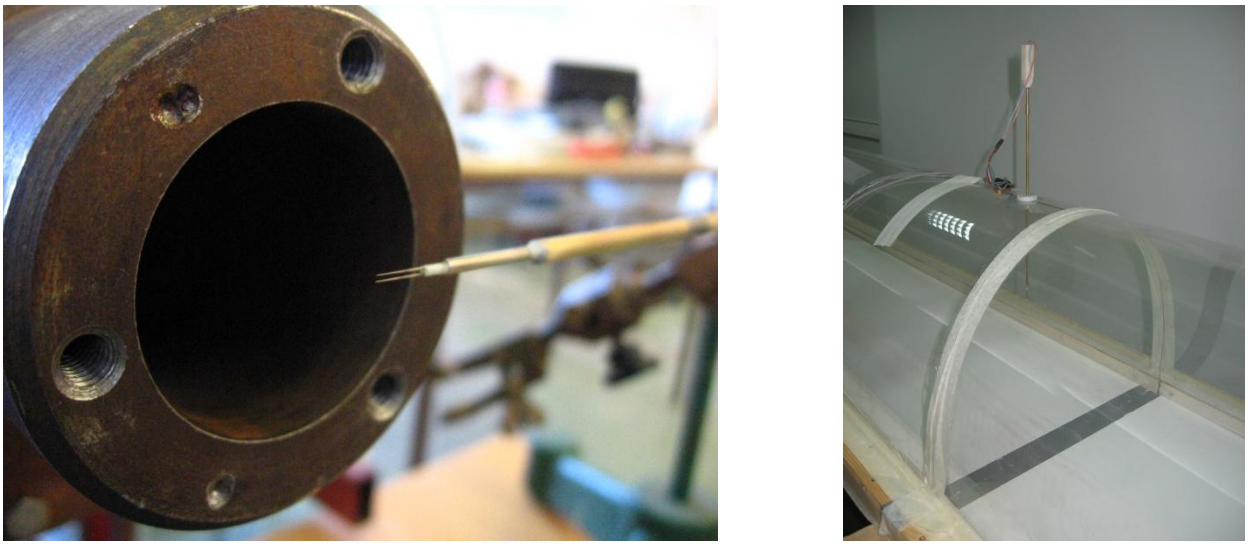
The ventilation efficiency depends on the following factors (Šekularac and Radulović, 2011; WOODS, 2012) fan exhaust velocity, fan jet swirl, tunnel mean air flow velocity, presence and number of vehicles in the tunnel, and fan installation (coaxial vs. angled positioning of the fan's axis with respect to the tunnel's longitudinal axis).

Friction losses in all further calculations in this paper were estimated using the Halland's formula for friction coefficient of the longitudinal friction pressure-loss, with the measured effective relative roughness of the tunnels listed above (Eq. (1)):

$$\xi = \frac{1}{\left(-1.8\, log\left(\left(\frac{\varepsilon}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right)\right)^{2}} \qquad (1)$$

4. Experimental setup for air flow transition experiments

Hot-wire probe constructed in the laboratory, was used for these experiments. It was calibrated using a laboratory air-tunnel, which creates a laminar air jet flow at the nozzle, Fig. 4(a) The details about calibration and construction of these and similar multi-sensor probes can be found in (Bruun, 1996; Vukoslavčević and Wallace, 1996The velocity is measured by Pitot's tube connected to a differential air pressure transducer. By processing the calibration data, a dependence of air velocity to anemometer voltage is obtained. Hot wire probe was then placed on the traffic model tunnel's roof, at *2.2* [m] away from one of the tunnel portals, perpendicular to the tunnel's axis. The probe's tip (sensor) was positioned at the midpoint of the tunnel's roof height. Anemometer voltage as a function of time recorded during the experiments can then be processed to obtain the time history of air flow velocity. In the flow transition experiments, the fans were oriented so that within the three batteries of two fans each in the model tunnel, one side fan blows the air in one (positive) while the neighbor fan blows the air in the opposite (negative) direction, see Fig. 5. Both positive and negative-direction fans are connected to separate control devices, for they can be started and their thrust intensity can be separately adjusted, as desired.



(a) (b)

Fig. 4.
Use of hot wire probe: **(a)** *probe calibration using air-tunnel nozzle,* **(b)** *probe in use*

Computed time-history of the velocity was further processed by time-averaging the signal, in order to remove the turbulent fluctuations in the velocity signal and use a time-averaged (mean) air velocity value. Time-averaging was performed by averaging the original velocity signal in a square window function, of adjustable window width. Local window width was narrow in the transient periods of the mean velocity signal and wider in the quasi-stationary periods of the mean velocity. Linear interpolation between the adopted minimum value for window width of 0.25 [s] and a maximum value of 2.5 [s] was used here; By sliding the square window along the original signal with an equal time step, i.e. between two successive signal readings ($\Delta t = 0.001$ [s]), and averaging the original signal within it, a time-averaged value of probe air velocity as a function of time is obtained.

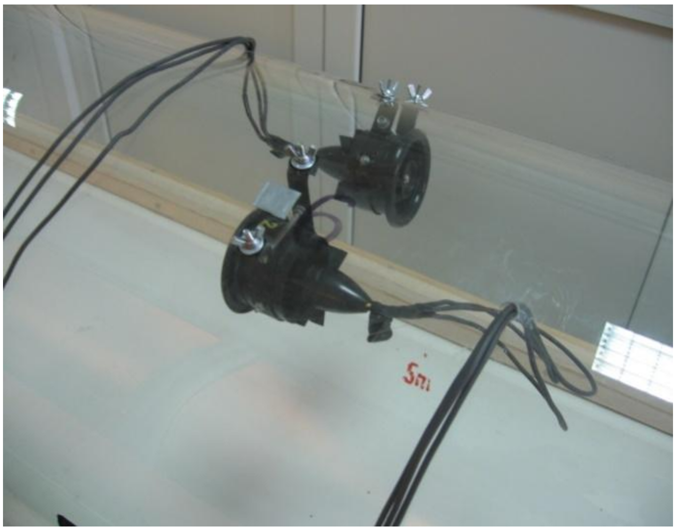


Fig. 5.
Fans orientation for flow transition experiments

Positive direction fans were switched on at a particular level of fan thrust, to achieve a certain air flow velocity, and kept as such for a certain time. Negative direction fans were prepared for operation and kept in a stand-by mode, until a particular moment in time where the air flow change will occur. The working fans were abruptly reduced to zero power, while approximately simultaneously the negative direction flow fans were abruptly switched on, to the same level of thrust control, but exerting thrust in the opposite direction. In this way a transient flow regime is created: the air is decelerated to zero velocity and then accelerated in the opposite direction. Later the fans are switched off. During the experiment the longitudinal component of air velocity was recorded by the hot-wire anemometer system.

Experiments were performed with the fan thrust forces corresponding to: *50%* and *70%* of full ventilation thrust force available when using two sets with 3 fans each. These produce a static ventilation thrust of approx. *7.22* [N], and *8.891* [N]. The corresponding mean air velocities in the tunnel are *4.26* [m/s] and *4.62* [m/s], Fig. 6.

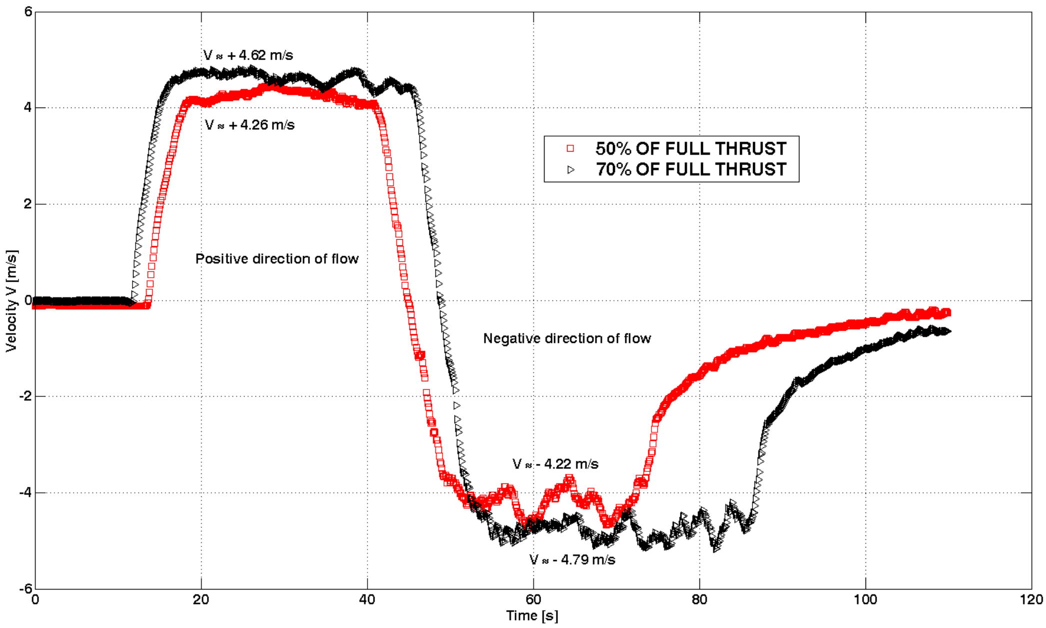


Fig. 6.
Time history of recorded air velocity in the flow transition experiments: at 50% and 70% of full thrust.

The obtained stationary velocity by hot-wire probe was compared to the mean value of air velocity in the tunnel measured by a turbine-type anemometer. This flow-meter was used in steady-flow conditions experiment, at the same ventilation thrust. A ratio of approx. 0.96 was obtained between the hot-wire sensor probe reading and the mean velocity value obtained using the turbine-type flow-meter approach previously described.

The measured values of air velocity at *50%* and *70%* of full ventilation thrust force, in the flow transition tunnel experimental setup, indicate the following values of ventilation efficiency - in this particular ventilation system layout:

- 50% of full thrust: $V \approx 4.26 \left[\frac{m}{s}\right],\ F_{AIR} = 3.97\ [N] \rightarrow \eta \approx 0.550$
- 70% of full thrust: $V \approx 4.62 \left[\frac{m}{s}\right],\ F_{AIR} = 4.67\ [N] \rightarrow \eta \approx 0.523$

where with F_{AIR} the resulting force acting on the tunnel's air is denoted.

5. Numerical 1D model of longitudinal air flow. Solution of the flow transition problem

A mathematical model of tunnel's air flow velocity can be derived using the law of conservation of momentum along the tunnel axis, resulting in a 1D model. The time rate of change of air momentum is equaled to the sum of all forces acting on the air mass inside the tunnel. These forces originate from: 1. Tunnel's ventilation thrust force, 2. longitudinal friction force, 3. local pressure-loss forces: entry and exit of the tunnel, 4. Forces from the moving vehicles: friction and piston-effect forces, 5. other atmospheric conditions (pressure differences between the tunnel exits, chimney effect and wind). For the transition conditions studied in this paper, no vehicles were used to obstruct the flow in the tunnel. Vehicle pressure-loss coefficients have been measured using scaled models of characteristic vehicles (car and bus), and can be found in paper (Šekularac and Radulović, 2011). In the model tunnel laboratory experimental conditions, the forces acting on the air consisted of the: 1st, 2nd and 3rd category listed above.

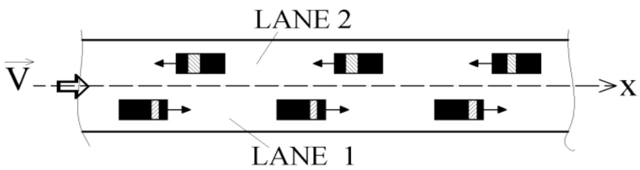


Fig. 7.
Model scheme

General differential equation used to model the main traffic tunnel's longitudinal air flow velocity with vehicles present is (Eq. (2)):

$$\frac{dV}{dt} = \frac{F_V}{\rho L A_T} + C_1 \frac{V^2}{2} sign(V) + C_2 \frac{(w_1 - V)^2}{2} sign(w_1 - V) + C_3 \frac{(w_2 - V)^2}{2} sign(w_2 - V)\ , \qquad (2)$$

with the following nomenclature:

- V [m/s], mean air velocity intensity in the tunnel,
- t [s], time,
- ρ = 1.16 [kg/m3], referent air density,
- L = 20.5 [m], tunnel length,
- A_T = 0.1479 [m^2], tunnel's cross section area,
- F_V [N], effective ventilation thrust force exerted on the tunnel's air,
- w_1 [m/s], velocity of the vehicles in the lane 1, "positive" direction of traffic (and air flow),
- w_2 [m/s], velocity of the vehicles in the lane 2, "negative" direction of traffic (and air flow).

The constants C_1, C_2, C_3 are (Eq. (3)):

$$C_1 = -\left(\frac{\xi}{D_H} + \frac{1+\zeta_{IN}}{L}\right), \quad C_2 = \frac{1}{LA_T}\sum_{i,POS} \zeta_i A_i, \quad C_3 = \frac{1}{LA_T}\sum_{i,NEG} \zeta_i A_i\ , \qquad (3)$$

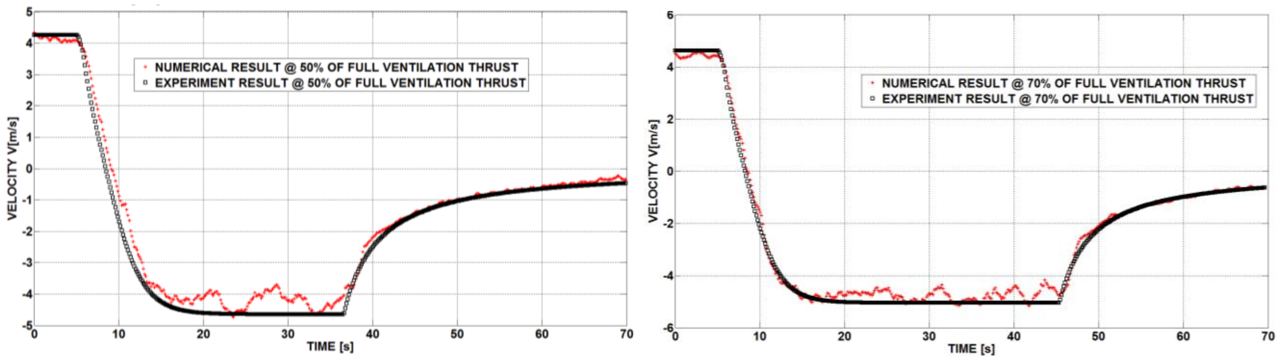
with the following nomenclature:

- ξ [/] , friction coefficient for longitudinal tunnel flow (Halland formula),
- D_H = 0.4 [m], the hydraulic diameter of the model tunnel,
- ς_{IN} = 0.56 [/], the hydraulic resistance of tunnel entry,
- ς_i, [/], the vehicle's hydraulic resistance coefficient of the particular vehicle type (car or bus), which is dependend upon vehicle to air-flow direction orientation,
- A_i [m^2], the area of the frontal cross-section of the respective vehicle type.

The C_2 constant refers to the vehicles which are oriented in the "positive" direction of flow and traffic (Lane 1, in Fig. 7.), while the C_3 constant refers to the vehicles with the opposite orientation, i.e. "negative" direction of traffic and flow. This model equation can be used also in the case of tunnels with unidirectional traffic. Also a situation resulting after an accident has occurred somewhere in the tunnel and the traffic is blocked, can be modeled.

In such a case, constants C_2, C_3 need to be multiplied by a linear decaying factor, which takes into account the time-decay of the number of vehicles moving in both lanes downstream of the accident position. To account for the resistance force exerted by vehicles which would remain blocked and stationary in such scenario, upstream of the accident position (in their respective traffic lanes), an extra resistance term must be added to Eq.2.

The governing equation (Eq. (2)) was solved numerically, using the "predictor-corrector" numerical technique. The forces acting on the fluid on the right-hand side of Eq. (2) can be prescribed to be time-dependent as desired. Ventilation thrust force which abruptly changes direction, was prescribed in accordance with the model tunnel ventilation characteristics. The Halland's formula for calculation of the longitudinal friction coefficient was used to compute the current longitudinal friction force in the tunnel according to the current Reynolds number of air flow. A MATLAB code was written to implement the presented solution algorithm.



(a) **(b)**

Fig. 8.
Time history of air velocity, experimental and numerical result: **(a)** *at 50% of full thrust,* **(b)** *at 70% of full thrust.*

Numerical results for the two cases are presented on Fig. 8(a) and Fig. 8(b). The figures give experimentally recorded velocity values in the two flow transition situations: operating at 50% and at 70% of total ventilation thrust. Numerical solution of presented model (Eq. (2)) for the particular ventilation thrust, efficiency, and model-tunnel parameters without vehicles, is given as well, Fig. 8. Good agreement can be observed. It is believed that the given model can predict mean air flow reasonably well.

6. Numerical CFD solution of steady flow in the model tunnels

A 3D CAD geometry of the model tunnel was created to perform the 3D numerical computation of flow field. ANSYS software package was used for this purpose. A finite-volume method (FVM) solver FLUENT was used to compute the flow. Relatively coarse numerical grid consisting of approx. $600 \cdot 10^3$ finite volumes was generated to discretize the model geometry. Mesh refinement trough inflating prisms of triangular base was used to cover the boundary layers on the tunnel walls, while interior bulk of the air volume was covered by tetrahedrons. Fans were modeled as solid cylinders of air, prescribing the air jet flow thrust at the fan exit, according to the measured thrust of fans used in the ventilation system of this model tunnel.

The incompressible, SIMPLE-based solution algorithm was used, and a standard formulation of $k-\varepsilon$, 2-equation, turbulence model, with the standard wall function. Model constants were: C_{mu} = *0.09*; $C_{1\varepsilon}$=*1.44*; $C_{2\varepsilon}$=*1.92; TKE Prandtl number* value of *1*. The *QUICK* differencing scheme was used for advection terms, and the first order upwind scheme for the $k-\varepsilon$ model equations.

Numerical grid and appropriate cuts through the velocity field are shown on Fig. 9. Velocity magnitude in a vertical cut plane and a cross-section plane, cutting the flow field through the fans and fan-model surfaces, is displayed in Fig. 9(b). The velocity vectors in a cross-section plane positioned just nearly upstream of the fans are displayed in Fig. 9(c). Flow streamlines in a vertical cut plane are displayed in the Fig. 9(d). Pressure field in a vertical and cross-section planes cutting through a battery of fans is displayed in Fig. 10.

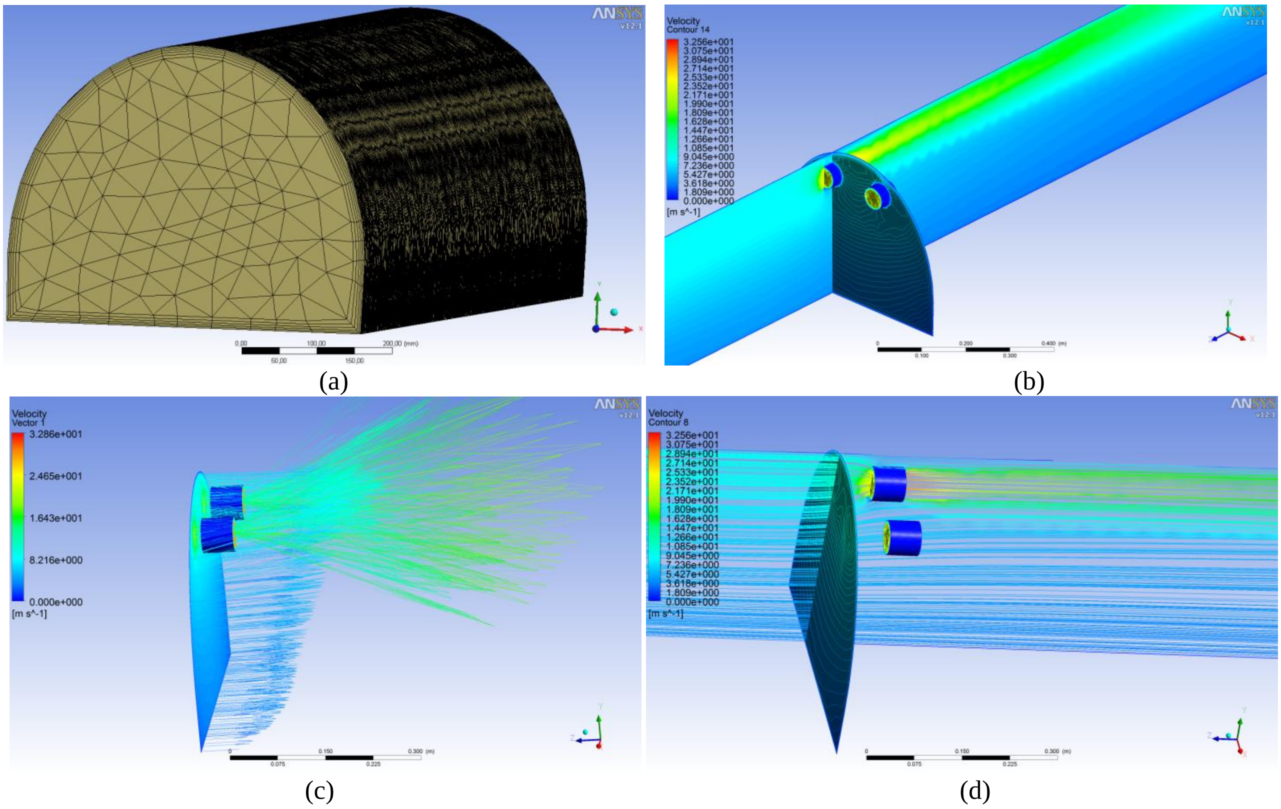


Fig. 9.
*CFD solution: **(a)** Numerical grid, **(b)** Velocity contours in a vertical plane cut, **(c)** Velocity vectors from a plane*
***(d)** Streamlines of flow in a vertical plane cut*

For the experimental case of ventilation being operated at *50%* of full thrust force, the following values of mean air flow velocity were computed, and measured in the model experiment:

- *CFD of the model tunnel flow:* $V = 5.95$ [m/s]
- *Model tunnel experiment:* $V = 6.27$ [m/s]

Same approach was used to compute the flow field in the evacuation tunnel. A numerical grid of approx. $400{\cdot}10^3$ CV's was generated. Here only the solution of flow in the case of one operating fan, working at 50% of it's full thrust force, will be presented. A more-detailed modeling of the fan was performed here for testing purposes, and again a prescribed jet thrust was used as boundary condition on the fan jet exit. Tunnel-inlet pressure-loss coefficient was used, just as for the main traffic tunnel.

The obtained mean air velocity values, by CFD calculation and by experiments on the evacuation tunnel-model were:

- *CFD of the model tunnel flow:* $V = 5.45$ [m/s]
- *Model-tunnel experiment:* $V = 5.20$ [m/s]

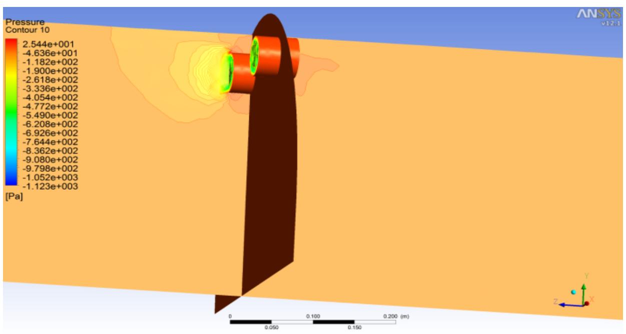
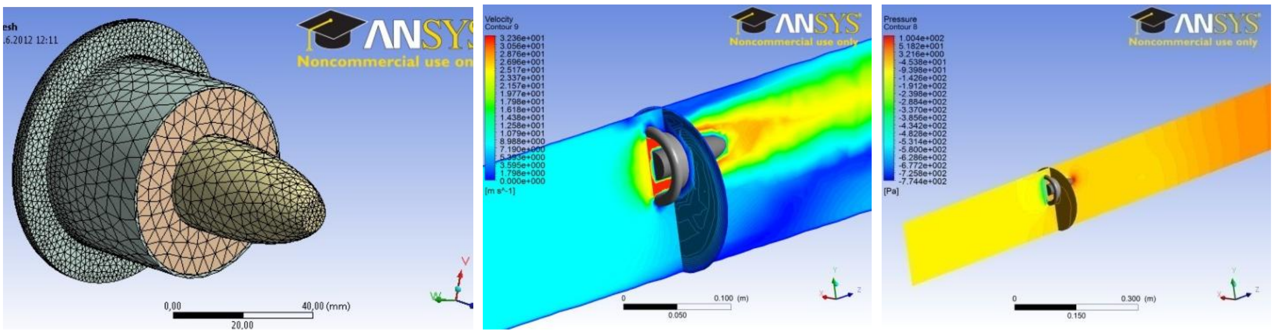


Fig. 10.
Pressure field contours in 2 cutting planes

Contours of velocity magnitude in the vertical symmetry plane near the fan are presented at Fig. 11(b). Pressure contours in the evacuation tunnel model near the fan are presented in Fig. 11(c).



(a) (b) (c)

Fig. 11.
CFD solution of steady flow through the evacuation tunnel: ***(a)*** *Fan modeling,* ***(b)*** *Flow field solution near the fan,* ***(c)*** *Pressure contours*

3. Conclusion

An approach based on a combination of experimental and numerical investigation of air flow in single-tube road traffic tunnels is presented. Using a scaled laboratory model of a real traffic-tunnel, with equally scaled longitudinal ventilation system, consisting of axial jet-fans, some phenomena of tunnel air flow were investigated. Efficiency of a particular ventilation system and model-tunnel geometry setup was determined, as well. Flow transition regime situation occurring during an abrupt change of ventilation operation regime was experimentally and numerically analyzed.

Results of 1D numerical model have been compared to available experimental findings, and good agreement was observed. It is believed that this simplified 1D model can describe air flow velocity during a transient regime, in a arbitrary real-scale vehicle-traffic tunnel equipped with a longitudinal ventilation system, reasonably well.

An onset of a 3-dimensional CFD research aimed to analyze the details of flows in the tunnels, and assess the physical quantities and operation schemes which are rather difficult to measure or very difficult to reproduce in real laboratory model conditions - has been presented. It was applied here to the main laboratory model tunnel, and evacuation tunnel, to solve flow in stationary conditions. Also, solid agreement between some flow characteristics computed by CFD and measured on experimental installation was ascertained.

Acknowledgements

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References

Bruun H.H. 1996. *Hot wire anemometry principle and signal analysis*. Oxford University press.

Vukoslavčević, P.; Wallace, J. 1996. A 12-sensor hot-wire probe to measure the velocity and vorticity vectors in turbulent flow. *Measurement Science and Technology* 7(10): 1451-1461.

Tarada, F.; Brandt, R. 2009. Impulse Ventilation for Tunnels - A State of the Art Review. *In 13th International Symposium on Aerodynamics and Ventilation of Vehicle Tunnels,* New Jersey, USA.

Tarada F. et al. 2000. Critical Velocities for Smoke Control in Tunnel Cross-Passages. *1st International Conference on Major Tunnel and Infrastructure Projects*. Taipei, Taiwan.

Jacques E.; Wauters P. *Improving the Ventilation Efficiency of Jet Fans in Longitudinally Ventilated Rectangular Ducts.*

International Conference on Tunnel Ventilation and Fire Safety. 2010. *Proceedings.* Graz, Austria.

Šekularac, M.; Radulović, P. 2011. Energy efficiency of ventilation systems of longitudinally ventilated road traffic tunnels. In *Proceedings of the International Conference of Renewable Energy and Energy Efficiency*, Montenegrin Academy of Sciences and Arts.

WOODS. 2012. Tunnel ventilation systems manual. Available from internet: <http://www.flaktwoods.co.uk >

EVALUATION MODEL OF POSTAL SERVICES

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Abstract: Given the size and complexity of the postal system, an experiment with the real system is not possible; therefore application of simulation modeling is required. Rapid development of communication technology and trends in globalization processes lead to growing customer demands and use of alternative services in relation to traditional postal service. In such dynamic market, service analysis is necessary on strategic decision making level, with decisions to improve postal system business. Multi-criteria analysis is a tool which enables evaluation of criteria and alternatives that affect business activities in postal traffic. Simulation is used to examine possible scenarios as well as to predict the impact of certain decisions in postal business. This paper shows multi-criteria model for simulation and evaluation of postal services.

Keywords: postal services, criteria, model, decision making.

1. Introduction

Postal services in the Republic of Croatia present a complex system, with many various criteria that are often mutually opposed. Market requires intensive analysis of postal services, to forecast development trends and to facilitate strategic decision making at management level. Strategic planning is to ensure optimal solution in the near future, especially in the environment of absolutes liberalization of postal market. Decision making process requires distinct determination of criteria and sub-criteria; experts with good knowledge of postal transport technology to be able to determine and distinguish relative values of each criteria and sub-criteria. Multi-criteria analysis has shown to be applicable in the process of solving problems that are present in postal business. When such model of set criteria and sub-criteria has been proposed, it can be simulated, resulting in a choice of an alternative as a strategic decision. This particular model has been set up to determine the way public operator should act in the context of market liberalization, to decide on investment policy and postal services development trends.

This research with the obtained results can contribute to strategic planning and decision making on the postal services market in the Republic of Croatia.

2. Postal services and multi-criteria decision making

Based on a general classification, postal services are material services or services that bring additional value, and as such have special society status. Modern postal service, however, is based on three growing and developing mutually interconnected markets: marketing, communication and logistics market. Postal services can be classified into four categories (and also represent alternatives of proposed model):

- Universal postal services, guaranteed by the state, they are defined by national legislation and postal directives;
- Value added services, which emerge from the courier service and are free at the market;
- Other non-universal services;
- New services, which emerge in the market according to the new market demands, and are integrated with electronic services.

Based on the analysis of the postal and courier services in the Republic of Croatia that was conducted by the Council for Postal Services, and the annual report on the work of the Croatian Post and Electronic Communications Agency, data related to the market share of Croatian Post ltd. is shown in Fig. 1. It is evident that the market share of the public operator ranges from 94.95% in 2005, to 88.67% in 2009. Postal services market in Croatia, as well as in Europe, in, showed a decline in the share of services, starting from the second half of 2008, and continuing until the end of 2011. The reason for this can be found in the global economic crisis, which began on the European market in 2008, and has directly influenced the postal market, mostly in the part of parcel services and direct mail.

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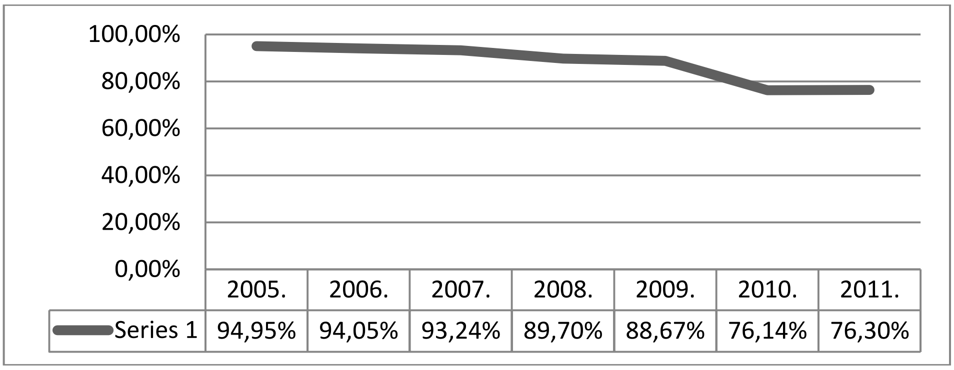

Fig. 1.
Market share of the public operator

When making strategic decisions, possible scenarios cannot be observed through only one criterion. For modeling and simulation of possible scenarios, it is necessary to apply some of the method of multi-criteria analysis which allows integration of different criteria that can be further described with associated sub-criteria. This model has been based on the AHP (Analytic Hierarchical Process) method of multi-criteria decision making analysis. This method is consisted of several phases. Problem is first decomposed to a series of minor problems, which are then ranked hierarchically. Modeling process is consisted of four basic steps: hierarchical model is developed, comparison of elements of the structure through Saaty scale of relative importance is conducted, the assessment of the relative importance of elements issued to calculate the local priorities, sensitivity analysis is determined in the end. In order to conduct analysis of weight values of each criteria and sub-criteria using Saaty scale of relative importance, survey method was used. Examinees that participated in the survey are experts working in the field of postal transport technology. Fig. 2 shows the structure and distribution of business level they are involved in. Each survey participant has approximately equivalent level of education which makes approximately equal values among the survey results.

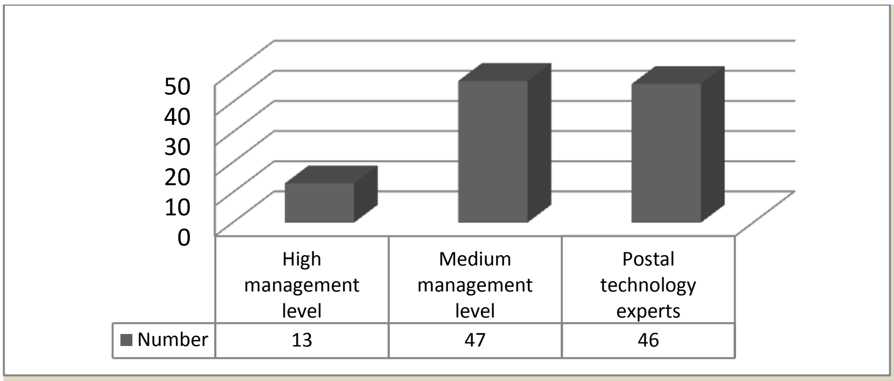

Fig. 2.
Structure of the survey examinees

3. Multi-criteria decision making evaluation model

After conducted research, five criteria have been identified at the first level of hierarchy, as well as a set of their belonging sub-criteria on the second level of hierarchy:

- *Organization and strategic competence of public operator* (sub-criteria: development strategy of the public operator, development strategy of postal services market in the Republic of Croatia, financial competence of public operator and subvention possibilities),
- *Economic indicators* (sub-criteria: revenue, number of services and presence of competition),
- *Availability of technological infrastructure* (sub-criteria: postal network, technical equipment of post offices, technical equipment of distribution centers, technical capacity of transport organization, technical organization of the shipment delivery),
- *Human resources* (sub-criteria: organizational unit of postal service development, availability of support staff for new services technical support, a system for continuous specialization of workers, a system for continuous specialization of workers in direct contact with costumers, organizational climate),
- *Regulation of postal services* (sub-criteria: services, with following sub-criteria: legal provisions for the implementation of services, quality control system of postal services, the role and impact of regulatory agencies).

Based on the defined criteria and sub-criteria, proposed alternatives are: *Universal services*, *Value added services*, *Other non-universal services*, *New postal services*.

Based on the criteria and sub-criteria that were defined, multi-criteria decision making model in the function of increasing efficiency of public operator efficiency has been suggested, as it is shown in Fig. 3.

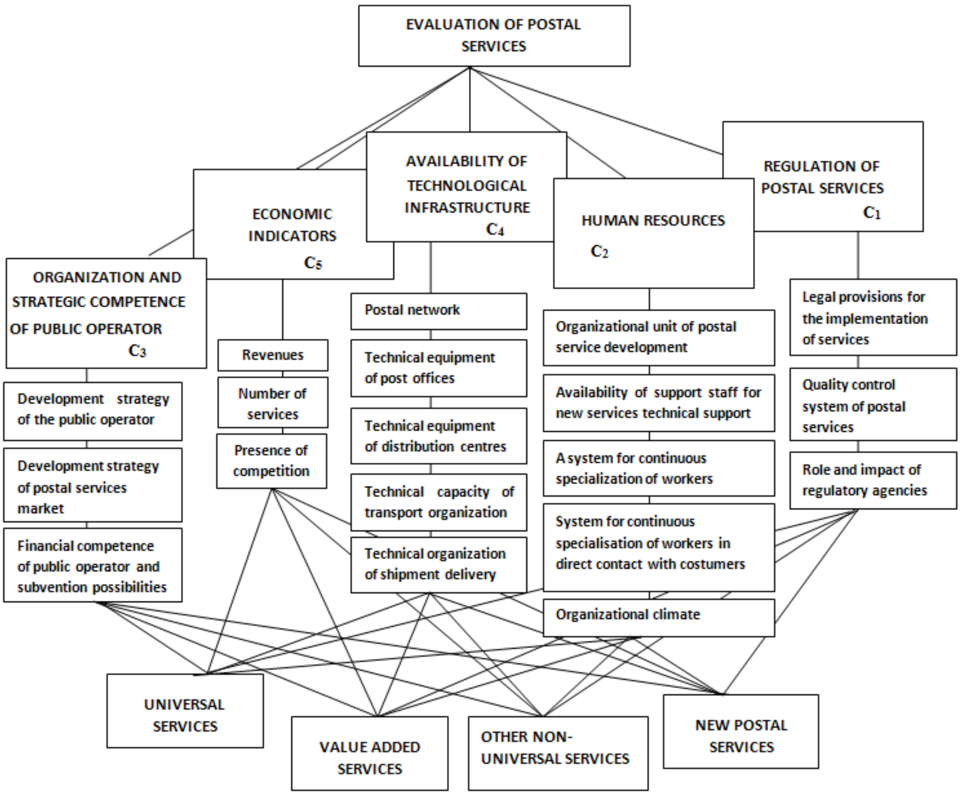

Fig. 3.
Multi-criteria decision making model of postal services

As an example, results of comparing criterion C_1, *Regulation of postal services*, to other criteria is shown on Fig. 4. In similar way other criteria have been compared to each other. When solving decision-making problem, data that allow analytical and simulation modelling of system which derives solutions and lead to the final result are required. Based on the data collected, simulations are performed on the defined model to set the weight values for each parameter, as well as a sensitivity analysis. Sensitivity analysis is an important advantage of simulation package, because it calculates and displays the dependence of the priorities of alternatives (or their changes) on the importance of criteria. This decision maker can easily examine different sets of alternatives, after selecting the importance of the criteria to change and changing the appropriate value, the program automatically calculates new value priorities of other criteria and alternatives. This is actually very important because it can determine which property (attribute) should be improved and how much to become a best alternative.

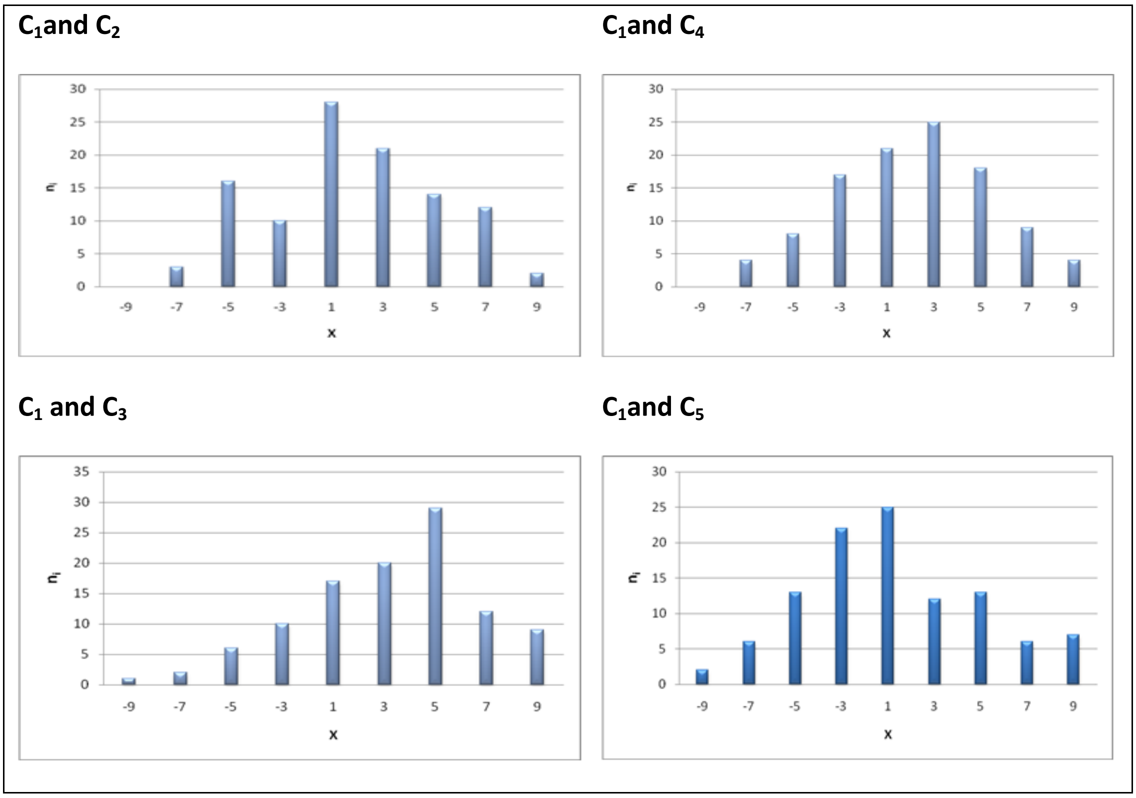

Fig. 4.
Results of survey using Saaty scale of relative importance for criterion C_1

3.1. Simulation results for criteria and sub-criteria values

Based on the collected and processed data on the importance of the criteria and sub-criteria, next step is to calculate relative weights (priorities) of each criteria and sub-criteria, based on the relative importance determined by the surveys, is carried out, as shown in Table 1.

Table 1
Criteria and sub-criteria of the model with their weight values

Criterion	Weight value of criterion	Sub-criterion	Weight value of sub-criterion	Criterion	Weight value of criterion	Sub-criterion	Weight value of sub-criterion
C_1	0.368	C_{11}	0.333	C_4	0.144	C_{41}	0.333
		C_{12}	0.333			C_{42}	0.333
		C_{13}	0.333			C_{43}	0.333
C_2	0.224	C_{21}	0.280	C_3	0.177	C_{31}	0.243
		C_{22}	0.280			C_{32}	0.243
		C_{23}	0.112			C_{33}	0.192
		C_{24}	0.169			C_{34}	0.192
		C_{25}	0.159			C_{35}	0.130
C_5	0.086	C_{51}	0.584				
		C_{52}	0.281				
		C_{53}	0.135				

Criterion C_1 *Regulation of postal services* is recognized as the most important with weight value 0.368. Sub-criteria of this criterion have the following values: sub-criterion C_{11} – Legal provision for the implementation of services 0.333; C_{12} – Quality control system of postal services 0.333; C_{13} – Role and impact of regulatory agency 0.333. Reasons for making this criterion the most important and all of the sub-criteria equally relevant can be explained from the status of postal services market in the Republic of Croatia.

This is primarily related to the fact that the market has not been fully liberalized. Public operator has the market primacy with the capacity of 80% shipments belonging to universal postal services market. Full liberalization of postal services market starts on January 2013.

Criterion C_2 *Human resources* is the second most important criterion with the weight value of 0.224, with its belonging sub-criteria: C_{21} – Organizational unit of postal service development (weight value 0.28); C_{22} – Availability of support staff for new services technical support (weight value 0.28); C_{23} – System for continuous specialization of workers (weight value 0.112); C_{24} – System for continuous specialization of workers with direct contact with customers (weight value 0.169); C_{25} – Organizational climate (weight value 0.159). Importance of the human resources criterion is recognized due to the need for high quality organizational units that will deal with the development and advancement of postal services. Continuous specialization of workers is also recognized with high priorities, together with favorable organizational climate and satisfaction of workers.

Criterion C_3 *Organizational and strategic competence of public operator* is the third criterion by importance, with weight value of 0.177 and it includes following sub-criteria: C_{31} – Development strategy of the public operator (0.333); C_{32} – Development strategy of postal services market (0.333) and C_{33} – Financial competence of public operator and subvention possibilities (0.333)

Criterion C_4 *Availability of postal technological infrastructure* is the following criteria by the importance, with weight value of 0.144. Sub-criteria and their belonging weight values are as follows: C_{41} – Postal network (weight value 0.243); C_{42} – Technical equipment of post offices (weight value 0.243); C_{43} – Technical equipment of distribution centers (weight value 0.192); C_{44} – Technical capacity of transport organization (weight value 0.192); C_{45} – Technical organization of shipment delivery (weight value 0.130). These two criteria are recognized as important, but not essential in decision making of future development strategy.

Criterion C_5 *Economic indicators* with weight value 0.086 is the final recognized by the importance. Its sub-criteria are C_{51} – Revenues, weight value 0.584; C_{52} – Number of services with weight value 0.281 and C_{53} – Presence of competition with weight value 0.135.

Using the results obtained by the research questionnaire, priorities of the alternatives were obtained, as shown in Fig. 3. Alternative *universal service*, which implicates investment in universal postal service, has gained the highest priority (0.350). An alternative *value added services* has a slightly lower priority (0.282), but indicates to the strategic objectives of the public operator. In previous years, the decreased share in the parcel shipments is evident, which is manifested in the area of value added services. Third ranked alternative is *other services* (0.205), ranked ahead of fourth alternative *new services* (0.163). As expected, lowest ranked alternative is *new services*, because the public operator is not currently on the market of new services, which are offered by the European operators in a significant extent. In order to implement these services, technological capacity of the public operator is necessary, which implies considerable investments. However, technological competence and technological development of the society in Croatia is still not at the level to give priority to new electronic services, such as hybrid mail, e-box etc.

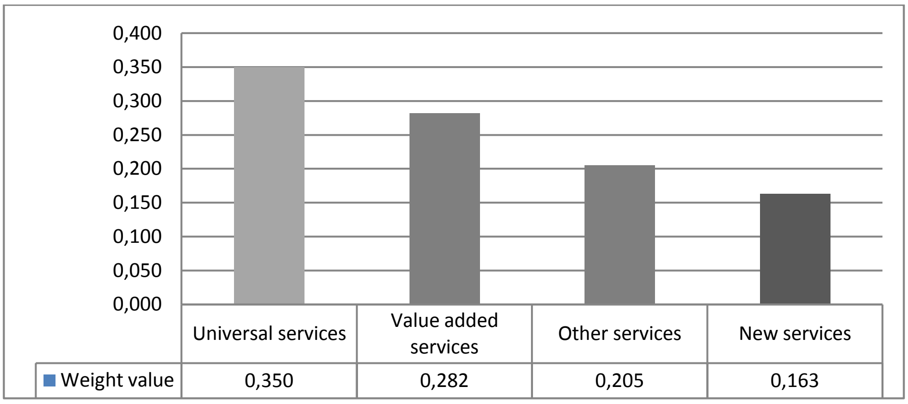

Fig. 5.
Results of decision making process simulation

Sensitivity analysis is carried out in order to determine to what extent the changes of the input data reflect to the changes of output results. In other words, priorities of alternatives are checked to see if the ranking of the alternatives is stable enough. Final goal is to select the alternatives which represent the best option for investments, with the aim of increasing the productivity of the public postal service operator.

By implementing sensitivity analysis for all alternatives, it can be concluded that the lowest priority has the universal service in relation to the value added services, while the most important advantage of a universal service is in relation to new services. This can be verified by the analysis of the situation on the market where is visible that the trend of increasing the share of value added services in the Republic of Croatia in relation to other services was 16% in 2010 compared to 2009. Reason for this is found in the operator adjustments to user requirements. Analysing the significant advantages of universal service in relation to the new services, it can be concluded that the new services are connected to user habits and are considered through the development and availability of broadband Internet access, which is in the Republic of Croatia is considerably below the average of EU member states.

The results of the sensitivity analysis show that comparing criteria *Human resources* and the *Regulation of postal services* highest priority have alternative *universal service* and *value added services*. If these two alternatives are compared, universal service has the advantage; due to the fact that it has a higher priority related to the criteria *regulation of postal services*, while both alternatives have almost the same priority in terms of the criteria. When comparing criteria *Human resources* and *Availability of technological infrastructure,* highest priority belongs to alternative *universal service*, with very little value difference for the alternative *value added services*.

Comparing criterion *Human resources* to criteria *Availability of postal technological infrastructure* and *organizational and strategic competence of public operator,* it is evident that the highest priority has the alternative *universal service* and *value added services*. If these two alternatives are compared, the universal service has the advantage, in terms that it has greater advantages from aspects of other criteria.

When comparing criterion *Regulation of postal services* to *Availability of postal technological infrastructure,* highest priority have 3 alternatives: *universal service*, *value added services* and *other services*. If these 3 alternatives are compared, advantage of *universal service* is evident, because of much greater advantage over the previous two alternatives in terms of the criteria *Regulation of postal services*. In similar way, sensitivity analysis compares *Regulation of postal services* to *Organizational and strategic competence of public operator*, giving highest priority to *universal service* and *value added services,* where *universal service* has the higher advantage.

In terms of the criterion *Regulation of postal services* and E*conomic indicators*, the highest priorities belong to *universal service* and *value added services,* where *universal service* compared to *value added services* has considerable advantage, from the aspect of both criteria considered.

Observing *Availability of postal technological infrastructure* and *Organizational and strategic competence of public operator,* highest priority are given to *universal service* and *value added services*, with a greater advantage to universal service from the aspect of criterion *Organizational and strategic competence of public operator*.

Comparing *Availability of postal technological infrastructure* and *Economic indicators*, highest priority have alternatives *universal service* and *value added services,* with a slightly greater advantage to the first alternative observed from the aspect of *Economic indicators* criterion.

Comparison of *Economic indicators* and *Organizational and strategic competence of public operator*, gave the highest priorities to *universal service* and *value added services,* with a slightly greater advantage to the first alternative.

Conducted sensitivity analysis confirmed the stability of the ranking of alternatives. If we consider the mutual relationships of criteria with respect to rank alternatives, results obtained by the sensitivity analysis are confirmed. The advantage of universal services in respect to value added services is small or almost equal, except for the comparison of following relation between criteria: *Regulation of postal services* and *Availability of postal technological infrastructure*; Regulation *of postal services* and *Organizational and strategic competence of public operator; Regulation of postal services* and *Economic indicators*.

4. Conclusion

This research focused on problems of planning the development of postal services in order to increase the efficiency of postal operator, application of comprehensive multi-criteria analysis is demonstrated. AHP method enables optimal solution when making strategic decisions related to investment in the development of business activities of the public postal service operator, based on the result of a survey. Main problem that occurs in the process is the choice of the relevant criteria and their belonging sub-criteria that in a greater or lesser extent influence the realization of services. By analysing all the observed criteria, five most important have been selected along with their associated sub-criteria: Regulation of postal services, Organizational and strategic competence of public operator, Availability of postal technological infrastructure, Economic indicators, and Human resources.

This model recognized the criterion Regulation of postal services as the most significant, with highest weight value, followed by Human resources criterion. Sensitivity analysis confirmed stability of the ranking of defined alternatives, and showed that the universal service has advantage comparing to other alternatives, followed by value added services.

References

Saaty, T.L. 2001. *Decision making for leaders. The Analytic Hierarchy Process for decisions in a complex world*. University of Pittsburgh.

Zeleny, M. 1992. *Multiple Criteria Decision Making*. McGraw – Hill, New York.

Kavran, Z.; Ćavar, I. 2004. AHP Model of Selecting Mobile Phones in the Republic of Croatia. In *Managing Uncertainty in Decision Support Models*: 5-12.

Kavran, Z.; Rakić, E.; Mostarac, K. 2012. Multi-criteria analysis in decision making of postal services, In *Proceedings of 15th International Conference on Transport Science ICTS 2012:* 1-7.

Kljak, T.; Grgurević, I.; Kavran, Z. 2011. Public Postal Network Access from Compatibility and Interoperability Aspects. In Proceedings of *9th International Scientific Conference POSTPOINT 2011*: 106-113.

Annual reports on work activities of Croatian Agency for Postal and Electronic Communications. 2005-2011. HAKOM, Zagreb.

Hrvatska agencija za poštu i elektroničke komunikacije. Available from Internet: http://www.hakom.hr.

Hrvatska posta. Available from Internet: http://www.posta.hr.

SHIP-BERTH LINK PERFORMANCE MEASURES IN SEA PORT TERMINALS – GENERAL ANALYTICAL APPROACH

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Abstract: The ship-berth link is one of the most important links in both the seaport terminals and the inland port terminals. As known, the ship-berth link capacity and throughput depend directly on the ship inter-arrival time intervals distribution, the size of ships, the kind and variable groups of cargo, ship service time distribution at berths and other traits of ship and terminal as whole system. The service of ship depends on the productivity of cargo handling equipment and immediate states of all other terminal links and nodes (storage area, receiving and delivery system, etc.) in given terminals. Theoretical optimal capacity and throughput of ship-berth link, same as whole terminal could be found with the help of different analytical and experimental methods. However, in the practice and for real cases of terminal operations, the ship-berth link throughput performance is not most often equivalent to optimal throughput according to expectation of port authorities and terminal operators. On other side, there are differences between seaport and inland port in ship arrival patterns within the ship-berth link. Single ships are predominant in seaports and they arrive with different sizes of loads in some time periods. Moreover, these variable groups of loads require single service. In an inland port/terminal, the kinds of arriving ships can be in the form of single ships and in groups (batches or bulk) as pushed or pulled tows of barges. Also, predominantly each barge requires single service at berth within the terminal. In both cases, there is an analogy between the arrivals in variable groups of loads and the number of barges in tows. It means that the methodologies for determination of ship-berth link capacity and throughput have to take into account these differences of ship arrival patterns in sea- and inland terminals.

Keywords: Seaport, Container terminal, Ship-berth link, Ship's waiting time ratio, General queuing system

1. Introduction

Based on practical investigations from seven main seaports (Busan Port, Incheon Port, Pyeongtack Port, Gunsan Port, Kwangyang Port, Masan Port and Ulsan Port) and 18 container terminals within these ports in the period from 2000 to 2005 in the Republic of Korea (Park, et al., 2006; Park, Radmilović, et al., 2006), we will try to develop the general, analytical methodology for the ship-berth link performances in both cases.

Presented methodology can be applied to determine the ratio of the average ship's waiting time or the average waiting time of ships in the queue in units of average service time depending upon berth occupancy, approximate optimal number of berths and the ship-berth link throughput in sea and inland port terminals.

On the basis of the mentioned investigations, the two hypotheses – "There is a high correlation between berth occupancy and berth throughput" and "The correlation between berth occupancy and the ratio of ship's waiting time is high" – have been statistically proved to be significant. But it cannot be said that a throughput performance is equivalent to an optimal throughput. As the berth occupancy is directly related to the service level, it is impossible to calculate an optimal throughput without a proper level of service (Park, et al., 2006).

Many studies and papers have been conducted in relation to the port operating systems as the queueing systems. They mainly focus their attention to the calculations and estimations of the berth occupancy, the ratio of ship's waiting time and ship-berth link throughput and their interdependent relationships. The cost and other units and/or combined operational and economic parameters were used as the criteria of efficiency.
The application of different queueing systems in the operational analyze of ship-berth link performances is often reduced to the determination of probability distributions of inter-arrival and service times of ship as presented, for example, in Table 1 for Korean container terminals.

Estimated probability distributions in big samples have different distribution types, and even if they have identical distribution estimation, their concrete distribution functions are different. Their types and traits can be quite different according to the probability distribution. For these reasons, if simulation models are conducted in a lump without taking into consideration the traits of each port, they can cause a serious error.

Secondly, disregarding on high degree of verification of statistical tests for all probability distributions of port performances, they can be changed in the same port's terminal, because of the change of current conditions, out of the port or within the port (environmental conditions, number of assigned cranes, type and size of the ship, the proper workspace in storage area, etc.).

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Table 1
Results of distribution estimation by terminal type

Terminal / Item	**Shinsundae**	**Jasungdaech Hutchison**	**Gamman – Korea Exp**	**Gamcheon - Hanjin**	**Kwnagyang – Korea Exp**	**Incheon - Sunkwang**
Period of data collection	Dec/28, ’04 – Dec/31, ‘05	Dec/31, ’03 – Dec/31, ‘04	Jan/01, ’05 – Nov/31, ‘05	Dec/31, ’04 – Dec/31, ‘05	Dec/31, ’04 – Nov/30, ‘05	Sep/12, ’05 – Nov/29, ‘05
Number of ships	1477	1531	318	420	416	28
Ship’s arrival time interval	Exponential distribution	Beta distribution	Beta distribution	Weibull distribution	Gamma distribution	Beta distribution
Lift per call (LPC)	Weibull distribution	Weibull distribution	Weibull distribution	Normal distribution	Beta distribution	Beta distribution
Gross crane productivity(1)	Lognormal distribution	Lognormal distribution	Lognormal distribution	Gamma distribution	Lognormal distribution	Lognormal distribution
Net crane productivity(1)	Lognormal distribution	Lognormal distribution	N/A(2)	Lognormal distribution	Lognormal distribution	Exponential distribution

Source: Park, N. K., Radmilović Z., et al., 2006
(1) Gross (net) working hours/LPC/number of assigned cranes
(2) Data not provided

For these reasons, we introduce the general queueing systems for the estimation of the ratio of ship’s waiting time, the approximate determination of number of berths and the ship-berth link throughput in sea- and inland port terminals. In that sense, we apply the approximations for general queueing systems *GI/G/c* (*GI* – single random ship arrivals follow arbitrary probability distribution, *G* – single ship service time with arbitrary probability distribution, *c* – number of berths) in seaport’s terminal and $GI^X/G/c$ (GI^X – bulk random ship arrivals with arbitrary probability distribution, *X* – probability distribution of tow size) in inland port’s terminal.

From the literature it is known that the queueing systems with general single and batch arrivals and single service patterns cannot be treated analytically (Bolch, et al., 2006; Radmilović, et al., 2007). Because of this, for approximating the performance measures of the *GI/G/c* queue, as well as, $GI^X/G/c$ queue, different approximating formulae could be applied for the ratio of ship’s waiting time, mean queue length, the number of berths and ship-berth link throughput, which only depend on the first two moments of the inter-arrival and service time distribution. These moments are known as the coefficient of variations. The general definition for the coefficient of variation as the normalized standard deviation (σ_X) can be written as (Eq. (1)):

$$C_X = \frac{\sigma_X}{\overline{X}} \quad (1)$$

where: $\overline{X}$ – mean value or expected value.

For seaport’s terminal, we use two coefficients of variation:

- coefficient of variation for individual ship inter-arrival time, C_A, and
- coefficient of variation for the ship service time, C_B.

Now, we can apply different, approximate formulae determining the following performance measures in ship-berth link, such as the ratio of ship's waiting time, mean queue length, the number of berths and ship-berth link throughput expressing with traffic intensity (Eq. (2)):

$$\theta = \frac{\lambda}{\mu}, \tag{2}$$

where: λ – mean arrival rate of ships; and
μ – service rate of ships at berths.

With regard to optimal number of berths and optimal throughput, this paper has focused on proving the necessity of terminal development through an economic analysis based on the direct and indirect costs to be caused by ship and cargo waiting.

The calculation can be performed for given number of berths (c), berth occupancies (ρ) and coefficient of variation for inter-arrival times of arriving ships (C_A) and single service time (C_B) in given pairs.

2. Determination of ratio of average ship's waiting time in seaport terminals

The ratio of average ship's waiting time or the average waiting time of ships in the queue in units of average service time or the average waiting time / average service time ratio is one of the operating performances and the measure of efficiency of each port or terminal in the ship-berth link (Radmilović, Z., 1992; Radmilović, Z., et al., 2006).

The ratio of the average ship's waiting time is usually presented as a function of the number of berths, c, berth occupancy, ρ, and the average number of ships in port / terminal, $\overline{L}$. In the general case, it is (Eq. (3)):

$$\gamma = f\left(c, \rho, \overline{L}\right) = \frac{\overline{T}_w}{\overline{T}_b} \tag{3}$$

where: $\overline{T}_w$ – average waiting time of the ship; and
$\overline{T}_b$ – average mean service time (Radmilović, Z., 1992; Chen, T., et al., 2006).

In queueing models, the average utilization of a berth or utilization factor, the quotient of arrival rate of ships, λ, and average service rate, μ, play a significant part (see Eq. (2)).

For the multiple-berth systems ($c > 1$), traffic intensity equals (Eq. (4)):

$$\theta_c = \frac{\lambda}{c\mu} \tag{4}$$

or as berth occupancy (Eq. (5)):

$$\rho = \left(\text{fraction of busy berths}\right) = \theta_c = \\ = \frac{\lambda \overline{T}_b}{c} = \frac{\lambda}{c\mu} = \frac{\theta}{c} \tag{5}$$

The ratio of average ship's waiting time for port queueing systems, holding ρ as the berth occupancy, defined in the Eq. (3), could be shown as (Radmilović, Z., 1992) (Eq. (6)):

$$\gamma = \mu \overline{T}_w = \frac{\mu \overline{L}_q}{\lambda} = \frac{\mu}{\lambda}\left(\overline{L} - \theta\right) = \frac{\overline{L}}{c\rho} - 1 \tag{6}$$

where: $\overline{L}_q$ = average number of ships in waiting line or mean queue length.

As mentioned, we will consider the seaport / terminal as general queueing system *GI/G/c* with queue discipline FCFS (First-Come-First-Served). Also, we will determine some theoretical values for the ratio of average ship's waiting time by applying approximations for the mean ship queue length.

By using the Allen / Cunneen and the Kraemer / Longenbach – Beltz formulae for the mean queue length in *GI/G/c* queueing system, which only depends on the first two moments of the inter-arrival time and ship service time distributions (Bolch, G., et al., 2006; Hanschke, T., 2006), as defined in Eq. (1), it could be (Eq. (7)):

(1) Allen / Cunneen formula

$$\bar{L}_{q_{AC}} \approx \frac{\rho P_c}{1-\rho} \frac{C_A^2 + C_B^c}{2} \tag{7}$$

where: C_A^2 = squared coefficient of variation of the inter-arrival time distribution for arriving ships;
C_B^2 = squared coefficient of variation of ship service time distribution at berth;
P_c = the probability of blocking.

P_c can be approximated by Erlang's formula for the *M/M/c* queue (Hanschke, 2006) as follows (Eq. (8)):

$$P_c = \frac{(c\rho)^c}{c!(1-\rho)\left[\sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!} + \frac{(c\rho)^c}{c!} \frac{1}{1-\rho}\right]} \tag{8}$$

The substitution of Eqs. (4), (5) and (7) into (6) yields the ratio of average ship's waiting time as follows (Eq. (9)):

$$\gamma_{AC} \approx \frac{P_c}{1-\rho} \frac{C_A^2 + C_B^2}{2c} \tag{9}$$

(2) Kraemer / Longenbach – Beltz formula

By using Kraemer / Longenbach – Beltz formula, which produces more accurate results, the approximate mean queue length (Radmilović, Z., et al., 2007) can be obtained as follows (Eq. (10)):

$$\bar{L}_{q_{KLB}} \approx \frac{\rho P_c}{1-\rho} \frac{C_A^2 + C_B^c}{2} G_{KLB} \tag{10}$$

or the ratio of average ship's waiting time, similarly as in the Eq. (9), is (Eq. (11)):

$$\gamma_{KLB} \approx \frac{P_c}{1-\rho} \frac{C_A^2 + C_B^2}{2c} G_{KLB} \tag{11}$$

where:

$$G_{KLB} = \begin{cases} \exp\left[-\frac{2}{3}\frac{1-\rho}{P_c}\frac{(1-c_A^2)}{C_A^2 + C_B^2}\right], \text{for } 0 \le C_A \le 1 \\ \exp\left[-(1-\rho)\frac{c_A^2 - 1}{C_A^2 + 4C_B^2}\right], \quad \text{for} \quad C_A > 1 \end{cases} \tag{12}$$

The coefficient of variation of the inter-arrival time of arriving ships (C_A) and ship service time (C_B) are adopted as usual values in the pairs: (1.2, 1.2), (1, 1), (1.2, 0), (1.1, 0.7), (0.7, 1.1), (0, 1.2), (0.7, 0.7) and (0.5, 0.5), and the berth occupancy, ρ = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9.

By applying the Allen / Cunneen formula (AC – Eq. 9) and Kraemer / Longenbach – Beltz formula (KLB – Eq. 11), some of our results for the ratio of average ship's waiting time are given in Tables 2 and 3 and Figs. 1 and 2 (KLB formula). These results refer to KLB formula as this formula gives better results.

Now, we can compare these theoretical results with annual real berth performances such as the berth occupancy, the ratio of average ship's waiting time and the berth throughput in frame of five big Korean container terminals. The real berth performances are presented in Table 4.

Table 2
Ratio of ship's waiting time for coefficient of variations $(C_A, C_B) = (0.5,\ 0.5)$ *– KLB formula*

c \ ρ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	0	0.0031	0.0186	0.0541	0.1181	0.2274	0.4230	0.8290	2.0701
2	0	0	0.0006	0.0066	0.0271	0.0722	0.1626	0.3599	0.9760
3	0	0	0	0.0008	0.0081	0.0317	0.0866	0.2139	0.6212
4	0	0	0	0.0001	0.0025	0.0158	0.0528	0.1449	0.4476
5	0	0	0	0	0.0007	0.0083	0.0347	0.1057	0.3455
6	0	0	0	0	0.0002	0.0045	0.0239	0.0807	0.2787

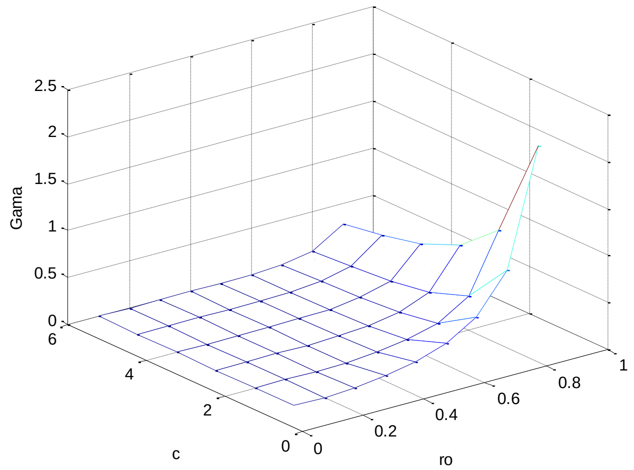

Fig. 1.
Ratio of ship's waiting time, $(C_A, C_B) = (0.5,\ 0.5)$ *– KLB formula*

Table 3
Ratio of ship's waiting time for coefficient of variations $(C_A, C_B) = (1.2,\ 1.2)$ *– KLB formula*

c \ ρ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	0.1514	0.3428	0.5913	0.9254	1.3967	2.1078	3.2990	5.6900	12.881
2	0.0138	0.0571	0.1365	0.2644	0.4656	0.7904	1.3584	2.5289	6.1015
3	0.0019	0.0141	0.0460	0.1089	0.2205	0.4154	0.7734	1.5344	3.8980
4	0.0003	0.0041	0.0183	0.0525	0.1214	0.2521	0.5050	1.0605	2.8186
5	0.0001	0.0013	0.0079	0.0276	0.0728	0.1659	0.3561	0.7882	2.1826
6	0.0000	0.0004	0.0037	0.0154	0.0462	0.1151	0.2639	0.6138	1.7655

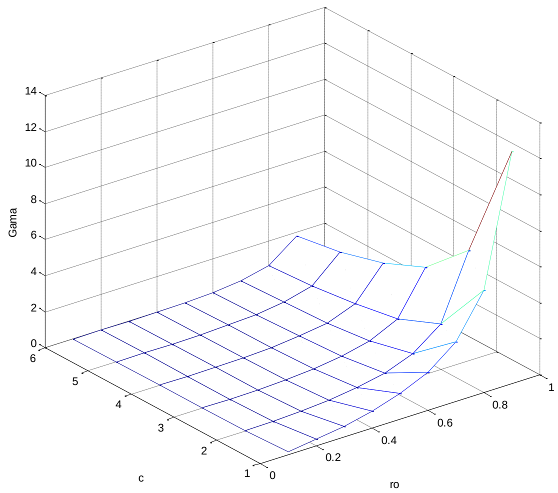

Fig. 2.
Ratio of ship's waiting time, $(C_A, C_B) = (1.2,\ 1.2)$ *– KLB formula*

Table 4
Berth occupancy, ratio of ship's waiting time and berth throughput (TEU) on annual level in five Korean container terminals

Year	Section \ Terminal	Shinsundae	Jasungdae	Gamman	Singamman	Uam
	Number of berths	4	4(1)*	1	2(1)	1
2000.	Berth occupancy	0.512	0.539	0.628	N/A**	0.538
	Ratio of ship's waiting time	0	0	0	N/A**	0
	Berth throughput (TEU)	341,903	317,081	442,280	N/A	223,070
2001.	Berth occupancy	0.459	0.505	0.556	N/A	0.538
	Ratio of ship's waiting time	0	0	0	N/A	0
	Berth throughput (TEU)	351,936	281,363	480,635	N/A	319,780
2002.	Berth occupancy	0.521	0.568	0.701	0.359	0.672
	Ratio of ship's waiting time	0.016	0.021	0.027	0.006	0.002
	Berth throughput (TEU)	407,543	339,369	565,371	229,134	358,892
2003.	Berth occupancy	0.604	0.668	0.718	0.482	0.687
	Ratio of ship's waiting time	0.022	0.034	0.042	0.024	0.039
	Berth throughput (TEU)	476,297	350,392	636,597	353,253	379,920
2004.	Berth occupancy	0.678	0.661	0.705	0.535	0.637
	Ratio of ship's waiting time	0.016	0.029	0.029	0.016	0.045
	Berth throughput (TEU)	531,968	403,709	680,933	463,231	391,443

Source: Park, N. K., et al., 2006
[*] The terminal has 4 and 2 berths respectively and one more berth capable of accommodating feeder ships simultaneously.
[**] Data not provided.

3. Conclusions and guidelines for further research

The major conclusions drawn in this paper are as follows:

1. The approximate, analytical solutions could be used in port planning and in the analysis of existing state for determination of the ratio of average ship's waiting time. In the same way, these solutions can, also, be used in different transport and port systems and links, particularly in container terminals.
2. The expressions (9) and (10), the curves in Figs. 1 and 2 and numerical results in Tables 2 and 3 may be used for the estimation of the ratio of average ship's waiting time and berth throughput depending on the number of berths, berth occupancy and coefficient of variations of ship inter-arrival time and ship service time distributions.
3. For the different combinations of input parameters (number of berths, berth occupancy and ratio of average ship's waiting time), the estimation of total ship time spent in the port system can be promptly found, as well as berth throughput.
4. The ratio of average ship's waiting time, as well as the components of these ratios are more sensitive to changes in coefficient variation of inter-arrival time distribution (C_A) than to changes of coefficient variation of service time distribution (C_B). It means that, for the prevention of congestion in transport and port links, firstly, we must reduce, for example, ship queues with new organization and, secondly, we must find good arriving patterns of ships for each port in appropriated network.
5. There is a high coinciding between real berth occupancy and ratio of ship's waiting time and our analytical solutions, particularly in the case of applying Kraemer / Longenbach – Beltz approximate formula for the estimation of the ratio of ship's waiting time (see Tables 2 and 3 and Figs. 1 and 2).

The analytical solutions presented herein can be used for fast and effective computation and review of basic ship-berth link performances, particularly in seaport container terminals. The application of numerical results from Tables 2 and 3 and Figs. 1 and 2 is not restricted because of the predetermined probability distributions of inter-arrival and service times since the single random ship arrivals and single ship service time follow arbitrary probability distributions.

The analytical solutions and numerical / graphical results presented in this paper are convenient for different approaches in port planning and development, for example, increasing the number of berths or berth utilization depending on the required proper level of services for ships, the estimation of average berth occupancy for all similar berth groups. The numerical results and graphs can be used, even without using the detailed analysis outlined above, to provide important information for port planning and development.

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References

Bolch, G.; Greiner, S.; Meer, H. De; Trivedi, K.S. 2006. *Queueing Networks and Markov Chains*, John Wiley and Sons, New Jersey, USA.

Chen, T.; Dragović, B.; Radmilovć, Z. 2007. *Port Logistics*, TongMyong University, Busan, Korea (in Korean).

Hanschke, T. 2006. Approximations for the mean queue length of the $GI^X/G^{(b,b)}/c$ queue, *Operations Research Letters* 34(2): 205-213.

Park, N.K.; Radmilovic, et al. 2006. *A Study on Improvement of Calculation System of Optimal Throughput per Berth in Korea Container Terminal*, Ministry of Maritime Affairs and Fisheries, Seoul, Republic of Korea.

Park, N.K.; Seo, C.G.; Choi, H.R.; Dragović, B.; Chen, T.; Radmilović, Z.; Lee, Y.C.; Lim, C.K.; Lee, S.Y.; Cho, K.S.; Lee, J.Y. 2006. *PORT LOGISTICS 2006, Optimal throughput of Container Terminal*, Port and Logistics Industry Institute, TongMyong University, Ministry of Maritime Affairs and Fisheries, Seoul.

Radmilović, Z. 1992. Ship-Berth Link as Bulk Queueing System in Ports, *Journal of Waterway, Port, Coastal and Ocean Engineering* 18(5): 474-495.

Radmilović, Z.; Dragović, B.; Meštrović, R. 2005. Optimal Number and Capacity of Servers in $M^{X=\bar{a}}/M/c(\infty)$ Queueing Systems, *International Journal of Information and Management Sciences* 16(3): 1-16.

Radmilović, Z.; Jovanović, S. 2006. Berth Occupancy at Container Terminals: Comparison of Analytical and Empirical Results, *Scientific Journal on Traffic and Transportation Research – Promet* 18(2): 99-103.

Radmilović, Z., Maraš, V., Jovanović, S. 2007. Ship Lock as General Queeuing System with Batch Arrivals and Batch Service, *Scientific Journal on Traffic and Transportation Research – Promet* 19(6): 343-352.

THE FUTURE OF SHIP´S PROPULSION IN MARITIME TRANSPORT

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Abstract: Due to high fuel prices on the world market and regulations for emission reduction, nowdays many shipping companies are forced to experiment with different types of ship propulsion in order to minimize fuel consumption and meet the criteria for CO_2 release into the atmosphere, and thereby to reduce the transportation costs. This article will give an insight into the range of alternative energy sources and various possible alternative solutions for ship propulsion. Some of these projects will enter commercial operation in late 2014. A new generation of ships is a technical concept that is highly advanced and very practical for the environment in the near future. This article will also present the amount of fuel savings and CO_2 emission reduction compared to conventional ships, as well as the advantages and disadvantages of different solutions for ship propulsion. In the next few years, we can expect a further major investment in the development of vessels with greater fuel efficiency and reduced CO_2 emission by 30%. That is very useful information that must be taken into account, as the fuel prices on the world market are growing, and requirements for the allowable amount of exhausted CO_2 in the atmosphere are becoming more stringent.

Keywords: alternative fuels, alternative propulsion, IMO agreement for CO_2, environmental protection.

1. Introduction

Because of the high fuel prices and restrictions imposed by policy of reducing environmental pollution, the world's major shipping companies are faced with seeking new alternatives in ship propulsion. The International Maritime Organization adopted the measures on CO_2 output in the atmosphere, which are presented in Annex VI of the International Convention for the Prevention of Pollution from Ships - MARPOL. IMO measures include the reduction of greenhouse gas emissions from ships through the concept of evaluation (Energy Efficiency Design Index - EEDI), monitoring and improving ship performance, due to various factors that can contribute to CO_2 emissions (Ship Energy Efficiency Management Plan - SEEMP).

These measures and regulations are expecting to enter into force on 1 January 2013. For that reason, a new generation of ships are being built. In combination with new technologies in the ship design and propulsion, they will result in reducing CO_2 release into the atmosphere in accordance with regulations and measures proposed by the IMO. In the upcoming years, the industry believes that they will also provide a significant decrease in discharge of greenhouse gases into the atmosphere.

2. World maritime transport and reduction of CO_2

The world seaborne trade is increasing each year with more number of ships (Table 1), with that in mind the releasing of CO_2 is also increasing. Taking into account that the sea transport is cheapest transportation alternative solutions in ships propulsion found their way in this sort of traffic. In July 2011 the International Maritime Organization (International Maritime Organization - IMO) adopted a new package of measures to reduce CO_2 emissions in Annex VI of the International Convention for the Prevention of Pollution from Ships (International Convention for the Prevention of Pollution From Ships - MARPOL), which includes package of mandatory technical and operational measures to reduce greenhouse gas emissions in the international shipping industry, to improve the energy efficiency of ships, through improved design and propulsion technology, as well as through improved operational practices. These measures are expected to come into force on 1 January 2013. These amendments include:

- Energy Efficiency Design Index - EEDI,
- Ship Energy Efficiency Management Plan - SEEMP

2.1. Energy Efficiency Design Index - (EEDI)

Energy efficiency design index for new ships would be similar to concept evaluation which applies to cars and electrical appliances. With these measures, IMO EEDI (Energy Efficiency Design Index) will result in approximately from 25 % to 30% emission reduction by 2030 in relation to the present measures. So EEDI has only one goal, to reduce greenhouse gas emission from ships (Table 2). In the last few years a discussion on environmental protection in the IMO, has resulted in the development of energy efficiency design EEDI, which has wide support of governments, industry associations and organizations that represent the interests of civil society.

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They are all united in the same mission: to ensure that EEDI delivers environmental effectiveness through improved energy efficiency and through significant reduction in greenhouse gas emissions from ships. The measures contained in the EEDI also promote technological development of all parts of the ship which affect the consumption of fuel on board. It should be noted that the EEDI formula is not suitable for all types of ships, especially those ships who are not designed to carry cargo and for all types of propulsion systems (for example, the one that comes with a diesel-electric, turbine or hybrid propulsion systems will require an additional correction factor).

Table 1
Number of ships in the world merchant fleet from 2009 to 2011 by ship type

Ship type	January 1, 2009	January 1, 2010	January 1, 2011
General cargo ships	17949	17715	17365
Crude oil tankers	9159	9740	10035
Bulk carriers	7481	7772	8652
Container ships	4639	4706	4882
Passenger ships	4161	4195	4131
Liquid gas tankers	1419	1489	1536
Chemical tankers	1347	1331	1232
Total	46155	46948	47833

Source: Statista

Table 2
IMO package includes 25 to 30% reduction in emissions from ships into the atmosphere.

Source: Imo, 2011a

The first version of the EEDI is designed for the most energetic and most intense segment of the commercial fleet as follows: tankers, bulk carriers, general cargo ships and container ships. For ship types that are not included in the current formula, suitable formulas will be developed in the near future to solve the world's biggest polluters.

EEDI formula gives a certain state for an individual ship design, expressed in grams of CO_2 per capacity of the ship - miles (smaller EEDI value means more energy-efficient design of the ship) and is calculated by the following formula based on the technical parameters of the ship (Eq. (1)):

$$EEDI = \frac{CO_2 emission}{transport\ work} \tag{1}$$

The CO_2 emission represents the total CO_2 emissions from fossil fuel combustion, including propulsion and auxiliary engines and boilers, taking into account the carbon content in fuels. If mechanical or electrical energy-efficient technologies are built into the ship, their effect is subtracted from the total CO_2 emission. Energy collected by using wind or solar power is also deducted from the total CO_2 emission, which is based on the actual system performance.

Assuming that the measures will come into force on 1 January 2013, the introduction of the EEDI for all new ship means that between 45 and 50 million tons of CO_2 per year will be removed from the atmosphere by 2020. This assumption is based on the current situation ″business as usual″ (BAU), without the growth of the world trade. It is also expected that by 2030 the reduction will be between 180 and 240 million tons a year, since the introduction of EEDI. It can be said that EEDI establishes minimum energy performance requirements for new ships, depending on the type and size of the boat. EEDI also leaves the choice of technologies and solutions to use in the design of the ship, but only under the condition that the required level of energy efficiency is achieved. Reducing the level of the first stage is set to 10% and will be tightened every five years to keep pace with the technological development. The IMO has set reduction of CO_2 for 2025 up to 30%. (Table 3)

Table 3
Reduction factors (%) for the EEDI relative to the EEDI Reference line

Ship Type	**Size**	**Phase 0** **1 Jan 2013 -** **31 Dec 2014**	**Phase 1** **1 Jan 2015 -** **31 Dec 2019**	**Phase 2** **1 Jan 2020 -** **31 Dec 2024**	**Phase 3** **1 Jan 2025 -** **and onwards**
Bulk carrier	20 000 DWT and above	0	10	20	30
	10 000 - 20 000 DWT	n/a	0-10*	0-20*	0-30*
Gas carrier	10 000 DWT and above	0	10	20	30
	2 000 - 10 000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20 000 DWT and above	0	10	20	30
	4 000 - 20 000 DWT	n/a	0-10*	0-20*	0-30*
Container ship	15 000 DWT and above	0	10	20	30
	10 000 - 15 000 DWT	n/a	0-10*	0-20*	0-30*
General Cargo	15 000 DWT and above	0	10	20	30
ships	3 000 - 15 000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated	5 000 DWT and above	0	10	20	30
cargo carrier	3 000 - 5 000 DWT	n/a	0-10*	0-15*	0-30*
Combination	20 000 DWT and above	0	10	20	30
carrier	4 000 - 20 000 DWT	n/a	0-10*	0-20*	0-30*

* - Reduction factor to be linearly interpolated between the two values dependent upon vessel size.
The lower value of the reduction factor is to be applied to the smaller ship size.
n/a - means that no required EEDI applies.
Source: IMO, 2011b

2.2. Ship Energy Efficiency Management Plan – SEEMP

Ship Energy Efficiency Management Plan (SEEMP) - this kind of a plan would allow shipping companies and ships to monitor and improve the performances, considering the various factors that can contribute to CO_2 emissions. This includes, among other things: improving planning trips; velocity control, weather routing, optimizing engine power, the use of the rudder and propeller, hull maintenance and use of different types of fuel. These regulations apply to all ships of 400 GT and above and are expected to enter into force on 1 January 2013. Amendments to MARPOL Annex VI represent the first mandatory global greenhouse regime for the international branch of the transport mode. Assuming that the measures come into force on 1 January 2013, the introduction of the EEDI for all new ships will mean that between 45 and 50 million tonnes of CO_2 per year will be removed from the atmosphere by 2020, compared to ″business as usual″ - BAU.

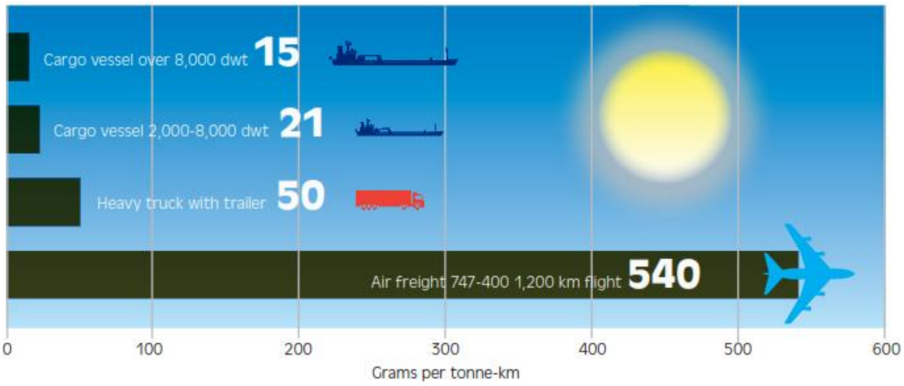

Fig. 1.
Comparison of CO_2 emissions between different types of transport
Source: NTM, Sweden

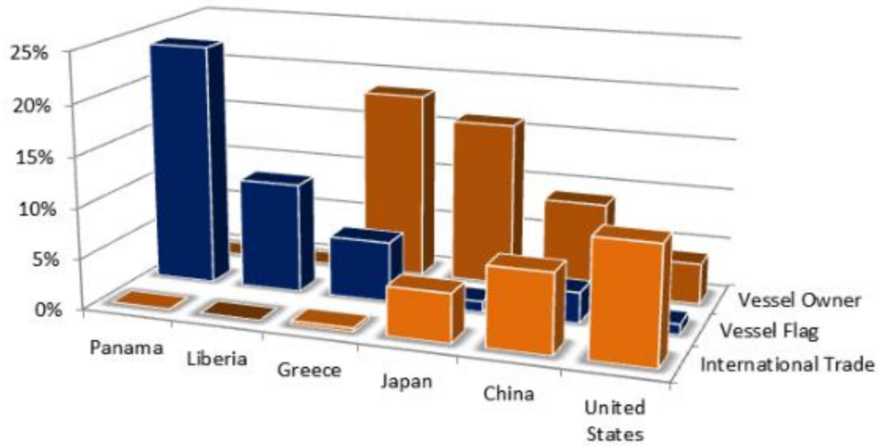

Fig. 2.
Comparison of International Trade (Percent of Global Value of Merchandise Trade), Vessel Flag (Percent of Global Deadweight Tons, DWTs), and Vessel Owner (Percent of Global DWTs) by Country
Source: Center for Climate and Energy Solutions

Maritime shipping complicates the efforts for reducing emissions in maritime sector. Ownership of the international maritime fleet is particularly complex. For example, a ship owned by the company in Spain can be registered under the Panamanian flag, and carrying cargo from Australia to China. These political realities greatly complicate the task responsibilities of greenhouse gases in the international shipping and they must be taken into account when developing policies regarding solutions for discharge of greenhouse gases from international shipping. Fig. 2 shows comparison of International Trade (Percent of Global Value of Merchandise Trade), Vessel Flag (Percent of Global Deadweight Tons, DWTs), and Vessel Owner (Percent of Global DWTs) by Country.

Significantly reduced emissions in the maritime sector will require that any adopted significant measures apply on a global basis, to avoid a significant release of CO_2 into the atmosphere. Since, according to the current situation, many shipping companies have the free will to choose the ship flag of the country that has not signed and ratified the Kyoto Protocol Annex I. According to the data from 2009 only 35% of the world merchant fleet is registered in the countries that have signed the Kyoto Annex I. For this reason, one should find a meaningful reduction of CO_2 in maritime transport, and this could be achieved through the MARPOL with included package of mandatory technical and operational measures for reducing greenhouse gas emission in the international shipping industry, with a goal to improve the energy efficiency of ships.

If the world merchant fleet continues to operate under ˝business as usual˝ (BAU), the emission from the global shipping fleet is expected to double by 2050. Greenhouse gases in the atmosphere can be limited through changes in operating practices and improving the fuel efficiency of ships.

When combined together, these changes can reduce the proportion of emissions by 50% below "business-as-usual" by 2050, which would mean that the amount of emission remain at approximately current levels, despite a very large increase in the shipping fleet by the mid-century. International shipping complicates global political efforts to reduce emissions. Working with transnational actors will be an important step towards creating meaningful global regulations.

International and domestic shipping plays an important key role in a globalized world, moving goods within and between countries. Global demand for the transport of goods between the markets of international trade has increased. From 2000 to 2007 the volume (in tons) of world merchandise exports increased by an average 5.5% per year (almost twice the rate of world GDP), with the fact that more than 80% of trade is transported by ship (WTO, 2008; UNCTAD, 2008). Fig. 3 shows the part of each cargo type in the world maritime trade in terms of tons per a mile of transportation. The World Trade Organization (WTO) estimates that manufactured goods account for more than 70% of the total value of the world trade (UNCTAD, 2008).

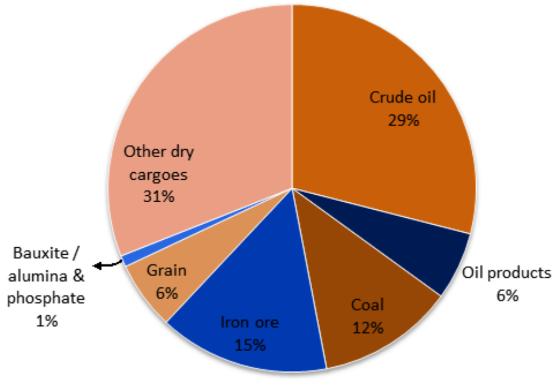

Fig. 3. *World seaborne trade by type as a percent of total ton-miles*
Source: UNCTAD, 2009

3. Future of ship's propulsion

In the long term perspective, depending on technological development, the industry believes it will succeed and provide a greater reduction in discharge of greenhouse gases in the atmosphere. In the near future it is expected that the shipping will still depend on fossil fuels. Although today the shipping industry is energy-efficient, further improvements in the technology of the hull, engine, propeller design, will allow for less fuel consumption.

There is also the possibility of using waste heat to reduce consumption. Better operational measures (better speed control through the voyage) will also contribute to reducing fuel consumption and it will be in accordance with the Ship Energy Efficiency Management Plan - SEEMP.

The shipping companies also have a good reason to reduce fuel consumption, which contributes to CO_2 reduction. The reason for that is the cost of bunkering, which represents a significant part of operating costs, and which is an increase of about 300% in the last 5 years. It is expected that marine bunker prices will remain high. In addition, it is expected that the price of marine fuel will increase by 50%, as a result of increased use of distillate fuel, which will monitor the implementation of the new IMO regulations (MARPOL Annex VI) to be applied on a global level in areas that control the emission by 2015 (UNCTAD, 2009).

In different parts of the shipping industry – ship-owners, shipbuilders and classification societies are conducting researches in order to reduce CO_2 emissions for new and existing ships, which were primarily related on the reduction in fuel consumption. Shipping industry is also investigating in a number of alternative fuel sources to reduce CO_2 emissions.

With current technology, renewable energy sources, such as wind and solar energy, can be used for some additional requirements, such as the lighting of ships. However, for the time being, these energy sources are not suitable to provide enough power to operate as the main propulsion engine of a large merchant ship.

Looking ahead in long term, fuel cell can be an opportunity for ship's propulsion in the future, although they are technologically limited in range to serve as the only solution for now. It can be expected that the ships of new generation (in the next couple of years) are going to use hybrid propulsion and they will continue to depend on fossil fuel, but consumption will be reduced with the help of solar energy, lost exhaust heat and the further development of hull and propeller design.

One of these ships (the concept Ishin-III), is going to be released late 2014 for the commercial purpose by the shipping company Mitsui OSK Company Lines (MOL), which will reduce the exhaust of CO_2 in the atmosphere by about 30% in ideal conditions.
This ship is characterized by:

- Steam turbine that generates electricity using heat of exhaust gases from the engine,
- Hybrid system that converts rotational force from the compressor into electrical energy,
- Electrical energy obtained through steam turbines and hybrid system will provide ship propulsion.

Reduced exhaust of CO_2 for such system include: motor system optimization (10%), fuel additives (1.5%), reduction of friction resistance (10%), propulsion efficiency optimization (5%), hull design optimization (2%), use of renewable energy sources (0.1%) - by using solar panels. Solar panel will be located on the entire stern of the boat and on the navigation bridge allowing 150kW of electricity. Such energy (from solar panels) would be stored in rechargeable lithium-ion batteries of total capacity 10 000 kWh for the crew and ship propulsion.

The next option in future ship propulsion is nuclear propulsion. This type of propulsion is a very cost-effective and technically feasible solution for merchant ships. However, there is a question of security and infrastructure costs if this propulsion appears in the market, considering that maritime traffic is increasing each day. Therefore, this is a very delicate question that requires additional consideration. Moreover, insurance of nuclear vessels is different from the insurance of conventional ships. The consequences of an accident could span national boundaries, and the magnitude of possible damage is beyond the capacity of private insurers (World Nuclear Association).

Propulsion on bio fuel - production of bio fuel is expensive, and (according to some studies) the amount of energy consumed in the production of bio fuels is greater than the amount of energy than it can generate. The other problem for bio fuels is the raw material such as soybeans, which can reduce biodiversity and cause environmental problems. Bio fuels are mainly derived from sugar cane, corn, soybeans and rapeseed. The great paradox in all this is that, due to for providing additional resources for the production of bio fuels, the Amazon rainforest is being destroyed, in order to obtain large farmland. Brazil is the second producer of ethanol in the world, behind the U.S. (Planb.hr).

Bio fuels are reducing the emission of carbon dioxide into the atmosphere and are less polluting than fossil fuels, but they are also depending on the material (biomass) from which they are made. For example, if the bio fuel is produced from corn for production, then it is harmful to the environment because consuming large amount of pesticides and nitrogen fertilizers results in pollution of soil and water. At the same time, due to deforestation in order to obtain land for planting corn, the soil erosion is increased (landslides), and in this way, the biological diversity of forests and meadows is reduced.

According to a roadmap unveiled by the International Energy Agency (IEA), bio fuel is set to provide 27% of transportation fuel by 2050 (IEA, 2012).

The use of bio-fuels is does not solve the problem of carbon dioxide emissions, which are not significantly lower than those that can be released by using fossil fuels. Although, the described first generation of bio-fuels still dominates, the second generation of bio fuels is being developed. Second-generation bio fuels are derived from agricultural and timber industries waste products, and thus they can avoid competition with food production resources. Experts, among other things, are working on obtaining a fuel from household waste. Commercial production of the second generation is still expected in the upcoming years because the technology of the first generation is generally still effective.

Second generation of bio fuels can provide a possible alternative, although, there is a significant public debate in production costs and environmental (social effects), but also the cost and effectiveness of such fuels. Although the second-generation of bio-fuels are not fully operational, the third and fourth generation are being developed.
The third generation of bio fuels are derived from algae, and the fourth generation requires the use of genetically engineered bacteria to produce hydrocarbon chains. It is a genetically modified bacterium that produces hydrocarbon chains, which make up the fuel. The big oil companies have been following the story of bio fuel because this method of energy production is less dependent on geographic, economic and political factors. To significantly contribute to the reduction of CO_2, such fuels should be substantially lower than the conventional fuels which they should replace.

Further development in ships propulsion tends towards the use of wind energy. Such projects are not far from us, but further research is needed regarding these technologies. For example, the project of the University of Tokyo, and several ship-builders and shipping lines (Wind Challenger Project) uses wind energy (using sails across the whole deck), which would manage to reduce exhaust of CO_2 by 50%. The project will be launched in the next few years. The aim is to reduce CO_2 emission 69% by 2030, and eliminate it by 2050. There is also a project to build wind turbines on ships that would utilize wind energy. However, the use of wind turbines has not become intense in large commercial ships, because of the requirement for constant wind.

The other wind propulsion system for ships is the kite propulsion system for merchant ships. The kite propulsion system consists of a fully automatic towing kite system and routing software, which allows for the use of the most favourable winds. With a kite, the fuel consumption can be reduced. With the use of a kite (for example: SkySails system) is claimed to reduce a cargo vessel's fuel consumption by an average of 10 to 35 %, and by up to 50 % temporarily (Gizmag).

Table 4
Summary of GHG Reduction Potentials in 2050 by Abatement Option and Sector

Sector	Category	Measure	Reductions under BAU Conditions (% in 2050)	Additional Reductions from BAU emissions in 2050 (%)	Combined Potential Potential (% in 2050)
Marine	Operations	Speed reduction, Optimized routing, Reduced port time	20	27	47
	Ship Design and propulsion	Novel hull coatings, propellers, Fuel efficiency optimization, Combined cycle operation and Multiple engines	20	17	37
	Alternative Fuels and Power	Marine diesel oil (MDO), Liquefied natural gas (LNG), Wind power (sails)	2	38	40
	Total Reduction from BAU Emissions in 2050			62	

Source: Greenhouse Gas emissions from aviation and marine transportation: mitigation potential and policies

LNG as a fuel for ship propulsion - according to a study at IMO, under BAU conditions, using LNG for ship propulsion would result in a reduction of CO_2 for 2% until 2050. However, there is a problem of availability and infrastructure of LNG in ports. Using LNG combined with alternative energy sources (wind, solar) can reduce CO_2 emissions by 40% from current levels to 2050. Other alternative fuels, such as bio fuels and solar cells, seem uncertain as the only long-term option.

It is assumed that the ships will continue to sail with fossil fuels in the foreseeable future, and that the CO_2 reduction will be achieved with further improvements in hybrid technologies and efficiency throughout the whole transport chain.

3. Conclusion

The major role in the world sea transport of goods between countries implies international and domestic shipping. Global demand for the transport of goods between the markets of international trade has been increased. If the maritime transport continues to operate under "business-as-usual", then the emissions from the world shipping fleet will double by 2050.

In the near future it is expected that the shipping still be dependent on fossil fuels, but further improvements in the technology of the hull, engine, propeller design, will allow less fuel consumption. Operational measures (for example: better speed control through the voyage) will also contribute to fuel reduction and will be in accordance with Ship Energy Efficiency Management Plan - SEEMP. The first version of the EEDI formula is designed for the most intense segment of the commercial fleet such as: tankers, bulk carriers, general and containerized cargo carriers. A new EEDI formula for other types of ships needs to be made, which is not included in the current formula. Shipping companies have a good reason to reduce fuel consumption, (which contributes to the reduction of CO_2), due to the high cost of bunker. Also, ownership of the international maritime fleet needs to be regulated, because only 35% of the world merchant fleet is registered in countries that have signed the Kyoto Annex I. For that reason, a meaningful reduction of CO_2 needs to be found in maritime transport.

References:

Center for Climate and Energy Solutions. Available from Internet: http://www.c2es.org/technology/factsheet/MarineShipping.

Gizmag. Available from Internet: http://www.gizmag.com/cargill-ship-will-be-largest-ever-to-utilize-kite-power/18005/.

IEA. 2012. Available from Internet: http://www.china.org.cn/business/2012-05/25/content_25472345.htm.

IMO. 2011a. Agreement on CO2 Technical Rules. Available from Internet: <http://www.shippingandco2.org/imopackage.htm>

IMO. 2011b. *Technical and operational measures to improve the energy efficiency of international shipping and assessment of their effect on future emissions*. 22 p.

Institute of Shipping and Logistics - shipping Statistics and Market Review, Volume 55 No 1/2, Institute of shipping Economics and Logistics, 2011. <http://www.isl.org

McCollum, D.; Gregory, G.; *Greenhouse emissions from aviation and marine transportation: Mitigation potential and policies, Pew Center on Global Climate Change*. 56p.

Planb.hr. Available from Internet: http://planb.hr/2011/12/buducnost-biogoriva/.

Statista. Available from Internet: http://www.statista.com/statistics/29147/number-of-merchant-ships-worldwide-by-type/.

United Nations Conference on Trade and Development (UNCTAD). 2008. *Review of Maritime Transport 2008*. 200 p.

United Nations Conference on Trade and Development (UNCTAD). 2009. *Review of maritime transport* 2009. 219 p.

United Nations Framework Convention on Climate Change; International Maritime Organization. 2009. Shipping, World Trade and the Reduction of CO_2 Emissions. Available from Internet: <http://www.shippingandco2.org/CO2%20Flyer.pdf>

World Nuclear Association. Available from Internet: http://www.world-nuclear.org/info/inf67.htm.

World Trade Organization (WTO). 2008. *International Trade Statistics*. Geneva, Switzerland. 255 p.

PORT OF DURRES THE DOOR OF THE PAN –EUROPEAN CORRIDOR VIII

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Abstract: Ports serve as sea-land interfaces for cargo and passengers movement. Thus they play the role of big doors for each country's economy, relating it to other countries' economies. A crucial part of the multimodal transport, they are of a great economic and strategic importance for Albania. Covering 427 km of the Albanian seacoast from North to South, the throughput of four principal ports, located in Shëngjin, Durrës, Vlorë and Sarandë, raised at 4.3 million tons of cargo in 2007, representing 68% of the external trade. Many interventions related to legal aspects of port ownership and administration, and a tidy international funding by World Bank, European Commission, EIB, EBRD,etc., aiming efficiency by the improvement of ports' infrastructure and superstructure, opened way to structural, operational and financial development for Albanian ports. This paper is an attempt to highlight the main efforts made by Albanian ports for their respective development, within the perspective of the Pan-European Corridor VIII, signed in 2002 between Italy and South-Balkan countries, a question of many interest that should push the Government of Albania (GoA) toward new ideas and strategy, to give the right attention to the Albanian seacoast with natural deep water in report to the main Mediterranean sea-lanes from Gibraltar to Black Sea and from Suez Canal to North Adriatic area.

Key words: port strategy, port reform, port development, concessions, Corridor VIII

1. Introduction

Albania is a natural crossroads, an important transit corridor between Europe and Asia. The Republic of Albania has four ports; Port of Durres, Vlora port, the Port of Shengjin, and the port of Saranda. Of the four ports, the Port of Durres is the most developed, because that is the introduction of Pan European Corridor VIII, and the road 7 (CORE) that connects the port with European Corridor X Pan in Nis, Serbia.

Durrës accounts for around 80% of the total volume of international trade processed in Albanian ports. The port handled 794,000 passengers in 2008, equivalent to 3% growth on year. The corridor VIII is under construction, linking the Albanian port of Durres to Varna (Bulgaria) via Tirana, Qafë Thana, Skopje, Deve Bair, Sofia, Plovdiv and Burgas. The corridor is the main artery which crosses from West to East of Albania and vice versa, being very important for Balkan and Mediterranean countries.

Completion of construction of route 7 and its connection in Nis (Serbia) will significantly affect the increase the flow of goods from different countries in relations Adriatic Sea –Black Sea.

2. Port of Durres

Port of Durres is the starting point for Corridor 8 and is situated 40 km from Tirana city. It lies to the north of Durres bay, 41˚19'V in geographical width and 19˚27'L in geographical length, registered the 41670th in the list of World Ports (Report on Ports and Multimodal Facilities at National and Macro regional Level, Albania, 2010).

Fig. 1.
Port of Durres
Source by: Albania, new area and a new opportunity in the transport Research)

Fig. 2.
Durres Passenger Terminal
Source by: Albania a new area and a new opportunity in the transport Research

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Durres port is the biggest port which handles 42% of import-export volume on national scale.

The Durres port basin covers 70 hectares. The Port has a surface area of 80 hectares, of which:

- Warehouses cover around 12,500 m²,
- Ferry terminal 36,300 m²,
- Anchorage quays 66,685 m²,
- 213,565 m² serve for the roads, railways, parking areas, general storage, etc.

The storage spaces have a capacity of 4-6 tons/m2.Some 152,960 m² of undeveloped land is available for expansion in the future within the port area, near the ferry terminal; there is a vessel repair workshop with a dry dock and fishing harbor.

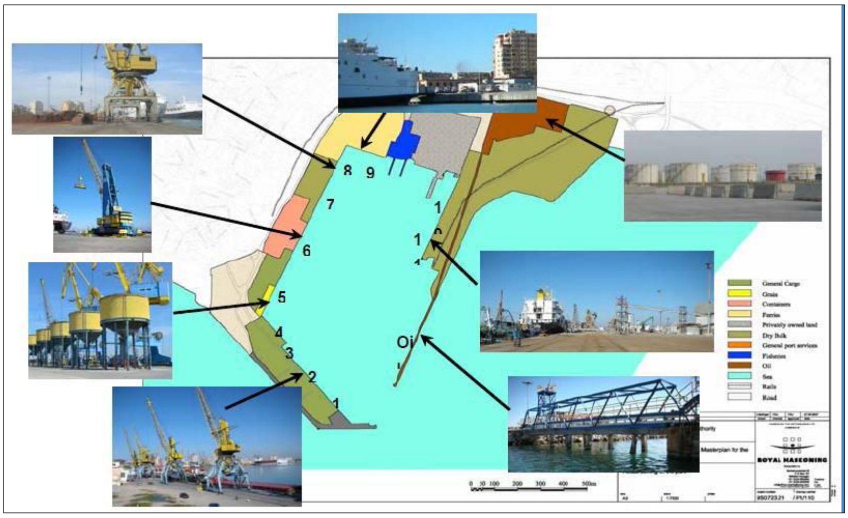


Fig. 3.
The Durres port's existing plan

The storage sites are in better condition in comparison to the warehouses in terms of their structure and investments made in the last 5-6 years. The main reason for creation of docks and new spaces has been demolition of amortized warehouses using more spaces for movement of vehicles, passengers and commodities in the port.

There is a general length of quays of around 2,205 meters including 11 quays, at a quay length carrying from 30 m to 292 m, as well as a projected depth from 7.35 m to 11.5 m (Report on Ports and Multimodal Facilities at National and Macro regional Level, Albania, 2010).

Table 1
Imports Durres in tons

Item	2005	2006	2007	2008
Dry Bulk	1,197,750	1,238,733	883,541	743,046
Liquids	234,299	225,166	270,447	263,383
General	969,099	929,847	781,783	714,467
Containers	130,471	188,178	287,751	424,942
Military	2,968	0	0	2,430
Ferries	240,380	314,750	404,372	608,898
Total	2,774967	2,896,674	2,627,894	2,757,166

Source by: Master plan Porto Romano Bay, Albania

Table 2
Exports Durres in tons

Item	2005	2006	2007	2008
Dry Bulk	156,280	272,309	493,336	249,931
General	7,688	20,924	25,136	20,273
Containers	16,970	26,443	69,423	157,185
Military	1,095	240	0	3,580
Ferries	155,458	206,044	225,760	516,018
Total	337,491	525,960	813,655	946,987

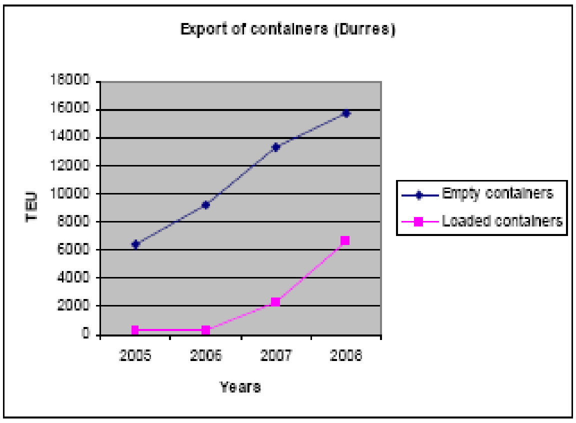
Source by: Master plan Porto Romano Bay, Albania

Albania-National Transport Plan phase 2 study phase (2004) showed the traffic forecast for the port of Durrës in 2023 should be handled with some precautions because of the uncertainty which prevails on some major factors like the level and pace of privatization of the operation of the terminals, the competition between container and Roll on – Roll off (ferries) traffic in Durrës, the schedule of the AMBO pipe line project, and eventually, the investment and marketing policy of the competing ports in the region (Bar in Montenegro, Thessaloniki and Igoumenitsa in Greece).

Table 3
TEU and Tonnage (Port of Durres)

Year	Tonnage	TEU	Ratio(Ton/TEU)
2005	147,441	15,286	9.65
2006	214,621	21,879	9.81
2007	357,174	33,127	10.78
2008	582,127	46,798	12.44

Source by: Master plan Porto Romano Bay, Albania



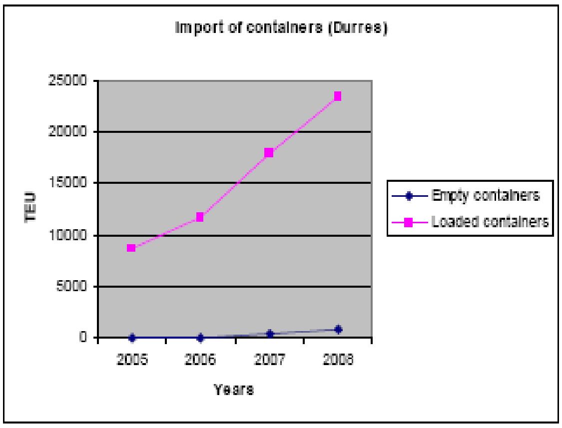


Fig. 4.
Export of Containers (Port of Durres)

Fig. 5.
Import of Containers (Port of Durres)

3. Pan European Corridor VIII

Pan-European Corridor 8 crosses Albania, FYROM and Bulgaria. A Memorandum of Understanding on the development of Pan-European Corridor 8 has been signed in 2003. Italy will have the chairmanship of the organising committee. The corridor will constitute of a road axis with an approximate length of 960 kilometres and of a railroad with a length of 1270 kilometers.

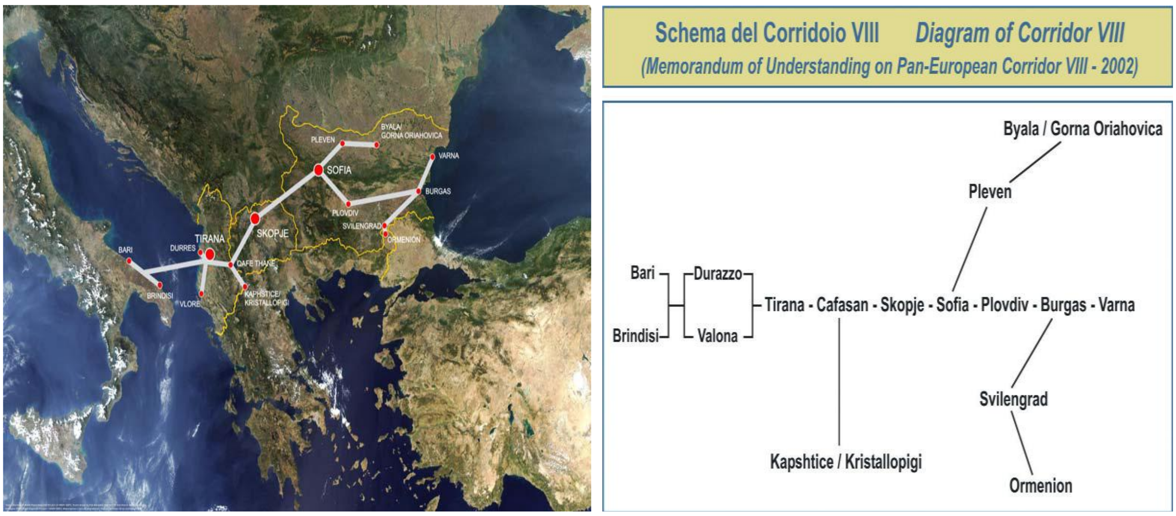


Fig. 6.
Pan-European Corridor 8
Source: www. secretariat-corridor8.it

The Corridor VIII also includes three other road connections, as:

- Burgas-Svilengrad-Ormenion, which connects it to Corridor IV, IX and Trans-European Network;
- Sofia-Pleven-Byala/Gorna Oriahovica (Bulgaria), which connect it to Corridors IV and IX; and
- QafëThanë-Kapshticë (ALB)/Kristallopigi (GR), which connect it to the Trans-European Network.

The Corridor IV links Sofia to Istanbul, Corridor IX links Russia to Greece and Corridor X links Serbia to Greece via Bulgaria and Macedonia.

The inter-modal Pan-European Corridor VIII refers to ports and other transport modes, when appropriate, combining the respective transport infrastructures, including ancillary installations such as freight and passenger terminals, warehouses and installations necessary for the traffic management, etc. Further cooperation for improving port activities and their maritime links will be addressed in the context of the Pan-European Transport Areas concerned. The criteria for identifying priorities for financing and construction of the Corridor will be defined by the Steering Committee of the MoU.

As for the South Italian1 regions' economy and production system, which will profit of a potential export of 2 billion euros with all Balkan and Black Sea countries, Corridor VIII (Fig. 7) could act as a development engine for the interested countries and for the entire Balkan since it complements, instead then competing with, the other main transport infrastructures under construction in the region.

Fig. 7.
The main cargo and passengers flow in Corridor VIII

Of fundamental importance was an initial joint assessment by all interested countries on common targets and expected results, including current status evaluation, technical design standards and related performance. Consideration is also given to all development and reinforcement programs, planned by individual Countries and receiving support from EU institutions or private donors. Results of Socioeconomic and transport studies are collected and carefully evaluated. A final important consideration is the multi-modal outlook, in order to give adequate space in the analysis to roads, railroads, inter-ports, ports, waterways and airports.

As noted, the Albanian ports of Durrës and Vlorë are foreseen to play a major role in the framework of this important Pan-European Corridor, which role cannot be assumed as it should be if the financing for new facilities (freight and passenger terminals, warehouses, equipment for cargo handling, etc.) does not correspond to the real needs of both ports.

The cost for the construction of the corridor is expected to reach € 1419.5 millions. (Pan-European Corridors of the TINA network IV, VIII, IX and X, 2005). Fig. 8 presents the cost of the sections of the corridor in the three countries being crossed by it.

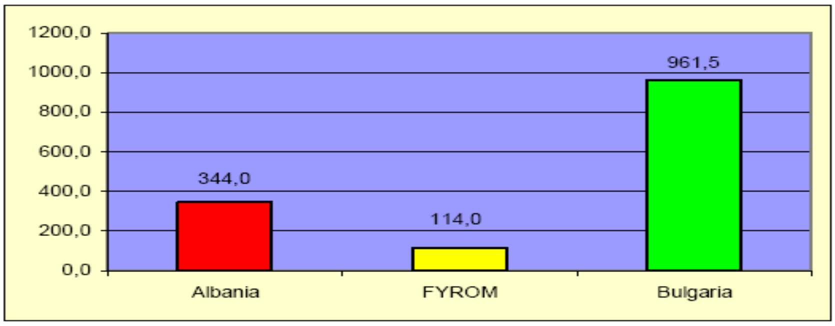


Fig. 8.
Costs for infrastructure investment along Corridor 8 (in million €)

3.1. Zone of Influence of Pan-European Corridor 8

The construction of Pan-European Corridor 8 will have a positive effect in all three countries the corridor crosses. In the cities a tendency of residential development will appear, while a boost in services, trade, tourism and industry is expected to take place. This will have as a consequence an increase in the GNP. The connection of three major harbors in Adriatic and Black Sea (Durres, Varna and Burgas) will result in the faster transportation of goods. Moreover Pan-European Corridor 8 will connect 4 international airports (Tirana, Skopje, Sofia and Varna) and give access to 6 minor airports giving the opportunity to people for faster travelling in the area (www.iata.org). Fig. 9 depicts the zone of influence of the Corridor.

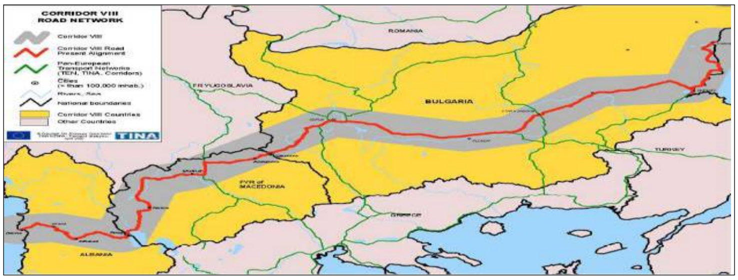


Fig. 9.
Zone of influence of Pan-European Corridor 8

4. Conclusion

Port of Durres is located in the western part of the Balkans is one The largest ports in the Adriatic Sea. Complete construction of Pan European Corridor VIII, and road 7 which linking Durres with Pan-European Corridor X, enhance the exchange of goods in the Balkans through Albania as this is one of the shortest routes between the Adriatic Sea to the Black Sea, this geographic advantage is not exploited enough in the past due to insufficient development road and rail network in the country. Flow of goods in short road, transit is direct economic interest of the state, with ever to achieve transport flows return to Albania ports, especially the port of Durres have made significant improvements not only in infrastructure (roads, rail and port), but also the modernization of services, eliminating the long wait at the port, customs facilitation and security. As soon as this is done the greater will be the ability to attract and transit of goods in the above destinations, making the port of Durres among the most frequented points of the Adriatic Sea in the western Balkans.

References:

Kersten, M.K. 2010. *Master plan Porto Romano Bay*, Albania: 14-72.

Berger, L.S.A. 2004. *Albania National Transport Plan – Phase 2 Study*, Report: 23-67.

Dedej, A. 2011. Albania, a new area and a new opportunity in the transport Research. 9 p.

Report on Ports and Multimodal Facilities at National and Macro regional Level, Albania. 12-13.

Pan-European Corridors of the TINA network (IV, VIII, IX and X). 2005.

Secretariat Corridor 8. Available from Internet: www.secretariat-corridor8.it

Berger, L. Int. Corp. 2000. Land Use Plan Report: 43-64p.

Corridor VIII. 2007. Pre-Feasibility Study on the Development of the Railway Axis, Final Report September: 88 p.

Haskoning, R. 2008. *Establishment/Update of the Master plan for PDA Final Report*: 6-43p

Moffatt & Nichol Int. 2002. *Intermodal Container Facility - Phase II Report*. 54p

Ministry of Public Works and Transport General, Directorate of Transport Policies and Planning. 2010. Tirana. 4 p.

Transport Infrastructure Development in the Balkans and their Impact on the economy of Southern Italy. 2005. Part 3. 71 p.

World Bank. 2007. *Performance Assessment Report–Durrës Port Project Final Report*: 32-67.

ANALYSIS OF THE METHODS FOR TESTING THE QUALITY OF ROAD MARKINGS

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Abstract: Modern traffic demands the safe movement of vehicles under normal conditions and especially at night and in reduced visibility (fog, rain, sleet, etc.). Quality and quantity of participants visual guidance in traffic directly depends on the visibility and the reflective properties of road markings are of crucial importance. Using the latest methods and procedures of testing road markings a high and constant quality level can be achieved, and thus the security level of individual roads can be raised. Road markings are made in accordance with the Regulations on traffic signs and equipment on roads and Croatian and EU standards. One of the most important elements for testing the quality of road markings is testing day and night visibility of road markings. These tests can be done in two ways: method for static test of road markings reflection (daytime and night-time visibility) and dynamic method for testing retroreflection of road markings (night-time visibility).

Keywords: safe, road markings, retroreflection, static method, dynamic method

1. Introduction

Road traffic safety aims to reduce the harms (deaths, injuries, and property damage) resulting from crashes of road vehicles traveling on public roads. Main goal of road traffic safety is protection and security of all those who travel on roads. The reflective properties of road markings are of crucial significance, and represent one of the main factors increasing the safety of participants in road traffic.

Major factors that contribute to the road traffic safety can be grouped in three categories (Dawson, 2007):

- roads
- vehicles
- drivers' behaviour.

In this paper focus will be on the analysis of the methods for testing the quality of road markings. These methods can be done in two ways: method for static test of road markings reflection (daytime and night-time visibility) and dynamic method for testing retroreflection of road markings (night-time visibility).

Tests are carried to ensure the prescribed quality of road markings are:

- Preliminary examination or testing facilities,
- Your own or running tests,
- Control tests,
- Additional control tests,
- Arbitration tests,
- Tests before the warranty (if the same contract).

In night and in wet conditions, road markings play important role in road traffic safety and because of that different types on road marking have been developed to insure safety.

2. Static method for testing the quality of road markings

Static testing of road markings can be done by using the static retroreflectometer (Fig. 1). Weighing of device is 52x218 mm. The device simulates the visual distance markings on the pavement 30 meters from the eyes of drivers, with an eye height of 1.2 m and 0.65 m height of the lights from the road surface. Daily visibility module Qd is expressed and measured in $mcd \bullet m^{-2} \bullet lx^{-1}$ observed at an angle of 2.29 ° at a distance of 30 m and represents the value of the diffuse scattered light received by the observer. Night-time visibility or value expressed by the coefficient of retroreflection RL and measured in $mcd \bullet m^{-2} \bullet lx^{-1}$. For measurement night visibility device measures retroreflection luminous rays from the study area at an angle of 2.29 °, the input light angle of 1.24 ° and at a distance of 30 m with a low beam. Measurements are performed according to European standards EN 1436, Materials for Road markings- Characteristics required for road users.

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Static testing of day and night visibility can be done by two methods: According to "Kentucky" method (old one), and according to new guidelines and technical requirements of the test procedure, ie. measurement and valuation of derivative road markings shall be carried out in accordance with the German regulation ZTV M 02.

Fig. 1.
Device for measuring retroreflection of road markings
Source: Prepared by the authors

2.1. Kentucky method

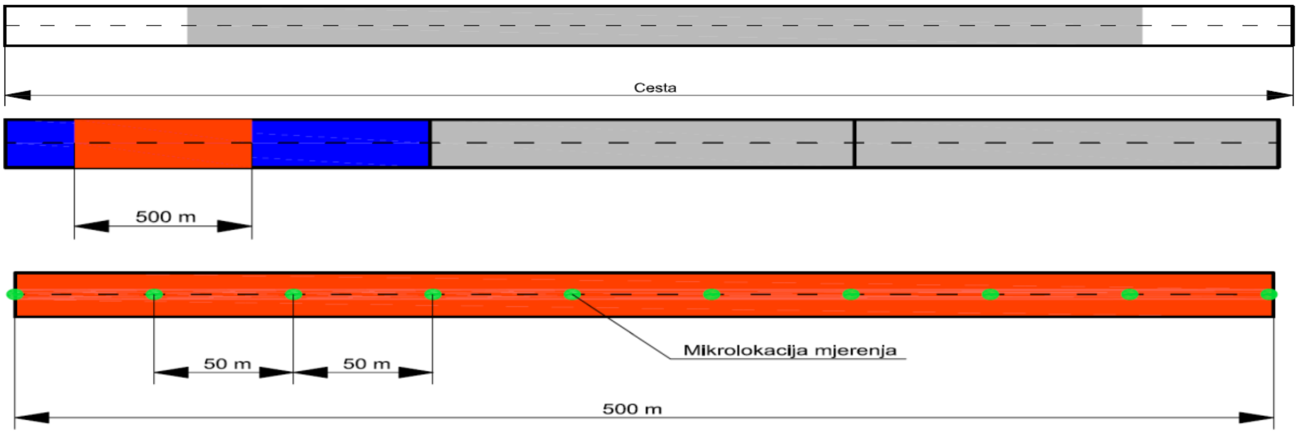

Fig. 2.
Measurement principle according to Kentucky method
Source: Prepared and adapted by the authors

In Kentucky method (Fig. 2), measurements are performed on a single zone of 500 m on each section, where the section is part of the label performed from one team in one day. Start measuring zone is in the first third of the length of the section. In each zone shall be 10 measurements at distances of 50 m. For all 10 microlocation is carried out by three measurements and obtained an average value of these measurements is taken as authoritative. The main disadvantage of this method is that the test is performed only in the first third of the test section, where you cannot get the value of retroreflection of complete testing section.

2.2. Method in accordance with the German regulation ZTV M 02

ZTV M 02 (FGSV, 2002) includes measuring the thickness of dry paint film, the assessment day and night visibility derived labels in dry conditions, night-time visibility in wet conditions and the slip resistance expressed in units of the SRT and the measurements are carried not earlier than 30 and no later than 60 days after execution road markings.

The scope of measurements of longitudinal labels is determined by the daily execution of the working group that performed on pavement according. In the diary, for section of road that is necessary to assess, must be specified data when the works are executed and with what daily effect (especially for the central and especially for the edge line), and the number of measurement sequences is determined by the following Table 1.

Table 1
Number of measurement sequences

The length of longitudinal markings done in one day (km)	The length of the other markings done in one day (m2)	Number of measuring sections
< 1	< 120	1
1 - 5	120 - 600	2
>5 - 10	> 600 - 1200	3
> 10	> 1200	4

Source: Prepared and adapted by the authors

Measurement sequences are selected according to the principle of randomness. Within each segment measuring selects five (5) measuring points (Fig. 3). For full labels longitudinal measurement points are distributed at 100 m in length at equal intervals (beginning, 25 m, 50 m, 75 m in the end). For discontinuous measurement of longitudinal labels are allocated to the middle point of each other full lines. In relation to the Kentucky method, it is possible to take sequence in the end of testing section, and can get a more realistic view of retroreflection on the entire section.

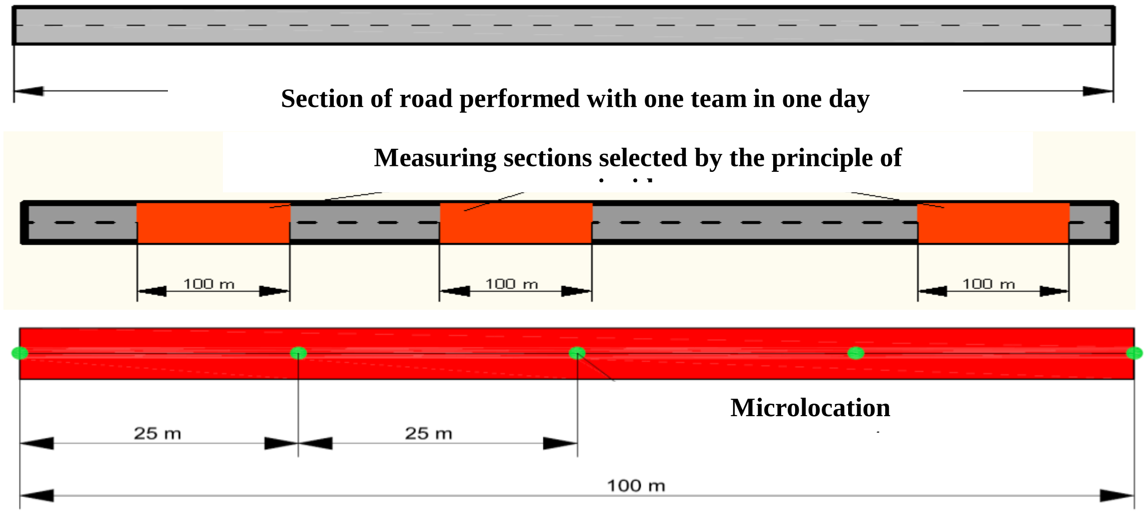

Fig. 3.
Measurement principle according to ZTV M 02
Source: Prepared and adapted by the authors

3. Dynamic method for testing retroreflection of road markings (night-time visibility)

Dynamic method for testing retroreflection of road markings involves the measurement of night visibility with dynamic measuring device throughout its length. It can be performed with dynamic retroreflectometer which is installed on a vehicle measuring and thus allows continuous measurement of the night visibility (Rl) road markings while driving vehicles.

Principle of measuring visibility at night with dynamic retroreflectometer is the same as in static measuring device, i.e. at measuring the night visibility of the device measures retroreflection of light rays from the study area at an angle of 2.29°, the angle of input light of 1.24° and at a distance of 30 m at short lights. (Fig. 4)

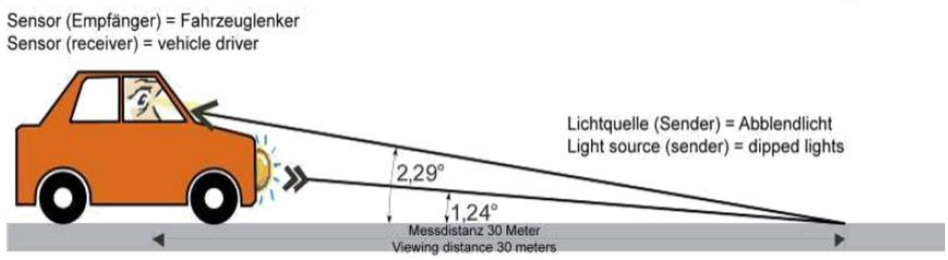

Fig. 4.
Principle of measuring night visibility with dynamic retroreflectometer
Source: Prepared and by the authors

Fig. 5.
Measurement vehicle with dynamic retroreflectometer
Source: Prepared by the authors

The dynamic retroreflectometer (Fig. 5) has following features (ZTI, 2009):

- Measurement of road markings night visibility R_L in the day and night conditions
- It is suitable for measuring all kinds of night visibility of road markings, and profiled benchmark to 9 mm
- It is suitable for measuring night visibility in dry and wet conditions
- Has an integrated surveillance cameras, takes pictures automatically every 25 m, and also has the ability of shooting photos manually
- It has a built-in GPS system that captures the movement of vehicles and has sensors for measuring temperature and humidity
- Has the possibility of sending and processing data in a RetroGrabber software package and the ability to switch data into .xls format that allows statistical analysis of measured values.

The Dynamic Retroreflectometer R_L System consists of several elements that are necessary for operation:

- Measuring head
- Cockpit installation
- Laptop
- Carbox
- Wiring of the car

The laptop is used to operate the measuring system. With its installed Retro-Grabber software it is able to communicate with the measuring head and record measured data to its hard drive. For measuring, the laptop needs to be in the docking station in the car.

Measurements are done in a way that the measuring vehicle moves along the road surface and reads the coefficient of road markings retroreflection along which it moves. Before the measurements it is necessary to select the length of the measurement interval at which the device will measure the average value of each measurement section (i.e. the length of the measurement interval of 100 is set, this means that the device while measuring the shares for every 100 m will give an average value of visibility in this night measurement interval). Our experience shows that the optimal length of measurement interval is 50 or 100 m.

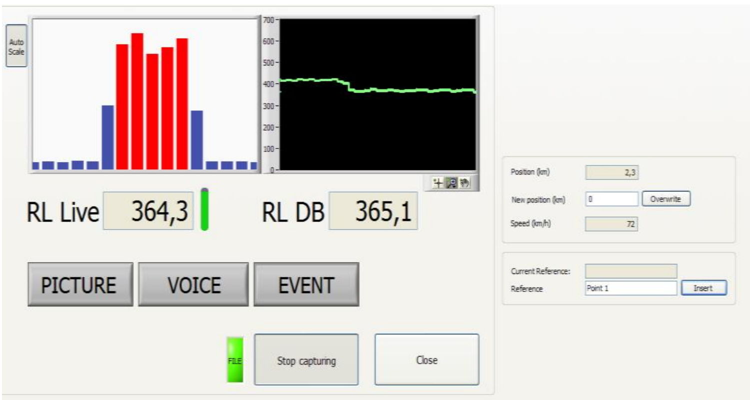

Fig. 6.
The screen display of driver at the time of measurement
Source: Prepared by the authors

On the Faculty of Transport and Traffic Sciences, specifically in the Department for traffic signalization we have developed the new software (Fig. 6) that will significantly enhance and accelerate the course of preparing reports and interactive viewing the results of measurements.

Main advantages of the newly developed software:

- On-line review of the results on an interactive map, complete with a report made (Fig. 7)
- data entry and data delivery to end user
- eliminating the use of CDs or DVDs that have been used as a medium for the delivery of results
- ability to analyse data from previous years with more recent data
- enter the amount of reconstructed line on a particular road in a given county by the contractor marks on the road
- currently easier business end users with better insight into the current state
- Automatic itinerary (software itinerary creation) in a given county, according to the amount of reconstructed line on a particular road

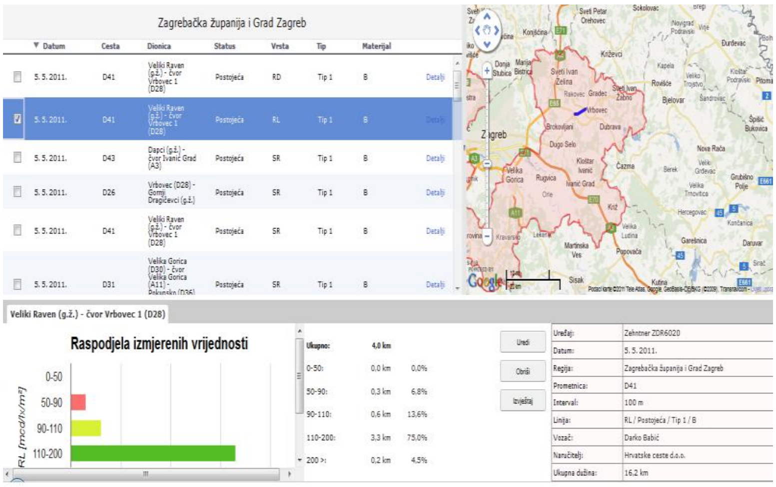

Fig. 7.
The appearance of the interface after the selected region (county of Zagreb)
Source: Prepared by the authors

4. Comparison of methods for testing the quality of road markings

As already stated, the reflective properties of road markings are of crucial significance, and represent one of the main factors increasing the safety of participants in road traffic. In order to achieve a better quality of road markings, measurements should be done in compliance with internationally recognized methods. Also, methods for testing the quality of road markings must be recognized by the road authorities and in accordance with the technical requirements in each country.
Each of these methods has its advantages and disadvantages and it is on the employer to conduct the measurements by a particular method in accordance with their own needs. However, for the detailed control of road markings quality the best method is of dynamic method. Table 2 shows the main advantages and disadvantages of each method.

Table 2
Advantages and disadvantages of each method for measuring the quality of road markings

METHOD	ADVANTAGES	DISADVANTAGES
KENTUCKY	- enough measurements in the first third of length the section (10 out of every 50 m), which gives a better insight into the quality of the road marking	- only the first third of length of the section is being measured
ZTV M02	- gives a more realistic picture of the quality of road markings on the entire length of the section in relation to the Kentucky method	- measurement sequences are selected according to the principle of randomness
DYNAMIC	- measures of night visibility throughout the whole length of the section or road - provides an overview of results in computer application displaying GPS coordinates and pictures from the field	- does not measure day visibility

Source: Prepared by the authors

5. Conclusion

Testing road markings with a measurement vehicle (dynamic method) equipped with dynamic retroreflectometer offers the possibility of obtaining a continuous measurement results for the whole section intended to be measured, in a short time. At the static method Measurement sequences are selected according to the principle of randomness. In the dynamic method selected road section is examined in its entirety while static method tested only selected sequences of selected road.

At the same time, the process of testing, measuring vehicle with dynamic retroreflectometer performs accurately, and disruption of traffic is reduced to a minimum (the operating speed of testing the quality of road markings is 60 km/h).All the above suggests the possibility of systematic testing the quality of road markings on the Croatian roads and getting quality results for individual sections which represents a solid basis for the optimal maintenance plan, and savings in the maintenance of road markings.

The results obtained in tests enable you to:

- efficient maintenance of certain roads,
- review of critical places,
- prioritization of maintenance,
- optimize the order of applying the markings on the roadway.

Using this measurement method it is possible to organize a system of road maintenance, which provides a constant high level of visibility markings on the roadway, which affects the safety of drivers, especially when driving in adverse weather conditions.

From the above it can be concluded that the static methods for measuring the quality of road markings are appropriate for certain quality checks, but for a systematic and detailed analysis and monitoring of the quality of road markings dynamic method should be performed.

References

Croatian Standards Institute. HRN EN 1436:2008 Materijali za oznake na kolniku - Značajke nužne za korisnike ceste. Available from Internet: http://www.hzn.hr/HZN/Todb.nsf/6ad9a4914e2c693cc1256d250062f748/e36afa7b0939f5abc125757b00351d37?OpenDocument.

Dawson, J. 2007. Part 1 - The EuroRAP Programme - an overview. In Proceedings of *The EuroRAP International Conference.* London, UK.

FGSV. 2002. Forschungsgesellschaft für strassen und verkehrswesen: Dodatni tehnički uvjeti ugovora i smjernice za oznake na cestama ZTV M 02, Koln, 2002.

Zehntner Testing Instruments. 2009. Instruction manual ZDR 6020 Dynamic Retroreflectometer RL, Sissach. Available from Internet: http://www.zehntner.com/download/uebersichtsprospekt_strasse_e.pdf.

Session 11: Transport Modeling and Decision Making

EVALUATION OF TRANSPORT PROJECTS USING MULTI-CRITERIA DECISION MAKING METHOD

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Abstract: Consideration of various relevant criteria, with different nature, and numerous stakeholders with different preferences for evaluation of transport projects requires applying the multi-criteria approach. Assessment of transport projects using the multi-criteria decision methods is relatively new approach, and in last two decades was very often suggested by many authors. For sustainable business of a transportation company, it is inevitable to follow demands' changes of its actual and potential users, as well as technical and technological innovations and trends of competitive companies. The transport company should follow these changes, should be flexible to adapt and use them. For these reasons, we emphasize here the importance of the relevant external projects. The relevant external projects can be national or domestic, infrastructure, ecological or social projects, etc. These projects can be very important because of the fact that the transport network of one country is very dependent of its surrounding, including the transport system in the considered country and the neighboring countries. The main goal for each transport company is adequately using and directing its available resources. In this paper, the developed model considers railway infrastructure projects of rail Corridor X through Serbia. The alternatives are the projects of improvement for all double-track section of the network, as well as the doubling track project for the single-track section. The authors suggest applying the multi-criteria decision making method – Analytic Network Process, which enables consideration of the network structure problems. Beside clusters with technical-technological criteria relevant for considered problem, the clusters with relevant external projects and stakeholders are also defined. The realization of external projects is considered uncertain and is determined by initial probability of its realization.

Keywords: Transport projects, Rail infrastructure projects, Multi-criteria decision making method, External projects, Analytic network process.

1. Introduction

Setting priorities among projects in the public sector is very complex and delicate issue, considering the size of investment, limited budgets, mutually conflicting criteria, the impacts of the current government.

The relevant decision making regarding the allocation of financial resources in upgrading or construction of transport infrastructure is one of the main issue for all transport networks, especially in countries in transition. Long period of non-investment in infrastructure leads to a decline in the quality of transport services and unambiguous requirements to consider all combinations of these variants for the infrastructure improvements at the same time, it makes a problem extremely complex. Some of the questions on which the infrastructure manager should answer are: what should be done - only infrastructure reconstruction or improvement of its performance (which significantly increases the investment); and which project is a priority, which part of the network becomes a priority?

Models for selection and ranking of rail infrastructure projects are very complex, not only because of the large number of criteria, that are relevant to this issue, but also because of the numerous external factors, a large number of stakeholders, significant financial resources necessary for investment, and a limited budget.

Rail infrastructure projects are important for economic and social development of the country. They are also relevant for the strengthening the competitiveness of railways in the transport market.

This paper considers the problem of selection and railway infrastructure projects, such as a multi-criteria problem. The considered projects are the reconstruction and improvement projects on rail Corridor 10 in Serbia, as well as the construction of the second rail track on the single track lines.

Developed model in this paper, beside economical and technological criteria relevant for the transport projects ranking and selection, take into consideration the impact of relevant external projects. Their realization is uncertain, and therefore it is appropriate to express them by the initial probabilities of realization. The authors suggest using the Analytic network process for considered problem, because of the relationship among system elements. The model has a network structure made from several clusters, such as: criteria, alternatives, external projects and stakeholders.

This paper is organized as follows. After Introduction, authors presented brief relevant review. In second section, a model for evaluation of rail infrastructure projects using MCDM is developed. Conclusions remarks are given in the last section.

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2. Brief Literature Review

Cost benefit analysis, CBA, is well known method for project evaluation. In transport sector, this traditional approach is most used method. For instance, in rail sector for transport evaluation in 60% cases CBA is applied. Thereafter, multi-criteria approach, MCA, 14% and other methods only 26%. For road projects, CBA is used in 56% cases and 20% MCA. For internal waterway projects the proportion of used methods is 32% for CBA and 6% for MCA, and for sea transport projects situation is very similar.

The goal of CBA depends on expected project quality. If there are expected projects of high quality, CBA can help in project selection process, with the aim to contribute to the better exploitation of available resources. In the other cases, CBA can be used for elimination of bad project proposals.

There are numerous different approaches and methods for evaluation of transport projects, such as: CBA – Cost Benefit Analysis (Berechman and Paaswell, 2005; Van Wee, 2007), MAUT - Multi Attribute Utility Theory (Tsamboulas, 2007), GP - Goal Programming (Ahern and Anandarajah, 2007), AHP - Analytic Hierarchy Process (Lee, 1998; Yedla and Shrestha, 2003; Ferrari, 2003; Gercek, et al., 2004; Tudela, et al., 2006; Caliskan, 2006), ANP - Analytic Network Process (Shang, et al., 2004; Piantanakulchai, 2005; Wey and Wu, 2007; Chang, et al., 2009; Longo et al., 2009, Macura et al., 2011).

The most of named references, which are from last decade, critically analyzed the application of CBA for transport project evaluation. The authors mostly suggested applying the multi-criteria methods for solving the considered problem. Some of the mentioned papers are briefly described below.

Macura et al. (2011) proposed the ANP application for railway infrastructure projects ranking. The model was applied for ranking the projects of railway modernization and the construction of the second track on the sections of Corridor 10 through Serbia. Relations between elements of the system caused the application of ANP.

Chang, Wey and Tseng (2009) developed the model for the strategic project selection relating to the historic Alishan Forest Railway in Taiwan. In order to evaluate different revitalization strategies, authors considered the following criteria: benefits-B, opportunities-O, costs-C and risks-R. A synthesis of projects was obtained using rated BOCR. The considered problem has been solved by fuzzy Delphi, ANP method and zero-one goal programming.

Longo et al. (2009) developed the AHP and ANP models and compared their main characteristics. The case study was a railway infrastructure, actually selection among the solutions regarding a new railway connection. The authors were considering four main groups of criteria: costs (project costs), transportation efficiency (safety, running efficiency – capacity and reliability), environmental impacts (natural, physical and urban resources) and procedural aspects (modification of the original project and interferences on the existing network). The results obtained by AHP and ANP were the same. The decision maker should choose the multi-criteria decision method so that it can precisely describe real situations. For instance, the ANP allows taking into account the dependences of the elements of the upper level, i.e. criteria, from the lower level elements, i.e. alternatives. The ANP is quite more complex to be applied; the analysis of the problem has to be much more detailed compared to the requirements of AHP. This makes the practical application of the ANP approach more problematic. However, AHP framework is often very rigid, and not flexible enough to describe in detail the decision makers' opinions.

Tsamboulas (2007) proposed the tool for prioritization transport projects in a multinational transport network, considering 21 countries. This issue became important in recent years, because of the globalization and liberalization of the transportation network in Europe. The author applied the multi-criteria approach MAUT, appearing in applications involving risky choice. A model for project prioritization was developed taking into account financial, economic, social, environmental and traffic impact and benefits of the projects.

Using the goal programming method, Ahern and Anandarajah (2007) developed the model for prioritizing railway investment projects. Goal Programming is a multiple objective linear programming technique. By maximizing the objectives with the limited budget the model defined optimal project mix. All considered railway projects are identified by the Department of Transport, Ireland.

Van Wee (2007) pointed out that the most frequently used method for estimating the railway projects in the West European countries is CBA. From the theoretical point of view, this method was very suitable for the application, because all costs could be accurately determined / estimated, and the most dominant benefits were largely known.

However, the practice is somewhat different. The existing Trans-European network makes future rail projects very important at the national level and EU level. Adoption of multi-criteria decision in the public sector, relating to the planning of large railway projects, is delicate and complex tasks. The author has singled out several relevant criteria, and one particularly important is "Railways as part of a comprehensive plan". Here, the importance of simultaneous consideration of projects in different sectors was given.

For example, road and rail projects together can be sustained, although the road is only rated as a viable project, and rail as unprofitable. Indeed, getting public support in such cases is necessary, and it is the job of the current political power-wielders.

Wey and Wu (2007) suggested an integrated approach for transportation infrastructure project selection problem using: fuzzy Delphi, ANP and zero-one goal programming. In order to overcome some shortcomings of goal programming, authors applied the ANP to set priorities for objectives and determine trade-offs among them. The ANP approach takes into consideration the interdependent relationship among the system’s elements. The empirical example was transportation projects selection in Taiwan. The authors have modified and improved this model through BOCR (Benefits, Opportunities, Costs, Risks) criteria application (Chang, et al., 2009) two years later.

Tudela, Akiki and Cisternas (2006) used two approaches for transport project selection. They compared the output of CBA and AHP. The obtained results were not the same, but the authority decision was in line with the suggestion of the AHP approach. The authors emphasized the importance of the public opinion in such decision making processes. Although CBA has been widely used for the transport project selection, there are some limitations of this analysis. Noise, accidents and air pollution are just some of the project impacts that are not easy to take into consideration using the CBA.
Caliskan (2006) presented the model for the estimation of potential transport investment, which is based on the experience and knowledge of the experts. Cognitive maps and AHP were applied in this paper. He considered problem of building new bridge on Bosfor, Turkey, because existing 25 bridges were not sufficient for daily needs. The author defined 265 criteria, which were grouped into 6 categories: economic variables, transportation system variables, environmental and technical variables, public, cultural and social variables and political variables. The experts were asked to estimate groups of criteria and each criterion separately. Then, after finding average values for all elements, the author choose 11 variables with the highest coefficient of priorities.

Piantanakulchai (2005) proposed using the ANP approach as a helpful tool to deal with interdependent relations within the multi-objectives and multi-stakeholders environment. The aim of the developed model was solving the multi-criteria highway corridor selection problem in the South of Thailand. Considered criteria were grouped into six categories: economic, engineering and construction, traffic and transportation, environment, land use and social.

Berechman and Paaswell (2005) developed methodological frame for the transport project estimation in New York, USA. The main goal of the model was suggestion addressed to stakeholders how to rationally and systematically make decisions about investing in transport infrastructure. The aggravating circumstances of the decision making process are lack of required data, lack of the comprehensive regional transportation plan and goals, etc. The authors grouped crucial questions on which assessment of transport investment projects should offer the answers. The model is based on the application of CBA.

Shang, Tjader and Ding (2004) considered the transportation project selection. Following the comparison of the AHP and ANP approach, decision makers chose the ANP approach so as to develop a model for the selection of the transportation project in one of China’s oldest cities. The considered criteria were: benefits, opportunities, costs and risks. The authors emphasized that ANP is better than conventional evaluation methods as it allows feedback and interdependence among various decision levels and criteria. They also mentioned a limitation of the proposed approach, i.e. when the model is large, it is time-consuming.

Gercek, Karpak and Kilincaslan (2004) analyzed three alternative proposals for the rail transit network in Istanbul. The model was developed using the AHP approach. The hierarchical structure is composed of goals, scenarios, criteria and alternatives. Based on the executed analysis, decision-makers have developed the new alternative as combination of the two most similar alternatives for the rail transit network. Sensitivity analysis was performed, showing different outputs depending on the priority criteria, which is especially important for decision-making process.

Yedla and Shrestha (2003) proposed the model for the election of transportation options and sustainable urban transport in Delhi, India. Six criteria were developed: potential energy savings, potential emission reductions, cost, existence of technology, flexibility of options, and difficulties in implementation. The advantage of the model is, primarily, in the integration of qualitative and quantitative criteria. AHP allows consideration of all criteria in one model. The specificity of the above model is that it includes all groups that have direct or indirect impact on the transport in Delhi.

Ferrari (2003) suggested AHP approach for the selection of transportation projects. The author emphasized that decision making process in the field of transport can be observed through three stages: the first-level is goal to be achieved, the second level is political level, and the third level is technical level. Attributes of the projects are, in fact, their effects that can be seen from the viewpoint of different stakeholders.

Lee (1998) examined the methods of multi-criteria analysis and its application for evaluation, selection and ranking of transportation projects in his thesis. The chosen methodology for the efficient planning of transport investment in Korea was supported by the AHP approach. CBA and other financial analysis, as methods for the assessment of transport investment projects are very often used in Korea. The government representatives, as well as decision makers, continue to play leading role and directly or indirectly influence on transport investment projects. For these reasons, the latest studies highlight the importance of public involvement in decision-making process, as well as socio-economic impacts and environmental impacts. Lee presented the basic principles of the method for selection and ranking of transportation projects such as CBA, Maut, ELECTRE, SAW, AHP, and then compared following approaches: CBA vs. MCDM, MCDM, and round. MCDM.

3. A Model for Evaluation of Rail Infrastructure Projects Using MCDM

A model developed in this paper is improved version of the model suggested by Macura et al. (2011). The modification implies the inclusion of two extra clusters in the model, stakeholders and relevant external projects. The used approach is the Analytic network approach developed by Saaty (1996). The considered transport network is rail Corridor 10 through Serbia.

The authors suggest using the ANP approach for ranking transport projects. The ANP is very suitable for many realistic problems, because of its characteristics, such as: using the eigenvector method for expert's consistency evaluation; interrelationships and feedbacks among system's elements; commercial user-friendly software; pair wise comparison matrices; etc.

3.1. Basic Assumptions of the ANP Approach

The pairwise comparison matrices, presenting the priority among elements, should be developed using the fundamental Saaty scale (1996) (Table 1).

Table 1
The Fundamental Saaty Scale

The importance	Definition
1	Equal
2	Intermediate
3	Moderate importance
4	Intermediate
5	Strong importance
6	Intermediate
7	Very strong importance
8	Intermediate
9	Extreme importance

The matrix "*A*" shows a comparison among elements a_{ij}, representing the experts' priority of one element over the others. The matrix "*M*" is normalized matrix "*A*" with elements a'_{ij} (Eq. (1) and Eq. (2)):

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_j \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccc} A_1 & A_2 & \cdots & A_i & \cdots & A_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1i} & \cdots & a_{1n} \\ a_{21} & 1 & & & & a_{2n} \\ \vdots & & & & & \vdots \\ a_{j1} & a_{j2} & & 1 & & a_{jn} \\ \vdots & & & & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{ni} & \cdots & 1 \end{bmatrix} \end{array} \quad , \; a_{ji} = 1/a_{ij} \tag{1}$$

$$M = \begin{bmatrix} a'_{11} & a'_{12} & \dots & a'_{1n} \\ a'_{21} & & & \\ & & & \\ \dots & & a'_{ij} & \dots \\ a'_{n1} & \dots & & a'_{nn1} \end{bmatrix}; a'_{ij} = a_{ij} / \sum_{i=1}^{n} a_{ij} \tag{2}$$

The vector of priorities, "*W*", is an eigenvector of the matrix "*A*". The factor λ_{max}, where *n* is a number of criteria, is used for calculation of the consistency index of a matrix of comparisons, *CI*. This is the main advantage of the eigenvector method (Eq. (3) – Eq. (5)):

$$W = \begin{bmatrix} w_1 \\ \vdots \\ w_i \\ \vdots \\ w_n \end{bmatrix}; \; w_i = \frac{1}{n} \sum_{j=1}^{n} a'_{ij} \tag{3}$$

$$\lambda_{\max} = \sum_{i=1}^{n} \left(w_i \cdot \left(\sum_{i=1}^{n} a_{ij} \right) \right) \tag{4}$$

$$CI = \left(\lambda_{\max} - n\right) / \left(n - 1\right) \tag{5}$$

After the consistency index is calculated, the consistency ratio, *CR*, can be considered as a relation of the consistency index and the random index, *RI*. For *CR* > 0.1, the degree of consistency is satisfactory. Otherwise, the judgment of a decision maker should be revised (Eq. (6)):

$$CR = CI / RI \tag{6}$$

Table 2
The Values of RI

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The super-matrix, "*SW*", is made of several matrices showing the priorities among system elements, and representing the importance of some nodes, and clusters, comparing with the others. Assuming that a model, has *N* clusters, with mutual influences of elements. Cluster C_i (i=1,…, N) has m_k elements (k=1,…, n). The matrix0 "*SW*" should represent the impact of all the elements in the i-th cluster on each element in the j-th cluster. The matrix "*SW*" is zero, when the element i is not in a relation with the element j.

$$\begin{array}{cc} & \begin{array}{cccc} C1 & C2 & \dots & Cn \\ e_{11}\ e_{12}\ e_{1m1} & e_{21}\ e_{22}\ e_{2m2} & & e_{n1}\ e_{n2}\ e_{nmn} \end{array} \\ SW = \begin{array}{c} e_{11} \\ C1\ e_{12} \\ e_{1m1} \\ e_{21} \\ C2\ e_{22} \\ e_{2m2} \\ \vdots\ \vdots \\ Cn \end{array} & \begin{bmatrix} W_{11} & W_{12} & & W_{1n} \\ & & \dots & \\ & & & \\ W_{21} & W_{22} & \dots & W_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ & & & \\ & & & \\ W_{n1} & W_{n2} & \dots & W_{nn} \end{bmatrix} \end{array}$$

For calculating the final rank of alternatives, the normalized super matrix and limit matrix should be developed. The limit matrix is made by multiplying the super matrix by itself. When the columns of the matrix become the same, the limit matrix has been reached, and the matrix multiplication process is finished.

3.2. Ranking the Rail Infrastructure Projects – A Case Study of Serbian Rail Network

The presented approach is applied for ranking the rail infrastructure projects. Considered rail projects are real projects from rail Corridor 10 through Serbia. All defined relevant criteria (Table 3) and alternatives (Table 4), as well as the model inputs, are taken from the paper Macura et al. (2011). There are two new criteria, Relevance of stakeholders and Probability of realization relevant external projects. Also, the model is modified by consideration of the impacts of relevant external projects and stakeholders. The model structure is presented at the Fig. 1.

Table 3
Considered Criteria

Criteria	Measures
Cost-benefit ratio	/
Criteria of speed restriction	Travel time lost [train hours/km]
Criteria of rail infrastructure capacity utilization	The percent of rail line capacity utilization [%]
Criteria of inconsistency with AGC & AGTC	[%]
Criteria of traffic volume	[train/day]
Relevance of stakeholders	/
Probability of realization relevant external projects	/

Table 4
Considered Alternatives (Railway Stations on Corridor 10 through Serbia)

Alternatives	
A_1	Šid-Stara Pazova
A_2	Subotica-Stara Pazova
A_3	Resnik-Mladenovac-Velika Plana
A_4	Velika Plana-Stalać
A_5	Stalać-Đunis
A_6	Đunis-Trupale (Niš)
A_7	Niš-Preševo
A_8	Niš-Dimitrovgrad

The model structure is presented at the Fig. 1. The developed model has 4 clusters, such as: Alternatives, Criteria, Relevant external projects and Stakeholders. Authors defined 4 relevant external projects for considered network: Vidin-Calafat Bridge (also known as Danube bridge 2); Marmaray tunnel; Revitalization of Corridor 4; and Privatization of the Port of Bar. These projects influence the rail projects which should be ranked. The cluster Stakeholders has 4 elements: Government; Infrastructure Manager; Operators; and General Public.

The clusters' connection is presented by oriented arrows, and the node relations are presented by a loop.

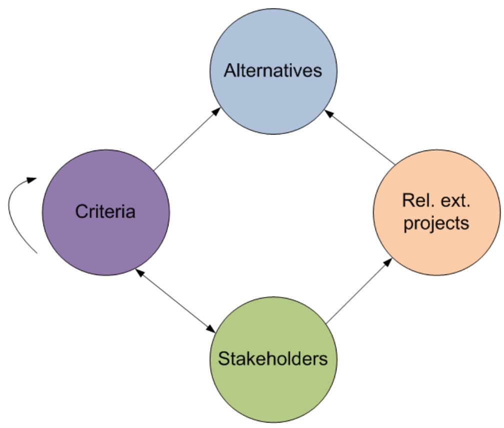

Fig. 1.
ANP Structure of the Model

Using the commercial user-friendly software "Super Decisions", final results are obtained (Table 5). The first ranked alternative is Resnik-Mladenovac-Velika Plana.

Table 5
Final Results

Alternatives		Rank	
A_1	Šid-Stara Pazova	0.064	5
A_2	Subotica-Stara Pazova	0.163	3
A_3	Resnik-Mladenovac-Velika Plana	0.226	1
A_4	Velika Plana-Stalać	0.097	4
A_5	Stalać-Đunis	0.163	3
A_6	Đunis-Trupale (Niš)	0.033	7
A_7	Niš-Preševo	0.055	6
A_8	Niš-Dimitrovgrad	0.198	2

4. Conclusion

The most used approach for transport project evaluation is Cost benefit analysis. Considering the new characteristics of transport projects, such as: inclusion of several stakeholders, uncertainties, difficulties in monetizing the relevant inputs of the model, etc., in many relevant papers the application of multicriteria approach is suggested.

In this paper, the model for rail projects' ranking is developed using the ANP approach. Beside relevant economical and technological criteria, there are considered various stakeholders and relevant external projects. All system's elements make the network structure of the model, with lot of relations and feedbacks. The model is tasted on rail infrastructure projects in rail Corridor 10 through Serbia.

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References

Ahern, A.; Anandarajah, G. 2007. Railway projects prioritization for investment, *Application of goal programming. Transport Policy* 14: 70-80.

Berechman, J.; Paaswell, R. E. 2010. Evaluation, prioritization and selection of transportation investment projects in New York City, *Transportation* 32(3): 223-249.

Caliskan, N. 2006. A decision support approach for the evaluation of transport investment alternatives, *European Journal of Operational Research* 175(3): 1696-704.

Chang, Y-H.; Wey, W-M.; Tseng, H-Y. 2009. Using ANP priorities with goal programming for revitalization strategies in historic transport: A case study of the Alishan Forest Railway, *Expert Systems with Applications* 36(4): 8682-8690.

Cheng, E.; Li, H. 2005. Analytic network process applied to project selection, *Journal of Construction Engineering and Management* 131 (4): 459-466.

Ferrari, P. 2003. A method for choosing from among alternative transportation projects, *European Journal of Operational Research* 150: 194-203.

Gercek, H.; Karpak, B.; Kilincaslan, T. 2004. A multiple criteria approach for the evaluation of the rail transit networks in Istanbul, *Transportation* 31: 203-228.

Lee, S-M. 1998. Analytic Hierarchy Process for Transport Project Appraisal – An application to Korea. Ph.D. Dissertation, University of Leeds. 271 p. Available from Internet: http://etheses.whiterose.ac.uk/927/1/uk_bl_ethos_511978.pdf.

Longo, G.; Padoano, E.; Rosato, P.; Strami, S. 2009. Considerations on the application of AHP/ANP methodologies to decisions concerning a railway infrastructure. In: *Proceedings of the International Symposium on the AHP*.

Macura, D. 2012. Multicriteria model for ranking and selection of the rail infrastructure projects. *Ph.D. Dissertation*, University of Belgrade, Faculty of Transport and Traffic Engineering. Belgrade, Serbia.
Macura, D.; Bošković, B.; Bojović, N.; Milenković, M. 2011. A model for prioritization of rail infrastructure projects using ANP, *International Journal of Transport Economics* XXXVIII: 265-289.

Piantanakulchai, M. 2005. Analytic network process model for highway corridor planning. In Proceedings of the *ISAHP 2005*, Honolulu, Hawaii.

Saaty, T.; Vargas, L. 2001. *Models, methods, concepts and applications of the Analytic Hierarchy Process*. Kluwer Academic Publisher, USA

Saaty, T.L. 1996. *Decision making with dependence and feedback: The Analytic Network Process*. RWS Publications, Pittsburgh.

Shang, J.S.; Tjader, Y.; Ding, Y. 2004. A unified framework for multicriteria evaluation of transportation projects, *IEEE Transactions on Engineering Management* 51(3): 300-313.

Tsamboulas, D. 2007. A tool for prioritizing multinational transport infrastructure investments, *Transport Policy* 14: 11-26.

Tudela, A.; Akiki, N.; Cisternas, R. 2006. Comparing the output of cost-benefit and multi-criteria analysis – An application to urban transport investments, *Transportation Research Part A* 40: 414-423.

Wee, B.V. 2007. Rail infrastructure: Challenges for Cost-benefit analysis and other ex ante evaluations, *Transportation Planning and Technology* 30(1): 31-48.

Wey, W-M.; Wu, K-Y. 2007. Using ANP priorities with goal programming in resource allocation in transportation, *Mathematical and Computer Modeling* 46: 985-1000.

Wey, W-M.; Wu, K-Y. 2008. Interdependent urban renewal project selection under the consideration of resources constraints, *Environment and Planning B: Planning and Design*, 35(1): 122-147.

Yedla, S.; Shrestha, R. 2003. Multi-criteria Approach for the Selection of Alternative Options for Environmentally Sustainable Transport System in Delhi, *Transportation Research - Part A: Policies and Practice* 37(8): 71-83.

A MODEL FOR THE MICROSIMULATION OF PORT ACTIVITIES

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Abstract: Modelling and simulating the activities of heavily used but protected environments such as seaports and airports are of increasing importance. This article shows the characteristics, the components and the obtained results of a micro simulation model of a seaport. Micro simulations use a discrete event approach to each single service and movement of different typology of vehicles over time. The behaviour of the port system is represented as a chronological sequence of events where elements within the simulation have a set of parameters and policies that they use to come to decisions. Microscopic activity simulation models have unique characteristics because of their capacity of representation of interaction between vessels, trucks, light vehicles, handling equipments, workers and infrastructures. The increasing availability of powerful desktop computers has allowed sophisticated computer software to be used to model the behaviour of individual components in real time. Micro simulation model has been applied to different scenarios involving complex interactions in space and in time and it has been used to build a decision support system tool for port authority. The DSS could be used with historical data to analyze the performances of single port components or, using forecasting traffic data, to help the design of infrastructural and management improvements of the port or to support the choice of navigation priorities and berth allocation for vessels. The research in this paper involves simulations and real world data from the Port of Civitavecchia. It was chosen as it is one of the most important Ro-Ro and cruise traffic in the Mediterranean Sea, organized with some multipurpose berths and an important bottleneck represented by the internal navigation channel.

Keywords: port simulation, discrete-event simulation, port logistics.

1. Introduction

Modelling and simulating the activities of heavily used but protected environments such as seaports and airports are of increasing importance. In fact, such infrastructures are characterized by several, different activities, often in overlap in space and time, while the increasing level of freight and passenger traffic involves capacity and reliability scheduling problems with a strong competition among different structures. In this context, it is obvious that are requested satisfactory performance for the different users of services and terminals providing greater efficiency and effectiveness for the internal activities. This is particularly true for a complex structure, such as port, in which several activities are not managed as a standard industrial process. A simulation model can describe all the processes that are necessary to define the services and the internal movements of port, permitting to analyze and extract data, simulate different scenarios that allow to study any deficiencies and potential solutions.

Micro simulations use a discrete-event approach to represent each single service and each movement of different typology of vehicles over time. The activities of the port system are represented as a chronological sequence of events where simulation elements require a set of parameters, rules and policies that are used to make a choice. Microscopic activity simulation models have unique characteristics because of their capacity of representation of interaction between vessels, trucks, light vehicles, handling equipments, workers and infrastructures. The simulation model includes the representation of both the sea and the land side of port and it make possible to write, study, compare, over time, moment by moment, all relationships which interact with one another defining the best configuration of the system port.

The objective is to create an effective tool that can be useful for the design and the management of the port, using both historical data and design scenarios and real time applications. In fact, the increasing availability of powerful desktop computers has allowed sophisticated computer software to be used to model the comportment of single components with an adequate level of detail and, if needed, in real time.

Micro simulation model has been applied to different scenarios involving complex interactions in space and in time and it has been used to build a decision support system (DSS) tool for port authority. The DSS could be used with historical data to analyze the performances of single port components or, using forecasting traffic data, to help the design of infrastructural and management improvements of the port or to support the choice of navigation priorities and berth allocation for vessels. The model has been applied to simulate the operation of the Port of Civitavecchia using real world data. This has been chosen as it is one of the main Ro-Ro freight traffic and cruise services in the Mediterranean sea, organized with many multipurpose berths and an important bottleneck represented by the internal navigation channel.
The paper is structured as follows: a state-of-the-art on the port simulation and the allocation of ships is presented in the second section; the third section describes the simulation model; the fourth section describes the results of an application to a real size port while the last section concerns about some concluding remarks and possible research further developments.

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2. Literature Review

The simulation of a complex infrastructure as a port is not treated by a large number of authors in literature. In fact in this context, the works reported in literature range from studies of very general approach, usually about port performance analysis, to very specific aspects. These are generally related to the optimization of a single specific operation. The great evolution of operational research and the increasing power of computational machines have produced great and renewed interest for this second kind of problems, mainly related to the container terminals management. Voss and Stahlbock (2004) and Steenken and Voss (2008) represent the most complete reviews about the main operation problems as container pre-marshalling problem, landside transport, stowage planning problem, yard allocation problem.

Little has been published on the simulation of port facilities. Among the most remarkable works on this matter, we should mention El Sheik et al. (1987), Van Asperen et al. (2003), Koch (2007), Cortés et al. (2007) and Arango et al. (2011). El Sheik et al. (1987) propose a simulation model of a third-world port focusing the attention in the analysis of the ship-to-berth allocation rules. Van Asperen et al. (2007) study a specific model for the analysis of the jetty capacity of ports involving special attention to capture the ship arrival process. Koch (2007) propose a simulation model to allow the assessment of the operational and cost impact of introducing upstream monitoring of cargo containers within port facilities. Cortés et al. (2007) simulate the freight transport process in the inland port of Seville, considering all existing types of cargo and testing several scenarios. Also Arango et al. (2011) choose the simulation of the Seville inland port to study the problems associated with allocating berths for containerships. This work produce an optimization model for the berth allocation problem integrated with simulating techniques involving some specific operations (truck and containerships arrivals, berth assignment, towing vessels and berths).

3. The Simulation Model

The model for the simulation of the port activities is an innovative model developed by means of a discrete-event simulation and it is implemented using ARENA software. This uses the SIMAN simulation language and it combines power, flexibility and ease of deployment thanks to a system of modules that represent logical steps, animations and the collection of statistics necessary for the system description. This allows to simulate real world data in more detail than a static model based on average values and deterministic processes.

The model consists of a series of building blocks, organized for the reproduction of the different processes that take place within the port. Each of these blocks is a combination of elementary modules. These are available at different levels of detail and they can be variously combined. For each block, the arrival process and the service, queuing and processing times are defined and calibrated.

The model of port activities is formed by different module groups that represent the following operations: a) ship arrivals; b) ship navigation in the port channel; c) ship evolution and mooring operation; d) handling operation at berths; e) truck and cars arrivals; f) ship departure. All these modules are defined and calibrated specifically for each kind of ship and typology of freight transported. For each ship are defined several relevant properties as size (tonnage), length (not all the berths are available for long ships), product (each ship handles just one specific type of product), expected date and time of arrival, assigned berth, shipping company, expected date and time departure, quantity of freight transported disaggregated in loading or unloading, number of equipments and workers used for handling.

The simulation of the port activities starts with the creation of the ships with all related attributes and their insertion in the simulation process. The ships enter in the navigation channel to reach the basin of evolution, make the evolution and start the mooring operations. The simulation of the internal channel of navigation is performed taking into account the rules to manage the use of this obliged passage. In particular, the structure of the sub-model "channel navigation" permits to give the priority to the ships exiting from the port, taking into consideration a different capacity of the channel for the entrance (only 1 ship) or for the exit movements (till 4 ship). These rules ensure a greater capacity in terms of berths available. The system used the first-come-first-served allocation strategy. Hence when a ship arrives at the port it has to wait in the queue until the navigation channel becomes free. From simulation are recorded, moment by moment, all data concerning the transition and use of the channel, the presence of a queue and his length, both for arriving and exiting ships.

After this, each ship, berth loaded attribute assigned, is simulated during the evolution and the mooring operation. Each berth has its own time of call, which depends on the available space inside the port and the type of call requested. The mooring operation, in the model, is simulated as one busy time slot using the berth. Even here, all types of ships have a different average time of mooring, based on what the ships handle and the berth configuration. This level of detail allows estimating an additional spent time, increasing the performance of the model, making it as close as possible to represent the real world data.

After the phase of mooring, the model starts the unloading and/or loading operation simulation. Everything is simulated with different resources that take into account the number of rosters and workers used and the handling equipments at disposal. Each handling operation is performed differently depending on the type of product and movement involved. For instance, the cruises ships perform unloading, loading and transit of passengers; the coal ships make unloading phase following a simulated chain of steps (cranes with crampons that downloading from the hold into the hoppers from which the coal is discharged into the truck trailers); car carrier ships are simulated calculating the turnaround time that employees take to make a complete roster: starting from the ship, reaching the berth, travelling in the land side of port to find the parking and the car storage point. An example of an unloading and/or loading operation process is illustrated in Fig.1. The simulation of the ro-ro and ro-pax ships handling operation is performed, for each ship, considering the events of arrival in the port of the cars and of the trucks to be loaded. The arrival processes are defined using a specific probabilistic distribution, different for cars (a gamma distribution with different parameters depending on the different destinations of ferries) and trucks (an equidistance arrival processes during the day).

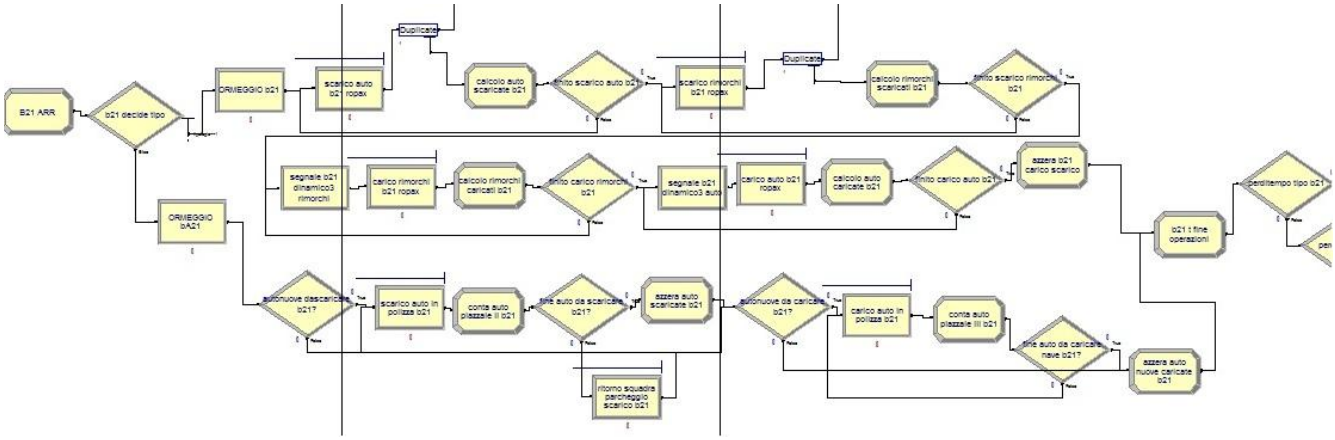

Fig. 1.
Berth Module for Handling Operation

The simulation model has been realized as a tool whose graphic user interface (GUI) is showed in Fig. 2, implemented in the C# language. The software ARENA is used to perform the model simulation of port activities. This tool helps decision makers about the design and the management phase in the port offering a very easy way to set the input data, to modify these to create different scenarios.

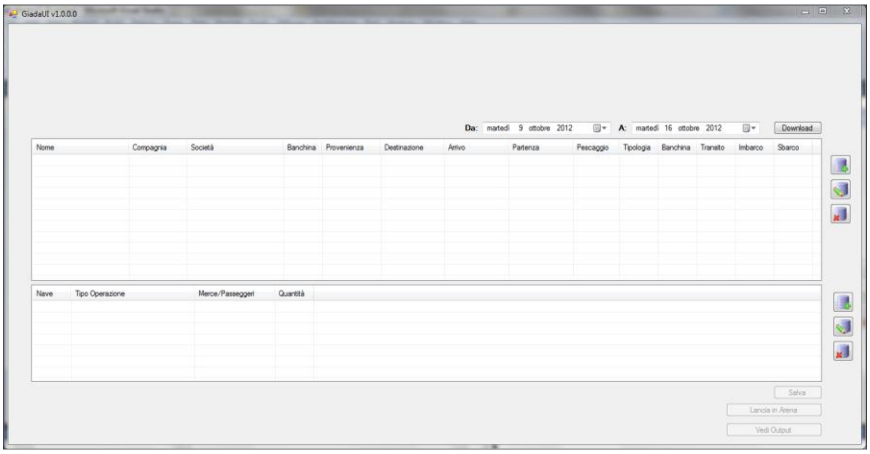

Fig. 2.
Graphical User Interface for the Simulation Model Tool

4. The Simulation Results

The simulation model has been applied to simulate the activities within the Port of Civitavecchia using real world data. This infrastructure has been chosen as it is one of the main Ro-Ro freight traffic and cruise services in the Mediterranean sea, organized with many multi-purpose berths and an important bottleneck represented by the internal navigation channel. It is located on the Tyrrenian sea, in the Central Italy, close to the city of Rome and it can be accessed by rail, road and motorway. It has always been one of the Italy's main ports for the Ro-Ro ships and ferries services directed to Sardinia, Sicily and other international connections with regions in the western part of the Mediterranean Sea. Due to the closeness with the city of Rome, Civitavecchia is becoming in the last years the main port for the cruises traffic in Europe with more than 2 millions of passengers every year.

A large amount of replications are carried out to verify and validate the simulation model. Data from the first simulations have been extracted and compared with real data at disposal. In other word, to calibrate and to optimize the performance of the model, the values of variables and parameters, the sequence of processes are defined comparing, in a iterative process, the results of the model and the statistical data in our possession for the year 2010. The final validation phase is performed for 5 different weeks characterized by different level of ships traffic and typologies (week of February, April, July, August and September of year 2010). The outputs of these replications of the model are reported in Table 1 and they are related to the occupancy rate of the berths, the occupancy rate of the navigation channel, the number of ships that have to wait in queue in the phase of arrival and departure.

Table 1
Main Simulation Outputs of Port of Civitavecchia Simulation Model with Historical Data during Year 2010

Simulation period	Ships calls at port (#)	Berth average occupancy rate	Navigation channel average occupancy rate (%)	Arrival ships in queue (%)	Exiting ships in queue (%)
February 2010	37	15%	10%	2%	11%
April 2010	64	23%	21%	16%	12%
July 2010	112	37%	36%	23%	23%
August 2010	117	28%	38%	33%	31%
September 2010	103	36%	33%	42%	18%

Additional replications of the simulation model are performed to evaluate his capacity to assess port performance, eventual critical issues related to capacity of single elements, modifying some data (increase of ships in arrival, different berth allocation of ships, etc.). These other simulations are also replied, always on a weekly basis, to compare the various outputs of model respect to the current condition before simulated.

The model have allowed, as shown by results reported in Table 2, to identify specific critical element in the port activities and possible strategies for improving the efficiency of the port infrastructure, such as the increase in the percentages of berth utilization, as well as the decrease of the number of ships in queue during the arrival and exiting phase.

Table 2
Main Simulation Outputs of Port of Civitavecchia Simulation Model with New Scenarios

Simulation period and scenario	Ships calls at port (#)	Berth average occupancy rate	Navigation channel average occupancy rate	Arrival ships in queue	Exiting ships in queue
July 2010 New handling operations	112	35%	36%	23%	23%
August 2010 Different berth allocation	117	29%	37%	32%	30%
August 2010 New Ro-pax services	138	38%	45%	40%	36%
August 2010 Additional new Ro-pax services	141	38%	46%	40%	37%
August 2010 Additional new Ro-pax services + different berth allocation	141	39%	44%	38%	36%

5. Conclusion

In this paper, authors propose a simulation model that describes all the processes defining the services and the internal movements of port. Such model permits to analyze and extract data, simulate different scenarios that allow to study any deficiencies and to find potential solutions. Micro simulation model uses a discrete-event approach to represent each single port element and to represent the interaction between ships, trucks, cars, handling equipments, workers and infrastructures. The simulation model includes the representation of both the sea and the land side of port.

The application results of different simulated scenarios, involving complex interactions in space and in time, has proved that the model can be consider robust and effective in producing reasonable representation of the port activities evolution. In addition, the same results shows that it can be used as a decision support system (DSS) tool for port authority to support berth allocation, improving internal organization and operations management.

Further developments will be focused on supplementary analysis for the refinement of specific operations within port areas. Additional effort has to be spent in the creation of additional tools to enhance the potentiality of the model as DSS tool also able to propose solutions to typical real time problems (peak traffic of cars and trucks, ship delay respect to the expected time of arrival, etc.).

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References

Arango, C.; Cortés, P.; Mununzuri, J.; Onieva, L. 2011. Berth allocation planning in Seville inland port by simulation and optimisation, *Advanced Engineering Informatics* 25: 452–461.

Cortés, P.; Mununzuri, J; Ibanez, J.N.; Guadix, J. 2007. Simulation of freight traffic in the Seville inland port, *Simulation Modelling Practice and Theory* 15: 256–271.

El Sheik, A.A.R.; Paul, R.J.; Harding, A.S.; Balmer, D.W. 1987. A microcomputer-based simulation study of a port, *The Journal of Operational Research Society* 38(8): 673-681.

Koch, D. 2007. PortSim – a port security simulation and visualization tool. In *Proceedings of the 41st annual IEEE international Carnahan conference on security technology*, 109–116.

Steenken, D.; Voss, S. 2008. Operations research at container terminals: a literature update, *OR Spectrum* 30: 1–52.

Van Asperen, E.; Dekker, R.; Polman, M; de Swaan Arons, H. 2003. Allocation of ships in a port simulation. In *Proceedings of the 15th European Simulation Symposium*.

Voss, S.; Stahlbock, R. 2004. Container terminal operations and operations research: a classification and literature review, *OR Spectrum* 26: 3–49.

FUZZY LOGIC SYSTEM FOR DETERMINING THE NUMBER OF WORKERS ON TOLL GATES ON HIGHWAYS

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Abstract: Variability of traffic flows is characteristic of many highways in the world. On the other side, the number of engaged workers on the toll gates is often constant over time. In spite of the fact that electronic toll collection is trendy, many countries still have manual toll collection systems on their highways. For manual toll collection system constant number of workers results in insufficient workers utilization in conditions of small traffic flow values, and appearance of long vehicle queues in front of toll gates during peak hours. In this paper, the model for dynamic control of the number of engaged workers is developed with the objective to determine optimal number of workers over time. Fuzzy logic and queuing theory represent the backbone for development of the model. System of toll gates is observed as a queuing system in which incoming vehicles represent clients and workers represent servers. The number of servers, i.e. the number of engaged workers is variable that is determined by using fuzzy logic and taking into account the queue length. The model is developed in Simulink and tested on many real numerical data. Data collected from toll gates in Bubanj Potok are used for development and evaluation of the model. The simulation results show that number of engaged workers must be coordinated with current traffic demands. In this way considerable decrease of engaged number of workers can be obtained, comparing to existing conditions on toll gates in Bubanj Potok. Consequently, this leads to the reduction of system costs. On the other side, level of service of the system is almost the same as in the case of engaging unnecessary number of workers.

Keywords: toll roads, toll gates, fuzzy logic, queuing system

1. Introduction

The construction of road infrastructure has direct impact on the population mobility and represents one of the main requirements for the successful economic development of each country. The funding is one of the biggest obstacles for the construction of new road network. One of the ways to ensure the part of the budget dedicated to the construction and maintenance of road infrastructure is to introduce toll collection system. Although the most countries are adopting an electronic toll collection system, the large number of toll gates on highways still has manual toll collection system. The design and control of these systems have an important role in order to determine the capacity, i.e. the number of input and output gates with hired workers, required for specific demands, i.e. the rate of traffic flow. Once provided capacity is very difficult to change, primarily due to existing space limitations. On the other hand, the traffic flow has its own variability on hourly, daily, weekly and yearly basis, and therefore there is a need for changing the capacity and the number of engaged workers. Hence, the main control task in the existing manual toll collection system is to determine the number of engaged workers that responds to changes in the traffic flow.

The aim of this paper is to present the model for dynamic determination of number of engaged workers on the toll gates. The dynamic control system is created by implementation of the fuzzy logic. This method, as very close to the human way of thinking, provides easy determination of the number of workers at the toll gates. Fuzzy logic adjusts the output taking into account current traffic flow described by human perception of numerous factors (Teodorović, 1999; Teodorović and Šelmić, 2012). In this paper, toll collection system is observed as a queuing system, while the number of servers, i.e. the number of engaged workers is determined by the fuzzy logic. This model is developed in Simulink, and the real data collected from toll gate Bubanj Potok, Serbia are used for case study validation and testing.

The paper is organized as follows. After Introduction, the description of the toll collection system is given in the Section 2. The Section 3 refers to the fuzzy logic system, while Section 4 presents the results of the simulations. Finally, the conclusions are in the last, fifth Section.

2. Description of the System

Queuing theory (QT) is the field of operations research which deals with queues phenomena, i.e. systems with queues of waiting customers (Teodorović, 2007). Queuing system (QS) has wide applications in the traffic design in order to determine required capacity, as well as in the evaluation of the existing system (Taha, 2007; Vukadinović, 1998). Waiting at toll gates is one among numerous examples of QS. As all QS have common characteristics that describe them, those characteristics can be observed for the case of toll stations, and level of service as well as directive for improvement of a station can be obtained by QT.

If we observe the toll station as queuing system we can see an analogy between the vehicles that arrive at the toll gate and the input stream of clients (arrival rate), then engaged workers and servers, as well as vehicles that leave the toll gate and the output stream of clients (departure rate). The capacity of queue in the case of toll gate is infinite, which means that all vehicles that arrive to the toll gate must be served.

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The model developed in this paper provides a response to changes in traffic flow in real time. It is queuing system with a Poisson distribution, and fuzzy logic controller embedded into model with aim to control the number of servers i.e. the number of engaged workers. The main elements of each fuzzy logic model are the fuzzy sets, membership functions and fuzzy rules (Teodorović and Šelmić, 2012). All these elements are tuned and modified after model testing. The final shapes of the membership functions and fuzzy rules are adopted when satisfactory results for a larger range of traffic flow were found. The simulation outputs are measures of performance of the toll gate system, such as average queue length, average waiting time in queue and the average waiting time in the system. Data collected from toll gates Bubanj Potok are used for development and evaluation of the model. Finally, the current characteristics of the toll gate Bubanj Potok are compared with the estimated values obtained by the fuzzy logic model.

2.1 Toll Gate Bubanj Potok as Queuing System

The toll gate Bubanj Potok is located at the entrance/exit of Belgrade, Serbia, on highway Belgrade-Nis which belongs to European road E75. At the entrance of Belgrade, i.e. exit of the highway, all toll collection and all payments are mostly done manually. Very small number of drivers uses electronic payment. The toll station has 12 exit lanes, i.e. maximum number of engaged workers can be 12. It contains of two parts. The first part (looking at the direction toward Belgrade) has five lanes, and the second part has seven lanes. One lane at the first part (rightmost) is provided for drivers that want to pay their toll at the second part, as well as for electronic payment. Two of seven lanes at the second part are designed for electronic payment, but as this is a rare case, they are used for manual collection as well.

The flow rates, average service time, and the number of engaged workers were recorded at this toll gate during eight hours of the business day (Tuesday), in two intervals, from 9h to 13h and from 16h to 20h. Using chi-square test the distribution of vehicle arrival moments is defined, in order to identify correct QS model for this toll gate. Considering observed flow rates (from 703 to 968 vehicles per hour and no more than 6 vehicles per 10 seconds) Poisson process is assumed and approved (Kuzović, 1987; Vukadinović and Popović, 2004). Further, if the number of vehicle arrivals is distributed according to Poisson distribution, then the inter-arrival times are distributed exponentially (Taha, 2007). The toll station system in Bubanj Potok is under first come, first served (FCFS) discipline and all vehicles that arrive at toll gates have to be served, which implies that there are no failures in the system and the queue is practically endless. Therefore, one can say that the toll gates system is queuing system without failures and with an infinite queue capacity. Finally, the system can be referred with the Kendall notation (Kendall, 1953):

$$M(\lambda) \,/\, M(\mu) \,/\, n \,/\, \infty$$

Where:

λ – rate of arrivals per unit time, $M(\lambda)$ – Arrivals occur at rate λ according to a Poisson process, $M(\mu)$ - Service times have an exponential distribution, μ – mean service rate, n – number of serving channels (servers), m – size of queue capacity is infinite, ∞.

The characteristics of the toll gate Bubanj Potok are calculated for different values of number of engaged workers for the time period of 8 hours at which date is generated. In this period the number of engaged workers varied from 8 to 10, with observed inconsistencies when the number of workers increases in periods of reduced flow rate. In the period from 9h to 13h the number of workers was 10, from 16h to 18:30h was 8, and in the period when the flow rate was the lowest, the number of employees has increased to 9. The service time was measured at sample of 100 vehicles and the average service time ($\overline{t_{ops}}$) was 16 seconds. The measurements were taken at different exit lanes, in order to exclude influence of the human factor i.e. the impact of a very efficient worker or a person who performs work very slowly.

The Table 1 shows the number of workers on toll gates (n), traffic flow rate for three specific periods (q), arrival rate (λ), service rate (μ) and average service time ($\overline{t_{ops}}$). The average length of queue (L_q) and the average waiting time in queue (W_q) are the output indicators of the toll gate Bubanj Potok. All parameters are obtained for three mentioned time periods during the day.

Table 1
Working Indicators of Toll Gate Bubanj Potok

Observed time period	n[-]	q [veh/h]	λ[veh/s]	t_{ops}[s]	μ [veh/s]	L_q[-]	W_q [-]
9-13h	10	3565	0.26	16	0.0625	0.0066	0.026
16-18:30h	8	2004	0.22	16	0.0625	0.0263	0.118
18:30-20h	9	1096	0.20	16	0.0625	0.0037	0.0187

As can be seen from Table 1, all values of time losses in queues are small, i.e. practically there are no losses. The number of engaged workers is more than necessary, since queues do not exist in this system and all servers are rarely busy simultaneously. From the users' perspective this system is very good (there is no time losses), but observed from an economic point of view it couldn't be said that this solution is an optimal (unnecessary number of workers are employed, and therefore system costs increased). This is the reason why it is necessary to find a balance between user and system cost. Such a system should be dynamic and able to monitor and respond to changes in clients' requirements over time.

The following Fig. 1 shows the observed values of current queue length and number of engaged workers for the reference period of 6 hours per working day.

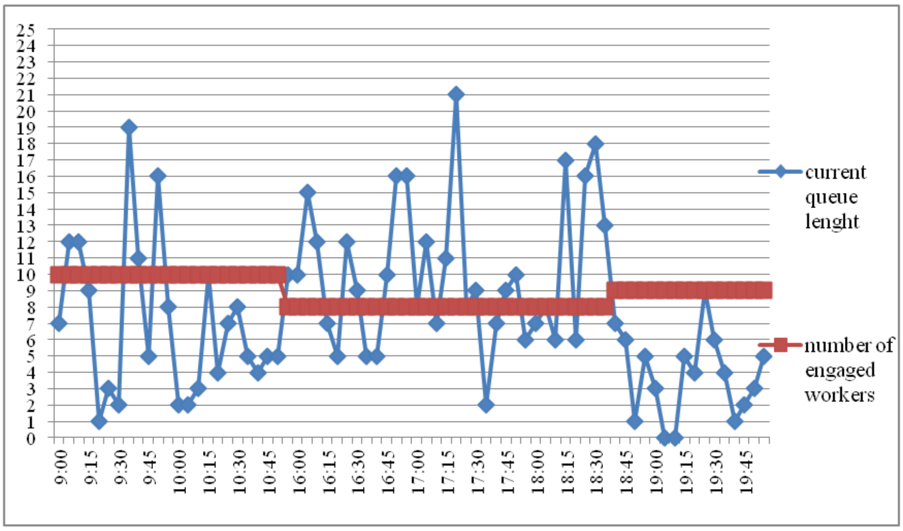

Fig. 1.
Current Queue Length and the Number of Engaged Workers

From Fig. 1 it can be seen that the lowest number of vehicles in the queue is zero, and the peak value is 21 (this is total number of vehicles for all lanes). All measurements were done on 5 minutes interval during six observed hours (from 9h to 11h, and 16h to 20h). The toll gate, as it was mentioned before, has two parts, so the clients that arrive to gate do not have visual review of the second part. Actually, the drivers do not know in advance how many lanes are opened and how many vehicles are in queue. That is a reason why numerous vehicles stop at the first part of the toll gate and form unrealistic queues, while the second part is almost empty. Due to this fact, the results derived from the measurements may be higher than the results obtained using the QT, where all vehicles form a single line and the first vehicle leaves queue when a server releases. The simulation results can show a slightly lower value of the output indices i.e. the number of vehicles in a queue. However, for these values of traffic flow, the possible differences would be within the acceptability limits. As well, in a real system this problem can be solved by variable message signs of queue lengths in exit lanes.

3. Fuzzy Logic System

As an alternative, fuzzy logic (Zadeh, 1965) provides a formal methodology for representing, and implementing a human's heuristic knowledge about how to control a system. In this paper the fuzzy logic system with Mamdani's inference method is developed according to the identified problems and measured values at the toll gate Bubanj Potok (number of employees, queue length, operating time, traffic flow). This method allows dynamic control of the number of engaged workers and its coordination with current traffic demands. The first step in creation of fuzzy logic model implies determination of input and output variables. All the fuzzy sets, as well as, appropriate membership functions values are determined subjectively.

3.1. Defining Fuzzy Variables

Since the input variables of each fuzzy logic model have to describe the current state of observed system, the first input variable in the model developed in this paper is *the current queue length (x_1)*. The term *queue length* refers to the total number of vehicles that are counted on all exit lanes.

In order to avoid unrealistic final, control decision, or decision based on just one queue length value, the authors introduced the second input variable, *the difference between the current queue length and the length of queue 5 minutes ago (x_2)*. Based on two previously mentioned input values, the final control decisions are obtained taking into account the circumstances of the observed system in a short time interval. For both input variables, the membership functions are most common triangular shapes.

The output variable is *the number of engaged workers (y)*. The membership function values are determined based on observed values of this variable on the toll gate Bubanj Potok, i.e., based on the range in which the flow is distributed according to Poisson distribution. Finally, an alignment of input and output variables' values are enabled by forming the fuzzy rule base. The shapes of membership functions are given in the following text.

The current queue length (x_1) has values (Fig. 2):

SQ – small queue; MQ – medium queue; LQ- large queue and VLQ – very large queue.

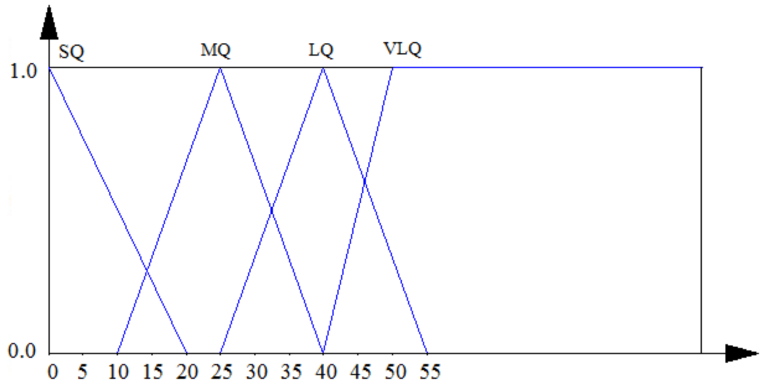

Fig. 2.
Membership Function of Input Variable X1

The difference between the current queue length and the length of queue 5 minutes ago(x_2) can be described using following fuzzy values (Fig. 3):

LND – large negative difference; MND – medium negative difference; SND – small negative difference; ND – neutral difference; SPD – small positive difference; MPD – medium positive difference; LPD – large positive difference.

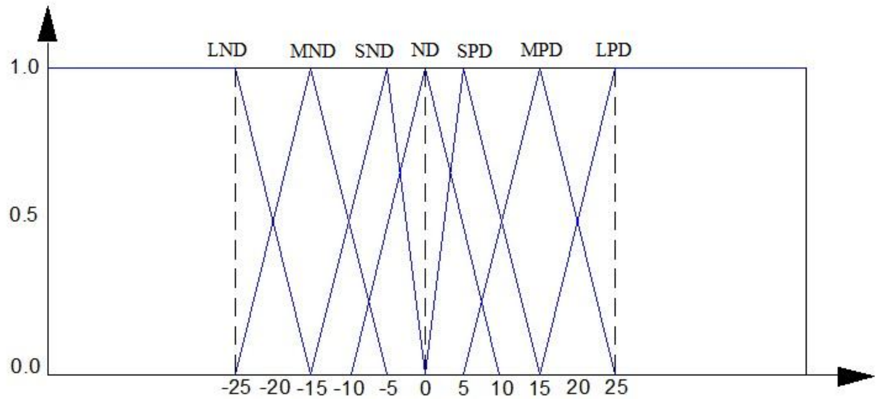

Fig. 3.
Membership Function of Input Variable X_2

The membership functions for output variable, *the number of engaged workers (y)*, are:

SN – small number of workers; MN – medium number of workers; LN – large number of workers and VLN – very large number of workers.

The maximal number of exit lanes i.e. engaged workers at Bubanj Potok toll gate is 12, so this is an upper bound of the output variable, *y*. For a determination of a lower limit, it is necessary to take into account certain criteria. First, measured flow rates on toll gates ranged from 703 veh / h to 968 veh / h. The membership functions are formed according to these values. In addition, the condition of the queuing theory, which implies that the input flow stream (λ) is less than the maximum capacity ($n\mu$) should be satisfied. Also, a highway is supposed to be a road with high level of service, so it is necessary to respond on this criteria. Therefore, the lower limit of the number of engaged workers is set to 4.

Anything less than this number in the daily rate of the traffic flow could create large queues. Under conditions where the traffic flow is less than observed daily values , which is probably at night, a fixed number of workers can be calculated.

The membership function of output variable *y* is given on Fig. 4.

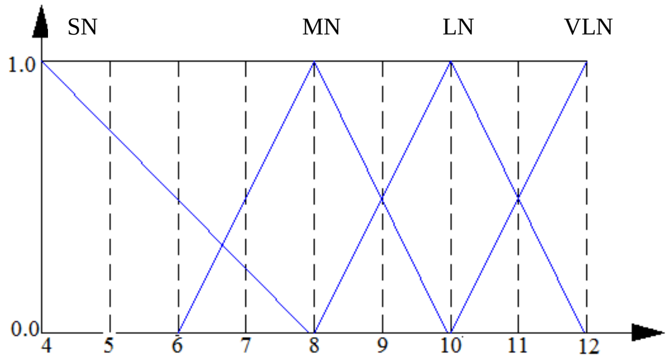

Fig. 4.
The Output Variable, the Number Of Engaged Workers (y)

3.2. Fuzzy Rules

The most important step in the phase when the fuzzy logic system is created is to properly define fuzzy rule sets. Fuzzy rule set consists of 22 rules and it is based on the input and output variables.

Table 2
Fuzzy Rule Set

Rules 1-11	Rules 12-22
If x_1 SQ and x_2 ND, Then y SN	If x_1 MQ and x_2 SND, Then y SB
If x_1 SQ and x_2 SPD, Then y SN	If x_1 MQ and x_2 MND, Then y MN
If x_1 SQ and x_2 MPD, Then y SN	If x_1 MQ and x_2 LND, Then y LN
If x_1 SQ and x_2LPD, Then y SN	If x_1 LQ and x_2 ND, Then y LN
If x_1 SQ and x_2 SND, Then y SN	If x_1 LQ and x_2 SPD, Then y LN
If x_1 SQ and x_2 SN, Then y MN	If x_1 LQ and x_2 MPD, Then y MN
If x_1 SQ and x_2 LND, Then y MN	If x_1 LQ and x_2 LPD, Then y MN
If x_1 MQ and x_2 ND, Then y MN	If x_1 LQ and x_2 SND, Then y LN
If x_1 MQ and x_2 SPD, Then y MN	If x_1 LQ and x_2 MND, Then y LN
If x_1 MQ and x_2 MPD, Then y MN	If x_1 LQ and x_2 LND, Then y MN
If x_1 MQ and x_2 LPD, Then y MN	If x_1 VLQ, Then y VLN

After testing the proposed model, obtained values are analyzed, and some of initial membership functions and rules are modified. The final shape of the membership functions and rules are adopted when the condition of satisfactory results for a larger range of traffic flow was satisfied.

4. Simulation Results

The authors collected and measured real data from toll gate Bubanj Potok, Serbia. The obtained results, i.e. the simulation outputs (average queue length, average waiting time in queue and the average waiting time in system.) are indicators of the toll collection system observed as QS. Additionally, the graph that shows the changes in the number of engaged workers, depending on the input variables is also considered as the simulation output.

In proposed simulation model, the traffic flow rates measured during one working day on toll gate Bubanj Potok are used as input values. According to these data, i.e. the values of the flow and their distributions, the random numbers are generated and variables that are the inputs for fuzzy logic system (queue length) are calculated using the QS. Every 5 minutes the number of required workers is calculated using fuzzy logic. This information is then sent back to QS where performance indicators are obtained. Before fuzzy logic system calculates the first output, i.e. the first number of engaged workers, the minimum value of workers, i.e. 4, is adopted as the initial value in the simulation. The simulation results for measured flow rates from 9 to 13h are given in Fig. 5.

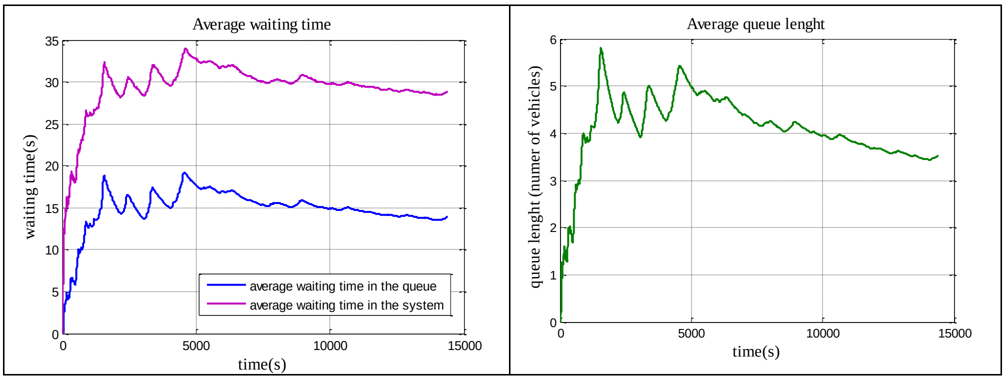

Fig. 5.
Simulation Results for Values Measured From 9h To13h

As it can be seen from Fig. 5, average queue length is approximately 4 vehicles. Considering that queue length refers to the total number of vehicles in all exit lanes, this means that if 4 workers are engaged, one vehicle is in each line. Besides, average waiting time in the queue is 14s, and average waiting time in the system is 28s after four hour period. Next Fig. 6 shows changes in the number of engaged workers and queue length during 4 hours. From Fig. 6, it is obvious that the longest queue is 26 vehicles.

If we compare those values with ones presented on Fig. 1 (real values measured from Bubanj Potok toll gate), it can be concluded that obtained queue length values are not higher than those observed at toll gate. The biggest leaps, i.e. the maximum length of the queues, and thus the change in the number of engaged workers can be seen in the first two hours of simulation, which can be explained by the highest flow rate (911 in the first hour, 968 vehicles in the second).

Also, the biggest changes in that period can be seen on performance indicators graphs, but, neither in this period, the average values are not much higher than 4 (highest value for the queue length is 6 vehicles).

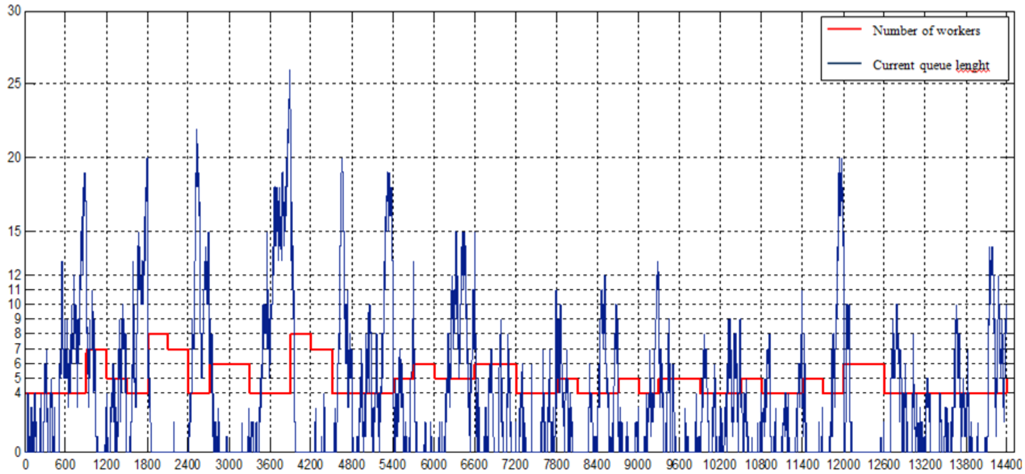

Fig. 6.
Number of Engaged Works from 9h To13h

From Fig. 6, it can be seen that changes in the number of engaged works are adjusted with queue length. The biggest number of engaged workers is 8 and that corresponds to the largest queue length. It is clear that number of workers doesn’t decline sharply after 5 minutes, which is primarily provided by introducing the second input variable, the difference between the current queue length and the length of queue 5 minutes ago. This ensures greater stability of the system, and does not engage unnecessary number of workers over a longer period. In the second part of the simulation (from 7200 to 14400s), it can be noticed that there are no large leaps in the queue length, which is caused by reduced flow of vehicles in that period.

The number of hired workers rises to 6 during just 10 minutes from the observed 2 hours, while in other periods this number is always 4 or 5 workers. If the number of engaged workers is compared with the current state from toll gate Bubanj Potok, which was 10 for this period, one can notice that the number obtained by simulation model is much lower.

On the other hand, the performance indicators point to a very high level of service, so it is clear that even with a much smaller number of engaged workers, very good results can be achieved.

The results of simulation for the flow rates measured during the time period from 16h to 20h are shown in the following Fig. 7.

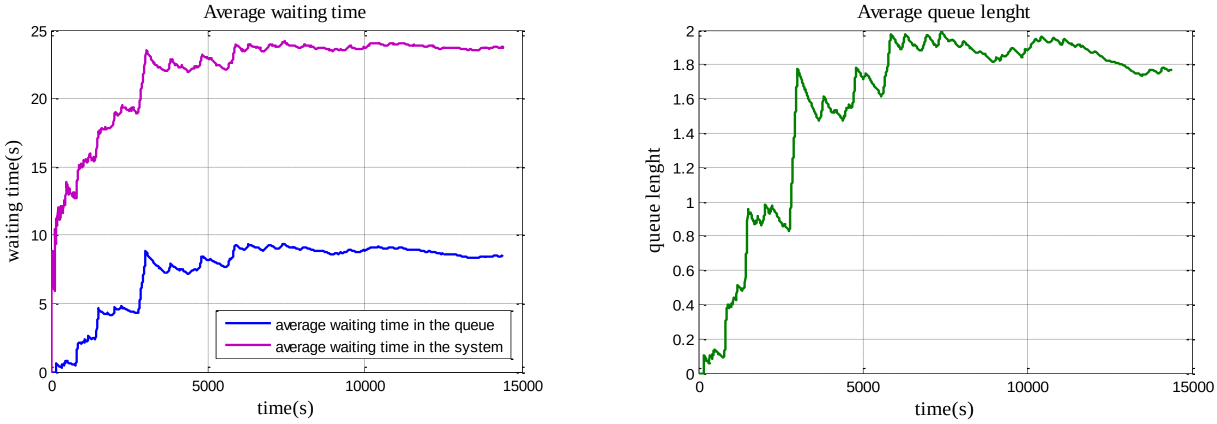

Fig. 7.
Simulation Results for Values Measured from 16h to 20h

During time period from 16 to 20h, the better performance indicators i.e. lower time losses values and lower lengths of queues are obtained. The average length of the queue after 4 hours is about 2 vehicles, and the time spent in the queue and in the system is 8.5s and 24s, respectively. The number of hired workers is generally 4, but it changes in 5 workers periodically, except for one moment in the second hour (3000th second of the simulation), when the number of workers is 8 because of the large increase in queue length (19 vehicles). Also, this change can be observed in the graphs of performance indicators, when the average values are faced with largest increase. Comparing with Fig. 1, for these flow rates, 8 and 9 employees are engaged. This number is unnecessarily high, because the simulations provide high-performance of the systems with a smaller number of workers involved.

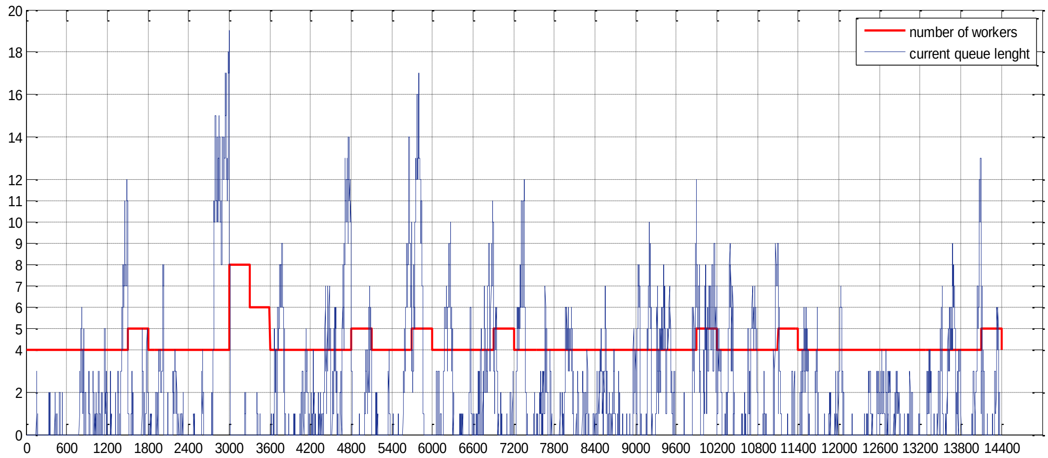

Fig. 8.
Number of Engaged Workers from 16h to 20h

5. Conclusion

In this paper, the model for dynamic control of manual toll gates on highways is developed. The toll gate is observed as QS with Poisson distribution. The number of required servers (engaged workers) is determined by fuzzy logic, and it is based on current queue length and the difference between the current queue length and queue length 5 minutes ago. The model is developed in Simulink and tested on a numerous real data from toll gate Bubanj Potok, Serbia.

Since the proposed model enables dynamic control of system, the question is when this type of control is applicable. Fuzzy logic provides a way to manage the real-time problems, and to adjust to the current conditions of traffic flow, but, of course, this is not necessary in all cases. This method of control corresponds primarily to systems where workers are engaged in multiple jobs (Zang et al., 2005). In the systems with variable number of employees, the workers can be active in activities other than toll collection, for a period when maximal number of employees at the toll stations is not required. Also, there should be a need for dynamic controlling, and that there are corresponding changes in the values of traffic flow over time.

In addition, this model is not applicable only to the toll gates systems, but also to all QS where servers (people or machines) can be engaged in other activities in order to maximize utilization.

The specific characteristics of every system lead to different fuzzy controller for each toll gate (or any other system where the model is applied). Therefore, it is necessary to do the research on toll gates and then to record their characteristic. Finally, the membership functions and fuzzy rule set have to be formed and tuned. In this paper data collected from Bubanj Potok toll gate are considered for fuzzy logic model validation and testing. It is noticed that the number of engaged workers obtained by the model is less than the number of employees currently working at the toll gate. The number of required workers for the tested flow rates is not more than 8. In future work, the model should be tested on larger flow rates. In that case, the required number of workers would possibly reach maximum 12 engaged workers.

Finally, it can be concluded that a significant reduction of required number of workers compared to the real situation at toll gate Bubanj Potok is achieved by application of developed model. Consequently, this leads to the reduction in system cost. On the other hand, the level of service of the system remains almost the same.

References

Kendall, D.G. Stochastic Processes Occurring in the Theory of Queues and their Analysis by the Method of the Imbedded Markov Chain, *Annals of Mathematical Statistics* 24(3): 338–354.

Kuzović, Lj. 1987. *Teorija saobraćajnog toka*, Građevinska knjiga, Beograd.

Taha, H.A. 2007. *Operations Research: an Introduction*, Pearson Education. 816 p.

Teodorović, D. 1999. Fuzzy logic systems for transportation engineering: the state of the art, *Transportation Research Part A* 33: 337–364.

Teodorović, D. 2007. *Transportne mreže*, Saobraćajni fakultet, Beograd.

Teodorović, D.; Šelmić, M. 2012. *Računarska inteligencija u saobraćaju*, Saobraćajni fakultet, Beograd.

Vukadinović, S.; Popović, J. 2004. *Matematička statistika*, Saobraćajni fakulet.

Vukadinović, S. 1998. *Masovno opsluživanje*, Naučna knjiga, Beograd.

Zadeh, L.A. 1965. Fuzzy sets, *Information and Control* 8: 338-353.

Zang, R.; Phillis, Y.A.; Kouikoglou, V.S. 2005. *Fuzzy Control of Queuing Systems*, Springer. 176 p

A COMPARATIVE ANALYSIS OF NEURO-FUZZY AND ARIMA MODELS FOR URBAN RAIL PASSENGER DEMAND FORECASTING

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Abstract: The success of strategic and detailed planning of urban rail transportation highly depends on accurate demand information data. Forecasting is the key to the success of rail passenger operations planning, such as timetabling and seat allocation. Adaptive neuro-fuzzy inference system (ANFIS) is a class of adaptive multi-layer feed forward networks, applied to nonlinear forecasting where past samples are used to forecast the sample ahead. ANFIS incorporates the self-learning ability of neural networks with the linguistic expression function of fuzzy inference. In this paper we made an application of ANFIS to model rail passengers flow on Belgrade urban railway network. The performance of the neuro-fuzzy network is compared with a traditional linear model (ARIMA). The models were evaluated for their ability to produce accurate forecasts.

Keywords: railway, passenger demand, forecasting, ANFIS, ARIMA.

1. Introduction

Passenger flow forecasting is a vital component of transportation systems which can be used to fine-tune travel behaviors, reduce passenger congestion, and enhance service quality of transportation systems. The forecasting results of passenger flow can be applied to support transportation system management such as operation planning, and station passenger crowd regulation planning. In some cases, it is used for establishing the daily train timetables which have direct impact on resource allocation and utilization. The success of strategic and detailed planning of public transportation highly depends on accurate demand in formation data. Also, passenger flow forecast represent a basic work for urban rail transport project investment decision analysis. It is a measure of the economic costs of construction projects. Therefore, scientific and reasonable passenger flow forecast helps the fundamental guarantee for investment decision.

The transportation forecasting approaches can be generally divided into two categories: parametric and non-parametric techniques (Smith et al., 2002). Parametric techniques and non-parametric techniques refer to the functional dependency assumed between independent variables and the dependent variable. In the traditional parametric techniques, historical average, smoothing techniques and autoregressive integrated moving average (ARIMA) have been applied to forecast transportation demand. For the non-parametric techniques, several methods have been used to forecast the transportation demand such as neural networks (Dougherty, 1995; Vlahogianni et al., 2004), non-parametric regression (Smith et al., 2002; Clark, 2003), Kalman filtering models (Wang and Papageorgiou, 2007), and Gaussian maximum likelihood (Tang et al., 2003).

In this paper, we studied the urban railway passenger demand in the city of Belgrade. On the base of available historical data about rail passenger flows two forecasting techniques are proposed and compared, a hybrid of Neural Network and Fuzzy Logic, known as Adaptive Network-based Fuzzy Inference System (ANFIS) and Autoregressive Integrated Moving Average (ARIMA) model. The presented models are used to provide one year ahead rail passenger demand forecast.

The remainder of this paper is organized as follows. Section 2 describes the underlying principle of neuro-fuzzy systems and the architecture of ANFIS. The main characteristics of ARIMA models are given in Section 3. Belgrade rail node, data used for forecasting and explaining variables are presented in Section 4. The applicability of proposed methods is demonstrated by modeling the urban rail passenger demand for Belgrade rail node in Section 5. The concluding remark is provided in Section 6.

2. Neuro Fuzzy Models

Neuro-fuzzy modeling refers to the way of applying various learning techniques developed in the neural network literature to fuzzy modeling or to a fuzzy inference system (FIS).

The fuzzy inference system (FIS) is a popular computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. Because of its multidisciplinary nature, the FIS is known by numerous other names, such as fuzzy expert system, fuzzy model, fuzzy logic controller, and simply fuzzy system (Pribyl and Goulias, 2003).

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The basic structure of a FIS is composed of five functional blocks, a rule-base that contains a number of fuzzy if-then rules, a database that defines the membership functions of the fuzzy sets used by the fuzzy rules, a decision-making subsystem that performs the inference operations on the rules, a fuzzification interface that transforms crisp measurement to degrees of membership to different fuzzy sets and finally, a defuzzification interface that transforms the fuzzy results into a crisp output (e.g. a control signal, a predicted value, etc).

FIS implements a non linear mapping from its input space to the output space. This mapping is accomplished by a number of fuzzy if-then rules, each of which describes the local behavior of the mapping. The parameters of the if-then rules (referred to as antecedents or premises in fuzzy modeling) define a fuzzy region of the input space, and the output parameters (also consequents in fuzzy modeling) specify the corresponding output. Hence, the efficiency of the FIS depends on the estimated parameters.

In the present study, the concept of the adaptive network, which is a generalization of the common back propagation neural network, is employed to tackle the parameter identification problem in a FIS.

2.1. ANFIS Architecture

ANFIS (Adaptive Neuro-Fuzzy Inference System) represents a class of adaptive multi-layer feedforward networks, applied to nonlinear forecasting where past samples are used to forecast the sample ahead. The ANFIS was created by Jyh-Shing R. Jang (1993) in order to incorporate the self learning ability of neural networks with the linguistic expression of fuzzy inference.

Consider for example, that the FIS has two inputs x and y and one output z: For the first order Sugeno fuzzy model, a typical rule set with two fuzzy if-then rules can be expressed as:

Rule 1: If X is A_1 and Y is B_1, then $f_1 = p_1 x + q_1 y + r_1$

Rule 2: If X is A_2 and Y is B_2, then $f_2 = p_2 x + q_2 y + r_2$

A_1, A_2 and B_1, B_2 are the MFs for inputs x and y, respectively. $\{p_1, q_1, r_1\}$ and $\{p_2, q_2, r_2\}$ are the parameters of the output function.

The ANFIS architecture and the reasoning mechanism are presented in Fig. 1. Fig. 1(a) illustrates graphically the fuzzy reasoning mechanism to derive an output f from a given input $[x, y]$. The firing strengths w_1 and w_2 are usually obtained as the product of the membership grades of the premise part, and the output f is the weighted average of each rule's output.

As we can see from the Fig. 1b, the corresponding equivalent ANFIS network architecture is composed of five layers, fuzzy layer, product layer, normalized layer, de-fuzzy layer and the total output layer.

Each layer contains several nodes described by the node function. Adaptive nodes, denoted by squares, represent the parameter sets that are adjustable in these nodes, whereas fixed nodes, denoted by circles, represent the parameter sets that are fixed in the system. The output data from the nodes in the previous layers will be the input in the present layer. The corresponding ANFIS structure is shown on Fig. 2b, where nodes within the same layer perform functions of the same type. Output of the node i in the layer j is denoted as O_i^j. To illustrate the ANFIS procedures, we consider the above system having two inputs $[x, y]$ and one output f. The relationship between input and output of each layer is discussed bellow.

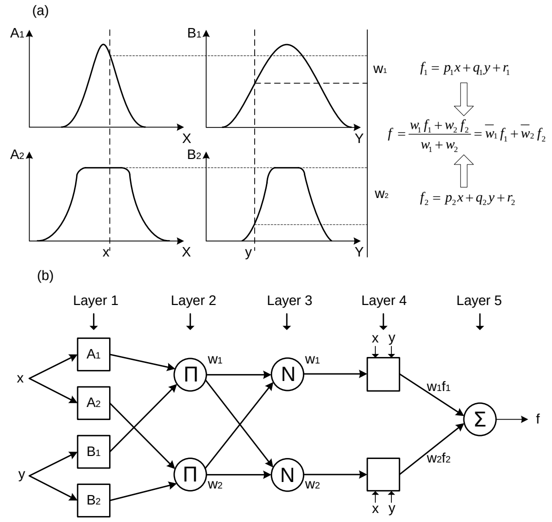

Fig. 1.
(a) Fuzzy Inference System (b) Equivalent ANFIS Structure (Jang, 1993)

Layer 1: In this layer, each node generates a membership grade of a linguistic label. The node function of the i-th node is generalized bell membership function (Eq. (1)):

$$O_i^1 = \mu_{Ai}(x) = \frac{1}{1+\left(\frac{x-c_i}{a_i}\right)^{2b_i}} \tag{1}$$

Where x is the input to node i, A_i the linguistic label associated with this node and $\{a_i, b_i, c_i\}$ the parameter set that changes the shapes of the membership function. ANFIS uses gradient descent to fine-tune them during the training process. Parameters in this layer are referred to as the premise parameters.
Layer 2: Each node in this layer multiplies the incoming signals, denoted as $\prod$, and the output represents the firing strength of a rule (Eq. (2)):

$$O_i^2 = w_i = \mu_{A_i}(x)\mu_{B_i}(y), \ i = 1,2 \tag{2}$$

Layer 3: Node i in this layer calculates the ratio of the i-th rule firing strength to the total of all firing strengths (Eq. (3)):

$$O_i^3 = \bar{w}_i = \frac{w_i}{(w_1 + w_2)}, \ i = 1,2 \tag{3}$$

Layer 4: Node i in this layer computes the contribution of i-th rule towards the overall output using the node function (Eq. (4)):

$$O_i^4 = \bar{w}_i f_i = \bar{w}_i (p_i x + q_i y + r_i) \tag{4}$$

where $\bar{w}_i$ is the output of layer 3 and $\{p_i, q_i, r_i\}$ is the consequent parameter set to be determined during the training process.

Layer 5: The single node in this layer computes the overall output as the summation of contribution from each rule (Eq. (5)):

$$O_i^5 = \sum_i \bar{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \tag{5}$$

3. A Brief Review of ARIMA Models

In real world applications, many processes can be represented using the time series as follows: $x(t-p),...,x(t-2),x(t-1),x(t)$. For making a prediction using time series, a great variety of approaches are available. Prediction of scalar time series $\{x(n)\}$ refers to the task of finding estimate $x(n+1)$ of next future sample $x(n+1)$ based on the knowledge of the history of time series (Rank, 2003).

Linear prediction, where the estimate is based on a linear combination of N past samples, can be represented as below (Eq. (6)):

$$x(n+1)=\sum_{i=0}^{N-1}a_i x(n-i) \qquad (6)$$

with prediction coefficients $\alpha_i, i=0,1,...,N-1$.

Introducing general nonlinear function $f(.):R^n \rightarrow R$ applied to vector $x(n)=[x(n),x(n-M),...,x(n-(N-1))M]^T$ of the past samples, nonlinear prediction approach $x(n+1)=f(x(n))$ is reached (Rank, 2003).

Traditionally, a time series forecasting problem is tackled using linear techniques such as Auto Regressive Moving Average (ARMA) and Auto Regressive Integrated Moving Average (ARIMA) models. ARIMA model of a time series is defined by three terms (p,d,q). Identification of a time series is the process of finding integer usually very small (e.g., 0,1, or 2) values of p, d, and q that model the patterns in the data. When the value is 0, the element is not needed in the model. The middle element, d, is investigated before p and q. The goal is to determine if the process is stationary, and, if not, to make it stationary before determining the values of p and q.

The simplest form of the ARIMA model is called the autoregressive model and is similar to linear regression model. Let z_t stand for the value of a stationary time series at time t. By autoregressive, we assume that current z_t values depend on past values from the same series (Eq. (7)). In symbols, at any t

$$z_t = C+\Phi_1 z_{t-1}+\Phi_2 z_{t-2}+...+\Phi_p z_{t-p}+a_t \qquad (7)$$

Where C is the constant level, $z_{t-1}, z_{t-2},..., z_{t-p}$ are past series values (lags), the Φ are coefficients (similar to regression coefficients) to be estimated, and a_t is a random variable with zero mean and constant variance. The a_t are assumed to be independent and represent random error or random shocks. Just as in regression, some of the Φ coefficients may be zero. If z_{t-p} is the furthest lag with a nonzero coefficient, the AR model is of order p, denoted as $AR(p)$.

In the case of autoregressive model in which the current observation depends on all past observations we would have too many parameters Φ to make estimation possible. However, if the Φ themselves are given by a few parameters, then estimation becomes feasible. If, for example, $\Phi_i = -\theta^i$ so that (Eq. (8) – Eq. (11)):

$$z_t = -\theta z_{t-1} - \theta^2 z_{t-2} - \theta^3 z_{t-3} - ... + a_t \qquad (8)$$

Solving for a_t gives

$$a_t = z_t + \theta z_{t-1} + \theta^2 z_{t-2} + \theta^3 z_{t-3} \qquad (9)$$

Multiplying the expression for a_{t-1} by θ, we obtain

$$\theta a_{t-1} = \theta z_{t-1} + \theta^2 z_{t-2} + \theta^3 z_{t-3} \qquad (10)$$

So by subtraction

$$a_t - \theta a_{t-1} = z_t \qquad (11)$$

This type of model represents a moving average model (MA) since z_t is a weighted average of the uncorrelated a_t 's. in general we can model z_t as (Eq. (12)):

$$z_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - ... - \theta_q a_{t-q} \tag{12}$$

Such a model is called a moving average model of order q or $MA(q)$.

We can combine the AR i MA models for stationary series to account for both past values and past shocks. Such a model is called an $ARMA(p,q)$ model with p order AR terms and q order MA terms (Eq. (13)):

$$z_t = \Phi_1 z_{t-1} + \Phi_2 z_{t-2} + ... + \Phi_p z_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - ... - \theta_q a_{t-q} \tag{13}$$

However, most real series show a trend, an average increase or decrease over time. Series also show cyclic behavior. We can remove trends and cycles from a series through differencing. For example, suppose t is in months and Y_t is a series with a linear trend. That is, every month the series increases on average by some constant amount C . Since $Y_t = C + Y_{t-1} + N_t$ where N_t is a random "noise" component with expectation zero, then the differences, $Y_t - Y_{t-1}$ are equal $C + N_t$. Thus, $N_t + C$ is a stationary series with the linear trend removed. We could now apply the ARMA model to $z_t = C + N_t$, even though it is not appropriate to do so to Y_t directly. One an ARMA model for z_t is known, we could reverse the differencing to form the original Y_t from the z_t . We term this process integration. The combined model for the original series Y_t , which involves autoregression, moving average, and integration (I) is termed the $ARIMA(p,d,q)$ model, with p AR terms, d differences, and q MA terms.

To simplify notation, the $ARIMA$ literature introduces the "backshift" operator, B . B operates on the observation Y_t by shifting it one point back in time. Thus, (Eq. (14) – Eq. (17)):

$$B(Y_t) = Y_{t-1} \tag{14}$$

B may be exponentiated in this manner:

$$B^2 = B[B(Y_t)] = B(Y_{t-1}) = Y_{t-2} \tag{15}$$

In general,

$$B_k(Y_t) = Y_{t-k} \tag{16}$$

For the general case, involving differencing d times,

$$z_t = (1-B)^d Y_t = \nabla^d Y_t \tag{17}$$

where the ∇ operator is substituted for $(1-B)$ and serves as a differencing operator. Using backshift notation, the $ARIMA$ model Eq. (18):

$$z_t = C + (\Phi_1 z_{t-1} + \Phi_2 z_{t-2} + ... + \Phi_p z_{t-p}) - (\theta_1 a_{t-1} + \theta_2 a_{t-2} + ... + \theta_q a_{t-q}) + a_t \tag{18}$$

Becomes (Eq. (19)):

$$z_t = C + (\Phi_1 B + ... + \Phi_p B^p) z_t + (1 - \theta_1 B - ... - \theta_q B^q) a_t \tag{19}$$

To simplify notation further, the autoregressive polynomial

$$(1 - \Phi_1 B - ... - \Phi_p B^p)$$

ss often abbreviated as $\Phi(B)$, and the moving average polynomial

$$(1-\theta_1 B - ... - \theta_q B^q)$$

is abbreviated as $\theta(B)$. Substituting, the model is compactly written as (Eq. (20) and Eq. (21)):

$$\Phi(B)\nabla^d Y_t = C + \theta(B)a_t \tag{20}$$

or

$$\nabla^d Y_t = \frac{C}{\Phi(B)} + \frac{\theta(B)}{\Phi(B)} a_t \tag{21}$$

4. Case Study Characteristics and Data Analysis

The city of Belgrade has its own commuter rail transit system called Beovoz which is operated by Serbian Railways. Beovoz (Беовоз) provides mass-transit service within the Belgrade metropolitan area. Belgrade suburban railway system connects the suburbs and nearby cities to the west, north and south of the city. Beovoz is operated by Serbian Railways.

In this paper we focused our investigation on a line Pancevo Bridge – Batajnica. This line belongs to Bg-Train as urban rail system that serves the city of Belgrade. It is operated by the public transit corporation GSP Belgrade and is a part of the integrated BusPlus system. Bg Train shares tracks and stations with the commuter rail system Beovoz.

4.1. The Data

A passenger flow dataset is collected to investigate the viability of the proposed ANFIS approach for forecasting the passenger flow. Available data belong to nineteen consecutive years from 1993. to 2011. (Fig. 2)

The dataset for average daily passsenger flow on Bg-train line is not available and it is evaluated on the base of an average daily number of passengers in Beovoz system and the share of Bg-train line in total passenger flow within the Beovoz system. This share is evaluated with respect to line-based passenger flow recordings performed by the Transport Institute CIP in time period from 1993 to 1995, 1997 to 2001, and for 2007 year (Milanovic, 2012)

Passenger flow recordings for Bg-train have also been performed for 2010 and 2011 but this time by the GSP Belgrade. For the time period from 2008 to 2010 we used a special function in Matlab to fill in missing values.

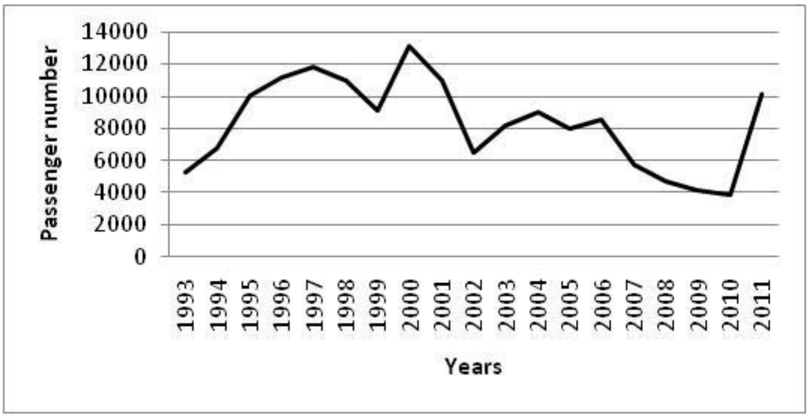

Fig. 2.
Average Daily Passenger Flow on Bg-Train Line

4.2. Explanatory Variables

To obtain accurate forecasts, the most relevant factors should be determined and included in the model (Owen and Phillips, 1987). We hypothesize that the demand for urban rail travel as measured in this study is a function of population, employment, economic activity and car ownership in narrower gravitation area surrounding considered Bg-train line.

It is well known and widely recognized that mobility and mode choice is affected by the urban population density. In general, dense cities are associated with a high use of public transport. Dense cities are expected to have large transport systems since supply becomes profitable (or less expensive) by taking advantage of scale and density economies. Employment level is a common demographic variable used in causal analysis of rail passenger demand (Liu, 1993).

We also hypothesize that the demand for urban rail travel on Bg-train line is a function of the level of economic activity. We used the GDP output series as the economic activity variable. The relationship between the demand for urban rail travel and this variable would be the outcome of two opposing tendencies. On the one hand, high income people would tend to do more travelling both in the course of their work and for leisure, but they would also tend to own more cars and therefore be less likely to make a given trip by rail. Cars undoubtedly represent an important source of competition for city rail passenger service. Rising car ownership increases the competition against the railway, and consequently should have a negative impact on rail demand.

5. Comparison of ANFIS and ARIMA Models for Urban Rail Passenger Demand Forecasting

In this section, the performances of the ANFIS are compared with a traditional linear ARIMA model. The models were evaluated for their ability to produce accurate forecasts for urban rail passenger flow on Bg-train line. The mean square error is used as the main criteria to assess the derived models.

5.1. ANFIS

In this section, ANFIS is trained and then used to predict the next year average daily passenger flow on Bg-train line. All input and output data were re-scaled to lie in the range 0-1. The number of membership functions (MFs) assigned to each input variable is chosen empirically, that is, by plotting the data set and examining it visually, or simply by trial and error. The model uses a hybrid learning algorithm to identify the parameters for Sugeno-type fuzzy inference systems. The first 60% of data was used for training the model and the 40% for testing the model. The training error goal is set to 0. The model was trained many times using different time of epochs. Finally, the best results obtained at 300 epochs. The Root Mean Square Error (MSE) was found to be around 0.00027 for training and 0.26821 for testing data. The output of the model is the next year's average daily passenger demand which is 9206 passengers. Table 1 summarizes the parameters of the system. Performance analysis of the ANFIS model is realized using MATLAB's ANFIS Toolbox and GUI editor.

Table 1
ANFIS Parameter Types and Their Values Used for Training

ANFIS parameter type	Value
MF type	Trimf
Number of MFs	3
Output MF	Constant
Number of Nodes	193
Number of linear parameters	81
Number of nonlinear parameters	36
Total number of parameters	117
Number of training data pairs	11
Number of testing data pairs	8
Number of fuzzy rules	81

5.2. ARIMA

Performance analysis of the ARIMA model is done using the trial version of SPSS package program. The best fit model obtained is ARIMA (1,0,0). Real and ARIMA system outputs related to urban rail passenger forecasting are given in Fig. 3.

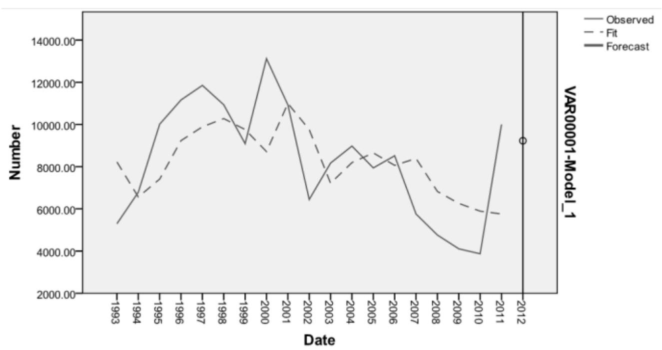

Fig. 3.
Real and ARIMA System Outputs Related to Urban Rail Passenger Flow Forecasting

The output of the model is the next year's average daily passenger demand which is 9230 passengers. The forecasting results for ARIMA are slightly different with respect to ANFIS model. The estimate equation obtained by the ARIMA (1, 0, 0) model is as follows:

$$Z_t = 8229.209 + 0.576 Z_{t-1}$$

Accuracy of the ARIMA (1,0,0) model, ACF and PACF corelograms are examined and shown in Fig. 4.

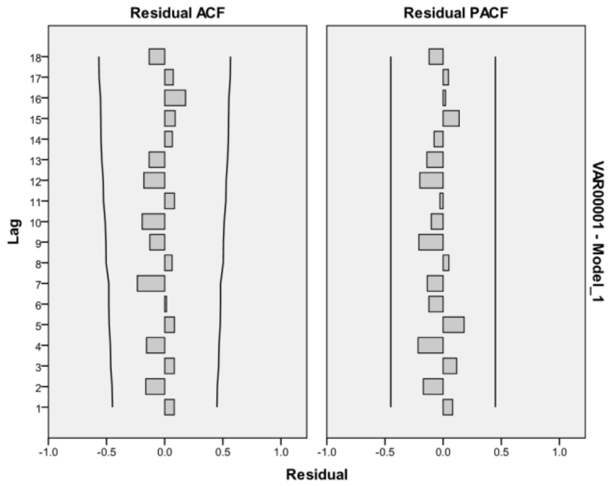

Fig. 4.
Residual ACF and PACF Corelograms of the ARIMA(1,0,0) Model

5.3. Comparison Results

In this study, four inputs and one output are used to forecast the urban rail passenger volume on Bg-train line in the ANFIS and ARIMA models. The performance comparisons of the ANFIS and ARIMA models due to RMSE – root mean square error criteria are shown in Table 2.

Table 2
Performance Comparison of ANFIS and ARIMA Models

	RMSE
ANFIS	0.00027
ARIMA	0.02356

As can be understood from Table 2, compared to the ARIMA, the ANFIS due to RMSE criteria gives much better results.

6. Conclusion

Short-term passenger flow forecasting can provide useful information for decision makers of urban rail passenger systems. An accurate and stable passenger flow forecasting model can be applied to support transportation system management such as operation planning, revenue planning, and facility improvement. ANFIS has gained a great popularity in time-series prediction because of its simplicity and reliability.

The performance of ANFIS and ARIMA is compared for the short-term forecasting the passenger flow volume on Bg-Train line. Both models give very close forecasts of the one-year ahead number of passenger on Bg-train line but compared to the ARIMA, the ANFIS can more efficiently capture dynamic behavior of the urban rail passenger flow on Bg-train line.

Acknowledgement

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References

Box, G.E.; Jenkins, M. 1976. *Time series analysis: forecasting and control*. Holden-Day, San Francisko, USA. 575 p.

Clark, S. 2003. Traffic prediction using multivariate nonparametric regression, *Journal of Transportation Engineering* 129(2): 161–168.

Dougherty, M. 1995. A review of neural networks applied to transport, *Transport Research Part C* 3(4): 247–260.

Jang, J.R. 1993. ANFIS: adaptive network based fuzzy inference system, *IEEE Transactions on Systems, Man and Cybernetics* 23(3): 665–683.

Liu, Z. 1993. *Determinants of Public Transit Ridership: Analysis of Post World War II, Trends and Evaluation of Alternative Networks*. Harward University, USA. 167 p.

Milanovic, Z. 2012. *Electronic business in transport planning based on modular application of micro-simulation models*, Ph.D. thesis, Graduate School of Business Studies, Megatrend University, Belgrade.

Owen, A.D.; Phillips, G.A. 1987. The characteristics of railway passenger demand, *Journal of transport economics and policy*, 21(3): 231-253.

Pribyl O.; Goulias K. 2003. On the application of adaptive neuro-fuzzy inference system (ANFIS) to analyze travel behavior, In *Proceedings of the 82nd Annual Transportation Research Board Meeting*. Washington, D.C., USA.

Rank, E. 2003. Application of Bayesian trained RBF Networks to nonlinear time-series modeling, *Signal Processing* 83: 1393-1410.

Smith, B.L.; Williams, B.M.; Keith Oswald, R. 2002. Comparison of parametric and nonparametric models for traffic flow forecasting, *Transportation Research Part C* 10(4): 303–321.

Tang, Y.F.; William H.K.; Pan L.P. 2003. Comparison of four modeling techniques for short-term AADT forecasting in Hong Kong, *Journal of Transportation Engineering* 129(3): 271–277.

Vlahogianni, E.I.; Golia, J.C.; Karlaftis, M.G. 2004. Short-term traffic forecasting: overview of objectives and methods, *Transport Reviews* 24(5): 533–557.

Wang, Y.; Papageorgiou, M. 2007. Real-time freeway traffic state estimation based on extend Kalman filter: a case study, *Transportation Science* 42(2): 167–181.

A CASE STUDY TO REDUCE ACCIDENT RATES AND WAITING TIMES AT A SELECTED ROUNDABOUT

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Abstract: In this study, the crash statistics for the roundabouts in Izmir, Turkey were analyzed. One of the roundabouts with the highest crash rates was selected and countermeasures for crash reduction at the selected roundabout were identified. The expected benefits were estimated by the use of before and after crash analysis data found in the literature. In addition to the countermeasures for crash reduction, the maximum waiting times at the roundabout were analyzed and minimized. The roundabout has 28 units of traffic signals. Phases of the traffic signals at the roundabout were evaluated for all directions and improved according to the Highway Capacity Manuel traffic signal timing formulas. The improved phases of the traffic signals were evaluated using ARENA simulation software. The maximum waiting time reduction at the roundabout was documented using the outputs of the simulation model. The fuel usage for the vehicles and the amount of emissions transmitted to the atmosphere are expected to reduce due to the reduction in the maximum waiting times at the roundabout.

Keywords: traffic signals, simulation, roundabouts

1. Introduction

In today's world, traffic accidents are still one of the major causes of fatalities. In order to provide a safe traffic environment for users and decrease the traffic accident rates, all responsible organizations make an effort to increase the level of awareness of drivers, pedestrians, and passengers. The efforts resulted in a decline in the traffic accident fatality rates; however, traffic accidents are still one of the biggest causes of fatalities in Turkey.

Traffic accidents cause fatalities, major and minor injuries, and property damages. According to *Turkish Statistical Institute (2011)*, the number of traffic accident is on rise year by year. In 2011, the total number of traffic accidents exceeded one million in Turkey. When the statistics of Europe and North America compared, the number of accidents in Turkey is higher than many countries.

In this study, Osman Kibar Roundabout, one of the biggest intersections in Izmir, Turkey was investigated. The roundabout connects major cities Manisa, Ankara, and Istanbul to Izmir and it has one of the highest observed traffic volumes in Izmir. Osman Kibar Roundabout is one of the roundabouts with the highest accident rates in Izmir, which made it the subject of this study.

This study has three main objectives. These are reducing the number of accidents and increase the roundabout safety, decreasing the waiting times and queues in the traffic lights, and reducing the fuel usage for the vehicles to protect the environment via reduced waiting times.

2 Background

The crash rate data at the roundabout was analysed. According to vehicle crash statistics from 'Tepecik Statistical Department', 347 accidents were reported in Osman Kibar roundabout from January 1, 2007 through December 31, 2008. Moreover, the data taken from this department indicate that the accidents in this roundabout were not related with weather conditions. The major causes of the accidents at the Osman Kibar roundabout were inadequate signing and faulty drivers.

The literature review resulted in many countermeasures to reduce the number of accidents at roundabouts. Some of them may be implemented and help to reduce the accidents at Osman Kibar roundabout. The countermeasures to prevent the accidents at Osman Kibar roundabout are given below along with their crash reduction potentials.

2.1 Speed Bumps

Speed bumps are widely used for reducing the speeds of the vehicles. The height of speed bumps changes between 7.6 and 10 cm. and the depth of the speed bumps is generally less than or near to 30 cm. The length of speed bumps typically changes between 300 and 430 cm dependent on the road width. The speed bumps are useful to reduce speed of the traffic.

However, when vehicles pass through the speed bumps with high speeds, especially for sport cars with low height, it may cause property damages (Institute of Transportation Engineers, 2004).

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Speed bumps are generally important traffic features for preventing the accidents; at the same time, they are cost effective. Before and after crash analysis shows that the accident reduction rates for speed bumps are nearly 5 % (Lawson, R.W. 2006.)

2.2 Rumble Strips

Rumble Strips alert or warn inattentive drivers to potential danger by causing a tactile vibration and audible rumbling. Rumble strips are useful and cost effective at reducing accidents due to inattention. According to Zwahlen et al, 2005, rumple strips are very effective to reduce accidents and may reduce run off the road crash rates as much as 65%. The use of the rumble strips at Osman Kibar roundabout would warn drivers especially when they are running of the road.

2.3 Flashing Beacon

A Flashing Beacon is a traffic signal which provides advance warning about the "red light ahead" conditions. It has one or multiple signal applications before the traffic signals at the intersections (Manual on Uniform Traffic Control Devices, 2009). At Osman Kibar roundabout the use of flashing beacons to warn drivers about the red light situation will help calming the traffic and reduce the traffic flow speed.

2.4 Raised Pavement Marker

According to Town of Herndon Traffic Engineering Improvement Committee, 2011, raised pavement marker is used to increase the road safety. They are little buttons on the road to warn driver when they are changing lanes. Markers are usually made up with different materials or shapes according to implementation locations. The use of reflective pavement markers at Osman Kibar roundabout will increase the visibility of the lanes for drivers especially at night and rainy weather conditions. White markers may be used for lane markings and to mark the right pavement edge and red markers may be used to warn about wrong travelling direction.

2.5 Changeable Message Signs

Changeable message signs (CMSs) can show any massages to warn drivers. These signs can be portable or permanent. However, permanent CMSs are much bigger than portable CMSs. They warn drivers about major crashes, unexpected or emergency situations. (Zwahlen et al, 2005). Using the portable CMSs to display information about weather helps to improve the safety (Zwahlen et al, 2006). The five countermeasure found in the literature showed potential for improved delineation through the roundabout and improved guidance for the drivers. There are many successful applications of these countermeasures in which the crash rates have been reduced. These countermeasures may be implemented at the Osman Kibar roundabout and their effects may be investigated using before and after crash statistics.

3 Problem Definition

Osman Kibar roundabout connects 10 different major and arterial roads in Izmir. Both heavy vehicles and passenger vehicles use these roads. There are two bridges (Izmir-Istanbul) and two tunnels (Izmir-Ankara) crossing through the Osman Kibar roundabout. However, tunnels and bridges do not directly affect the traffic at this roundabout. Five roads for entrance and five roads for exit are located at the roundabout. These entrance and exit points are named as Izmir Downtown, Aegean University Campus, Ankara highway, Istanbul highway and Bornova city center shown in Fig. 1. There are 28 units of traffic signals and 32 units of traffic signs are used at Osman Kibar roundabout, which also includes pedestrian signals.

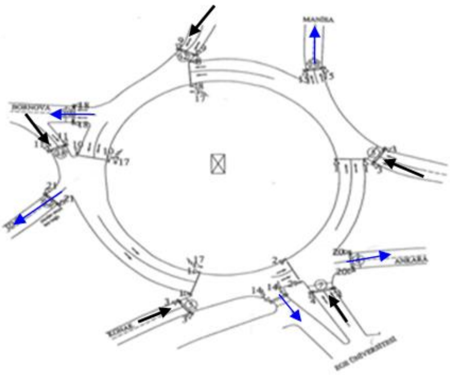

Fig. 1.
Osman Kibar Roundabout
Source: İzmir Traffic Signalization Department, 2012

Osman Kibar roundabout has one of the highest crash rates in the city of Izmir compared to other roundabouts. For this reason, countermeasures for crash reduction at this roundabout have been identified. The biggest cause of the high crash rates in the Osman Kibar Roundabout is connection between inter-city roads and local roads. The rush hour traffic is also very crowded and the traffic signs at the roundabout are not enough to warn the drivers. In addition, phases of the traffic signals at the roundabout have been evaluated for all directions and improved according to the Highway Capacity Manual guidelines.

3.1 Model Data and Assumptions

The traffic volume observations at Osman Kibar Roundabout are collected for 30 minutes in the morning and 30 minutes in the evening during rush hour traffic. The numbers of vehicles shown in Table 1 are for 30 minutes time interval. These numbers are multiplied by two to find hourly traffic volumes at Osman Kibar roundabout.

Table 1
Observed Traffic Volumes at Osman Kibar Roundabout

Entrance	Cars	Vans	Trucks	Buses	Tır	Total number of vehicle	Percentage of small vehicle	Percentage of large vehicle
Izmir Downtown	415	129	13	27	16	600	69	31
Agean University Campus	69	7	2	31	0	109	63	37
Ankara Road	401	54	11	17	23	506	79	21
Istanbul Road	416	61	20	16	56	569	73	27
Bornova	375	136	22	30	28	618	60	40

Source: İzmir Traffic Signalization Department, 2012

The types of vehicles using the Osman Kibar Roundabout were assumed to be composed of small and large vehicles. Cars are taken as small type of vehicles and vans, trucks, and buses are taken as large type of vehicles. The speed limit at the Osman Kibar Roundabout is 50 km/h and it was assumed that the average speed of the vehicles at the roundabout was same as the speed limit.

The small types of vehicles were assumed to be 3 meters long and the long types of vehicles were assumed to be 13 meters long. The car following distances for all vehicles was assumed to be the same, 2 meters (Pline, J. L. 1999).

Vehicles move through two lanes in the roundabout. It was assumed that 60% of all vehicles move on the right lane and the remaining move on the left lane. The lane changing behavior of the vehicles in the roundabout was not considered in the analysis, therefore the vehicles can directly exit the left lane of the roundabout.

There are 28 traffic signal heads in the roundabout; however only eight of them affect the traffic excluding the pedestrian traffic signals. The current traffic signal timing for the eight lights are given in Table 2.

Table 2
Signal timing for Osman Kibar Roundabout

Lights	Red signal timing	Green signal timing	Yellow signal timing	Red and yellow signal timing
Light 1	43	44	3	2
Light 2	13	74	3	2
Light 3	49	38	3	2
Light 4	79	8	3	2
Light 8	28	59	3	2
Light 9	64	23	3	2
Light 10	49	38	3	2
Light 11	43	44	3	2

Source: Unpublished Report, 2010

4. The Model

The data collected and gathered for the roundabout was used to model the roundabout traffic using Arena Simulation Software. The interarrival time distributions were assumed to follow a negative exponential distribution (May, 1993). The Arena simulation software has an option to model the traffic using conveyors of the system. In this model, the vehicles were taken as entities moving along the conveyors.

Accumulating conveyors were used in the model. In accumulating conveyors when a vehicle stops moving on the conveyor (e.g. red light), the following vehicles continue moving until they reach the vehicle at the front. The model simulates only two cases for the traffic signals; green phase and red phase. The yellow phase of the traffic signals was added to the red phase duration.

4.1 Performance Measures

The simulation model can be developed to generate one or multiple performance measures. In this study, the waiting times at the traffic signals and the queue lengths at the traffic signals during red light phases were investigated for each traffic signal i at the roundabout, waiting time(WT_i), queue length (QL_i). In addition, other performance measures relevant in identifying the reduction in the fuel usage were investigated. The time spent in system for each type of vehicle (ST_v).

4.2 Validation and Verification

Verification of a model is the process of ensuring that the model operates as intended. The roundabout model was verified using the sub-models and evaluating each of these sub-models. Animation was another tool used for verification and validation purposes of the model. According to Pegden et al.(1995), animation is perhaps the most effective tool for performing basic verification. Through animation, it is easier to follow operation of the overall system and detect errors in the program.

In addition, validation means the process of ensuring that a model represents reality. Face validity approach was used to validate the simulation model of the roundabout. The behaviour of the model was compared with the real system and the comparison showed that the model is similar with real system.

5 Determining Vehicular Signal Timing Requirements

One of the objectives of this study was to reduce the waiting times at the traffic signals in the roundabout. The traffic signal cycle time and phases of the green, red, and yellow lights were determined using Highway Capacity Manual Traffic Signal Timing requirements. Arena simulation software was then used to compare the recalculated traffic signal phases with the current traffic signal phase times.
The Institute of Transportation Engineers handbook, 2004 recommends the following methodology for signal timing:

Step 1. Determining the length of the yellow or change interval (Eq. (1)):

$$y = t + \frac{1.47\ S_{85}}{2a + (64.4 \text{ x } 0.01G)} \tag{1}$$

where:

y: length of the yellow interval, s
t: driver reaction time, s (default 1.0s)
S_{85}: 85th percentile speed of approaching vehicles, mi/h
a: deceleration rate of vehicles, ft/s^2 (default 10.0 ft/ s^2)
G: grade of approach, % (default -2.5)
64.4: twice the acceleration rate due to gravity, which is 32.2 ft/s^2

The formula above provides us the length of the yellow. This y helps to calculate the other steps below.

Step 2. Determining the length of all-red clearance if some pedestrian exists (Eq. (2)):

$$ar = \max\left[\left(\frac{w+L}{1.47\ S_{15}}\right), \left(\frac{P}{1.47\ S_{15}}\right)\right] \quad ; (2)$$

S_{15} = S - 5
S_{85} = S + 5

where:

ar: length of all-red phase, s (default 1.0s)
w: distance from the departure STOP line to the far side of the farthest conflicting traffic lane, ft. (default 48 ft.)
P: distance from the departure STOP line to the far side of the farthest conflicting crosswalk, ft. (default 60 ft.)
L: length of a standard vehicle, usually taken to be 18-20 ft.
S_{15}: 15th percentile speed of approaching traffic, mi/h.
S: average speed, mi/h (50 km/h = 31mi/h)

Step 3. Determining Lost Times

In this section, Highway Capacity Manual recommends the following default values. (Eq. (3) – (Eq. (5)):

$$Y = y + ar \tag{3}$$

$$t_L = l_1 + l_2 \tag{4}$$

$$L = \sum_i^n t_{Li} \tag{5}$$

where:

t_L : total lost time, s/phase
l_1 : Start-up lost time (default 2.0 s/phase)
l_2 : Clearance lost time, s/phase
e : Motorist use of yellow and all-red (default 2.0 s/phase)
L: total lost time per cycle, s.
n: number of discrete phases in cycle (5 phases)
t_{Li}: total lost time for phase i, s

Step 4. Determining Cycle Length (Eq. (6)):

$$C_{des} = \frac{L}{1-\left[\frac{V_c}{1615*PHF*(v/c)}\right]} \tag{6}$$

where:

Cdes : desirable cycles length, s.
L: total lost time per cycle, s/phase (number of phases in a cycle is 5)
PHF: peak hour factor (95%)
v/c : desired volume capacity ratio (1.00%)
V_c : critical volume. This is found that total number of vehicles at an intersection is added and then the total is divided by number of lanes.

Step 5. Determining Green Time (Eq. (7)):

$$g_{TOT} = C - L \tag{7}$$

where:

g_{TOT}: Total effective green time in cycle, s and C, L as previously defined (Eq. (8)):

$$g_i = g_{TOT} * \left(\frac{V_{ci}}{V_c}\right) \tag{8}$$

where:

g_i: Effective green time for phase i, s.
V_{ci}: Critical lane volume for phase or sub-phase i, veh/h
V_c: Sum of the critical lane volumes, veh/h (Eq. (9)):

$$Gi = gi - Yi + tLi \tag{9}$$

where:

Gi = actual green time for phase i, s
gi = effective green time for phase i, s
Yi = total of yellow and all red intervals for phase i, s
t_{Li} = total lost time for phase i, s.

The formulas were used to determine the traffic signal phases for the selected eight traffic signals in the roundabout. The traffic signal phase timings are given in Table 3.

Table 3
Alternative Signal timing for Osman Kibar Roundabout

Lights	Red signal timing	Green signal timing	Yellow signal timing	Red and yellow signal timing	All-red signal timing
Light 1	81	62	3	2	1
Light 2	33	110	3	2	1
Light 3	85	58	3	2	1
Light 4	133	10	3	2	1
Light 8	79	64	3	2	1
Light 9	86	57	3	2	1
Light 10	85	58	3	2	1
Light 11	81	62	3	2	1

6. Results

The simulation run length was assigned as 3600 seconds since the maximum waiting times and longest queues may be observed during the rush hours. The model was run for 75 replications in order to get independent and random outputs for the simulation. In addition, 10% of the simulation run length (360 seconds) was used as the warm-up period in the model. It provided enough time for the roundabout to be in the steady-state conditions.

The waiting time of the vehicles at the traffic signals, the number of vehicles waiting at the traffic signals, and the queue length at the traffic signals were recorded in the simulation model output to be able to compare the current and the improved traffic signal timings.

The performance measures for the current conditions, using the current traffic signal timings, were summarized below in Table 4. The output data was generated using the Arena simulation model. The name of the light number includes information about the related conveyor name and the lane (i.e. light name/convey name-lane). The waiting time columns represent the queue waiting time at the related lights. As seen Table 4, the maximum average waiting time observed at the traffic signals is at the right lane of the traffic signal 9 as 260.75 seconds and the maximum waiting time at the traffic signals is observed as 976 seconds for the right lane of the traffic signal 9. The maximum average queue length observed at the traffic signals is 104 meters long.

Table 4
Performance Measures for the Current Traffic Signal Timing from ARENA Simulation Model Results

Replication Time=3600 seconds per run							
Lights Number	Waiting Time (WT)					QL	
	Av. Waiting Time (sec)	Av. Min.Value (sec)	Av. Max. Value (sec)	Min. Value (sec)	MaxValue (sec)	Av. (m)	Max (m)
Light 1/i-R	0.137	11.28	15.89	0	53.36	80.3	90
Light 1/i-L	0.3730	0.206	0.676	0	14.96	74.2	90
Light 1/c-R	0.303	0.035	0.775	0	29.71	51.5	80
Light 1/c-L	0.133	0.027	0.381	0	29.78	2.4	15
Light 2/b-R	0.013	0.008	0.017	0	1.65	54.8	55
Light 2/b-L	0.01	0.007	0.015	0	0.071	53.6	55
Light 3/a-R	19.52	17.35	23.49	0	83.17	35	35
Light 3/a-L	15.80	13.90	18.35	0	61.87	35	35
Light 3/f-R	18.21	15.30	21.39	0	69.43	30	30
Light 3/f-L	16.11	12.97	18.29	0	59.86	30	30
Light 4/d-R	29.04	23.58	33.57	0	94.87	29.9	30
Light 4/d-L	22.415	17.27	28.89	0	83.87	25.5	30
Light 8/e-R	6.89	5.049	8.896	0	49.78	104	105
Light 8/e-L	3.59	2.047	4.962	0	49.49	101.	105
Light 9/h-R	260.75	175.3	324.0	0	976	30	30
Light 9/h-L	84.64	32.73	150.7	0	473	30	30
Light10/g-R	0.025	0.015	0.036	0	1.94	90	90
Light10/g-L	0.024	0.014	0.033	0	1.79	89	90
Light11/j-R	14.892	13.42	17.85	0	56.81	30	30
Light11/j-L	13.018	11.28	15.09	0	53.36	30	30

Table 5 and 6 show the time spent in the system for each types of vehicle. It is significant point that small vehicles spent more time than large vehicles. The minimum average time spent in the system is 36.726 seconds and the maximum average time spent in the system is 1954.1 seconds for the current system. The time spent in the system was calculated by finding the difference between the vehicle exit time from the system and vehicle entrance time in the system.

Table 5
Current Model Results from ARENA

System Time (ST)-Right Lane	**Small Types of Vehicles**			**Large Types of Vehicle**		
	Average System Time	Min. System Time	Max. System Time	Average System Time	Min. System Time	Max. System Time
Ankara-Exit	844.26	728.47	1000.6	578.94	413.90	751.60
Istanbul-Exit	642.17	552.76	751.47	468.94	315.13	626.92
Bornova-Exit	483.90	384.05	599.92	287.96	181.94	430.65
Izmir-Exit	375.29	288.99	476.00	240.74	116.31	385.33
Ege-Exit	243.48	63.270	534.88	164.66	56.646	459.17

Table 6
Current Model Results from ARENA

System Time (ST)-Left Lane	**Small Types of Vehicles**			**Large Types of Vehicle**		
	Average System Time	Min. System Time	Max. System Time	Average System Time	Min. System Time	Max. System Time
Ankara-Exit	51.413	37.234	78.457	47.586	36.726	67.156
Istanbul-Exit	532.62	410.04	656.16	390.53	214.00	612.28
Bornova-Exit	414.53	286.92	567.19	260.01	121.58	387.67
Izmir-Exit	328.97	232.79	455.75	208.85	113.27	348.12
Ege-Exit	1781.6	1592.8	1954.1	468.94	315.13	626.92

The recalculated traffic signal times based on the highway capacity manual were used to find out the performance measures for the improved system using Arena simulation model.

The maximum waiting time at the traffic signals was observed for the right lane of the traffic signal 4 as 249 seconds and the maximum average waiting time was observed for traffic signal 4 right lane as 52.18 seconds. The maximum average queue length observed is 105 meters.

Table 7
Performance Measures for the Recalculated Traffic Signal Timing from ARENA Simulation Model Results

Replication Time=3600 seconds per run							
Lights Number	**Waiting Time (WT)**					**QL**	
	Av. Waiting Time (sec)	Av. Min.Value (sec)	Av. Max. Value (sec)	Min. Value (sec)	MaxValue (sec)	Av. (m)	Max (m)
Light 1/i-R	22.19	21.42	23.18	0	32.29	54.9	55
Light 1/i-L	20.5	19.34	21.43	0	32.32	55	55
Light 1/c-R	44.37	40.92	47.83	0	78.06	80	80
Light 1/c-L	8.01	5.04	10.9	0	44.89	3.27	15
Light 2/b-R	24.38	19.82	29.96	0	86.09	54.9	55
Light 2/b-L	0.027	0.022	0.34	0	0.07	55	55
Light 3/a-R	16.43	14.42	18.92	0	78.14	35	35
Light 3/a-L	14.14	11.32	16.87	0	67.91	33.8	35
Light 3/f-R	39.97	35.02	43.63	0	127	30	30
Light 3/f-L	26.38	20.57	30.93	0	106	30	30
Light 4/d-R	52.18	39.3	66.31	0	249	29.6	30
Light 4/d-L	40.25	27.39	52.02	0	138	6.4	30
Light 8/e-R	1.79	1.58	2.20	0	62.45	105	105
Light 8/e-L	1.78	1.49	2.27	0	45.89	104	105
Light 9/h-R	15.14	9.04	30.40	0	178	30	30
Light 9/h-L	4.41	2.04	8.02	0	93.89	30	30
Light10/g-R	22.0	17.36	28.07	0	60.26	89.9	90
Light10/g-L	21.83	17.16	26.48	0	59.12	89.9	90
Light11/j-R	35.62	32.4	39.56	0	106	30	30
Light11/j-L	29.14	25.12	33.84	0	95.91	30	30

Table 8 and 9 show the time spent in the system for each type of vehicle after the recalculation of the traffic signal phases. It is significant point that small vehicles spent more time than large vehicles. The minimum average time spent in the system is 74.043 seconds and the maximum average time spent in the system is 1478.2 seconds for the recalculated traffic signal phase times.

Table 8
Recalculated Traffic Signal Timing Model Results from ARENA for Right Lane

System Time (ST)-Right Lane	**Small Types of Vehicles**			**Large Types of Vehicle**		
	Average System Time	Min. System Time	Max. System Time	Average System Time	Min. System Time	Max. System Time
Ankara-Exit	1058.6	923.96	1210.9	878.45	710.26	1107.2
Istanbul-Exit	692.33	592.31	816.18	596.35	457.10	814.43
Bornova-Exit	809.09	655.50	1038.0	733.28	455.78	996.46
Izmir-Exit	572.03	487.70	681.61	519.40	383.85	739.83
Ege-Exit	635.34	137.70	1121.7	663.60	74.043	1478.2

Table 9
Recalculated Traffic Signal Timing Model Results from ARENA for Left Lane

System Time (ST)-Left Lane	**Small Types of Vehicles**			**Large Types of Vehicle**		
	Average System Time	Min. System Time	Max. System Time	Average System Time	Min. System Time	Max. System Time
Ankara-Exit	180.01	97.265	279.48	221.46	86.473	420.79
Istanbul-Exit	635.80	439.01	837.85	530.85	308.96	760.46
Bornova-Exit	725.13	549.00	861.98	680.62	443.75	1012.2
Izmir-Exit	502.82	357.53	684.86	431.61	285.29	607.23
Ege-Exit	1834.2	1645.1	2000.3	1771.3	1352.3	2273.6

7. Conclusions

The analysis of the waiting times of the vehicles at the traffic signals shows improvement when the maximum waiting times are observed. The maximum waiting times were decreased as much as 70% when the HCM traffic signal phase calculation formulas were used. The decrease in the average waiting times is expected to result in higher customer satisfaction and reduced fuel usage and emissions. The comparison of the maximum queue lengths at the traffic signals did not show any significant differences for the current and improved versions of the traffic signal timings.

In addition to comparison of the waiting times and queue lengths at the traffic signals, total time spent in the roundabout for the vehicles were compared. There has been 25% decrease in the maximum time spent in the system. The smaller travelling time in the roundabout would result in decreased emissions and reduced fuel usage for the vehicles. This study shows rather than making expert adjustments on the traffic signal timing, approved and proved methodologies should be used to adjust traffic signal timing and phases at the roundabouts.

Future work

The simulation model developed in this study has various simplifications and assumptions about the real system. The lane changing behavior is not modeled in the simulation. The study is also based on limited amount of hourly traffic volume data. The model will be modified and improved after additional data collection efforts.

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References

Chung C.A. 2004. *Simulation Modelling Handbook A Practical Approach*. CRC Press, 172-176

Institute of Transportation Engineers. Traffic Calming Measures - Speed Hump. Available from internet: <http://www.ite.org/traffic/hump.asp>

Lawson, R.W. 2006. Speed Humps Have No Significant Effect on Road Traffic Accidents. Available from internet: http://www.bromleytransport.org.uk/Speed%20Humps%20Have%20No%20Effect.pdf

Institute of Transportation Engineers. 2004. *Engineering Countermeasures to Reduce Red-Light Running (RLR)*. 3 p.

Zwahlen, H. T.; Oner, E. 2006. *Improved Work Zone Design Guidelines and Enhanced Model of travel Delays in Work Zones*. 37 p.

Manual Uniform Traffic Control Devices. 2009. Available from internet: <http://mutcd.fhwa.dot.gov/htm/2009/part4/part4l.htm#section4L03>

Town of Herndon Traffic Engineering Improvement Committee. 2011. *Neighborhood Traffic Calming Guide.* 10 p.

Zwahlen, H.T. et al. 2005. *Human Factors Opportunities to Improve Ohio's Transportation System*. 169-170.

Zwahlen, H.T.; Oner, E. 2006. *Improved Work Zone Design Guidelines and Enhanced Model of travel Delays in Work Zones.* 31 p.

May, A.D. 1990 *Traffic Flow Fundamentals.* Prentice Hall Inc.: 11-51.

Mannering, F.L. 2009. *Principles of Highway Engineering and Traffic Analysis.* Wıley, 236-266.

Turkish Statistical Institute. 2011. Traffic Accident Statistics (Road). Available from internet: <www.tuik.gov.tr/IcerikGetir.do?istab_id=70>

Pegden et al. 1995. *Introduction to Simulation with Using SIMAN*. McGraw Hill, 261-268

Pline, J.L. 1999. *Traffic Engineering Book* [Washington, D.C.]. Institute of Transportation Engineers.

Roess, R.P. et al. 2004. *Traffic Engineering Third Edition.* Prentice Hall Inc., 515-520.

PASSING MANEUVER: SURVEY, SOME MODELS AND SIMULATIONS

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Abstract: Head-on collisions cause more serious consequences of road accidents. These collisions are often due to an error of passing maneuver, on two-lane highways. The Passing Sight Distance (PSD) has always been a subject of studies and research that underline two series of factors that influence the PSD mainly: the first is the size and performance of vehicles, the second is the driver responses to environmental stimuli. This paper presents a study on the differences in some current procedures and guide-lines used to estimate minimum PSD requirements for highway design. The research starts from a field study of passing maneuvers on two-lane highways and from a collection of characteristic data of passenger cars. A data obtained by video recordings was used to study some factors influencing the distance value as the actual speed, acceleration (pickup) of vehicles. From the two classical rule models (flying passing, Italian rules, accelerative passing, U.S.) and some modified to these it has simulated the PSD values with data brought by physical characteristics and performance of the passenger cars sold in Italy. The data were corrected with some behavioral characteristics hypothesized for the drivers. It has been supposed three kinds of drivers: a prudent, a normal and an aggressive driver. These drivers with different behavioral kinds influence the simulation data. At the end is showed an analysis of different PSD models and a first approximate model that could link the PSD to the passing vehicle speed.

Keywords: Road safety, Passing Sight Distance, Rural road, Design speed, Driver behavior.

1. Introduction

The Passing Sight Distance (PSD) has been a subject of studies and research (for all Harwood et al., 2008, NCHPR 2005). that underline two sets of factors that influence the PSD mainly: the first is the size and performance of vehicles, the second is the driver behavior. This paper shows an analysis of the PSD through the two main models: the first model with a constant difference of speed between passing and passed vehicle (Flying passing, CNR 1973, 1980 and MIT 2002), the second model with the passing vehicle that accelerates while it changes lane (Accelerative passing, AASHTO Green Book (2004) and MUTCD 2009). For the second model of passing maneuver (accelerative model) it was considered that the driver could accelerate even in a different way and for a different length by the original AASTHO model.

This work starts from a survey on road of the real passing maneuvers. The survey has provided the characteristic values for about 100 passing maneuvers. At the same time it has built a database with car models sold in Italy from the years 2004 to 2010. For passenger cars was considered the size and performance characteristics (speed, acceleration and pickup). The measured values were split on engine displacement classes and the percentages of the survey samples were compared to the same percentage classes of Italian vehicle fleet. It has supposed, also, three kinds of driver behaviors: a prudent, a normal and an aggressive driver.

It has realized a simulation software for the random extraction of vehicles with physical characteristics and performance typical of different displacement classes in the real fleet. The drivers with different behavioral kinds influence the simulation data both of car classes and of car performances. For each extraction the program has provided values of three different kinds of drivers and vehicles that could realize the overtaking maneuver or not. The same sets of congruent values were used to calculate the mean of PSD for all the proposed models.

The aim of this work was to obtain a first critical comparison among the values of the PSD according to the different computational models and the values acquired with the road survey and check what model gives the best results with behavioral simulation data.

2. Passing Maneuver Models

Two different basic models have been used for the definition of PSD. The first has been chosen by Italian rules (Flying passing, CNR 1973, 1980 e MIT 2002), the second is the U.S. model (Accelerative passing, AASHTO Green Book 2004).

2.1. Flying Passing

The flying passing model has been adopted in Italy and has always been the same since the years seventies. According to rules the minimum PSD is equal to the sum of the product of the speed of the passing vehicle for the sum of the times needed to do three steps of the passing maneuver (see Fig. 1): in a first step the vehicle (A) moves on the opposite lane and start to passing the vehicle on his right (B), in a second step the vehicle (A) passes this vehicle and in last step the passing vehicle return on its lane. The safety minimum condition considers that a vehicle running in the opposite lane (C) has covered the same distance at the same speed of the passing vehicle in this same total time.

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The calculation assumptions are:

- the passing vehicle run at uniform speed equal to that of oncoming vehicle in the opposite lane;
- the passed vehicle run at slower speed than passing vehicle.

Given that (Eq. (1)):

$$PSD = 2 \bullet v(t_1 + t_2 + t_3) = 20 \bullet v \tag{1}$$

where: PSD = passing sight distance (m); v = speeds of the passing vehicle (m/sec); t_1 = time for passing vehicle to moves on the opposite lane equal to 4 sec; t_2 = passing time equal to 2 sec; t_3 = time for passing vehicle to return on its lane equal to 4 sec.

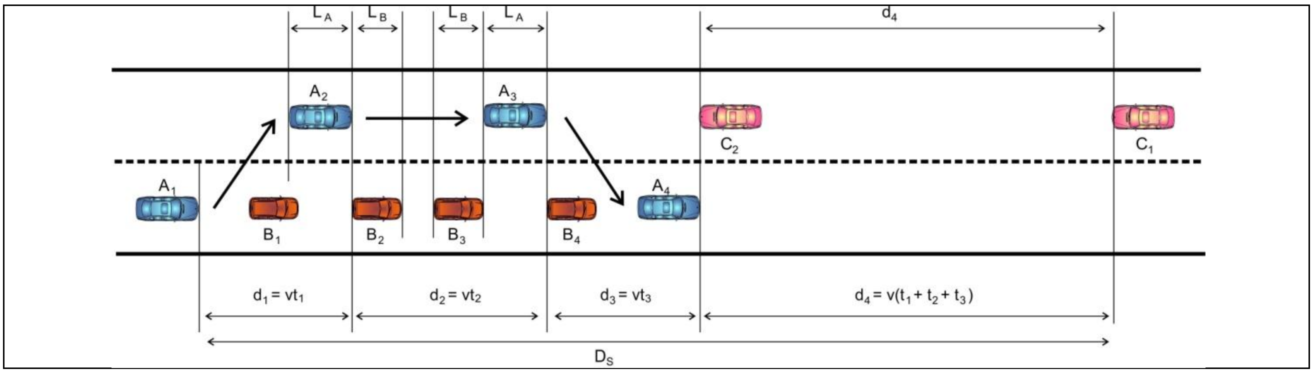

Fig. 1.
Flying Passing Scheme

Passing time is (Eq. (2)):

$$t_2 = (L_1 + L_2)/\Delta_v \tag{2}$$

where: t_2 = time of the passing maneuver (sec); L_1 = length of passing vehicle (m); L_2 = length of passed vehicle (m); Δ_v = difference between the speed of vehicles (m/s).

The factors that affect the PSD value are the speed of the passing vehicle, speed of passed vehicle and lengths of vehicles. Note that the maneuver is not possible if the speed of oncoming vehicle is higher that speed of passing vehicle.

2.2. Accelerative Passing

Also this design criterion is essentially unchanged from the criterion established in the years fifties by AASHO. The minimum PSD is the sum of the following four distances (Fig. 2) (Eq. (3)):

$$PSD = d_1 + d_2 + d_3 + d_4 \tag{3}$$

where: PSD = passing sight distance; d_1 = distance traveled during perception and reaction time and during initial acceleration to the point of encroachment on the left lane; d_2 = distance traveled while the passing vehicle occupies the left lane; d_3 = distance between passing vehicle and opposing vehicle at the end of the passing maneuver (as safety margin); d_4 = distance traveled by an opposing vehicle for two-thirds of the time the passing vehicle occupies the left lane, or 2⁄3 of d_2.

The calculation assumptions are:

- the passed vehicle travels at uniform speed;
- the passing vehicle reduces speed and trails the passed vehicle as it enters the passing section;
- when the passing section is reached, the passing driver requires a short period of time to perceive the clear passing section and to begin to accelerate;
- passing is accomplished under what may be termed a delayed start and a hurried return in the face of opposing traffic. The passing vehicle accelerates during the maneuver, and its average speed during the occupancy of the left lane is 16 km/h (10 mph) higher than that of the passed vehicle;
- when the passing vehicle returns to its lane, there is a suitable clearance length between it and any oncoming vehicle in the other lane.

Given that (Eq. (4) and Eq. (5)):

$$d_1 = t_1 \bullet \left(v - \Delta_v + \frac{a \bullet t_1}{2} \right) \tag{4}$$

$$d_2 = t_2 \bullet v \tag{5}$$

where: t_1 = time of initial maneuver (sec); v = average speed of passing vehicle (m/sec); Δ_v = speed difference of passed vehicle and passing vehicle (m/s); a = average acceleration (m/sec^2); t_2 = time of occupation of the left lane.

An interpolation of the values given in the AASTHO tables furnish the relationships in order to the times required during the first and second phases of the maneuver and the acceleration as function of the average passing speed in m/sec (Eq. (6) – Eq. (8)):

$$t_1 = 0{,}074 \bullet v + 2{,}50 \tag{6}$$

$$t_2 = 0{,}166 \bullet v + 6{,}75 \tag{7}$$

$$a = 0{,}004 \bullet v + 0{,}57 \tag{8}$$

Basically the factors that affect the PSD, for a flat roads, are: speeds of the passing vehicle, of the passed vehicle and of the vehicle coming in the opposite direction; vehicle dimensions; headway between vehicles, which depends on the speed; skill and reaction time of the driver; acceleration of passing vehicle.

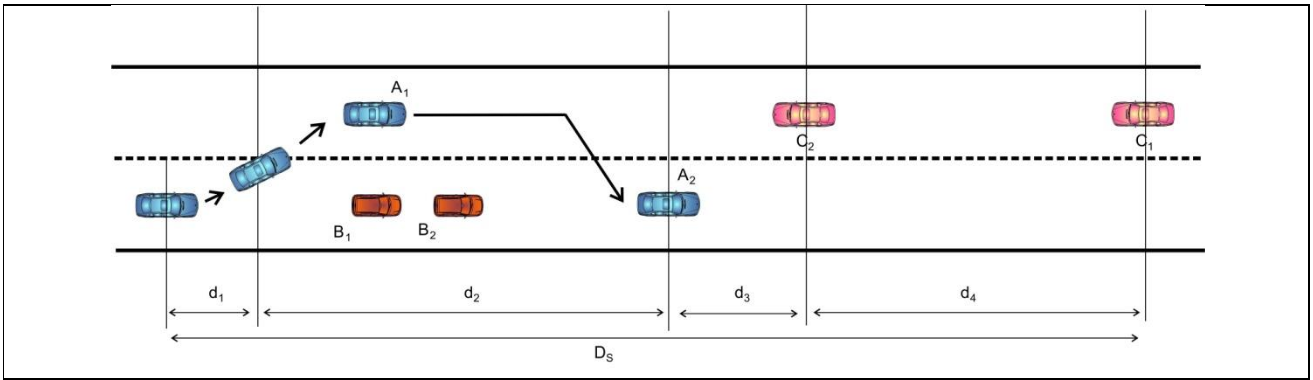

Fig. 2.
Accelerative Passing Scheme

Fig. 3.
Road Test Picture

Fig. 4.
Target Lines On Road Test

3. Road Survey

Fig. 3 shows a satellite picture of the road chosen for the surveys. It has examined the road section (Fig. 4) by placing six targets at a fixed distance of 20 m for a total measured base of 120 m. The width of each lane was 4.70m with a lateral shoulder of 0.30 m. It took record movies in three different days for a total of two hours of record and with the acquisition of 101 passing maneuvers.

For the running vehicles and for those who have completed the passing maneuver it has registered: the transit number, the transit times on all the bases, the speed and acceleration between markers for passing and passed vehicles. In case of passing maneuver has also evaluated the safety distance between opposite vehicles on the same lane through the time and the speed of opposite vehicle and its transit time on the first marker.

It has observed 71 regular maneuvers of passing, 12 irregular maneuvers with unsafe passing; 18 maneuvers were unclassified. The main results obtained are shown in Table 1. In Fig. 5 shows the accepted PSD as function of speed differences between the vehicles: the trend line have a slightly negative angle. Fig. 6 shows the trend of the average acceleration of the passing vehicle on the next target lines.

The result analysis (see Table 1 and Fig. 5 and 6) shows that:

- the highest average acceleration of the passing vehicle is about 1,17 m/sec^2 and the driver continues to accelerating the car for more than 60 m from the start of passing maneuver;
- the speed difference between the vehicles that pass is high and about of 25 km/h with a Std. Dev. of about 13 km/h;
- the headway between passing vehicles is about 1.5 sec;
- the accepted passing distance is considerably less than that calculated with the Italian rules for the average speed of the passing vehicle indicated in Table 1 (for about 75 km/h, PSD is about 400 m, the accepted distance is less than about 60%).

4. Passenger Cars Survey and Vehicle Fleet

The passenger car data were taken by a widely Italian magazine (Quattroruote 2004, 2011) and have covered all models tested «on the road» from year 2004 until 2011. The models were split on engine displacement classes. In addition to the engine displacements, for each model were recorded: the length, maximum speed, acceleration between 0 and 100 km/h, pickup between 70 and 100 km/h. The values of survey results for more than 500 models are shown in Table 2.

The Italian vehicle fleet in the year 2011 was obtained from report ACI (ACI 2012). The class 0 - 800 and the class 800 - 1.200 were joined in the only class 0 - 1.200. The percentages of the classes of the engine displacement compared to total number of passenger cars are shown in Table 3 (see also Fig. 7). The values of these percentages have been used as base in order to the random generation of the vehicle sets.

Table 1
Characteristic Values of Survey Results

Values	Mean	St. Dev.	Coeff. of Var.	85° perc.
Average passing speed (km/h)	74,52	10,21	0,14	85,71
Highest passing speed (km/h)	79,84	10,03	0,13	90,00
Average passing acceleration (m/sec^2)	0,57	0,85	1,50	1,29
Highest passing acceleration (m/sec^2)	1,17	0,50	0,43	1,60
Average passed speed (km/h)	49,62	11,02	0,22	62,04
Average speed diff. between vehicles (km/h)	24,89	13,05	0,52	37,92
Average headway (sec)	0,98	0,87	0,89	1,53
Average headway (m)	19,15	15,92	0,83	29,69
Average PSD (m)	241,21	125,50	0,52	386,09

5. Driver Class Behavior

It was hypothesized three classes of drivers with different preferences for the displacement classes of vehicles and with different driving behavior:

- a class of drivers «prudent» (15% of the total) with driving performance lower than the standard and that buy predominantly vehicles of displacement classes not excessive;
- a class of drivers «standard» (70% of total) that has not special driving behavior or purchase;
- a class of drivers «aggressive» (15% of the total) that tries to get the minimum travel time and does it, preferably, with more powerful cars, on the one hand, and utilizes also the cars of lower displacement classes even more than the other kinds of drivers.

All of these different behaviors hypothesized are summed in Table 4: is shown (as %) the purchases of each displacement class for kind of driver and for the performance differences (always as % from standard) that these drivers demand to the purchased vehicle. The distribution of total car purchases as in Table 4 is equal to that of the Italian car fleet in 2011.

6. Data Simulation of Passing Maneuvers

The software for random vehicle generation furnishes, for each extraction, three different and independent drivers (as members of kind of guide) linked to three different vehicles as members of engine displacement class that these drivers prefer. The probability of extraction for a single class of passenger car compared to other class is proportional to the percentage specified in Table 4. For each class, the extractions were made hypothesizing a normal distribution for the characteristics of the vehicles: lengths with the mean and standard deviation as in Table 2, speed, pickup with the mean and standard deviation as in Table 5.

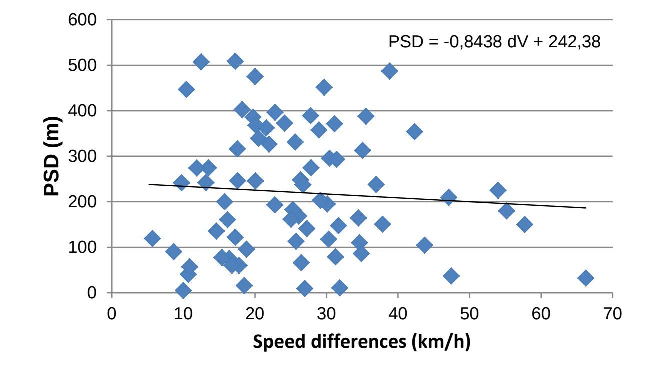

Fig. 5.
Survey - PSD versus Speed difference

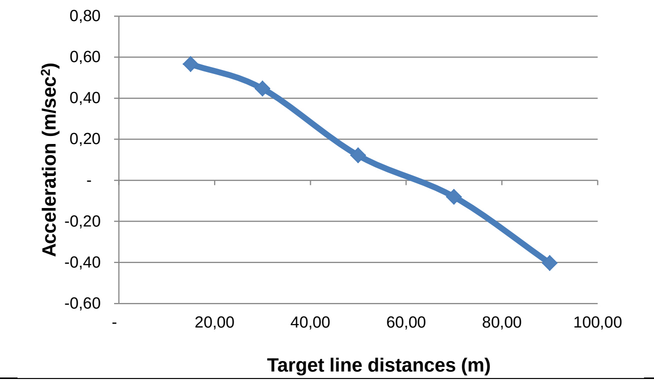

Fig. 6.
Survey - Passing Vehicles Acceleration On Target Lines

Table 2
Passenger Car Survey Results (By Quattroruote)

Classes	Values	Mean	Std. Dev.	Coeff. of Var.	85° perc.
Class 0 - 1.200 cc	Vehicles Length (m)	3,54	0,17	0,05	3,70
	Max speed (km/h)	153,41	7,82	0,05	161,65
	Acceleration 0 - 100 km/h (m/sec^2)	1,89	0,26	0,13	2,12
	Pickup 70 - 100 km/h (m/sec^2)	0,69	0,32	0,46	1,04
Class 1.200 - 1.600 cc	Vehicles Length (m)	4,00	0,30	0,08	4,34
	Max speed (km/h)	177,18	17,74	0,09	193,69
	Acceleration 0 - 100 km/h (m/sec^2)	2,38	0,46	0,19	2,72
	Pickup 70 - 100 km/h (m/sec^2)	0,78	0,24	0,30	1,00
Class 1.600 - 2.000 cc	Vehicles Length (m)	4,45	0,24	0,05	4,71
	Max speed (km/h)	200,60	19,20	0,10	224,83
	Acceleration 0 - 100 km/h (m/sec^2)	2,90	0,65	0,33	3,44
	Pickup 70 - 100 km/h (m/sec^2)	1,02	0,50	0,49	1,42
Class 2.000 – 2.500 cc	Vehicles Length (m)	4,56	0,21	0,05	4,75
	Max speed (km/h)	202,95	24,06	0,17	223,96
	Acceleration 0 - 100 km/h (m/sec^2)	2,84	0,55	0,19	3,24
	Pickup 70 - 100 km/h (m/sec^2)	1,07	0,49	0,86	1,72
Class over 2.500 cc	Vehicles Length (m)	4,22	0,25	0,05	4,96
	Max speed (km/h)	242,98	40,20	0,16	292,62
	Acceleration 0 - 100 km/h (m/sec^2)	4,22	1,44	0,34	5,55
	Pickup 70 - 100 km/h (m/sec^2)	2,26	1,15	0,51	3,20

Among the different sets of three passenger cars extracted were chosen those who have a speed difference between the passing and passed vehicles a value extracted from normal distribution with a mean of 25 km/h and Std. Dev. of 7 km/h (about 50% that in Table 1) and the speed of the opposite vehicle not greater than that of the passing vehicle. It has obtained 338 passing maneuver set from 5000 total extractions. The characteristic values of cars distribution results of simulations linked to the Italian car fleet 2011 are shown in Table 5 and Fig. 7.

Table 5
Classes Of Italian Fleet Vehicles (2011) And Simulation Results

	ACI 2011	Simul.
Displ. Classes	%	%
0 - 1.200	25,97	23,27
1.200 - 1.600	42,81	35,70
1.600 - 2.000	23,87	29,78
2.000 - 2.500	4,26	3,94
over 2.500	3,06	7,30
Total		100,00

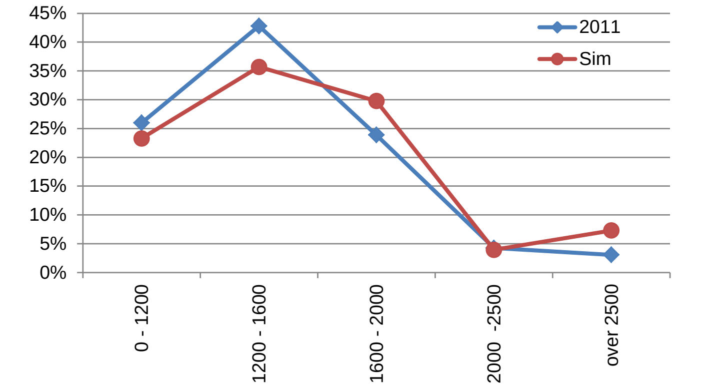

Fig. 7.
Classes Of Italian Fleet Vehicles (2011) And Simulation Results

Table 4
Driver Kinds And Their Purchase Cars Percentage - Performance Differences Respect The Standard Drivers

Driver \ Car Class		0 - 1.200	1.200 - 1.600	1.600 - 2.000	2.000 - 2.500	Over 2.500
Prudent	15,0%	45,0	35,0	19,0	1,0	0,0
Performance difference %		0,0	-10,0	-20,0	-30,0	0,0
Standard	70,0%	27,0	41,0	24,0	4,0	4,0
Performance difference %		0,0	0,0	0,0	0,0	0,0
Aggressive	15,0%	7,0	51,0	35,0	5,0	2,0
Performance difference %		30,0	20,0	10,0	0,0	0,0

Table 5
Passenger Cars Data for Simulations

Class	0 - 1.200	1.200 - 1.600	1.600 - 2.000	2.000 - 2.500	Over 2.500
Mean pickup 70 - 100 km/h (m/sec^2)	0,54	0,62	0,82	0,96	1,81
Std. Dev.	0,29	0,34	0,44	0,52	0,99
Mean speed (km/h)	69,03	79,45	90,27	89,53	109,34
Std. Dev.	4,00	7,75	11,64	11,37	18,50

7. Models Adopted

Basically has been used the two models mentioned above. The calculation parameters have been replaced by the results of random extractions.

For the model Flying passing (FPM) has been used the speed of the passing vehicle and its length, the speed of the passed vehicle and its length, the speed of the vehicle on the opposite lane.

For the model accelerative passing has been used the relationships (4) and (5) with the values obtained from the relationships (6), (7) and (8). More it has been modified the original accelerative passing models with three different steps of acceleration (greater than the basic model and equal to the distances d1, d2 and d3 of Fig. 1) most adequate to results of road survey. Has been investigated the behavior of the models in acceleration. In the model APM_1 the passing vehicle follows the vehicle that has to pass at same speed and then the passing vehicle accelerates until start of the passing maneuver; passing vehicle completes maneuver at constant speed. In the model APM_2 passing vehicle accelerates more until full passing of the vehicle on the right and then completes maneuver at constant speed. In the model APM_3 the passing vehicle completes the whole maneuver accelerating.

For the all simulations of the accelerative passing models the initial speeds of passenger cars (passing and passed vehicles) were the same and the headways between vehicles were equal to the length of the passed vehicle. The results are reported in Table 7. In the Table are not shown the results furnished of APM_03 model that are little real.

Table 6
Value Parameters from Simulation

Parameters values	Mean	Std. Dev.	Coeff. of Var.	85° perc.
Passing speed (km/h)	77,99	10,09	0,13	88,43
Passing acceleration max (m/sec^2)	1,17	0,47	0,41	1,60
Passed speed (km/h)	47,80	6,69	0,14	54,53
Difference speed between vehicles (km/h)	24,71	12,08	0,49	38,00

Table 7
Passing Sight Distance and Statistic Parameters for All Models

Model values	Mean	Std. Dev.	Coeff. of Var.	85° perc.
Italian Flying Passing Model	433,28	56,07	0,13	491,28
U.S. Accelerative Passing Model	536,83	69,47	0,13	608,65
Accelerative Passing Model 1	260,46	52,69	0,20	302,95
Accelerative Passing Model 2	192,01	21,52	0,11	213,72

8. Results Considerations and Further Developments

This work has been useful for checking some assumptions of two classical passing models (Italian Flying Passing Model and U.S. Accelerative Passing Model) compared to the real behavior of the driver. These two models of the PSD give both very high values in order to provide the road safety.

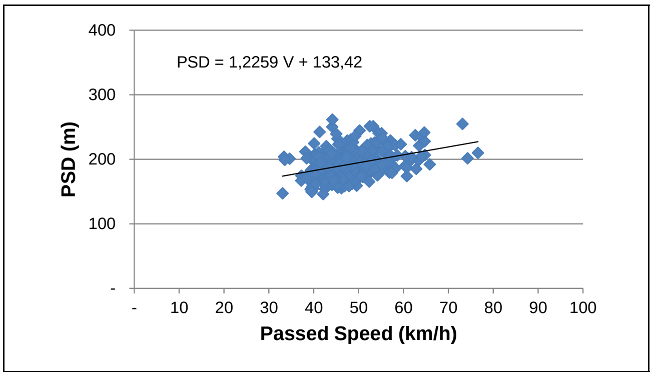

Fig. 7.
APM_01, PSD Versus Passed Speed And Relationship

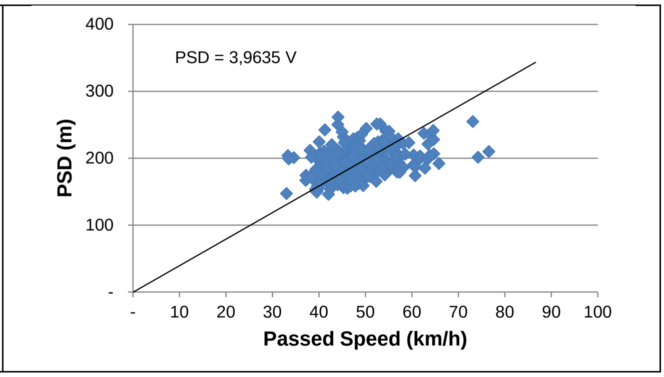

Fig. 8.
APM_01, PSD Versus Passed Speed And Relationship Starting From Zero

The vehicles simulation values are very near to those given from surveys. Also the driver kinds in input are 15-70-15% and in output are 13-68-19%, about the same. The displacement classes simulated are reported in Table 3.

The values of the random extractions (Table 6) are also about the same of those given by road surveys (Table 2). Anyway the value of 85° percentile of the passing speed is lower than the value of 85° percentile of operating speed obtained on rural roads (Capaldo et al. 1997).

Of the three proposed models (APM_1, APM_2 and APM_3) the first model seems to adapt better to experimental data than the original models. In this model the length travelled in acceleration is similar to that the results obtained from surveys. Also the relations between PSD and speed differences are similar. It seems also congruent the relationship between the PSD and the speed of the passed vehicle (Fig. 7). Not congruent is the relationship between the PSD and passing vehicle: the PSD decreases when the speed of passing vehicle increase. This could be explained because if the passing vehicle is faster then it also has good performance characteristics (pickup) and these reduce the value of the PSD.

A first approximate model could link the PSD to the passing vehicle speed (Fig. 8). The relationship link PSD to the results of the passed vehicle speed with a straight line starting from zero (Eq. (9)):

$$PSD = 4 \bullet V \tag{9}$$

Utilizing this with the speed value of passing vehicle (mean about 80 km/h) from Table 6 the PSD is about 320 m: these value is the 75% of the value obtained with model of Italian rules and 60% of the U. S. rules model. This measure is however over 30% of mean PSD from surveys, in other words over 30% of mean of real PSD on two-lane highway. But this is only a model of first approximation and surely it will be enhanced with further studies.

In any case, the parameters that most seem to affect the results were, in addition to vehicle speeds and accelerations of the passing vehicles, also the vehicle headways at the start and end of the maneuver.

The prosecution of the work should realize a more extensive experimental data base with greater emphasis to the headway measures. The realized software should be modified to consider a complete passing maneuver on road section. And the driver classification will be object of a specific survey with interviews.

Finally this paper has considered only passing maneuvers between passenger car: other passing maneuvers should be explored with different kind of vehicles.

References

ACI. 2011. I dati sugli incidenti stradali rilevati nel 2010. ACI - Automobile Club d'Italia. Available from Internet: <www.aci.it/sezione-istituzionale/studi-e-ricerche/dati-e-statistiche.html >

ACI. 2012. *Annuario Statistico 2011*, ACI - Automobile Club d'Italia - Sistema Statistico Nazionale, ACI, Roma. Available from Internet: <www.aci.it/sezione-istituzionale/studi-e-ricerche/dati-e-statistiche/annuario-statistico-2012.html>

AASHTO. 2004. *A Policy on Geometric Design of Highways and Street*. Green Book AASHTO, Washington, D.C., USA.

Capaldo, F.S. 2008. Diagrammi di velocità su strade extraurbane: misure sperimentali. In Proceedings of the *17° Convegno Nazionale S.I.I.V., Le reti di trasporto urbano, Progettazione, costruzione, gestione*. Abstract Book with CD, Enna.

Capaldo, F.S.; Guzzo, F. 2011. *Vademecum dell'Esperto in Infortunistica del Traffico e della Circolazione Stradale*, EPC Libri ed., Rome, Italy

Capaldo, F.S.; Risoli, L. 2012. Passing Maneuver: Models, Surveys and Simulation. In Proceedings of the *8th International Conference on Traffic and Transportation Studies*, Changsha, China, August 1–3, 2012, Procedia - Social and Behavioral Sciences 43 (2012) 790 – 798.

CNR. 1973. *Norme sulle caratteristiche geometriche delle strade*. CNR, Bollettino Ufficiale n. 31, Roma.

CNR. 1980. *Norme sulle caratteristiche geometriche delle strade extraurbane*. CNR, Bollettino Ufficiale n. 78, Roma.

Harwood, D.W.; Gilmore, D.K.; Richard, K.R.; Dunn, J.M.; Sun, C. 2008. *Passing Sight Distance Criteria*. NCHRP Report 605, Transportation Research Board, Washington, D.C., 2008.

HCM. 2010. *Highway Capacity Manual*. TRB Special Report 209, Transportation Research Board, Washington, D.C., 2011.

Lamm, R.; Psarianos, B.; Mailander, T. 1999. *Highway Design and Traffic Safety Engineering Handbook*. McGraw Hill.

MIT. 2002. *Norme funzionali e geometriche per la costruzione delle strade*. Ministero delle Infrastrutture e dei Trasporti, Ispettorato generale per la circolazione e la sicurezza stradale, Decreto Ministeriale 5 novembre 2001, S.O. n. 5, G.U.R.I. n. 3 del 4.01.02.

NCHRP. 2005. *Passing Sight Distance Criteria*. Interim Report, NCHRP Project 15-26, MRI Project 110348, Midwest Research Institute.

Quattroruote. 2011. Ed. Domus, Milano, 2004-2011.

Session 12: Human Factors

NATURALISTIC OBSERVATIONS OF DRIVERS' HAND POSITIONS WHILE DRIVING WITH AND WITHOUT ADAPTIVE CRUISE CONTROL

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Abstract: Researchers use various measurements (e.g., travelling speed, headway to the vehicle in front) to assess the impact that new traffic/transport measures (e.g., changes to road design, introduction of in-vehicle technologies) might have on road safety and on drivers' behaviour. In the recent years, the measurement of hand position on the steering wheel was proved to be interesting for the assessment of mental workload and perceived risk, with the clear advantage that the hand position can be easily measured both in driving simulator and naturalistic driving studies. In order to find out more on the topic, a small scale Field Operational Test (FOT), involving 8 participants, was performed to assess the effect that the usage of Adaptive Cruise Control (ACC) might have on the chosen drivers' hand position. Video clips of the first 5 participants, using the vehicle in low demanding driving conditions, with and without the ACC, were selected to allow the comparison between the two experimental conditions. As a preliminary result, driving with ACC was not associated to a lower control on the steering wheel. Further research is suggested on the topic.

Keywords: hand position, steering wheel, Adaptive Cruise Control, mental workload, risk assessment, Field Operational Test.

1. Introduction

Various measurements have been used to assess the impact that new traffic/transport measures (e.g., changes to road design, introduction of in-vehicle technologies) might have on road safety and drivers' behaviour. Those measurements encompass travelling speed, headway to the vehicle in front, steering wheel adjustments, lane position, seat belt usage and several others. In the recent years, the assessment of hand positions on the steering wheel has been gaining validity for the measurement of driver's perceived risk and mental workload. Compared to the previous mentioned measurements, the position of the hands on the steering wheel can be easily assessed both in driving simulator and naturalistic driving studies and, therefore, it deserves the consideration of road safety researchers.

In a study performed by Walton and Thomas (2005), 4804 hand positions of motorists were collected while observing vehicles passing at eight road sites. The hand positions were classified according to the number of hands on the top half of the steering wheel (that is above the dotted line in Fig. 1): two hands, one hand and no hands were the 3 categories identified. Instead of the 'ideal' hand positions on the steering wheel (namely, the '10/2' o'clock alignment), the data analysis showed that, across all sites, 50% of drivers were observed with only one hand on the top half of the steering wheel. In addition, 42% of the participants changed hand positions after travelling through a 10 km accident area even if it was not spotted a clear trend for the change (the number of drivers who increased the control on the steering wheel was similar to the number of drivers decreasing the control). This result might mean that drivers change their hand positions due to the intervention of different factors but, given the experimental setting, it was not possible to determine which factors.

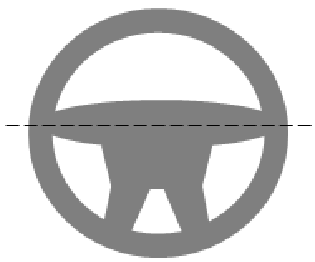

Fig. 1.
Dotted line discerning the top half of the steering from the bottom half

In a consecutive study, Thomas and Walton (2007) adopted the same measurement to determine differences in hand positions on the steering wheel between SUV and car drivers. The results showed that SUV drivers were less likely to place two hands on the top half of the steering wheel compared to other car drivers. In addition, the researchers administered questionnaires to the SUV and car drivers in order to acquire information about their opinions related to the hand position on the steering wheel. Drivers reported to perceive the 2 hands on the top half of the steering wheel as the position which gives most control over the vehicle (95.1% of car drivers) and as the position which is chosen when drivers are tense (92.6% of car drivers). Also, 76.4% of the drivers stated that, during typical driving, they have 2 hands on the steering wheel but this self-assessment was not confirmed by the actual observations of hand positions made by the authors during the experiment.

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Overall, SUV drivers were observed and also reported to exert less control on the steering wheel. Given that SUV are deemed safer than other vehicles by the SUV owners and by the general public (Davis and Truett, 2000), the lower control on the steering wheel shown by SUV drivers could be linked to the reduced perception of risk compared to car drivers.

Later, De Waard et al. (2010) studied the relationship between mental workload/perceived risk and the hand positions on the steering wheel in a driving simulator study. Due to the experimental conditions, the researchers had access to the whole steering wheel and, therefore, adopted a different measurement to take into account also its bottom part (which had been discarded in the previous 2 studies due to the lack of information). The scoring of hand position was divided in high, medium and low control. High control meant that left and right hands were located respectively in the left and in the right blue areas in Fig. 2. Medium control meant that two hands were placed on the steering wheel but, at maximum one (left or right) was located in the respective left or right blue areas: however, if the 2 hands were located in the pink area in Fig. 2, the position was rated as low control. Finally, low control meant that the 2 hands were placed in the pink area in Fig. 2 or that 1 hand or no hands were on the steering wheel. During the experimental setting, drivers had to perform a lane merging task in variable situations of traffic, merging lane length and number of cars in the acceleration lane. The results showed that, during the lane merging manoeuvre, a change in hand positions on the steering wheel seemed to reflect changes in drivers' mental workload and reported risk. Notably, drivers assumed a lower control position after merging into the highways, once they reached the left lane (higher speed lane). However, it should be mentioned that, during the ride, the majority of drivers (about 70%) kept the same hand position. In addition to the previous findings, age differences were found within the panel concerning hand positions: old divers ride more often with high control position compared to young drivers.

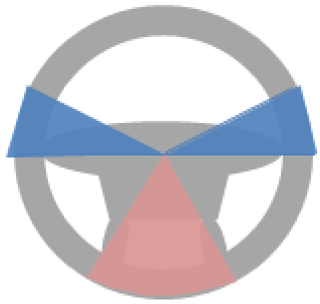

Fig. 2.
Scoring of hand position as in De Waard et al. (2010)

In a following study, Fourie et al. (2011) attempted to link the drivers' hand positions on the steering wheel to the travelling speed and headway to the vehicle in front. They collected observations of drivers' hand positions from the roadside of a State Highway, in Australia. Concerning speeds, drivers who placed 2 hands on the top half of the steering wheel drove slower than drivers who placed 1 hand on the top half of the steering wheel. Similarly, drivers who placed 2 hands on the top half of the steering wheel had lower reciprocal headways than drivers who placed 1 hand on the top half of the steering wheel. Based on those findings, it seems that hand positions on the steering wheel could be related to drivers' characteristics (e.g., sensation seeking), given that drivers who had 1 hand on the steering wheel drove faster and closer to the vehicle in front compared to drivers with 2 hands on the steering wheel. In addition, the authors found gender differences about the hand positions: males, tended to place 1 hand on the top half of the steering wheel significantly more frequently and 2 hands on the top half of the steering wheel significantly less frequently compared to females.

On the whole, from the studies performed on the topic, a general model, such as the one in Fig. 3, can be proposed. The variables which, from previous research, seem to influence the hand positions on the steering wheel are: type of vehicle, risk perception, mental workload level, demographics (gender and age) and personal characteristics. However, other factors, not yet studied, might have a relevant role on the drivers' decision about where to place his/her hands on the steering wheel.

Some of those factors could be, for example, road related variables (e.g., level of traffic, type of road), the usage of Advanced Driver Assistance Systems (e.g., Adaptive Cruise Control, Emergency Braking System) and the socio-cultural context.

In the present study, the attention was directed to investigate, in a preliminary manner, how the usage of Adaptive Cruise Control (ACC) might affect drivers' hand position on the steering wheel. ACC is an Advanced Driver Assistance System (ADAS) which maintains specific speed and headway to the vehicle in front, according to the settings defined by the user. Based on ACC functioning, the following hypothesis was made:

1. Riding with ACC activated, drivers will adopt lower control hand positions compared to driving without the system.

The rationale behind this hypothesis is that, given that the usage of ACC might lead to a lower level of driver's mental workload (Stanton et al., 1997; Hoedemaeker and Brookhuis, 1998), according to the model in Fig. 3, a corresponding reduction of steering wheel control is expected being the other variables (type of vehicle, risk perception, etc.) kept fixed. In order to test the hypothesis formulated, a small-scale Field Operational Test (FOT) was performed in Portugal with 8 users of Adaptive Cruise Control.

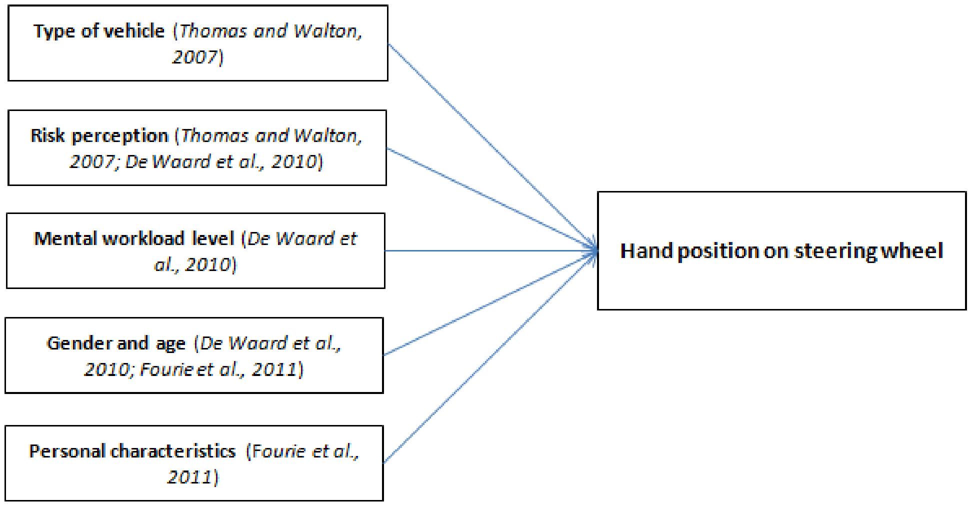

Fig. 3.
Model of variables influencing hand position on the steering wheel

2. Method

A luxury vehicle (Volvo S80) equipped with several Advanced Drivers Assistance Systems (ADAS), including ACC, was instrumented with a recording platform, from now on called Data Acquisition System (DAS). The DAS included, among others, the following elements:

- 4 cameras inside the vehicle: to acquire videos from the driver, the vehicle's left side, the dashboard and the road ahead (Fig. 4).
- GPS/GPRS module: to measure the vehicle's position and speed.
- Triaxial accelerometer: to assess the vehicle's accelerations on the x, y and z axes.
- Microswitch sensors: to determine when the pedals (clutch, accelerator and brake) were pressed.
- On-board computer: to collect the information originated from the other elements of the DAS.

The DAS was originally designed and developed in the frame of the project INTERACTION ('Understanding driver interactions with in-vehicle technologies'), financed by the European Commission Seventh Framework Programme (FP7/2007-2013).

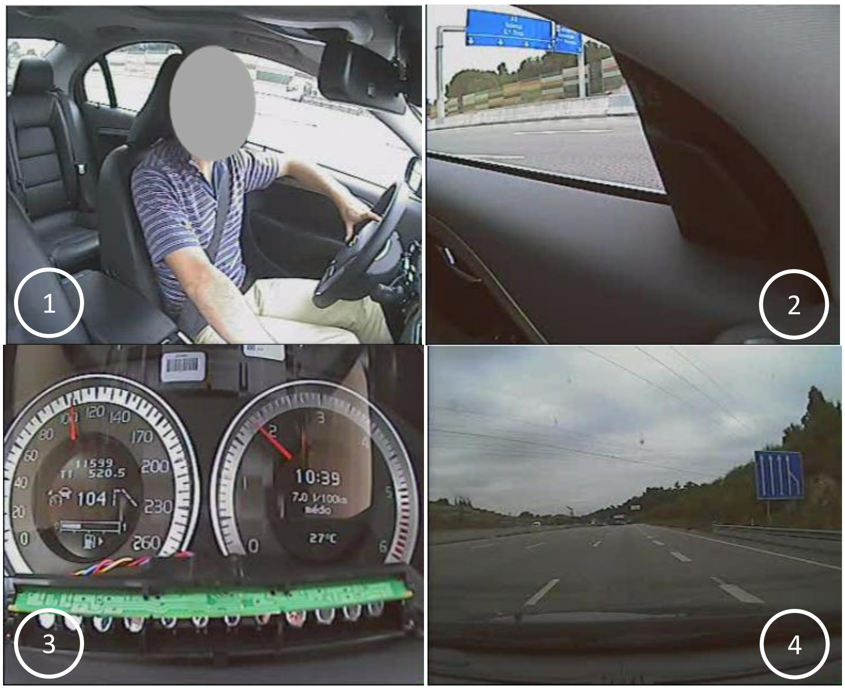

Fig. 4.
Sample of images retrieved from the cameras mounted inside the vehicle

Given the limited number of ACC drivers in Portugal, the help of a Volvo dealer in the north of Portugal was sought to find participants for the study. The recruited sample was made up of 8 participants, all experienced drivers (more than 150000 km driven since getting the driver's licence) and ACC users. The participants got a brief explanation about the purpose of the study and they were instructed to use the experimental vehicle as they would do with their usual car. Each participant picked the vehicle up at the dealer and, once completed the experimental period, he/she returned it at the same location. The study began at the end of June 2012 and, at the moment of the writing of this article (beginning of September 2012), was still running.

The videos recorded by the DAS were reviewed by one researcher through the usage of the coding tool ELAN, developed by the Max Planck Institute for Psycholinguistics and freely downloadable from the website http://tla.mpi.nl/tools/tla-tools/elan (for more information about the coding tool, please see Wittenburg et al., 2006). During the reviewing process, the variables reported in Table 1 were coded.

Table 1
Variables coded during the reviewing process

Variable	Definition used during the coding process
Type of road	The roads were divided in three categories: highway, rural roads and urban roads.
Traffic level	The traffic was coded using the definition of Level of Service (Highway Capacity Manual, 2010).
Weather	The weather conditions were divided in four categories: sunny, cloudy, foggy and rainy.
Light	The lighting conditions were divided in two categories: day and night.
ACC usage	The ACC usage was coded reporting if the system was used or not by the driver.
Hand position	The hand position on the steering wheel was scored according to De Waard et al. (2010).

The independent variable was the ACC usage which assumed two levels (ACC activated or ACC deactivated). The dependent variable was the assessed hand position on the steering wheel (low control, medium control or high control). The objective of the study was to determine if the usage of ACC might change the drivers' hand position on the steering wheel: to achieve the scope, the influence of some confounding variables, which might have an impact on the hand position (e.g., type of road, traffic level, weather conditions, lighting conditions), was reduced, selecting only video clips with similar external environment.

Notably, for the choice of the video material to be coded, the below reported criteria were followed:

- The road type had to be highway with 2 or 3 lanes and speed limit equal to 120 km/h.
- The traffic level had to be equivalent to Level of Service A or Level of Service B.
- The weather conditions had to be either sunny or cloudy.
- The driving had to be performed during daylight conditions.

The rationale behind the selection of the criteria was headed by two considerations:

1. According to previous studies (Strand et al., 2010; Piccinini et al., 2012), the ACC is mostly activated in the above mentioned road type and traffic conditions.
2. The environment, resulting from the criteria selection, can be considered as a low demanding driving context and, therefore, a minimum confounding effect is expected on the final outcome of the study.

Overall, the video clips selected showed situations of highway driving, in low traffic level, with good weather and good lighting conditions. In order to test the hypothesis made for the study, the video clips included parts with ACC driving and parts with regular driving (without ACC).

3. Results

In this article, the results, issued from the data analysis of the first 5 participants, are reported.

In Table 2, the time duration of the selected video clips (during driving with and without ACC) is displayed for each participant.

Table 2
Time durations of video clips for each participant (driving with and without ACC)

Participant	Coded time with ACC [s]	Coded time without ACC [s]
P1	1793	1125
P2	1724	1115
P3	1475	1125
P4	1468	1150
P5	1695	1150

During the data analysis, for the testing of the hypothesis, the variable of interest was the time spent by the participants driving with the hands in the high control position on the steering wheel (that is the hand position with left and right hands located respectively in the left and in the right blue areas in Fig. 2). This position is the one which gives more control on the steering wheel and, therefore, a significant change in this variable during the two experimental conditions (driving with and without ACC) would mean a possible effect of the Adaptive Cruise Control on the drivers' hand position choice. The results are shown in Fig. 5: the graph reports the percentage of time spent driving in the high control hand position in each experimental condition (driving with and without ACC) for each participant (from P1 to P5).

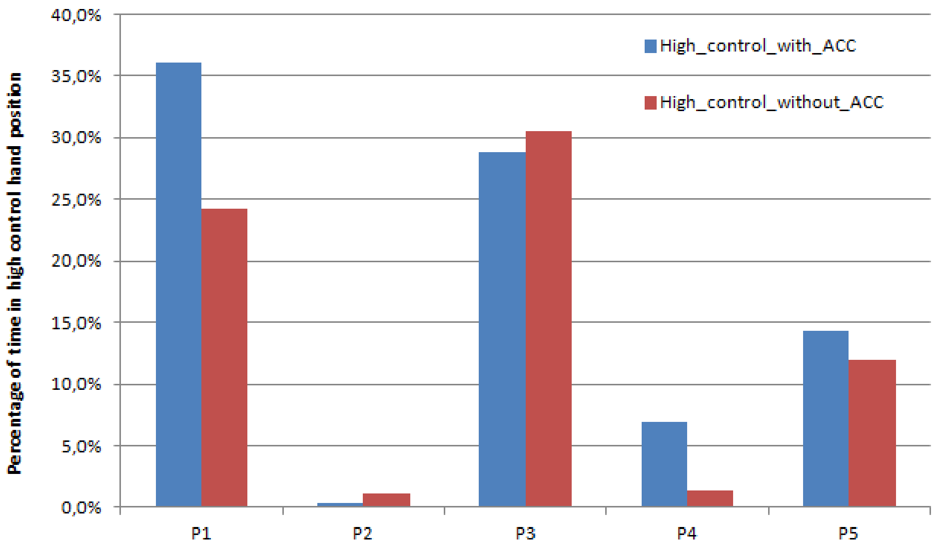

Fig. 5.
Percentage of time in high control hand position with and without ACC (for each participant)

From Fig. 5, it is not possible to detect any effect of driving with ACC on the high control hand position, compared to the situation of regular driving (without ACC). Actually, for some participants (P1, P4 and P5), driving with the assistance of ACC was associated to an increase of control on the steering wheel whereas, for the remaining drivers, the findings are opposite. Therefore, based on the findings, the hypothesis formulated in the first section of this paper is rejected.

4. Discussion and conclusions

The assessment of hand position on the steering wheel had been demonstrated, by previous research, to be a promising measurement of drivers' mental workload and perceived risk. In order to find out more on the topic, the present study was designed to assess how ACC usage might influence drivers' hand position on the steering wheel.

A small scale Field Operational Test (FOT) was performed, with 8 experienced drivers and ACC users (however, only the data from the first 5 participants were analyzed and reported in this article). From the overall material, some video clips were selected in order to make available recordings of drivers' hand positions while driving with and without ACC in highway, with low level of traffic, good weather and good lighting conditions. Considering that lower control hand positions were previously associated to lower mental workload and that driving with ACC is linked to a decrease in mental workload, the following hypothesis was formulated:

1. Riding with ACC activated, drivers will adopt lower control hand positions compared to driving without the system.

The findings, resulting from the small scale FOT, showed no evidence about the effect of ACC on drivers' hand positions and, therefore, the hypothesis is rejected. Different explanations might be found to justify the fact that the assumption was not confirmed:

1. Other confounding variables, different from the ones considered, might have perturbed the results.
2. The hand position on the steering wheel is not an accurate assessment of driver's mental workload.
3. The ACC, in real driving context, does not bring a reduction of mental workload (especially for drivers which are already used to the system).

From this study, it is not possible to establish which one might be the correct explanation for the failed hypothesis testing. Additional research on the subject is, therefore, suggested.

In conclusion, it is important to mention that the study has clear limitations. First of all, the sample was small (especially, the one considered for the data analysis and reporting) and no statistical treatment could be performed on the data. Then, the time duration of the video clips used for the coding process was limited. Finally, given the data collection method chosen (Field Operational Test), the resulting experimental control was low.

Acknowledgements

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This study would have not been possible without the help of the Volvo dealer "Auto Sueco Minho" which assisted in recruiting the participants and made available the vehicle used during the study.

References

Davis, S.C.; Truett, L.F. 2000. An Analysis of the Impact of Sport Utility Vehicles in the United States. Available from internet: <http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2000_147.pdf>.

De Waard, D.; Van Den Bold, T.G.M.P.R.; Lewis-Evans, B. 2010. Driver hand position on the steering wheel merging into motorway traffic. *Transportation Research Part F* 13 (2010): 129-140.

Fourie, M.; Walton, D.; Thomas, J.A. 2011. Naturalistic observation of drivers' hands, speed and headway. *Transportation Research Part F* 14 (2011): 413-421.

Highway Capacity Manual. 2010. *Highway Capacity Manual*. Transportation Research Board of the National Academies, Washington, D.C. 150 p.

Hoedemaeker, M.; Brookhuis, K.A. 1998. Behavioural adaptation to driving with an adaptive cruise control (ACC). *Transportation Research Part F* 1 (1998): 31-39.

Piccinini, G.F.; Simões, A.; Rodrigues, C.M. 2012. Usage and effectiveness of Adaptive Cruise Control (ACC): a focus group study. *Paper presented at the First International Symposium on Occupational Safety and Hygiene*, February 9-10, Guimarães, Portugal.

Stanton, N.A.; Young, M.; McCaulder, B. 1997. Drive-By-Wire: The case of driver workload and reclaiming control with Adaptive Cruise Control. *Safety Science*, 27 (2/3): 149-159.

Strand, N.; Nilsson, J.; Karlsson I.C.M.; Nilsson L. 2010. Exploring end-user experiences: self-perceived notions on use of adaptive cruise control systems. *IET Intelligent Transport Systems*, 5 (2): 134-140.

Thomas J.A.; Walton, D. 2007. Measuring perceived risk: Self-reported and actual hand positions of SUV and car drivers. *Transportation Research Part F* 10 (2007): 201-207.

Walton, D.; Thomas, J.A., 2005. Naturalistic observations of driver hand positions. *Transportation Research Part F* 8 (2005): 229-238.

Wittenburg, P.; Brugman, H.; Russel, A.; Klassmann, A.; Sloetjes, H., 2006. ELAN: a Professional Framework for Multimodality Research. In *Proceedings of LREC 2006, Fifth International Conference on Language Resources and Evaluation*.

METRO SUL DO TEJO: IMPROVING MOBILITY IN ALMADA

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Abstract: After four years operating, the Metro Sul do Tejo (MST), a light rail transport built in Almada – Portugal, has not fulfilled the initial expectations and may be considered a flop. The implementation of the modern, fast and non-pollutant public transport was part of the City Hall's political strategies to reduce pollution, noise and traffic congestion, creating therefore a more enjoyable city centre for its residents. A high number of users were estimated, assuring the financial viability of the project, and reassuring the State about the revenues of the large investment needed. Today, the number of users doesn't match those expected, and some issues such as the high percentage of fraud or MST held responsible for the closing commerce inside the city and for the so-called "desertification" of Almada. The project's second and third phases of construction are compromised. In this paper we examine the reasons that caused the fail of the service. Analyzing the data gathered by the City Hall and other documentation from the MST we inflect conclusions about the real impact of the tramline in the life of Almada's residents.

Keywords: Sustainable transport, mobility, transportation planning.

1. Introduction

The Metro Sul do Tejo (MST)[2] is a street tramline that was inaugurated in August 2008, when the first phase of its construction was concluded. The companies engaged in the project of MST were part of a consortium to whom belonged the City Halls of Almada, Seixal, Moita and Barreiro. These cities, part of Lisbon' Metropolitam Area – LMA, had the intention to improve mobility of their inhabitants and reduce the use of private transport in the accesses to Lisbon. Three phases of construction were estimated in the contract. Studies were made to prevent the impact from construction's work on the city and to estimate the number of users for the service. Public informative sessions were held by the City Hall, promoting debate over the benefits and disadvantages of the MST.

Despite all optimistic premonitions, after 3,5 years from its inauguration, the initial estimate number of passengers was not achieved, and the service revenues are much lower than what was expected. Almada's residents blame MST for the gradual "desertification" of the city, stating that the rail line increased the obstacles for people wanting to reach the centre of town. Many shops in the central streets closed during MST's construction and remained closed afterwards. Metro Sul do Tejo faces serious problems of economic viability and the government disapproves the continuation of works (second and third phases of construction), endangering the original purpose.

In this work I analyse the real responsibility of MST in the so-called "city desertification" of Almada, and why is the actual number of transport usage so low comparing with previous numbers. After this analysis some hypothesis that could give answers to the raised problems are debated.

In the remaining paper, Section II provides a general idea about the development of Almada, in what concerns its demographic and urbanistic evolution. The short insight of Almada's history has the purpose of facilitating the understanding of mobility problems that affect its inhabitants in our days. Section III presents MST and the main purposes from its project. The analysis of the real usage of the MST *versus* the expectations is presented in Section IV. In Section V hypothesis for the flop are given and finally, in Section VI we conclude.

Fig. 1.
Map of Almada
Source: www.google.maps.com

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[2] Metro sul do Tejo (MST) Tram South from Tagus Tram Public transport, which operates in Almada.

2. The city of Almada and its mobility

2. 1. Historical insights

When the Arabs settled in the place that much later came to be known as Almada, they were certainly not unaware of its natural beauty and unique conditions in terms of defence and relationship with the river. Archaeological remains dating from this period have been found in holdings such as Quinta do Almaraz, a wide promontory facing the river. The site had optimal conditions for the life of the people that settled there, subsisting through agriculture, fishing and trade. The Tagus River, was the main line of communication and trade between these people, constituting also a natural boundary and obstacle between the north bank and the south bank.

Throughout the middle Ages and the Renaissance, the county's land was organized in farms and remained like this until the seventeenth century, when the first industries settled there. During the seventeenth and eighteenth centuries, chemical and pharmaceutical industries were settled within the limits of the county, attracting people primarily from the south. In 1801 3.363 people lived in Almada, in 1849 the number of registered inhabitants was already 6.440. These values have dramatically changed during the twentieth century (See Table 1) that witnessed a slow and controlled urban growth, despite a sharp increase in the population. The affordability of land along the river, the gradual decline of agriculture and the industrial growth attracted people but also boosted the construction and urban redefinition of the then Village of Almada (Silva and Vieira, 1995). Access to places outside the county's centre was difficult and slow; people were forced to walk great distances in their daily commutes. Crossing the river to Lisbon was also a complicated and time-consuming process. Only in 1922 did the first diesel ferry (*Cacilheiro*) start to operate, carrying a small number of passengers between the southern and northern banks (Rodrigues, 1999).

Table 1
Number of Residents in Almada per Year

Year	Residents number in Almada
1801	3.363
1849	6.440
1900	15.764
1930	23.694
1960	70.968
1981	147.690
1991	151.783
2001	160.825
2008	166.103
2011	174.030

Source: INE. Census 2011

2.2. The urban plan of Almada

During the first forty years of the twentieth century many people were housed in shacks without running water or electric light and in 1936, the Municipality of Almada prepared a preliminary draft for the urbanization of Almada's southern slope (Rodrigues, 1999), demonstrating the growing concern with the chaotic way in which the county was developing. The cheaper land and the location along the Atlantic coast and river, near the capital, were major attractions, in contrast to housing prices practiced in Lisbon.

In 1945 the government signs a contract with Etienne de Gröer, renowned urban planner, and the architect Faria da Costa, for the implementation of Puca – Urbanization Plan of the city of Almada. According to Ana Bonifácio (2004) the plan of Gröer mirrored the ideology of the time and the vision of a city as a compartmentalized core, where the spaces for its various functions: housing, recreation, trade and services and industry were well separated from each other. The large avenues provided access to squares where the civic centre was installed (court, church, town hall), the commercial area, administrative offices, shops, small factories, garages, theatres and meeting rooms could also be found here (Rodrigues, 1999). The residential buildings complied with a hierarchy that was defined by social class from the residents housed there. The grassland areas outside the centre should be preserved, so that the construction would not adversely affect the enjoyment of the countryside, which also served as a reservoir of clean air and leisure.

With this model of functional city[3] – Gröer followed the vision of Le Corbusier, the great promoter of this idea of “separation of urban functions, multiplication of green spaces; rationalization of collective housing, creation of functional prototypes” (Carvalho, 2003) adding also the idea of an urban-rural design, where there was a more dispersed occupation of the land, a search of the countryside for the sake of health and contact with nature.

War in Europe and the difficulties that came upon it, led to a deterioration of rural workers living conditions, and increased the migratory movement towards the coast, creating even more pressure on these sites (Rodrigues, 1999). In 1945, Gröer created *Puca* taking into account a number of 100,000 inhabitants for the next 30/50 years; this number had already been exceeded by almost 48,000, just 40 years later (See Table 1).

2.3. Mobility

Although largely responsible for the establishment of people in the county, the river was also a natural barrier to circulation between the two margins. In 1944, 10.000 passengers crossed the river every day. In 1954, this number doubled, and there is a registry of 20.000 passengers doing this journey daily (Museu da Cidade, 2005a). The bridge over the river, a long discussed project, becomes urgent and it is at last inaugurated in 1966.

The bridge’s construction and the strengthening of existing links between the two banks of the river improved mobility, but it also caused the growth of urban denser areas near access roads to the bridge and river, thus leaving the interior areas of the peninsula more sparse, clearly benefiting the use of private transport and also allowing a more dispersed and disordered occupation of the Setúbal Peninsula’s territory.

The use of private transport was somewhat refrained during the 70’s due to a global oil crisis, but in the 80’s “traffic on the bridge accelerated again to extraordinary rates of growth of around 6,5 percent per year” (Museu da Cidade, 2005a). These values increased exponentially during the 90’s and, according to the Mobility Plan: Accessibility 21 “140.000 car trips are generated per day in the centre of Almada [in 2001] (...) and about 3.500 vehicles cross Centro Sul [rotunda at the entrance of Almada], heading towards Lisbon or Seixal (Museu da Cidade, 2005a). The excess of vehicles in the city centre causes environmental and public space occupation problems, “around 40 percent of vehicles parked in the centre of Almada do it illegally, occupying a total area of about 340,000 m²” (Museu da Cidade, 2005a). They are responsible for environmental pollution, excessive noise and traffic congestion. The public space that should be reserved for pedestrians, leisure, green spaces, is deprecated in relation to the space occupied by the various means of transport, including private automobiles.

3. The Metro Sul do Tejo (MST)

The project of a light rail transport system that would connect the centre of Almada to Cacilhas and other counties in the south was part of the City Hall strategies to reorder and requalify urban space and improve the environment quality and circulation in Almada (Vasconcelos, 2007). Previously to the MST construction, Almada had only a public bus service: Transportes Sul do Tejo (TST – Transport from South Tagus).

TST provides frequent connections to Almada’s downtown but are less frequent for its surroundings. TST main energetic resource is diesel, and according to *Elac* – Local Strategy for Climatic Alterations (Câmara Municipal de Almada, 2010) – they are responsible, along with private vehicles, for 43 percent of CO_2 emissions.

Fig. 2.
The Three Lines Initially Projected
Source: Vasconcelos (2007)

[3] The Functionalism of Louis Sullivan, followed the maxim “Form follows function” and profoundly influenced the architecture and design in Europe until mid-twentieth century.

MST's line construction started in 2006. Three phases of works were planned, connecting the centre of the city to main transportation interfaces, and also creating new interfaces in locations outside the city's centre, serving the populations from Seixal, Moita e Barreiro (See Fig. 1). The first phase, concluded in 2008, corresponds to lines 1, 2 and 3 (See Fig. 2) the benefits of this project, pointed out by the MST/Government studies, were:

- Accessibility improvement to Almada and better connections to Lisbon;
- Mobility improvement for the entire south bank population, better articulation between modal transportation systems;
- Less waste in resources and time of travel;
- Increase of the capacity and quality of public transports;
- More comfort for public transport users (Vasconcelos, 2007).

The same studies estimated a total number of 28 million people being transported in the first years: 90.000 per day in week days. The second and third phases of construction would help to solidify these numbers.

Fig. 3.
First Phase of Implementation
Source: http://transportesalmada.ageneal.pt/upload/docs/PDFs/Metro.pdf

4. Usage of the MST

In spite of its best intentions and good foresight, José Luís Brandão, MST's administrator, stated that user numbers were only 35/40 percent of what was expected in the preliminary studies (Silva, 2010). In 2011 *Agência Lusa* (National Agency for Information) announced that the second and third phases of construction were stopped, and the contract between the State and Consortium would be renegotiated.

This information was released after the MST's Audit Follow-up, held in 2011. Thus, the Court of Auditors Report states that "The MST project does not present evidence to be economically feasible, and the concessionaire itself recognizes that economic viability (...) is not possible without State support." (Tribunal de Contas, 2011).

Amongst the economic unavailability reasons that imply interrupting the network's construction are: (1) the high fraud rate of passengers actually transported – about 25 percent in December 2010. According to the concessionaire, some passengers do not validate tickets because of the existing "open" validation system. The validation machines are inside the trains, many users only validate tickets when control occurs; (2) the network design is not suited to current population needs, since it left out the *Garcia de Orta Hospital* (located on the edge of the central nucleus of the county) and *Almada Fórum*, a shopping centre in Feijó (southern limit of the county), both not served by the MST's. The Concessionaire argues that the project for the network was made in the early 90's, and it was built almost twenty years later, without being upgraded (Tribunal de Contas, 2011); (3) high amounts of compensation paid by the State between 2008 and 2011, that reach to about seven and a half million Euros per year.

Contrasting with the poor results (not conform to the original estimates – See Table 2), studies of satisfaction surveys conducted by MST found that the degree of overall satisfaction with the "new" means of transport stood at 7.70 percent in 2009 and 7.81 percent in 2010. Convenience of vehicles, appearance of the staff of MST, and the reduced travel time are mentioned as positive aspects (Tribunal de Contas, 2011).

Table 2
Traffic Forecast through 2011 versus Actual Traffic

	2008	2009	2010	2011
Minimum Limit	16.139.445	88.064.228	88.228.363	88.681.649
Estimated real traffic	1.889.278	24.725.862	29.329.763	32.261.410

Source: Auditoria de Seguimento da Concessionária MST. Tribunal de Contas, 2011, p.10.

Therefore we ask ourselves why, despite the high percentage of user satisfaction with the MST, is traffic volume so small compared to what was originally planned? The estimate of the user numbers was made based on the construction of all MST's lines and not only on the first phase of work. The current line of the MST, serves almost exclusively the centre of the municipality, the area that was already relatively well served by public transport. There are still no efficient solutions for people moving from outside the municipality of Almada (coming from Seixal or Barreiro) to Cacilhas or Lisbon, and tram is not feasible for these users. The private automobile continues, moreover, to increase its share of use and the issue of congestion in accesses to the main city, was only partially resolved.

The use of private transport as the main means of travel, follows a pattern similar to other European countries. During the last twenty years of the twentieth century, Europe witnessed a steady decline in public transport usage, replaced by private transport (European Commission, 2010), a direct effect of the improvement in population's financial conditions and lack of urban development strategies and problems in public transport – poor quality vehicles, inefficiency, unnecessary mandatory walking routes and lack of parking facilities in the vicinity of the stations / bus stops (Vasconcelos, 2007).

Gray designates the reasons for the preference of private transport over public ones, by the acronym SCARCE: Safety, Comfort, Accessibility, Reliability, Cost and Efficiency, stating that the automobile dominates over bus or other public transport because of quickest travel time, freedom from schedules, reliability, protection from weather and security. In Almada, despite its comfortable trams and high frequency of connections, MST could not substitute public transport for people coming from outside the county.

Another goal of MST line was to create better life quality in the town centre. The initial project included the construction of public parking, so people would have a place to park their vehicles outside main streets, and these streets could be safer and more enjoyable for everybody. However, during the construction process, this was not entirely achieved. Owners from the shops in 25th April Street, Afonso Henriques Street and D. Nuno Álvares Pereira Avenue (three main arteries of Almada) demonstrated in 2007 against the lack of security, lack of accessibility for pedestrians and dirtiness caused by the dust from the MST shipyards (Museu da Cidade 2005b).

Restrictions in circulation inside the city centre were pointed out as a cause of Almada's gradual "desertification". An average big number of commercial services closed in the sequence of MST construction, and it seems that people have no reasons to come to Almada. However, according to Trocado (2001), 55 percent of the local population refers Almada as a good place to live, 20 percent has the opinion that Almada has "everything necessary for living" (p. 31).

The author argues that even the negative connotation of peripheral urban spaces (spaces built outside the city centre previously connoted with criminality, for instance) is not correct, since these outskirts of Almada are also "potential places where the demographic growth and the existence of young people represent a positive value, contrasting with central town areas with weak demographics and an aging population" (Trocado, 2001).

Another factor that contributed for the displacement of commerce (and consequently the displacement of people from the city centre) was the construction of a big shopping centre in the outskirts of Almada. The Almada Fórum was inaugurated in September 2002. The building, parking areas and other support areas occupy 110.000 m^2.

With 260 shops, intended to receive around 18 million people per year, the new shopping centre created 2000 new jobs and its promoters were responsible for the construction of new accesses to the city (bicycle path, petrol station, tunnels and new roads around the shopping) improving the mobility of people in the entry of the city. At the time of construction, local commerce owners demonstrated against it, arguing that this new space "would accentuate the disequilibrium that already existed between local smaller shops" (Azenha, et al., 2002).

As pointed before, this new site was not included in the MST line. People mostly use their private automobiles to visit it; another option is the bus line. The tram takes travellers until Centro Sul and from there it is still 1,5 Km to reach the shopping.

5. Hypothesis for the flop

According to the analysis presented, we can conclude that the city of Almada did not always grew in the most appropriate or pleasant way for its inhabitants. In early years of the twentieth century, despite the good intentions of planners and City Hall, the expansion of the city was so chaotic, that caused serious problems of housing in areas where population growth was very strong. This demographic boom created also problems of transport for people used to travel short distances, by bicycle or on foot. Between the 70's and 90's there is a disproportionate increase of pollution levels, noise levels and traffic congestion caused by the excess of private vehicles circulating on the bridge over the Tagus River, and in the entries of Almada. Finally, in the last decade of the twentieth century several public entities attempt to solve this state of things, moving forward with the MST's project, a public transport, fast, quiet and clean, which would also allow more efficient connections to the city of Lisbon.

Despite the impact studies done prior to the completion of the project, and the debate promoted amongst its stakeholders, the MST implementation was always controversial, due to the assumed investment and required territory reorganization. In addition to necessary changes in long-established habits, MST had impacts on city's urban form that have not been fully provided. As stated by Lamas "Today it seems there is already consensus on the misdeeds of functionalism: central areas empty at night and dormitory cities are problems already reported *ad nauseam* and abandoned in the practice of planning" (Lamas, 2004). Almada mirrors itself on this description and contrary to what was expected, the implementation of MST was not able to solve the lack of population during weekends and evenings. The chaos of construction and repeated delays in its completion, has forced many shops to close doors, leaving a main city's artery almost deserted.

We can also argue that the city centre has changed, with the new principal MST stops, where the greater influx of people occurs.

Finally, I further strengthen that the draft that gave rise to the initial impact study and estimates of passenger numbers (very auspicious for the MST) has not been fully met. If the increase in population density leads to more pollution, noise, traffic congestion; the existence of areas farther from the centre also influence the use of private automobile for people who have no viable alternatives. The MST is not an alternative for residents outside the limits of the municipality of Almada, because the 2nd and 3rd phases of work were not completed.

People continue to find easier to use private automobiles and go shopping where it is possible to park just outside the shops, like is the case of Almada Fórum. Even if this massive commercial area brought an increase of jobs offer to Almada, the direct impact on the city's life was not considered, and it would have been of most importance to include a MST sop in this location.

6. Conclusions and future work

This paper examines mobility in Almada after the MST implementation. We discussed some hypothesis to explain the fail of this new tramline and its consequences to the city's life. First, the lack of urban planning in Almada created inhospitable areas that were abandoned by its residents – the city centre had already evidences of being "deserted" before MST inauguration; second, the city centre has changed, and this factor was not predicted. Finally, the original project intended to serve Almada and also residents from the surrounding municipalities, but only with the first phase concluded it has fewer users than it was expected.

We plan to continue this research with an empirical study as a way of obtaining concrete numbers about the actual users of MST. This will take place in two phases: (1) with a short enquiry in the main tramline stops, to have a more accurate understanding of who are the "real MST users"; (2) with interviews intended to collect feedback about user experiences (with the tram service, its preeminent touch points, staff, amongst other important issues).

Conclusions from this study will be part of an action plan proposition for MST.

References

Azenha, A.S.; Fernandes, D.; Marques. R. 2002. De olhos postos em 20 milhões de clientes. Correio da Manhã, Lisboa. Available from Internet: http://translate.google.pt/translate?hl=pt-PT&sl=pt&tl=en&u=http%3A%2F%2Fwww.correiodamanha.pt%2Fnoticia.aspx%3Fcontentid%3D00009369-3333-3333-3333-000000009369%26channelid%3D00000009-0000-0000-0000-000000000009&anno=2

Bonifácio, A. 2004. *Almada "Waterfront". Contributos para síntese da evolução do espaço público urbano. Espaço público e regeneração urbana: arte e sociedade*. UN Barcelona, Barcelona.

Câmara Municipal de Almada (Eds.). 2010. *Estratégia Local Para as Alterações Climáticas do Município de Almada*. Câmara Municipal de Almada, Almada.

Carvalho, J. 2003. *Ordenar a cidad.* Quarteto Editora, Coimbra.

European Commission. 2010. EU Energy and Transport in figures. Statistical Pocketbook. Available from Internet: http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf.

Gray, G.E. Perceptions in Public Transportation. Available from internet: http://ntl.bts.gov/data/letter_ak/Chapter22.pdf

Lamas, J.M.R.G. 2004. *Morfologia Urbana e Desenho da cidade*. (3rd Ed.). Fundação Calouste Gulbenkian. Fundação para a Ciência e Tecnologia, Porto.

Museu da Cidade. Câmara Municipal de Almada (Eds.). 2005a. *Mobilidade em Almada. Dossiers de informação*. Centro de Documentação – Museu da Cidade, Almada.

Museu da Cidade. Câmara Municipal de Almada (Eds.). 2005b. *Transportes em Almada: a evolução dos transportes em Almada. Dossiers de informação*. Centro de Documentação – Museu da Cidade, Almada.

Silva, R.; Vieira P. 1995. *História do Urbanismo em Almada*. Câmara Municipal de Almada, Almada.

Silva, N.M. 2010. Concessão do Metro Sul do Tejo vai ser renegociada, in Diário Económico. Available from internet: http://economico.sapo.pt/noticias/concessao-do-metro-sul-do-tejo-vai-ser-renegociada_101955.html

Rodrigues, J. M. S. 1999. *A expansão programada de Lisboa para a margem Sul: Almada, 1938-1950*. Retrieved from Master Dissertation. Instituto Superior de Ciências do Trabalho e da Empresa, Lisboa.

Tribunal de Contas (Eds.). 2011. Auditoria de seguimento à concessão Metro Sul do Tejo, Tribunal de Contas, Lisboa Available from internet: http://www.tcontas.pt/pt/actos/rel_auditoria/2011/2s/audit-dgtc-rel022-2011-2s_1.shtm

Trocado, F. 2001. *Modo de especialização social e apropriação quotidiana na cidade de Almada*. Câmara Municipal de Almada – Museu da cidade, Almada.

Vasconcelos, C. 2007. Projecto Metro Sul do Tejo – 12ª Reunião Intermédia de Comités Técnicos da ALAMYS – Sessão Plenária. Available from internet: http://www.alamys.org/documentos/CCTT_lisboa_MAY07/04_Metro_Transportes_do_Sul-MTS-Cristina_Vasconcelos.pdf.

PROBLEMS OF CREW FATIGUE MANAGEMENT IN AIRLINE OPERATIONS

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Abstract: Crew fatigue is increasingly recognised as a major threat to air traffic safety. Although there is plenty of research in risks related to human fatigue in different industries, more research is needed to precisely establish the correlation of crew fatigue and risk in airline operations. Current practice of fatigue risk management through appliance of flight time limitations has proven inadequate. On the other hand, the emerging methods of systematic fatigue risk management are heavily dependant on organisation's safety culture. Our work outlines the basic principles of risk management, observed problems of flight time limitations scheme, anticipated problems of fatigue risk management system and proposed solutions.

Key words: air traffic, fatigue, flight time limitations, fatigue risk management system, safety culture

1. Introduction

15-20% of fatal accidents related to human errors have pilot fatigue as a contributing factor. 160 people died in 2010 in an accident in India and 52 people in 2009 in an accident in the USA. Fatigue played a decisive role in both cases. Fatigue is a reality in Europe's cockpits today. 50-54% of pilots recently surveyed in several EU countries said they had already fallen asleep in the cockpit (Pilot fatigue).

Current practice of fatigue risk management through appliance of flight time limitations has proven inadequate, but the emerging methods can also fail, if the possible problems are not addressed in time.

2. Fundamentals of Sleep Science

There is plenty of knowledge in risks related to human fatigue, but the format of this paper does not allow us to address it in detail. However, some fundamentals (Caldwell and Caldwell, 2003) have to be mentioned before progressing to applications in aviation.

Fatigue is a function of three basic interconnected parameters:

- Sleep inertia – a short-term feelings of grogginess and disorientation, occurring when someone is woken up suddenly;
- Circadian parameter – a present position of peson's "body clock";
- Homeostatic sleep pressure – the body's need for slow-wave sleep, a function of time passed since last sleep.

All three of these parameters are further modulated with personal differences.

3. The Relationship between Fatigue and Fatigue Risk in Aviation

Throughout history, technology has outpaced human ability to adapt. Operating an aircraft produces fatigue, sleep loss and inetruption of circadian cyclus, initiating (Cabon, 2011):

- Microsleep (Eurocontrol, 2005) – short periods (several seconds or less) of total perceptual disengagement. MIcrosleeps are possible during critical flight phases, such as take off or landing.
- Prolonged reaction time.
- Instable cognitive ability (greater performance variations)
- Divergent processing (creative, inventive problem solving) – under greater influence than convergent processing (rule-based and check-list based problem solving).

Environmental factors, such as limited space, reduced airflow, background noise and vibrations in aircraft cockpit, are also contributing to fatigue. Besides, the increased cockpit automation has fundamentally changed the tasks pilots face. Manual handling has been substituted with systems monitoring, a low-effort task which throught extended time bears boredom. This implies the automation increases the symptoms of fatigue and sleep loss.
Different operational environment brings different operational demands, performed in different regulatory frameworks and by different populace. Therefore, every operational environment represents specific psychological challenges to people involved.

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The most notable examples of different operational environments:

- Short haul flights are specific for high number of sequential short flights, often with long duty days, short-spaced high-intensity workloads (take-offs and landings) with high proportion of time in the dense terminal zones. Additionally, these duties usually start very early or end late in the night. Long flight duties combined with periods of circadian low can result in degraded human performance. On the other hand, short haul flights require almost constant cognitve processing. Fatigue related risks in short haul operations are degraded cognitive and psyho-motorical abilities, which represent a partial pilot incapacitation. Full incapacitation (sleep) is not likely to occur.
- Long haul flights are characterised by long flight duties with long period of low workload. These duties are usually accompanied by a change in time zones, often during local nighttime. Fatigue related risks in long haul operations are mainly related to probability of one or both pilots falling asleep.

Jet lag syndrom is a continuous problem for long haul pilots. Crewmembers do not spend enough time in one zone to be able to adapt. A routine change of time zones produces a cronic jet leg, compromising the ability to stay awake and alert. Additionaly, a cockpit environment restricts body movement while low light and high automatisation demotivate alertness.

The other problem associated with circadian rhythm disruption is **work in shifts** and at night. Non-standard and variable work schedules require awakeness during normal sleeping hours and sleep during normal hours of activity. This is called Shift Lag. Although the symptoms with Shift Lag are similar to Jet Lag, the problems last longer because the local time cues are opposed to one’s circadian rhythm. Circadian rhythm disruption in shift work is present in:

- night shifts
- early-morning shifts
- change of shifts.

4. Methods of Fatigue Control in Aviation

4.1. Flight Time Limitations

Crewmembers' work hours are regulated by flight time limitations (FTL). These limitations prescribe in detail maximum amount of time on duty, cumulative time on duty, flight hours and minimum rest periods. For example, European FTL rules (EC, 2006) prescribe maximum flight duty time as 13 hours, reduced if encompassing a window of circadian low (0200-0559 LT), and further reduced by 30 minutes for each additional sector after the third. The rest period before start of flying duty must be minimum 12 hours or the lenghth of previous duty, whichever is greater.

Therefore, the main aim of the FTL concept is to ensure the control of fatigue risk by providing equal rules for all. However, it is applied on one-size-fits-all principle. Significant differences between different kinds of operation (long or short range; mainline, charter or general aviation) are disregarded. Also, the concept assumes a linear relationship between working hours and fatigue.

In its application, another major disadvantage emerges: these rules are crew planning target, not guidelines. They represent a legal line dividing what is safe (a flight duty time lasting 13:00 hours) from what is unsafe (a flight duty time lasting 13:01 hours). Can it be concluded that fatigue risk is acceptable for 13:00 and unacceptable for 13:01. Of course not.

Flight time limitations do not take into account (Stewart, 2009):

- Sleep opportunity and quality linked to crew traits and lifestyle;
- Fatigue risk associated with flexible shift patterns where it is more difficult to obtain sleep;
- The ability to perform complex tasks safely when sleep deprived;
- Risk associated with the flight before roster generation e.g. weather, ATC, route complexity, crew experience; aircraft serviceability;
- Workload on the day (task demand and number of block/duty hours programmed) and operational hassle factors (delays, aircraft AOG, complex and congested airspace) [4];
- That the protection of being “legal” does not necessarily equate to being safe.

To conclude, due to described deficiencies every operator and/or authority must determine if a specific rotation (combination of flights within single flight duty) is safe, even if it fits into FTL scheme. Again, a rotation legal under FTL is not necessarily safe.

[4] Operational hassle factors also include the availability of equipment on ground and weather. Ground equipment (e.g. ILS) defines the possibility of automation. Weather factors not only present risk in itself but significantly contribute to fatigue accumulation (e.g. prolonged turbulence).

4.2. Fatigue Risk Management System

Science and experience have clearly shown the fatigue risk in aviation must be managed better. Shortfalls in current regulatory practice must be corrected and guidelines to operators must be established how to set a safe system.

ICAO defines a Fatigue Risk Management System (FRMS) as:
A data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness.

FRMS is an integral part of Safety management system (SMS) and it also shares the building blocks of SMS.

The Fatigue Management SARPs (Annex 6, Part I and Appendix 8) prescribe components that must be in an FRMS, and the ICAO guidance material provides further information on how an FRMS should function. Annex 6 prescribes state regulations for fatigue risk management. This implies primarily to FTL, but also leaves provision for implementation of FRMS:
4.10.2 The State of the Operator shall require that the operator, in compliance with 4.10.1 and for the purposes of managing its fatigue-related safety risks, establish either

> a) flight time, flight duty period, duty period and rest period limitation that are within the prescriptive fatigue management regulations established by the State of the Operator; or
> b) a Fatigue Risk Management System (FRMS) in compliance with 4.10.6 for all operations; or
> c) an FRMS in compliance with 4.10.6 for part of its operations and the requirements of 4.10.2 a) for the remainder of its operations.

Therefore, the implementation of FRMS is not mandatory if an operator chooses to conduct its operations within prescribed flight time limitations. It is however recommended. The reason why most operators choose not to run an FRMS is simple – extra costs. Although, the benefits are hard to measure before the system is implemented, this comes down to a safety classic of productive versus protective functions of an organisation (Reason, 1997). The main advantages of FRMS implementation are (Stewart, 2009):

- avoiding pitfalls of FTL (as described above, but also);
- FRMS gives you measures of fatigue risk exposure;
- Safety links to commercial interest via brand protection;
- Facilitates increased rostering flexibility and workload balancing;
- Better packaging of work time and time off;
- Company insurance premiums are linked to risk signature;
- Reduction in frequency of medium and high risk events;
- Reduction in oversight from the regulating authority;
- Reduction in attrition (...);
- Reduction in fatigue lost duty days and sickness incidence due fatigue related factors.

5. Important Aspects of FRMS

5.1. FRMS Education and Trust

FRMS is focused on human performance and limitations. Therefore, the two most important FRMS building blocks are:

- Training and information sharing – a continuous training of all relevant stakeholders: crewmembers, crew schedulers, dispatchers, operational decision-makers, all members of Fatigue Action Safety Group (ICAO, IATA, IFALPA, 2011)[5], and personnel involved in overall operational risk assessment and resource allocation. It also includes senior management, in perticular the executive accountable for the FRMS and senior leadership in any department manageing operations within the FRMS (ICAO, IATA, IFALPA, 2011).
- Effective safety reporting based on generative safety culture. There must be adequate trust and respect among all relevant stakeholders. Management must trust their crewmembers to responsibly utilise their rest opportunity and not to abuse the reporting system for industrial reasons. Crewmembers must trust their management to use FRMS primarily to enhance safety, not profit. Authority must trust the operator to run the system in safe, generative manner.

[5] Fatigue Safety Action Group (FSAG) – A group comprised of representatives of all stakeholder groups (management, scheduling, crew representatives) together with specialist scientific, data analysis, and medical expertise as required), that is responsible for coordinating all fatigue management activities in the organisation

One example of training is a changed perspective on in-flight naps (UK CAA, 2003), or “controlled rest on the flight deck”, as ICAO, IATA and IFALPA prefer to call it. Controlled rest on the flight deck is an effective fatigue mitigation for flight crews (ICAO, IATA, IFALPA, 2011), keeping or restoring attention, performance and emotional state. If fatigue is experienced during flight operations, as little as 15 minutes of napping can significantly help[6]. While historically viewed as a sign of laziness, in-flight napping is today recognised as a very powerfull tool for fatigue control.

The example of enhanced understanding of fatigue science in crew planning is a consideration of “sleep gates” - periods when it is easier to fall and stay asleep and periods when this is very hard (forbidden zone).

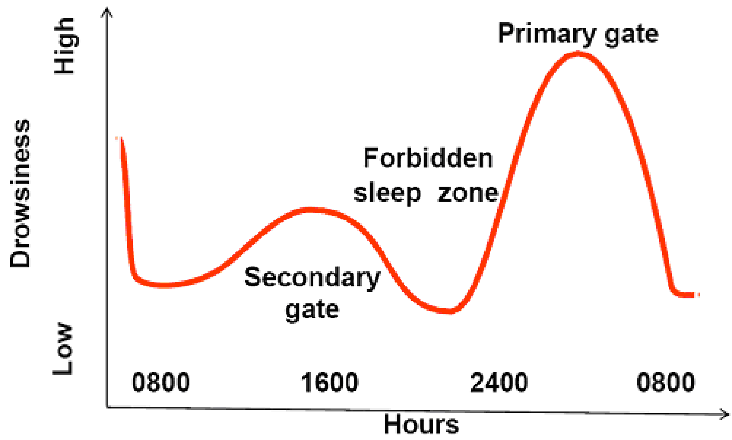

Fig.1.
Schematic representation of time periods favoring sleep onset
Source: Cabon, 2011.

Most of the training is actually a promotion of the system: building trust and reporting culture. This is a joint part of FRMS and SMS. Continuous education and awareness retention of management is at least as important as the education of operational personnel. If the management sees FRMS primarily as a productivity enhancement tool, the system will have a negative impact on safety. Not only will fatigue risk be sustained or even worsened, but the safety culture will be eroded, which will have a secondary impact on the entire SMS.

This leads us to the componenet that crucially determines FRMS utilisation and success: trust.

5.2. Measuring Fatigue

Fatigue is operationally defined …

- Subjectively by self-report, e.g., “I am tired.”
    - o Karolinska Sleepiness Scale (KSS)
    - o Samn-Perelli Fatigue Scale
- Objectively by degraded performance, for instance
    - o Psychomotor Vigilance Task (PVT)
    - o FOQA-derived metric

FRMS is actually mostly based on subjective fatigue reports, which is why reporting culture is crucial to its success. Besides fatigue reports, there are various computer applications for duty schedule analysys (e.g. FAID) utilised to analyse certain flight rotations or monthly schedules.

Since FRMS is data-based, more research is needed to develop standardised fatigue risk indicators. More operational feedback from the operators would create a collective experience database.

[6] Not usable on short-haul flights

6. Some problems with FRMS

Finally, a question must be asked if FRMS can provide an "equivalent or greater level of safety". There are several problems associated with its successful implementation or with the concept as a whole. Some of them are:

1. The prerequisite for safe FRMS is a well developed safety culture, which itself is unregulated.
2. FRMS will always shift the system from protective to productive. Otherwise it will not be implemented.
3. FRMS is a form of self-regulation, which can inherently be unsafe.
4. The core process of FRMS is safety assessment, objectivity of which is questionable.
5. Any form of fatigue self-assessment is of questionable value.

6.1. The Prerequisite of Safety Culture

It is undoubtedly agreed that "both SMS and FRMS rely on the concept of an 'effective safety reporting culture (ICAO, 2009; IATA, 2009), where personnel have been trained and are constantly encouraged to report hazards whenever observed in the operating environment" *(ICAO, IATA, IFALPA, 2011).

It would therefore be logical to expect the legal requirement for a 'effective safety reporting culture'. There is none. In fact, there is not even an industry standard, no widely accepted measuring method (Steiner et al., 2009). With approval to switch from FTL to FRMS, an authority provides guarantee to travelling public that the system is safe. But, how can it guarantee a specific operator's FRMS is safe if it cannot guarantee it has a 'effective safety reporting culture'?

6.2. The Balance between Productivity and Safety

Under current provision, an operator gets to choose whether to stay with FTL or switch to FRMS, with possibility of just switching a part of its operations. While the justification of extra costs was stipulated in chapter 4.2, it is worth addressing this issue from the perspective of historical safety management.

With resources always limited, management must always balance between production and protection (Reason, 1997). With results direct and immediately visible, there is a tendency for an organisation to drift to more production and less protection. Experience had therefore always shown (not just in aviation but in every conceivable industry) that an invention, even if it is a purely safety device, always ends up enhancing production, while safety remains on the previous level – better protection simply allows an organisation to exploit areas previously deemed to risky.

There is no reason FRMS would behave differently. It will ultimately evolve into production enhancing tool.

6.3. The Deregulation Controversy

Switching from prescriptive (FTL) to performance-based (FRMS) regulation is a form of deregulation, also known as self-regulation. It is a current trend in many industries and promoted by aviation authorities not just in fatigue control but in other areas of risk control. While it is still early to know what effect will self-regulation impose on aviation safety, it is possible to compare to other industries, where self-regulation concept had a longer chance to prove itself. The most current example of self-regulation is deregulation of financial sector and the resulting financial crisis. What had brought the world financial banking system on the brink of collapse were: complex products, lack of adequate and sufficient oversight (partly due to lack of expertise), deregulation and wrong incentives (where bonuses are calculated based on short term profits even if it means risking the company on the longer term) (Lewis, 2011; Stiglitz, 2010).

There is a large literature in economics and political science describing how regulators often get "captured" by those they are supposed to regulate. In the case of self-regulation, capture is obvious (Stiglitz, 2010).

There are many other examples in other industries (Deepwater Horison oil spill, Three Mile Island disaster, Ford Pinto etc...) that show self-regulation does not work. *Sometimes, the financial companies (and other corporations) say that it is not up to them to make decisions about what is right and wrong. It is up to government. So long as the government hasn't banned the activity, a bank has every obligation to its shareholders to provide funds so long as its profitable to do so* (Stiglitz, 2010). The government (by resposible agency) has obligation to its citizens to adequately regulate every industry. FRMS must not become self-regulation.

6.4. The Objectivity of Safety Assurance

The core operational activities of the FRMS are the FRM processes and the FRMS safety assurance processes (ICAO, IATA, IFALPA, 2011). The core activity of FRM is assignment of a certain risk level within probability/severity matrix. The risk is then proclaimed acceptable or not. No matter how the matrix is defined, its categories are not numerical, but rather fuzzy: for example, probability is frequent to extremely improbable, severity is catastrophic to negligible. This brings risk assessment down to "educated guessing".

While there is nothing fundamentally wrong with “educated guessing”, it is crucial who does it. It was already mentioned the management would be production-oriented, while crewmembers would incline to less work and more safety. The risk assignment would be biased accordingly. Therefore, there should be a representative(s) of crewmembers among the risk assessment group.

6.5. The Objectivity of Self-Assesment

One of crucial inputs for FRMS safety assurance process comes from crewmembers questionnaires, reports and surveys, self-assesing the level of fatigue. This information is inevitably subjective, and therefore its reliability is open to question. Reliability is a particular issue when crewmembers are asked to accurately recall details of past events, feelings, or sleep patterns. This is not to question crewmembers’ integrity – inaccurate recall of past events is a common and complex human problem. Concerns about whether some crewmembers might exaggerate in their responses, for personal or industrial reasons, should be minimal in a just reporting culture as is required for FRMS. But, who is to judge if the culture is just or not? Once again, this proves the requirement for crewmembers' representative to be involved in the establishment of FRMS from the beginning.

7. Conclusion

Crew fatigue is increasingly recognized as a major threat to air traffic safety. Both prescriptive (Flight Time Limitations) and performance-based concepts of fatigue risk control have their advantages and disadvantages. In order to achieve “equal or greater level of safety” various problems associated with FRMS must be addressed in advance. If this is not the case, FRMS could increase risk not only through increased crew fatigue, but secondary through decreased level of safety culture and negative impact on overall SMS.

8. References

Caldwell, J.A.; Caldwell, J.L. 2003. *Fatigue in aviation: a guide to staying awake at the stick*, Ashgate publishing LDT. Aldershot, England: 39-43.

Reason, J. 1997. *Managing the risks of organizational accidents.* Ashgate publishing limited, UK.

Lewis, M. 2011. *The Big Short: Inside the Doomsday Machine*, Penguin Books Limited, UK.

Stiglitz, J.E. 2010. *Freefall: America, Free Markets, and the Sinking of the World Economy.* New York: W. W. Norton & Company, Inc.

Dekker, S. 2007. *Just Culture – Balancing Safety and Accountability*, Ashgate publishing LDT. Aldershot, England.

Cabon, P. 2011. The science behind FRMS : the causes of fatigue, In *ICAO’s FRMS Symposium.* Montreal, Canada.

Stewart, S. 2009. EasyJet: Fatigue Management in Transportation Operations, In Proceedings of the *International Conference on Fatigue Management in Transportation Operations: A Framework for Progress.* Boston, USA.

Steiner, S.; Gradišar, T.; Smrečki, B. 2009. Problems of SMS implementation in transition. In *Proceedings of 21st annual European Aviation Safety Seminar*, Nicosia, Cyprus.

Pilot fatigue. Available from Internet: <http://www.dead-tired.eu/pilot-fatigue/facts/pilot-fatigue-danger>

Eurocontol. 2005. Fatigue and sleep management, DAS/HUM. Available from Internet: <http://www.skybrary.aero/bookshelf/books/220.pdf>

European Commission. 2006. Regulation (EC) No 1899/2006 of the European parliament and of the council of 12 December 2006, Subart Q Flight and duty time limitations and rest requirements. Available from Internet: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:254:0001:0238:EN:PDF>

ICAO, IATA, IFALPA, 2011. FRMS Implementation Guide for Operators, 1st Edition. Available from Internet: <http://www2.icao.int/en/FatigueManagement/Pages/FatigueManagementTools.aspx>

UK CAA. 2003. Paper 2003/8. A Review of In-flight Napping Strategies -Updated 2003. Available from Internet: <http://www.caa.co.uk/docs/33/2003_08.PDF>

ICAO. 2009. Safety Management Manual (Doc 9859). Available from Internet: <http://www.skybrary.aero/bookshelf/books/644.pdf>

IATA. 2009. Introduction to Safety Management Systems (SMS), 2nd Edition. Available from Internet: <http://www.mahan.aero/docs/docs/introduction_to_sms_2nded_october_2009.pdf>

Airbus. 2004. Getting to grips with fatigue and alertness management, Issue III. Available from Internet: <http://www.smartcockpit.com/download.php?path=docs/&file=Getting_To_Grips_With_Fatigue_and_Alertness_Management.pdf.>

Flight Safety Digest. 2005. A Roadmap to a Just Culture: Enhancing the Safety Environment, 24(3). Available from Internet: <http://www.skybrary.aero/bookshelf/books/233.pdf>

EASA. 2012. Notice of proposed amendment (NPA) No. 2012. Available from Internet: <http://www.easa.europa.eu/rulemaking/docs/npa/2012/NPA%202012-02.pdf>

Moebus Aviation, EASA. 2007. Final Report “Scientific and Medical Evaluation of Flight Time Limitations”. Available from Internet: <http://www.easa.europa.eu/rulemaking/docs/research/FTL%20Study%20Final%20Report.pdf>

WORK RELATED STRESS OF POSTAL CLERKS

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Abstract: Work-related stress has its roots in a form of work organization defined by work content and context, working methods and the time aspects of work. In cases where the stressor is prolonged, stress may affect health. The primary approaches to controlling stress require a redefinition of relations between workers and organizations, allowing greater communication and participation of workers in the work process. The study was aimed to show the sources of pressure at work and a way of coping with the stress of the personnel in five postal units of the Public Enterprise of PTT communications "Serbia", based on survey results.

Keywords: Stress at workplace, Sources of work pressure, Coping Strategies, Postal clerks.

1. Introduction

According to recent definitions stress could be described as a personal experience caused by pressure or requirements imposed to an individual as well as individual's ability to deal with them or her/his perception of this ability. Work related stress can be experienced when the requirements of work do not match the resources, capabilities or needs of the worker. Subjective evaluation and self-reports of stress are treated as "objective" data to the same extent as the statistics on accidents and absences from work.

The organization of this study is as follows: a review of the literature about work related stress will be presented. In the next section, a model for stress level assessment and coping strategies will be proposed. In the fourth section, the results of a research carried out at Serbian Post, analyzing 100 postal clerks working in five branches, are shown. Finally, we conclude with main findings of the study and further suggestions for the company.

2. A Literature Review about Work Related Stress

National Institute for Occupational Safety and Health (1999), as well as Bond et al. (2006) make the difference between stress and pressure, where the pressure could be defined as a subjective feeling of tension or anxiety initiated by a potentially stressful situation. However, when the pressure exceeds the individual's capacity to cope with, the result is stress.

There are six categories identified by National Institute for Occupational Safety and Health that can be clasified as key elements of job conditions that may lead to stress:

- *Task Design* **–** heavy workload, infrequent rest breaks, long work hours and shift work; hectic and routine tasks.
- *Management Style* **–** lack of participation by workers in decision- making, poor communication in the organization, lack of family-friendly policies.
- *Interpersonal Relationships* **–** poor social environment and lack of support or help from coworkers and supervisors.
- *Work Roles* **–** conflicting or uncertain job expectations, too much responsibility.
- *Career Concerns* **–** job insecurity and lack of opportunity for growth, advancement, or promotion; rapid changes for which workers are unprepared.
- *Environmental Conditions* **–** unpleasant or dangerous physical conditions such as crowding, noise, air pollution or ergonomics problems.

Another potential risk factor is the balance between the demands of work and family and private life. "Vicious circle" may occur when the accumulated stress in one area of life is transferred to another making the overcoming of the stress from the other sphere more difficult. Palmer et al. (2001) added the seventh driver of stress – the culture of organization. There are certain links between job stress and a number of physical and mental disorders despite the difficulties in proving a direct causal link since most diseases and syndromes that are attributed to stress may have a variety of causes. The effects of job-related stress are manifested in physiological, cognitive, emotional field and through the development of certain forms of behavior.

Estimates of the total costs of stress and illnesses caused thereby are very different. It is mainly because of the different methodologies used to obtain the final numbers:

- Self reported stress related to the job, depression and anxiety are responsible for the reported 12.8 million in lost workdays per year in the UK.

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- After musculoskeletal disorders, stress gives by far the largest contribution to the total number of days lost due to poor health caused by work in the UK.
- Considering average values, stress is the most expensive of all illnesses in terms of work days lost per case.

Statistics show that:
- The most cases of poor mental health caused by work occur in population between 35 and 44, and 45 and 54 years.
- There is a significant difference in the distribution of cases among men and women, with more cases among women in the age group of 25-34, and more cases among men in the age group of 35-44 years.
- Full-time employment is associated with higher levels of stress than part-time employment.
- 64% of public sector workers are likely to report stress as the main danger in their care on the job, compared with 48% of private sector workers.
- The stress levels increase with higher levels of education achieved.
- Stress is 29.1% more prevalent among black and ethnic minority workers than among white workers.
- Jobs that involve taking care of the sick, teaching, administrative work in government and related organizations and health care could be regarded as most stressful occupations.

It is believed that the amount of work is the most prominent factor that causes job related stress. There have not been many changes in the relative hierarchy of factors related to job related stress since 2000. Besides the amount of work, other factors such as reducing the number of staff, long working hours, abuse, shift work and sexual harassment or racism contribute to the development of stress in the work situation. It is clear that the forms of uncertainty change over time, such as changing the conceptual language we use to express consequences. Regardless of whether it is real or we just feel it through the emergence of subjective symptoms, stress can be quantitatively measured and demonstrated. Layard (2005) showed that increased wealth and prosperity does not necessarily lead to happiness of a person, even though the people who live in wealthier nations tend to be happier than those who live in the poorer. Layard (2005) identified the "big seven" factors that influence happiness of which the most important is a job, because except providing income, work gives additional meaning to life, affecting self-esteem and other social relationships. However, the reverse is also true: a job may create stress and frustration, which can be attributed to our innate need to achieve a better social status. Social position affects our health and longevity. Marmot (2004), by seeking ways to eliminate social disparities for the sake of public health improvements, observed stress in other ways, linking increased levels of stress with the lack of action/control that comes with the position of poorer status. This view is somewhat opposite to the usual notion that stress increases with the overload of workers, which is often attributed to higher status positions of social/professional excellence.

The question is whether it is really possible to measure stress. Some of the problems that we face with in the attempt to quantify the stress level are the following. The method of self-reports in the data collection process raises questions about the reliability of the data due to their subjectivity. Furthermore, the distinction between job related and stress caused by factors outside of work is important but problematic. Traditional methods of assessing the risks and physical dangers change the meaning when they are correlated with stress. Data on stressful events are often too reliant on a single dimension; usually self reported incidents and experiences. Finally, the controversy over the meaning and definition of stress impede progress in the treatment and monitoring, especially in prevention. Furedi (2003) noticed that there was a growing dominance of therapeutic culture in Western countries which promotes the concept of person as a weak, frail and incompetent to deal with the emotions that create new experiences without medical intervention. In addition to social and political debate, the issue of stress in the workplace requires specific responses from employers and policy makers. Although the context has been changing in both cases, it is clear that there is a growing liability for employers to contribute to the prevention and management of stress in the workplace.

In the organizational context, stress is defined as the emotional, cognitive, physiological and behavioral responses to aversive and noxious aspects of work, work environment and work organization. It is a condition characterized by high levels of anxiety and concern and often by a feeling that cannot be successfully overcome.

3. A Model for Stress Level Assessment

Existing literature in the field of human resource management refers to the appropriate and acceptable economic model of the working process, puts emphasis on the financial side of the organization, but not a unique concept for any particular organization. Management and company leaders, especially in the case of organizations in transition, should recognize the possibilities of existing theories based on modern practices and find the solutions suitable for them.

It is necessary to recognize the centers of responsibility and incorporate them into the organization, as it is, in our case, Serbian Post. Strategic planning is only one among the strategic management processes, and it consists of several stages.

Strategic planning defines the purpose of the company and its future desirable image, identifies the objectives, analyzes the environment and on the basis of the above forms the corporate strategy in order to achieve predefined objectives. It is an essential way to make important decisions, determine the tactics and implementation of actions needed to shape and lead the organization into the future, following its vision, direction and mode of actions. To achieve the above mentioned, it is important to continually raise the quality of service by training the employees, not only in terms of expertise, but in the way that will ensure the improvement of the level of communication between users and employees. If the organization provides to employees a positive work environment, they will often return the maximum effort and enthusiasm. The prerequisite for this is that workers can affect the development of their environment and are aware of that. The motivation is not always related to the financial aspect. Certainly the wages should match the qualifications and complexity of tasks; however financial incentives affect employees' motivation only in short-term. Besides inappropriate salary there are a number of other reasons that cause demotivation: bad employee relations, poor management, etc. The list of possible demotivation factors is huge, for example, workers receive information about the difficulties in the company or dismissions from the media, not as they should - from the management; the fear from losing the job; excessive supervisor's control, mobbing by a superior or colleague; employees' ideas or suggestions are not considered, the lack of praise for successfully completed projects, insufficient or excessive amount of work assigned to employee, injustice and cruelty, for example, when management announce mass cost reduction or dismissions, but at the same time increase their own salary. If companies successfully eliminate those factors or reduce bad effects of some unpleasant situation by appropriate information, communication, fairness and positive environment, their employees will be faithful to the organization even in difficult moments.

Each worker should be in position to know what it is possible to be done by herself/himself to improve the current situation. The prerequisite for this is that her/his actions have certain effects. In order to be trusted by work force, the supervisor must take into account their psychological state. In this sense various strategies can be used, among others to cope with employees' stress.

A recent report by the National Association for Mental Health confirmed that the personality and strategies for dealing with stress may have direct, perceptual or mitigating effects on stress consequences. For example, extraverted person will be considered socially isolated job more stressful than introverted person. On the other hand, introverted person may consider a job with higher levels of social interaction difficult and stressful. In addition, as remarked by MIND team (2005) previous experience of workers, individual characteristics and personal ingenuity seem to affect how he or she interpret and cope with the special conditions and requirements of the job.

The report of the National Association for Mental Health also made an important difference between stress and pressure. The pressure is defined as a subjective feeling of tension or disturbance provoked by a potentially stressful situation. Having in mind that it stimulates mental alertness and motivation, it may have a positive impact on employee's performance and satisfaction. However, when this pressure becomes extreme, persistent and unrelieved, there is a risk of irritability, fear, frustration, aggression and stress, and may even contribute to a variety of short and long-term physical and mental illnesses. When the pressure exceeds the ability of individuals to cope with it, the result is stress.

Although the experience of stress is subjective and mediated by a personal assess of the situation, there are many crucial factors which could be identified as potential causes of work-related stress. They are, of course, different in degree and importance depending on the specific job. Bond et al. (2006) have identified six categories of potential stressors:

- *Demands* – aspects of work to which people have to respond, such as work load, work patterns, and the work environment (for example, noise, temperature, lighting and ventilation).
- *Control* – the extent to which people are independent and have the influence on how they do their work; low levels of job control by employees are usually associated with higher level of stress.
- *Support* – the encouragement, sponsorship, and resources provided by the organization, line management, and colleagues,
- *Relationships* – relationships with superiors, subordinates and colleagues may have a share in the individual stress levels. Low levels of trust and support are likely to increase stress. Additionally, conflict and harassment in the workplace are associated with increased stress.
- *Role* – the extent to which people understand their role within the organization, and the degree to which people do not have conflicting roles.
- *Change* – the extent to which organizational change (large or small) is effectively managed and communicated within the organization.

The primary approaches of stress control are intended to prevent its appearance by changing the source of stress. These approaches can be in broader sense divided into two types: reactive and proactive. Reactive methods try to identify and change those aspects or workplace or workers who can easily cause stress.

Proactive strategy is focused to the job itself rather than to the individual employee, trying to create a working environment as much as possible free of stress. In practice, the primary approaches tend to focus on the individual rather than on the job for a number of reasons. Proactive interventions are often considered too costly or disruptive, and are often seen as more difficult to implement than strategies that focus on the individual. Organizations are also likely to feel more comfortable with the control strategies that focus on the individual rather than the job, so that programs that target organizational level are rare. Interventions focused on individual workers typically include techniques such as cognitive re-evaluation, a relaxation guide, education related to exercise and nutrition and training to develop skills to overcome stress. Such approaches have resulted in short-term improvements in the levels of stress experienced by employees. However, basic objection is that responsibility for the prevention and treatment of stress is putted to the wrong side - to the individual rather than to organizations that should take actions to prevent their jobs to be environment which cause stress for employees. Speaking about long term strategy, it is not enough to train the individual worker with techniques on how to deal with potentially stressful situations, it is also necessary to introduce fundamental changes in the organization in an attempt to reduce aspects of the job that cause stress.

This idea led to the development of "healthy organization", characterized as one that successfully balances the needs and demands of all interest goups - customers, stockholders, employees, government and society. In healthy organization the responsibility for reducing stress is on the organization. More responsibility is given to the individual employee in order to actively participate in changes and business redesign, to engage in honest communication, to provide certain feedback on committed changes and to improve understanding of the constraints within the organization.

Healthy organizations are defined as those organizations that put together work and expertise and needs of workers, effectively control and reward performance, inform employees about the changes and decisions and make them part of these processes, support family and home needs of the workers. Therefore, the fundamental idea of healthy organization concept require redefinition and clarification of the relations between workers and organizations, allowing greater communication and employee participation and recognition of the unique needs of each individual.

In order to determine the sources of pressure at work and ways of coping with the stress of employees in branches of Public Enterprise of PTT Communications "Serbia", usually called Serbian Post, survey was conducted using questionnaires for testing the effects of stress in the workplace.

The study was conducted in five branches of Public Enterprise of PTT Communications "Serbia". The respondents were 100 employees who voluntarily agreed to complete questionnaires, with the age ranged between 26-55 years, of whom 65% are women and 35% men. Half of the sample consisted of respondents with a high school diploma, and almost an equal number of college and university graduates. Croxton questionnaire was used to examine the stress in the workplace. The questionnaire was designed to measure the sources of stress, to identify groups of people who are more susceptible to the influence of stress than others, and to identify the ways of overcoming experienced stress. There were 31 questions in the part of the questionnaire relating to the sources of pressure at work and 22 questions in the section devoted to coping strategies. Answers were given by circling the alternative that best describes the attitudes of respondents to the offered items, with 6 and 5 rating scale respectively.

4. The Results and Discussion

The most examinees consider the following factors as significant sources of stress in the workplace: the lack of social support from colleagues, impossibility to make important decisions at work and factors that are not under direct control of employees. The minimum number of workers considers the following factors as very significant sources of stress: a job for which they think they do not have enough skills, dealing with company policy, the impact that business has on family life as well as the factors over which they do not have direct control. A large number of respondents said that the following factors definitely are not a source of stress in the workplace: to work with someone of the opposite sex, the impact of work on private life, a partner who is also pursuing a career, underemployed and supervising the work of others. The largest percentage of respondents felt that too much work, lack of power and influence, inadequate salaries, inadequate training, vague nature of work, overtime, and risk-taking decision-making cause elevated stress in the workplace (Table 1).

Table 1
The Sources of Stress at Work

	Very definitely is a source	Definitely is a source	Generally is a source	Generally is not a source	Definitely is not a source	Very definitely is not a source
1. I have far too much work to do	13	20	34	15	10	8
2. I have a lack of power and influence	13	18	24	20	20	5
3. Over-promotion – being promoted beyond my level of ability	3	5	13	18	34	27
4. Under-promotion – working below my level of ability	13	13	20	24	22	8
5. I do not have enough work to do	13	3	15	24	25	20
6. Managing or supervising the work of other people	5	15	23	27	15	15
7. Coping with office politics	3	22	32	13	20	10
8. Taking my work home	24	18	20	10	18	10
9. Rate of pay	8	34	24	18	13	3
10. Personal beliefs conflicting with those of the organization	8	12	13	37	17	13
11. Inadequate guidance and back up form superiors	13	18	24	25	10	10
12. Lack of consultation and communication	23	20	32	15	5	5
13. Keeping up with advances in technology	10	15	30	20	20	5
14. Ambiguity in the nature of job role	5	13	32	27	13	10
15. Inadequate or poor quality of training/ management development	10	15	29	20	8	18
16. I have a lack of social support from my colleagues	8	8	44	13	13	14
17. My spouse's/ partner attitude towards my job and career	8	10	15	20	18	29
18. Having to work very long hours	20	10	32	10	8	20
19. Mundane administrative tasks	15	17	15	22	18	13
20. A lack of encouragement by superiors	15	17	18	22	13	15
21. Demands my work makes on my relationship with my spouse/ partner/ children	8	10	13	27	10	32
22. Being undervalued	13	18	22	19	13	15
23. Having to take risks	8	25	32	15	15	5
24. Working with those of the opposite sex	10	10	8	20	18	34
25. Absence of emotional support from others outside work	8	8	24	25	15	20
26. Demands that work makes on my private/ social life	3	15	23	24	20	15
27. Factors not under your direct control	3	18	19	37	15	8
28. Home life with a partner who is also pursuing a career	5	13	13	20	15	34
29. Making important decisions	13	3	44	17	10	13
30. Personal conflicts with others	8	13	24	22	13	20
31. Pursuing a career at the expense of home life	13	15	13	19	18	22

Speaking about coping strategies, most respondents almost always deal with the problems immediately as they occur, but in the same time they are very aware of their own limitations. Most of them are seeking ways to make their work more interesting and trying to reorganize their work. The highest percentage of workers sometimes seeks for help and advice from close persons and resort to hobbies or pastimes to reduce tensions. Respondents often try to cope with the situation in an objective manner and to manage their time effectively, but at the same time they suppress their emotions. For most employees home is a kind of 'refuge' and they deliberately separate work and home, so they are not prone to transfer business problems to the family. On the other hand, they rarely try to stay busy in order to take their mind off the troubles. The largest percentage of workers plans their activities in advance and set priorities in addressing the problem. Almost half of respondents try to divert attention from problems just sometimes. It is interesting that a large percentage of respondents rarely manage to delegate their responsibilities to others. Clearly, the respondents have relatively well-developed coping strategies, but they mainly rely on themselves when trying to solve the problem, avoiding to burden family and close persons.

Although the atmosphere in the examined branches of Serbian Post is satisfactory, it is necessary to introduce certain changes to the organization in an attempt to reduce aspects of the job that cause stress and in order to address the sources of stress that are in the culture of the organization.

Table2
Coping Strategies

	Never	**Seldom**	**Sometimes**	**Often**	**Always**
1. I deal with the problems immediately as they occur	3	0	13	37	47
2. I try to recognise my own limitations	3	0	13	42	42
3. I 'buy time' and stall the issue	20	29	23	18	10
4. Look for ways to make the work more interesting	0	13	18	37	32
5. Reorganise my work	3	13	29	37	18
6. Seek support and advice	10	10	35	25	20
7. Resort to hobbies or pastimes	13	15	39	18	15
8. Try to deal with the situation objectively in an unemotional way	5	5	20	52	18
9. Effective time management	0	10	15	40	35
10. Suppress the emotions and try not to let the stress show	3	15	20	32	30
11. Having home that is a 'refuge'	8	3	10	27	52
12. Talk to understanding friends	3	8	18	34	37
13. Deliberately separate work and home	8	8	15	32	37
14. Stay busy	15	29	23	20	13
15. Plan ahead	5	5	28	28	34
16. Concentrate on a specific problem	8	8	34	32	18
17. Set priorities and deal with problems accordingly	5	10	8	39	38
18. Use distractions	3	18	49	13	3
19. Resort to rules and regulations	0	5	8	40	47
20. Delegation	32	30	20	10	8
21. Try to avoid the situation	15	32	15	20	18
22. Seek as much social support as possible	22	23	20	20	15

5. Conclusion

Each modern company struggling for success on the competitive market tends to make continuous improvement of its business process in order to achieve high quality of products or services. Some solutions may be good at first glance, but if they function in the way that they produce higher employee stress, those solutions are not sustainable in the future and could lead to stagnation or decline in productivity. This is the reason why it is important to analyze stress level of employees in a company.

In this paper, beside the basic principles and theories from the field of work related stress, a model for stress assessment of postal clerks is presented together with coping strategies. The results showed that the largest percentage of respondents felt that too much work, lack of power and influence, inadequate salaries, inadequate training, vague nature of work, overtime, and risk-taking decision-making cause stress in the workplace. The respondents have relatively well-developed coping strategies, but mainly rely on themselves when trying to solve the problem. These results suggest that although the climate in the studied branches of Serbian Post is satisfactory, it would be useful to introduce some changes in the organization in an attempt to adapt aspects of the job that cause stress. It is clear from the survey results that employees use individual coping strategies which would be more effective if they could be joined together with organizational.

Acknowledgement

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References

Bond, F.W.; Flaxman, P.E.; Loivette, S. 2006. *A business case for the Management Standards for Stress.* HSE Books, Suffolk, United Kingdom.

Furedi, F. 2003. *Therapy Culture: Cultivating Vulnerability in an Uncertain Age*, Routledge, London, United Kingdom.

Layard, R. 2005. *Happiness: Lessons from a New Science*, Penguin books Ltd, London, United Kingdom.

Marmot, M. 2004. *Status Syndrome*, Bloomsbury Publishing, London, United Kingdom.

MIND team. 2005. Stress and mental health in the workplace, Mindweek report, London, United Kingdom.
Available from Internet: <http://www.mind.org.uk/assets/0000/6976/Stress_and_MH_in_the_workplace.pdf>.

NIOSH - National Institute for Occupational Safety and Health team. 1999. *Stress at Work.* National Institute for Occupational Safety and Health, Department of Health and Human Services, U.S.A.

Palmer, S.; Cooper, C.; Thomas, K. 2001. Model of organisational stress for use within an occupational health education/promotion or wellbeing programme – A short communication, *Health Education Journal*, 60(4): 378 – 380.

EFFECT OF SHOCK VIBRATIONS DUE TO SPEED CONTROL HUMPS TO THE HEALTH OF CITY BUS PASSENGERS USING OSCILLATORY MODEL WITH SIX DOF

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Abstract: Speed control humps (SCH) are one of the most efficient means used in streets to slow down the vehicle flow, improving traffic safety. An analysis of the effects of shock vibrations on passengers due to driving the typical city bus over the humps is made. Evaluation procedure estimates accelerations on occupants' seats as the value influencing their health. Peak vertical accelerations of passengers are calculated as the response of flat longitudinal oscillatory model of the bus with six degrees of freedom (DOF) while passing over three types of SCHs. Simulation is carried out through program written in Matlab, and ISO 2631-5 Standard evaluation method and criteria are used. The results show that passengers' health, particularly of those using seats on rear platform, may be jeopardized even after one pass over the 5 cm high rounded profile hump at speed of 15 km/h.

Key words: city bus, speed humps, shock vibrations, ISO 2631 Standard, occupants health

1. Introduction

Vibrations are some of most harmful impacts that vehicle occupants are exposed. They may incite sensation of discomfort, reduce work capacity, and by longer exposure may jeopardize health and provoke injuries and even vehicle occupants disability (Dedović and Mladenović, 1999). Health problems that occur relatively often are musculoskeletal disorders – pain in shoulders, neck, upper part of the back and very characteristic low back pain (Kompier, 1996; Whitelegg, 1995; Okunribido, et al., 2007; Bovenzi and Hulshof, 1999).

Passenger's low back pain is often connected to the effects of shock vibrations (Stayner, 2001) having the origin in collision of wheel and pothole or bump on road surface. Stronger shocks can provoke serious damage and injuries of spinal column of the vehicle occupant (Bowrey, et al., 1996).

While passing over SCH vehicle occupants are exposed to high intensity vibrations (Granlund, J.; Lindstroms, F. 2003On the other side, SCHs are most efficient measure for vehicle speed reduction (Bjarnason, 2004) and in urban zones their use contributes to the reduction of the number of traffic accidents (ITE, 1993).

First cases of musculoskeletal disorders with bus passengers are noted in Great Britain (Bowrey, et al., 1996). The paper (Bowrey, et al., 1996) quotes the passenger felt acute low back pain while a double-decker passed over SCH. Roentgen control of the passenger confirmed the fracture of third lumbar vertebra. In the second example from (Bowrey, et al., 1996), in similar situation, passenger got neck injury and injury of the right shoulder soft tissue. Paper (Aslan, S., et al. 2005presents cases of five bus passengers with spinal column injuries that occurred while passing over SCHs.

The use of SCHs in Belgrade, for the reason of their positive influence to traffic safety, is frequent. That's why there is a need to analyze the effect of vibrations which occur during bus pass over SCH, to the health of vehicle occupants. This is particularly important for bus passengers in mass public transport.

The paper analyzes the effect of shock vibrations due to bus pass over SCH using the model with six DOF and their influence to passengers of city bus IK-103. This is a typical bus used in mass public transport in Belgrade and other cities. The analysis is made according procedure proposed by ISO 2631-5 Standard (2004). Evaluation of vibrations effect to the occupants is completed for three usual profiles of SCHs, considering number of passes over and different bus speeds.

2. Bus Oscillatory Model

The bus IK-103 (Fig. 1) is a typical modern city bus with two rigid axles and pneumatic suspension system (Nijemčević, et al., 2001). Front axle has two pneumatic suspension elements and four hydraulic telescopic shock absorbers, and rear one is equipped with four pneumatic suspension elements and four shock absorbers. Front axle is fitted with two wheels, and rear one with two twin wheels (four tires). All tires are of the same size.

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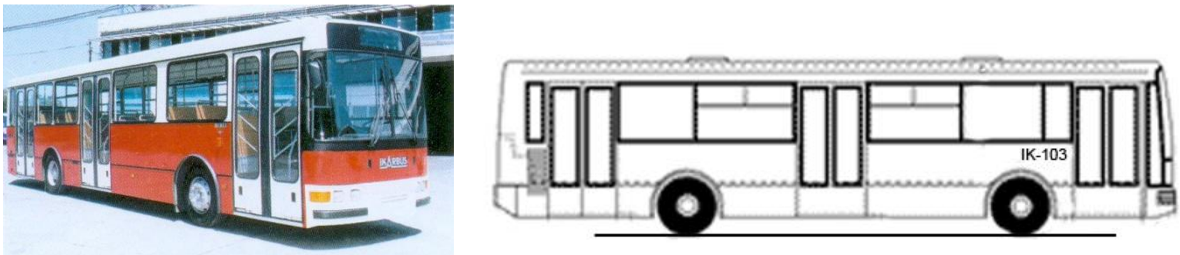


Fig. 1.
City Bus IK-103

Fig. 2 shows the arrangement of the rear axle of the bus considered and Fig. 3 presents the scheme of the rear suspension elements, with the geometry used for the calculation of equivalent stiffness and equivalent damping. Plane oscillatory model of the bus with six DOF is shown in Fig. 4.

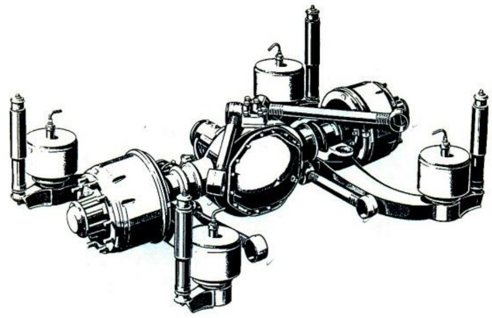


Fig. 2.
IK-103 Bus Rear Axle

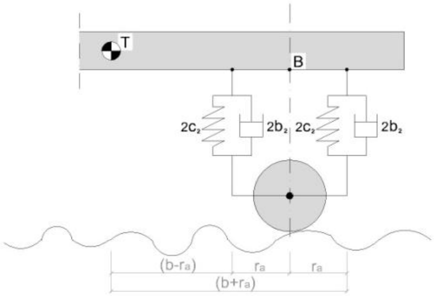


Fig. 3.
Rear Axle Suspension Elements

The independent displacements of the concentrated masses of the considered mechanical oscillatory system are vertical displacements of the passenger in the middle of the bus (*passenger1*), of the passenger in the rear end of the bus (*passenger2*), of the vehicle center of gravity (T) and of front and rear axles, as well as the angular motion of the suspended mass around the (transversal) y-axis.

Driver's working conditions and his exposure to shock vibrations are not considered here, and they were subject of another investigation (Sekulic, et al., 2012).

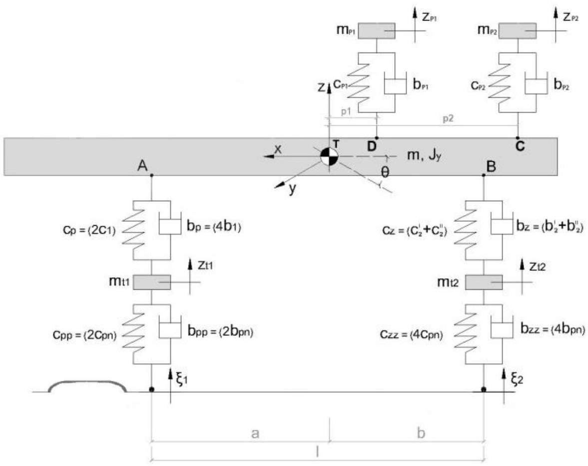


Fig. 4.
Plane Oscillatory Model of the Bus IK-103

The effect of vibrations transmitted from the road to the passengers' bodies depends also on the characteristics of their seats suspension. Considering that this is a typical city bus, passengers' seats are made in form of a plastic shell, with thin layer of elastic foam. The seats are fixed to the vehicle floor without any suspension element (Nijemčević, et al., 2001). Elastic and damping characteristics of the passengers' seats are given in Table 3.

Oscillatory model of the bus has been defined according the following assumptions:

- the bus is symmetrical relative to longitudinal (x) axis
- there are no angular movements around x-axis
- the excitations on both left and right wheels are the same
- all possible displacements of concentrated masses around the static equilibrium position are small
- all elastic and damping characteristics are linear
- the bus wheels are in permanent contact with road surface
- the bus movement is linear and at constant speed.

The meaning of the labels from Fig. 3 and 4 is shown in Tables 1, 2 and 3, together with the values of parameters used in simulation. The values are assumed after the relevant literature (Nijemčević, et al., 2001; Mladenović, 1997; Simić, 1979).

Table 1
Geometry parameters of the IK-103 bus

Geometry parameter	Value	
l - distance between axles	5.65	[m]
a - distance from the front axle to CG	3.12	[m]
b - distance from the rear axle to CG	2.53	[m]
$p1$ - distance from the *passenger1*'s seat to CG	-0.10	[m]
$p2$ - distance from the *passenger2*'s seat to CG	-4.23	[m]
r_a - distance from the rear axle suspension element to the vertical axis of the rear wheel	0.30	[m]

Table 2
Masses parameters of the IK-103 bus

Mass parameter	Value	
m_{p1} - mass of the *passenger1*	80	[kg]
m_{p2} - mass of the *passenger2*	80	[kg]
m - suspended mass of the partially loaded bus	11900	[kg]
m_{t1} - mass of the front axle	745	[kg]
m_{t2} - mass of the rear axle	1355	[kg]
J_y - inertia moment of the suspended mass related to transversal axis	50000	[kgm^2]

Table 3
IK-103 bus oscillatory model parameters

Oscillatory model parameter	Value	
c_{p1} , c_{p2} - passengers' seat spring stiffness	950000	[N/m]
b_{p1} , b_{p1} - passengers' seat damping	200	[Ns/m]
c_1 - one front axle pneumatic suspension element stiffness	175000	[N/m]
c_p - equivalent stiffness of front axle pneumatic suspension elements	350000	[N/m]
b_1 - one front axle shock absorber damping	20000	[Ns/m]
b_p - front axle shock absorbers equivalent damping	800000	[Ns/m]
c_2 - one rear axle pneumatic suspension element stiffness	200000	[N/m]
c_z - equivalent stiffness of rear axle pneumatic suspension elements	811250	[N/m]
b_2 - damping of one rear axle shock absorber	22500	[Ns/m]
b_z - equivalent damping of rear axle shock absorbers	91265	[Ns/m]
c_{pn} - front and rear tire stiffness (per tire)	1000000	[N/m]
c_{pp} - equivalent front axle tires stiffness	2000000	[N/m]
c_{zz} - equivalent rear axle tires stiffness	4000000	[N/m]
b_{pn} - front and rear tire damping (per tire)	150	[Ns/m]
b_{pp} - equivalent front axle tires damping	300	[Ns/m]
b_{zz} - equivalent rear axle tires damping	600	[Ns/m]

According to Fig. 3, the equivalent stiffness and equivalent damping for the rear axle are calculated using Eq. (1) and Eq. (2):

$$c_z = c_2' + c_2'' = 2c_2 \frac{(b-r_a)^2}{b^2} + 2c_2 \frac{(b+r_a)^2}{b^2} \tag{1}$$

$$b_z = b_2' + b_2'' = 2b_2 \frac{(b-r_a)^2}{b^2} + 2b_2 \frac{(b+r_a)^2}{b^2} \tag{2}$$

To start the analysis of the effect of shock vibrations to occupants' comfort, the differential equations of motion of concentrated masses of the oscillatory model are needed. Using the Lagrange's equations of second order, and considering earlier assumptions, the differential equations of motion of the proposed model are defined by following expressions (Eq. (3) – Eq. (8)):

$$m_{p1}\ddot{z}_{p1}+b_{p1}\dot{z}_{p1}+c_{p1}z_{p1}-b_{p1}\dot{z}-c_{p1}z+b_{p1}p_1\dot{\theta}+c_{p1}p_1\theta=0 \quad (3)$$

$$m_{p2}\ddot{z}_{p2}+b_{p2}\dot{z}_{p2}+c_{p2}z_{p2}-b_{p2}\dot{z}-c_{p2}z+b_{p2}p_2\dot{\theta}+c_{p2}p_2\theta=0 \quad (4)$$

$$\begin{aligned} &m\ddot{z}+(b_{p1}+b_{p2}+b_p+b_z)\dot{z}+(c_{p1}+c_{p2}+c_p+c_z)z+(ab_p-p_1b_{p1}-p_2b_{p2}-bb_z)\dot{\theta}+\\ &(ac_p-p_1c_{p1}-p_2c_{p2}-bc_z)\theta-b_{p1}\dot{z}_{p1}-c_{p1}z_{p1}-b_{p2}\dot{z}_{p2}-c_{p2}z_{p2}-b_p\dot{z}_{t1}-c_pz_{t1}-b_z\dot{z}_{t2}-c_zz_{t2}=0 \end{aligned} \quad (5)$$

$$\begin{aligned} &J_y\ddot{\theta}+(p_1{}^2b_{p1}+p_2{}^2b_{p2}+a^2b_p+b^2b_z)\dot{\theta}+(p_1{}^2c_{p1}+p_2{}^2c_{p2}+a^2c_p+b^2c_z)\theta+\\ &(ab_p-p_1b_{p1}-p_2b_{p2}-bb_z)\dot{z}+(ac_p-p_1c_{p1}-p_2c_{p2}-bc_z)z+p_1b_{p1}\dot{z}_{p1}+p_1c_{p1}z_{p1}+\\ &p_2b_{p2}\dot{z}_{p2}+p_2c_{p2}z_{p2}-ab_p\dot{z}_{t1}-ac_pz_{t1}+bb_z\dot{z}_{t2}+bc_zz_{t2}=0 \end{aligned} \quad (6)$$

$$m_{t1}\ddot{z}_{t1}+(b_p+b_{pp})\dot{z}_{t1}+(c_p+c_{pp})z_{t1}-b_p\dot{z}-c_pz-ab_p\dot{\theta}-ac_p\theta=b_{pp}\dot{\xi}_1+c_{pp}\xi_1 \quad (7)$$

$$m_{t2}\ddot{z}_{t2}+(b_z+b_{zz})\dot{z}_{t2}+(c_z+c_{zz})z_{t2}-b_z\dot{z}-c_zz+bb_z\dot{\theta}+bc_z\theta=b_{zz}\dot{\xi}_2+c_{zz}\xi_2 \quad (8)$$

Numerical solving of the differential equations is made through the program written in Matlab®, and Matlab's function *ode45* was used. Starting conditions defined for all variables were set to zero. According to ISO 2631-5 Standard, samples of the vertical acceleration signal are recorded at each 1/160 s. The time of simulation was limited to eight seconds.

Within the evaluation of the effect of shock vibration to the passengers' body in this paper, the dominant vertical acceleration on the passengers' seats was considered and the relevant part of the program from *Annex D* of the ISO 2631-5 Standard has been applied.

The *Annex D* considers the seated human body acceleration along all three axes (x, y and z). With this paper, only the part of program analyzing the effect of shock vibrations along the vertical axis on human health is applied. It is sufficient for the analysis, having in mind that vertical acceleration has major intensity and, accordingly, the most important negative effect to passengers' bodies.

3. Bus Excitation

Speed control humps, used on routes of city bus lines in mass passenger public transport (MPPT**)** in Belgrade wherever needed to considerably reduce vehicle velocity, have two main configurations. Fig. 5 shows a flat platform, and Fig. 6 the type with rounded profile. Characteristic dimensions of the humps are shown in Fig. 5 and Fig. 6, and corresponding parameter values are presented in Table 4 and Table 5.

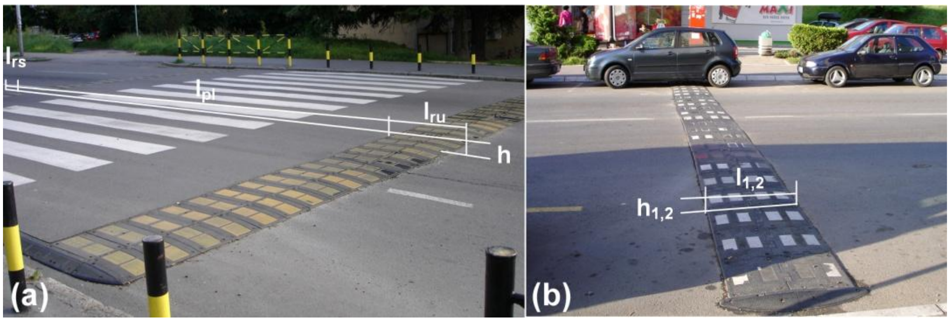


Fig. 5.
Speed Control Humps: A) Flat Platform B) Rounded Profile

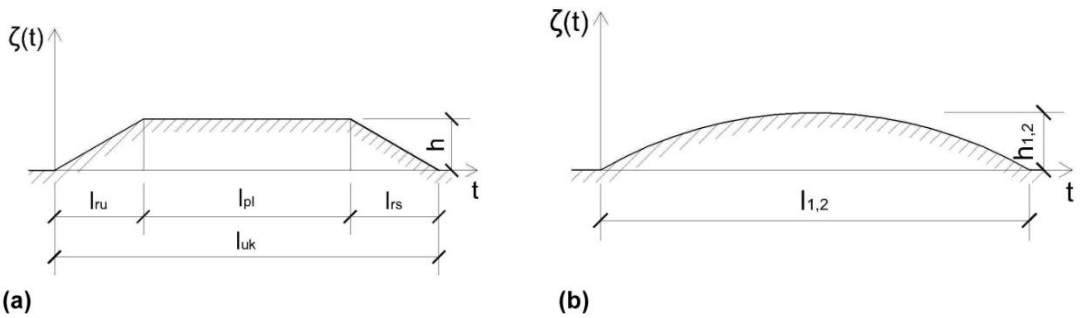


Fig. 6.
Cross Section of Speed Control Humps: A) Flat Platform B) Rounded Profile

The analytic expressions describing SCH in form of flat platform is given by Eq. (9), and one describing rounded profile by Eq. (10) (Salau, et al., 2004; Oke, et al., 2005). Characteristic dimensions are taken from manufacturer's data (Technical data for road humps, 2010).

$$\xi(t)=\begin{Bmatrix} \frac{h}{l_{ru}}\cdot V\cdot t,\ 0\le t<\frac{l_{ru}}{V} \\ h,\ \frac{l_{ru}}{V}\le t\le\frac{l_{ru}+l_{pl}}{V} \\ -\frac{h}{l_{rs}}\cdot V\cdot t+\frac{h\cdot(l_{ru}+l_{pl})}{l_{rs}}+h,\ \frac{l_{ru}+l_{pl}}{V}<t\le\frac{l_{ru}+l_{pl}+l_{rs}}{V} \\ 0,\ t>\frac{l_{ru}+l_{pl}+l_{rs}}{V} \end{Bmatrix} \tag{9}$$

$$\xi(t)=\begin{Bmatrix} h_{1,2}\cdot\sin(\frac{\pi\cdot V}{l_{1,2}}\cdot t),\ 0\le t\le\frac{l_{1,2}}{V} \\ 0,\ t>\frac{l_{1,2}}{V} \end{Bmatrix} \tag{10}$$

Table 4
Dimensions of Flat Platform

h - height of flat platform	0.08 [*m*]
l_{ru}, l_{rs} - length of ascending and descending ramp	1.00 [*m*]
l_{pl} - length of flat platform	10.00 [*m*]
l_{uk} - overall length of flat platform	12.00 [*m*]

Table 5
Dimensions Of Rounded Profile Humps

Rounded profile	Type 1	Type 2
$h_{1,2}$ - height of profile	0.03 [*m*]	0.05 [*m*]
$l_{1,2}$ - length of profile	0.83 [*m*]	0.96 [*m*]

The excitations due to flat platform and to rounded profiles for constant bus speed of 10 km/h are shown in Fig. 7.

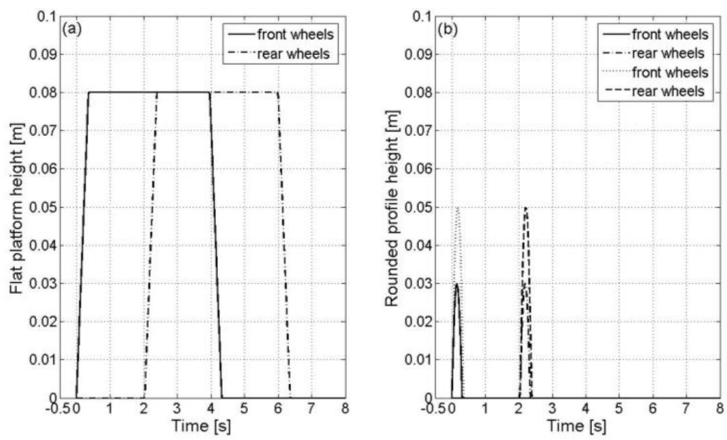


Fig. 7.
Excitation due to a) Flat platform h=0.08 m and b) Rounded profiles h=0.03 m and h=0.05 m, bus speed 10 km/h

4. ISO 2631-5 Standard

The ISO 2631-5 Standard defines the method of quantification of shock vibrations acting to the human body in sitting position. It also gives the procedure for the evaluation of vibrations effect to the human health. Based on the method described, the pressure exerted to the lumbar part of spinal column, consequent to shock vibrations, can be calculated. By comparison to the evaluation criteria, it is possible to assess the risk of getting health problems.

The ISO Standard defines *Daily equivalent static compression dose for lumbar spine - Parameter Sed* - as the value through which the effect of shock vibrations can be evaluated, (Eq. (11)).

$$S_{ed} = \left[\sum_{k=x,y,z} (m_k \cdot D_{dk})^6 \right]^{1/6} \tag{11}$$

where:

m_k - are constants with values $0.015[MPa/(m/s^2)]$, $0.035[MPa/(m/s^2)]$ and $0.032\ [MPa/(m/s^2)]$, for x, y and z axes respectively

$D_{dk(k=x,y,z)}$ - is the average daily acceleration dose for x, y and z axes $[m/s^2]$.

Average daily acceleration dose can be calculated according the Eq. (12):

$$D_{dk(k=x,y,z)} = D_{k(k=x,y,z)} \left[\frac{t_d}{t_m} \right]^{1/6} \tag{12}$$

where:

$D_{k(k=x,y,z)}$ - are the acceleration doses for x, y and z axes $[m/s^2]$,

t_d - is the period of daily exposure to shock vibrations and

t_m - is the time interval referring to which acceleration doses $D_{k(k=x,y,z)}$ are defined.

Acceleration dose can be calculated according the Eq. (13):

$$D_{k(k=x,y,z)} = \left[\sum_i A^6{}_{ik(k=x,y,z)} \right]^{1/6} \tag{13}$$

where:

$A_{ik(k=x,y,z)}$ - are the peaks of the lumbar spine acceleration responses for x, y and z axes $[m/s^2]$;

The procedure for calculation of the parameter *Sed* is described in detail in the *Annex A* of the ISO 2631-5 Standard (2004). For the calculated values of the parameter *Sed* one can estimate the effect of vibrations by comparison with the limit values - criteria, as follows:
- if *Sed<0.5* [MPa] the probability of negative effect of vibrations to health is low
- if *Sed>0.8* [MPa] the probability of negative effect of vibrations to health is significant

The evaluation criteria for the parameter *Sed* are set with the assumption that human body is exposed to shock vibrations during 240 days per year.

5. Results of the Simulation and Their Analysis

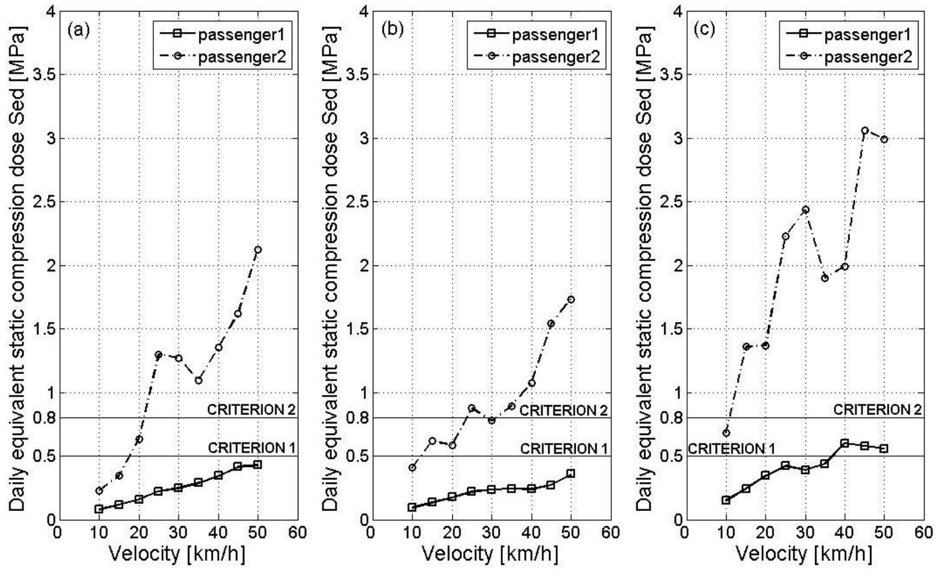
The law administrates the maximum speed of 50 km/h for MPPT bus (Subotić, 2009). The actual bus speed range in Belgrade is 10 to 50 km/h (GSP Beograd, 2005). That is why the range of 10 do 50 km/h is considered for the analysis of the effects of shock vibrations caused by SCH to the occupant's body.

Fig. 8 shows the change of parameter *Sed* for passengers in function of the bus speed for three types of SCH. The change of parameter *Sed* is analyzed for six passes over per day. The analysis is made for two positions of sitting passenger – in the middle part of the bus (*passenger1*) and on the rear bus overhang (*passenger2*).

After the Fig. 8, in all three cases, the parameter *Sed* has greatest values for the *passenger2*. In case of flat platform, values of the parameter *Sed* for the *passenger2* overcome both criteria 0.5 MPa and 0.8 MPa, at bus speeds greater than 18 km/h and 21 km/h respectively (Fig. 8a). For the bus speed of 50 km/h the value of the parameter *Sed* rises above 2.0 MPa, so shock vibrations have particularly negative effect to his health.

Passing over SCH with rounded profile h=0.03 m, *passenger2* is exposed to high risk of getting health problems at speed over 22 km/h (Fig. 8b). The highest value of the parameter *Sed*, over 1.5 MPa, corresponds to the speed of 50 km/h. For the *passenger1* the values of parameter *Sed* are lower than 0.5 MPa for all bus speeds considered, so the risk of negative influence of shock vibrations to its health is low.

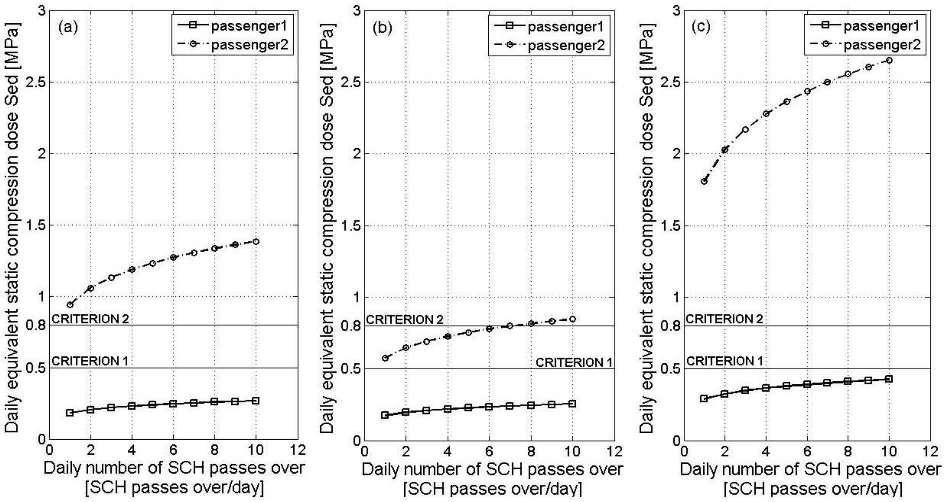
Passing over SCH with rounded profile h=0.05 m the value of the parameter *Sed* for the *passenger2* overcomes the criterion of 0.8 MPa at speed greater than 10 km/h (Fig. 8c). The parameter *Sed* for the *passenger2* has the greatest value of 3.1 MPa at the bus speed of 45 km/h. Such a great pressure in lumbar spine points to high risk for the *passenger2* health. The value of parameter *Sed* for the *passenger1* overcomes 0.5 MPa at speed greater than 35 km/h.



a) Flat platform *b) Rounded profile h=0.03m* *c) Rounded profile h=0.05m*

Fig. 8.
Change Of Daily Equivalent Static Compression Dose Sed For Passengers As Function Of Bus Speed For 6 Passes Over Per Day, For Three Profiles Of SCH

Fig. 9 shows the change of parameter *Sed* as a function of the number of passes over, for three types of SCH, both for *passenger1* and *passenger2*. The analysis is carried out for the bus speed of 30 km/h, for up to 10 passes over per day.
Parameter *Sed* for the *passenger2* has the greatest value in all three cases considered. High risk for health damage of *passenger2* is present even at first pass over the flat platform and over rounded profile h=0.05 m (Fig. 9, a) and b)). The highest value of parameter *Sed* for *passenger2* reaches 2.7 MPa for 10 passes over rounded profile 0.05 m high. In all three cases *passenger1* is exposed to low risk of health damage due to effect of shock vibrations.



a) Flat platform *b) Rounded profile h=0.03m* *c) Rounded profile h=0.05m*

Fig. 9.
Daily Equivalent Static Compression Dose Sed for The Passengers As Function Of Number Of SCH Passes Over, At Bus Speed Of 30 Km/H

5.1 Estimation of maximum daily number of passes over SCH for bus occupants regarding evaluation criteria for parameter Sed

Maximum daily number of passes over SCH where a risk for the health of occupants may occur can be defined, after the ISO 2631-5 Standard, from the Eq. (15) and Eq. (16):

$$N_{0.5} = \left(\frac{0.5}{S_e}\right)^6 \quad (15) \quad , \qquad N_{0.8} = \left(\frac{0.8}{S_e}\right)^6 \qquad (16)$$

where:

S_e – is the equivalent static compressive stress for the acceleration dose $D_{k(k=z)}$.

Tables 7 and 8 present maximum daily number of passes over SCH for *passenger1* and *passenger2* to reach evaluation criteria defined by ISO 2631-5 Standard. Maximum daily number of passes over for *passenger2* is considerably lower regarding *passenger1*. Maximum daily number of passes over for *passenger1* decrease when the speed increases, for all profiles of SCH. At the bus speed of 40 km/h two passes over rounded profile h=0.05 m are sufficient to produce moderate negative influence to the health of *passenger1*. At the bus speed of 25 km/h and more, one pass over daily, for all types of SCH, is sufficient to significantly jeopardize health of *passenger2*. Comparing to the passengers in the middle area of the bus, *passengers on the seats in the rear end of the bus when passing over SCH, are considerably more exposed to harmful influence of shock vibrations*.

Table 7
Maximum Daily Number of Passes Over SCH for Passenger1 Regarding Evaluation Criteria

		Maximum daily number of passes over for *passenger1*								
Bus speed [km/h]		**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Flat platform	*(S_{ed}=0.8)*	6881345	609092	93929	13555	7122	2674	942	305	253
Flat platform	*(S_{ed}=0.5)*	410160	36305	5599	808	424	159	56	18	15
Rounded profile h=0.03 [m]	*(S_{ed}=0.8)*	2500230	272201	55031	13978	9469	7926	8309	3876	749
Rounded profile h=0.03 [m]	*(S_{ed}=0.5)*	149025	16224	3280	833	564	472	495	231	45
Rounded profile h=0.05 [m]	*(S_{ed}=0.8)*	144057	7388	931	276	445	222	34	42	52
Rounded profile h=0.05 [m]	*(S_{ed}=0.5)*	8586	440	56	16	27	13	2	2	3

Table 8
Maximum Daily Number of Passes Over SCH for Passenger2 Regarding Evaluation Criteria

	Maximum daily number of passes over for *passenger2*								
Bus speed [km/h]	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Flat platform (S_{ed}=0.8)	11582	931	24	1	1	1	1	1	1
Flat platform (S_{ed}=0.5)	690	55	1	1	1	1	1	1	1
Rounded profile h=0.03 [m] (S_{ed}=0.8)	344	29	39	3	7	3	1	1	1
Rounded profile h=0.03 [m] (S_{ed}=0.5)	20	2	2	1	1	1	1	1	1
Rounded profile h=0.05 [m] (S_{ed}=0.8)	16	1	1	1	1	1	1	1	1
Rounded profile h=0.05 [m] (S_{ed}=0.5)	1	1	1	1	1	1	1	1	1

6. Conclusion

Speed control humps (SCH) are widely used to reduce vehicle speed and improve safety in some urban areas. The bus passengers are generally exposed to shock vibrations, particularly intensive when passing over SCH. Repeated and/or long-term exposure of human body to shock vibrations can produce musculoskeletal disorders and even injuries.

The simulation analysis of the effects of shock vibrations to the health of the passengers of a typical modern city bus is performed in this paper through simulation, by means of an original oscillatory model with six degrees of freedom and using evaluation method and criteria approved by ISO 2631-5 Standard.

The influence of shock vibrations due to SCH to bus occupants depends of the bus speed, geometry of SCH, number of passes over and passenger position in the bus.

Generally, lower speeds help to reduce negative influence of vibrations to the health of passengers.

The results of simulation prove that shock vibrations due to SCH mostly endanger passengers seated on the rear end of the bus. Negative influence of vibrations to the health is noted even at bus speed lower than 30 km/h. The pass over rounded profile 0.05 m high is particularly significant. It follows that the passengers using city buses which have SCH on their routes should avoid seats located in the rear end of the bus, i.e. they rather should use seats in front and middle area. This is particularly valid for aged persons, for the reason of increased sensitivity of their spine and other bone tissues.

Some preventive measures for the reduction of negative effects of shock vibrations due to pass over SCH can be undertaken: (1) seats in the rear end of the bus should have improved elastic and dumping characteristics, (2) mounting seats on the rear platform should be avoided and (3) a recommendation to the aged persons should be to avoid seats in zone of bus rear overhang.

It should be noted that the risk of multiple passes over SCH for the passengers stays for the reason that on the same bus route one can find multiple SCHs (for example, there are five only on the route of the line 26 in Belgrade), but it is reduced for the reason of low probability that one will use the line from end to end and will take the same place in the rear end of the bus in multiple trips during the day.

One of the problems that may occur considering the recommendation to use lower speeds when passing over SCHs for the benefit of passengers is that this collides with the results of the investigation regarding drivers, which shows that driver is less exposed to shock vibrations passing over rounded profile SCH 0.05 m high at higher (Sekulic, et al., 2012).

References

Aslan, S., et al. 2005. Speed bump-induced spinal column injury, *American Journal of Emergency Medicine* 23(4): 563–564.

Bjarnason, S. 2004. Round top and flat top humps - The influence of design on the effects. Lund Institute of Technology Department of Technology and Society Traffic Engineering, Lund. 144 p. Available from Internet: <http://www.tft.lth.se/publ/5000/Thesis125SBscr.pdf>.

Bovenzi, M.; Hulshof, C.T.J. 1999. An updated review of epidemiologic studies on the relationship between exposure to whole body vibration and low back pain (1986-1997), *International Archives of Occupational and Environmental Health* 72(6): 351-365.

Bowrey, D., et al. 1996. Road humps: accident prevention or hazard?, *Accident & Emergency Medicine* 13(4): 288-289.

Dedović, V.; Mladenović, D. 1999. Dinamika vozila - Praktikum [*Vehicle dynamics: Practicum*]. Belgrade: University of Belgrade, Faculty of Transport and Traffic Engineering. 103 p. (in Serbian).

Granlund, J.; Lindstroms, F. 2003. Design of shock free speed hump, in *Proceedings of the 10th International Congress on Sound and Vibration*, ICSV10, Stockholm. 11 p.

GSP Beograd. 2005. *Analysis of structure and operation of urban and suburban public passenger transport network in Belgrade*. GSP Beograd. 15 p.

ISO/DIS 2631-5: 2004. Mechanical vibration and shock - evaluation of human exposure to whole-body vibration - part 5: method for evaluation of vibration containing multiple shocks. 22 p.

ITE Technical Council Task Force on Speed Humps. 1993. Guidelines for the Design and Application of Speed Humps. Institute of Transportation Engineers (ITE), Washington, DC, USA. 5 p. Available from Internet: < http://www.ite.org/traffic/documents/JEA93A11.pdf>

Kompier, M.A.J. 1996. Bus drivers: Occupational stress and stress prevention. Leiden: University of Nijmegen, 44 p. Available from Internet: http://www.bvsde.paho.org/bvsast/i/fulltext/bustress/bustress.pdf>.

Mladenović, D. 1997. An analysis of constructions parameters impact on the oscillatory behaviour of the bus. Master thesis, The Faculty of Transport and Traffic Engineering, Belgrade. 306 p.

Nijemčević, S.; Dragojlović, D.; Zečević, S.; Milosavljević, B. 2001. Technical-selling book. Ikarbus AD, fabrika autobusa i specijalnih vozila, Beograd, 237 p.

Oke, S.A.; Salau, T.A. O.; Adeyefa, O.A. 2005. Vehicle speed control using road bumps: Part 2, *Transport* 20 (3): 99-105.

Okunribido, O.O., et al. 2007. City bus driving and low back pain: A study of the exposures to posture demands, manual materials handling and whole-body vibration, *Applied Ergonomics* 38(1): 29-38.

Salau, T.A.O.; Adeyefa, O.A.; Oke, S.A. 2004. Vehicle speed control using road bumps, *Transport* 29 (3): 130-136.

Sekulic, D.; Dedovic, V.; Rusov, S. 2012. Effect of shock vibrations due to speed control humps to the health of city bus drivers, *Scientific Research and Essays* 7(5): 573-585.

Simić, D.; Savičević, A.; Ninković, D. 1979. Comparative investigation of oscilatory parametars of driver's seat, *MVM - Motorna Vozila Motori* 24-25: 7-68.

Stayner, R.M. 2001. Whole-body vibration and shock: A literature review. United Kingdom: RMS Vibration Test Laboratory. 106 p. Available from Internet: <http://www.hse.gov.uk/research/crr_pdf/2001/ crr01333.pdf>.

Subotić, M. 2009. An analysis of bus line 26 in Belgrade MPPT. Graduate thesis, The Faculty of Transport and Traffic Engineering, Belgrade, 134 p.

Technical data for road humps. 2010. Available from Internet: <www.model5.rs>.

Whitelegg, J. 1995. Health of Professional Drivers. Eco-Logica Ltd. A Report for Transport & General Workers Union, Eco-Logica Ltd, Lancaster, 10 p. Available from Internet: <http://www.eco-logica.co.uk/pdf/HealthProDrivers.pdf>.

IDENTIFICATION OF BEHAVIORAL PATTERNS OF TAXI DRIVERS IN THE CITY OF BOGOTA

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Abstract: This research is part of a global study called "Model Simulation of Bogotá City Mobility (sustainable approach)", that intended to identify some behavioral patterns that define mobility in the city. The project aims to determine the behavioral pattern of taxi drivers, without leaving behind the importance and influence of their behavior on mobility. When the research was over we analyzed the results, and identified that most taxi drivers are characterized by a specific behavioral pattern, which affects mobility in the city, this case will be carefully discussed in this document.

Key Words: Taxis, Mobility, Behavioral pattern, Traffic, Transport

1. Introduction

Bogota City, beside from been a great capital that represents the opportunity of economic, professional and academic growth for many people, it characterizes for having a problem with mobility. The 57% of the people in this city spend an average about an hour and an hour and a half to reach their destiny and an additional 6% of the people spends more than two hours, in other words, more than half of the people that live in Bogotá spends between two and three hours in their daily transportation. (Cámara de Comercio de Bogotá, 2010). The vehicles of collective public transportation in Bogotá travel at an average speed of 24 Km/h, while the private vehicles do this at 28 Km/h (Instituto de Estudios Urbanos, 2011). These speeds tend to get worst with the growing acquisitive power and the increment in the population, which affects the growth in the number of vehicles through the years; only between 2002 and 2010 this growth was of 105%, which implies a 13% annual growth (Secretaría de Movilidad, 2011).

taxis make less than 5% of the daily travels in the city and they contribute with more than 31% of the total congestion (Secretaría de Tránsito y Transporte, 2006). The taxis fleet grew from 48.943 in 2008 to 49.350 in 2009 (Cámara de Comercio de Bogotá, 2010). From which we notice the excessive amount of vehicles, since the recommended standards are a taxi for every 200 citizens (Duarte – Guterman y Cia Ltda, 2003). According to this the optimum number for Bogotá would be approximately 35.000 taxis against 51.342 authorized in September of 2007, without including the illegal ones that are about 25.000 (García, 2007).

Even though, the amount of taxi vehicles in Bogotá is frozen since 1993, according to the SETT registry (Servicios Especializados de Tránsito y Transporte), the number of taxis has been increasing, 41.000 new models where registered between 2001 and 2007, which means that they keep introducing vehicles illegally or as replacement of the old ones (Universidad de los Andes & Cámara de Comercio de Bogotá, 2008). Between 2006 and 2007 the increase of the total number of registered taxis in Bogotá was of 15%, this increase not only breaks the recommended standards and affects the size of the vehicle fleet, but it affects the average time of every way of transportation in the city (Duarte – Guterman y Cia Ltda, 2003).

The individual public transportation taxi has particular features as: culture, education, vices, delinquency and this respect for transit regulations, because of this there is no standard in the service or minimum requirements they offer.

The impact of taxis in the mobility makes reference mostly to: the amount of taxis that move around the city, the average time of taxi movements, the average driving speed, the number of infractions, the number of accidents that involve taxis, their work schedules and their labored experience.

The problem of mobility in this city obeys not only to quantitative factors but qualitative variables, such as habits and behaviors that have a close relation and together they impact on mobility; however the qualitative variables are their most relevant predictors (Fuller, *et al., 1985*/1986). This means that cultural aspects are necessary for understanding the problems of these drivers on the city. In the complex activity of driving a car there are many situational and behavioral variables, from which results obvious to support the idea of the decisive influence that driving has the participation of cognitive, motivational and emotional why (Sáiz, *et al.*, 1997).

One of the reasons why habits and behavioral patterns of the actors of the mobility are determinant is that the streets are a scenario in which the way of acting and the decisions of one individual are manifested, and the sum of each behavior results in the mentioned problem. Because of this we manifest the need to see the subject of mobility as a system and taxis as a subsystem that composes it from a cultural perspective.

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Nowadays they are not enough studies about behavioral patterns that identify taxi drivers. Some of the existing models are treated with characteristics of developed countries, which are not applicable to Colombia; this is because of the great gap between their culture and ours. Therefore motivation arises to deepen and to analyze the behavior of the taxi drivers and their influence in mobility, as indispensable part in the development of the global project.

In conclusion, the document presents enough statistical evidence to determine the predominant behavioral pattern of the taxi drivers in the city and to identify whether the influence of the subsystem to the mobility is positive or negative.

General Objective:
Determine the behavioral pattern that characterizes taxi drivers of Bogota, and reveal the importance and influence that their behavior has on the mobility on the city.

2. Methodology

Scope
The scope of this project of investigation is to determine the characteristics of behavioral pattern of the taxi drivers in the city of Bogotá, with the goal of determining the influence that the taxis subsystem has in the mobility of the city.

Limitations
The field study depends on the information provided by the taxi drivers who are poled, and the truth of their answers.
Hypothesis

Null Hypothesis: A characteristic behavioral pattern of most taxi drivers in Bogotá does not exist. This Hypothesis proposes a total unknown according to the behavioral pattern of Bogotá's taxi drivers.

Alternative Hypothesis: The characteristic behavioral pattern of most taxi drivers in Bogotá is Type N.

$H_{0:}$ p=0.5

$H_{a:}$ p≠0.5, with a significance level of 5%

Study Units:

- Study unit: Bogotá's taxi drivers.
- Analysis unit: taxi drivers characteristic behavioral pattern.
- Geographic unit: Bogotá, Colombia.
- Time unit: October 2009 – October 2011

Information Sources:

- Primary:
  - ✓ Small fleet owner interviews
  - ✓ Poll to city taxi drivers.
  - ✓ Secretaria de Movilidad.
  - ✓ Books.

- Secondary:
  - ✓ Information from internet.

Study Subject:
This investigation is initiated and developed in Bogotá and the population of study is the taxi drivers that work in this city. The field work is done principally from the information provided by 381 taxi drivers of the city.

Study Type:
The present investigation is not experimental, but transversal descriptive, because field work is done and the results are evidenced in order to set the characteristic behavioral pattern of taxi drivers.

Design of the measure instrument:
The measure instrument utilized for the development of this investigation are two polls, the first one used with owners of small taxi fleets, and the other one for the taxi drivers of different ages, all questions are designed to identify the characteristics of the subsystem according to the investigation subject.

Determination of the population and statistical hypothesis test:

With the population of taxi drivers of 49.350. (Cámara de Comercio de Bogotá, 2010),the sample of people polled is estimated by using simple random sampling for big population. The formula for calculating the sample shows that we need a sample of n=381. (Martínez, 2007) were x is a binomial variable with an average np and standard deviation $\sqrt{np(1-p)}$. The random variable distribution tends to normal standard according to the number of independent test $n \to \infty$. (Canavos, 2003).

The approximation is adequate when np>5

np = 190.5

H_0 is rejected when $Z^* > Z1_{-\alpha}$

Applying formula N°1 of hypothesis proportions test:

$$Z^* = \frac{\hat{P} - P}{\sqrt{\frac{\hat{P}\left(1-\hat{P}\right)}{n}}}$$

Fórmula N° 1 (Canavos, 2003)

$$Z^* = \frac{0.60 - 0.50}{\sqrt{\frac{0.60(1-0.60)}{381}}} = 3.9843$$

$$Z_{1-\frac{\alpha}{2}} = Z_{O,975} = 1.96$$

H_0 is rejected when $Z^* > Z_{1-\alpha/2}$

$Z^* = 3.98 \longrightarrow Z_{1-\alpha/2} = 1.96$

Then, we reject the null hypothesis taking into account that $Z^* > Z_{1-\alpha/2}$

According to the result, there is enough statistical evidence to claim that the hypothesis is rejected, and to say that the behavioral pattern in most taxi drivers is type N.

Data recollection process:

The data recollection is executed by making personal interviews to owners of small taxi fleets and 381 Polls to taxi drivers that work day and night shifts in different areas of the city.

Development of the incidence and result matrixes:

During the investigation we developed two matrixes of incidence which validate the relevance of each actor of the subsystem and of the considered variables.

To understand the situation it was necessary to recognize the relevant actors of the subsystem and the relationship they maintain. According to the results in the matrix, the more relevant actors are the taxi drivers. Because of this, they become the principal object of this investigation and on who the field work is targeted. (Aldana, *et al.*, 2004)

The incidence matrix of relevant variables allows identifying the fundamental variables to take into account in the study, as result, these are: accidents, congestion, experience of the driver has in this job, average speed at which they drive through the city, percentage of clients that express having hurry, their working schedule, the amount of taxis per person, and average travel time by taxi.

For the analysis of the results the behavioral patterns where parameterized and the information was registered in a result matrix which allowed organizing the information to interpret the results.

The parameterization was made according to the following typology:

Conduct pattern type S: in a descriptive level we can say that the drivers with type S conduct drive under an adequate perception and acceptance of risk, they drive carefully, attentively and responsibly, they drive with high level of security and they control adequately their conduct.

Conduct pattern type N: they present a deficient perception of risk, incapable of reacting adequately to emotional stress, they manifest impulsiveness, impatience, aggressiveness, and anti-social tendencies, they possess low personal control, show disrespectful and inadequate conducts to excessive frustration. The minor annoyance, jam, or unavailable cross, results in irritability, and disproportionate rage (Ponce, Aliaga, Delgado y Solís, 2006).

According to typologies of behavioral pattern and the results obtained, we identify the behavioral pattern of each taxi driver polled of the subsystem and finally the effect of this pattern on the mobility of the city.

From results of the matrix is established the causal relationship between the variables most relevant and influential in the mobility of the city.

3. Results

Being a taxi driver is a job that does not require an education level, which implies that only by acquiring a drivers license of fifth level is enough. The choice of hiring a driver obeys only to personal criteria of the employer and reputation of the possible driver in the guild. In the case of buying an own vehicle, the requirement is to have the amount of capital to acquire the taxi and its quota (the cost of permission by the state) respectively.

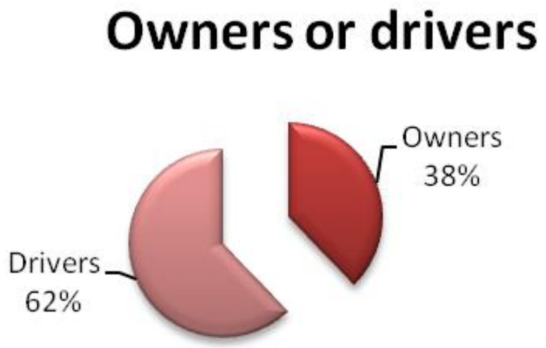

Fig. 1.
Are You A Taxi Owner?

As we see in Fig. 1, the 62%of taxi drivers are not owners of the vehicle, this situation with other factors might influence in their way of driving. The study also revealed that in the case of the taxi drivers that make more services per shift, most of them do not own the vehicle, and they have to pay a quota to the owner of the vehicle. In the cases where the driver thinks this quota is high, this value may influence their way of driving, generally putting pressure to drive faster, while who consider it appropriate does not get affected, nor changes their way of driving.

Fig. 2.
Which Shifts Do You Normally Work In?

In Fig. 2, we notice that 90% of the taxi drivers work 12 or more hour shifts (Long shifts) and 10% less than 12 hours (Other), which shows that is a demanding labor in work time.

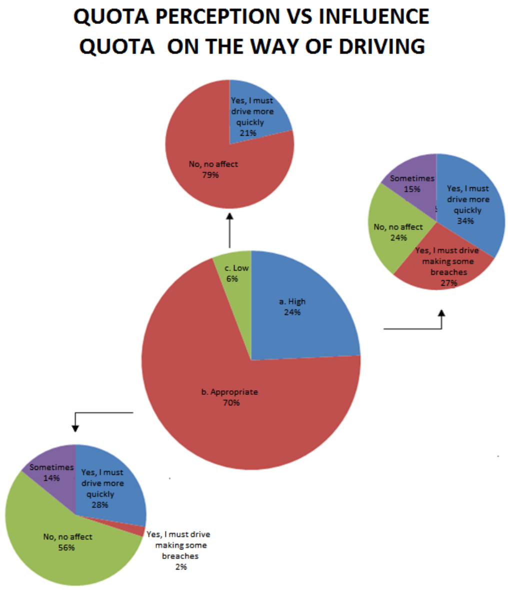

Fig. 3.
Quota Perception Vs Influence Quota on the Way Of Driving

The Fig. 3 relates two of evaluated situations: for taxi drivers that are not owners the perception of respect to the quota they have to pay, and if this value changes their way of driving. By relating this information we proof that the value demanded by the owner of the vehicle affects the way the taxi driver travels; we observe that those who consider that the quota is high, the value influences their driving, and for who consider this quota is adequate mostly this value does not affect their driving.

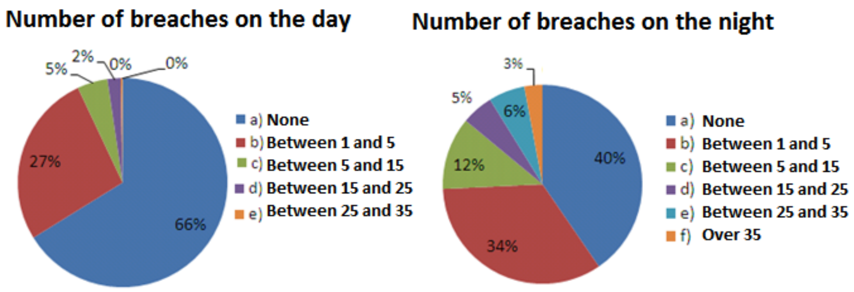

Fig. 4.
Day Infractions Vs Night Infractions

From the results is notorious that the number of infractions varies according to the time shift, the 66% of taxi drivers claim not to commit any infractions, at night this percentage decreases to 40%, but the number of drivers that commit between 5and 15 infractions raises from 5% on the day to 12% at night, also the percentage of drivers breaking the law rises from 34% during the day to 54% at night, as we can see in Fig. 4.

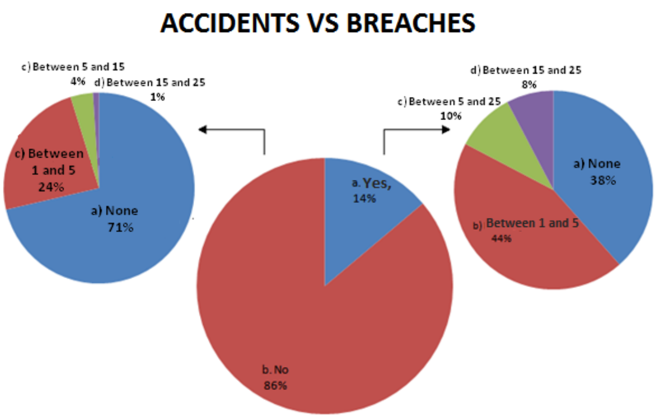

Fig. 5.
Accidentally Vs Infractions

From Fig. 5 we can conclude that those who have accidents in their great majority are offenders and vice versa.

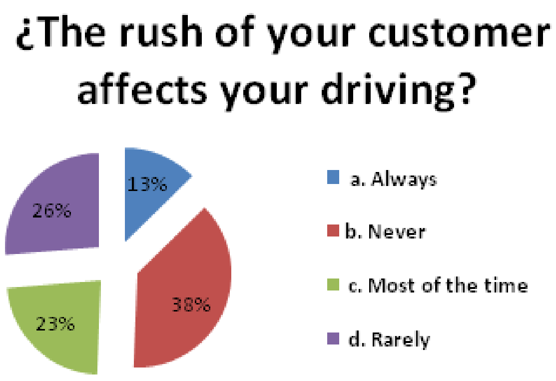

Fig. 6.
Does The Fact That Your Client Is In A Hurry Affect Your Driving?

In Fig. 6, the 38% of taxi drivers claim that when their client manifest hurry they change do not their way of driving, while for the rest it affects in some way their driving.

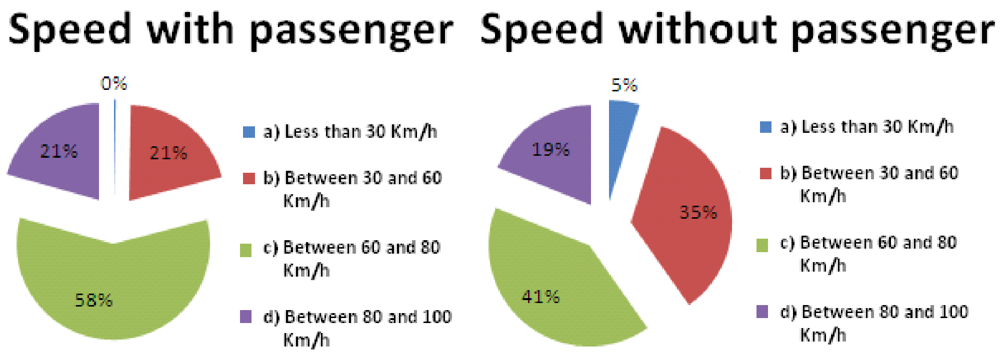

Fig. 7.
Average Speed with Passenger Vs Average Speed without Passenger
The study also revealed that the average speed of the taxi drivers without a costumer is less than the speed with a passenger, according to Fig. 7.

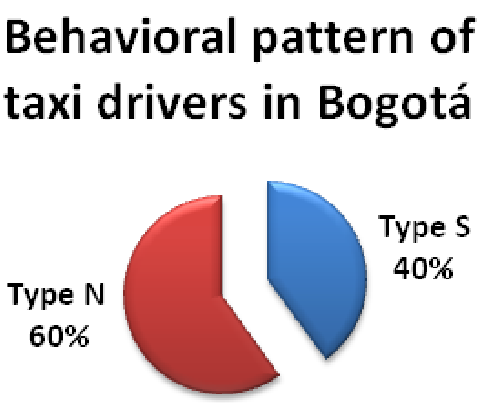

Fig. 8.
Characteristic Behavioral Pattern of Taxi Drivers In Bogotá, Colombia

As Fig. 8 shows, 60% of the polled taxi drivers have a characteristic behavior of pattern type N, they are drivers that manifest impulsiveness, impatience, aggressiveness and anti-social tendencies.

4. Causal diagram

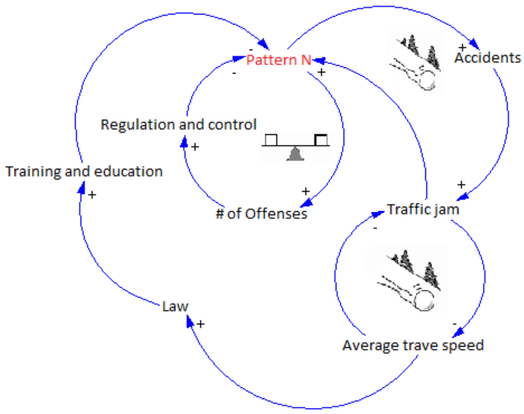

Fig. 9.
Causal Diagram between Important Variables, And the Characteristic Behavioral Pattern of the Taxi Subsystem

The characteristic behavioral pattern in the taxi drivers of the city is negative, these drivers do not react well when facing stress, they are impulsive, impatient, aggressive, and disrespectful offenders (Ponce, Aliaga, Delgado y Solís, 2006). This affects the mobility of the city in a negative way, in other words, the more negative conduct that the taxi drivers produce, increases the number of offenses, which increases the number of accidents, contributing a 15,5% of the number of accidents, 7,7% of deaths and 11,9% of injuries in 2010 (Universidad de los Andes & Cámara de Comercio de Bogotá, 2011); this generates more traffic jam, and a decreases the average speed of each travel, which also increases the type N behavioral pattern.

As shown in the Fig. 9, the increase in the regulation and control of the laws decreases the number of offenses, which decreases the chance of a taxi driver having a bad behavior too, the generation of specific laws for individual public transportation requires training and education of the drivers, but helps change the way they drive from insecure to responsible and cautious, to decrease the percent of taxi drivers that are characterized with the type N behavior and help to improve the mobility of the city.

5. Discussion

For taxi drivers in Bogotá, the fact of not being owners of the vehicle and the perception that they have about their quota to pay the owner, impact in their way of driving adding pressure to increase their daily productivity. Those, they have to work overtime to comply their economic responsibilities, different from results shown in studies from developed countries of taxi drivers labor, where they conclude that there is no evidence that the daily monetary income affects the number of worked hours (Farber, 2005).

The 44% of taxi drivers break traffic regulations while they work in the day, and this percent rises at night, which affects the mobility order, security and equality of conditions for who are moving around the city, taking into account that the main goal of drivers defined as the intention of traveling with the less amount of possible interruptions or inconveniences, can get frustrated and in consequence increases the possibility of experimenting hostility to other drivers and behaving in an aggressive and offending way (Poó, *et al.*, 2008).

According to the results and in concordance with a study made in 2009 about the individual public transportation; even though the subsystem represents a small fraction of the vehicular fleet, it produces significant externalities (Quijano, 2009). If most drivers of all means of transport adopt a behavior type S pattern (adequate), problems in mobility would be reduced considerably, and if there is no action taken, actual problems in mobility will get worst, as the data shows nowadays.

Conclusions

1. The study revealed that the fact of breaking the driving laws implies a higher chance of having accidents, unlike who obey them.
2. The fact that the average driving speed in the city without passenger is lower than the one with passenger, affects the average time of traveling of the taxi, and the average time of traveling of the city.
3. Taking into account that more than half of the taxi drivers are not the owners of the vehicle they drive, the economic aspect affects radically their way of driving, since the quota that they have to pay the owner of the vehicle and their personal responsibilities result in emotional stress.

4. The labor of driving a taxi is demanding in work time, what generates emotional and physical fatigue, and irritability, which evidently affects negatively his way of driving.
5. The pressure that clients put on the taxi driver influences their way of drive significantly.
6. According to the results of the investigation we resolve that the lack of attitude and aptitude evaluations to the candidates for the job of taxi driver, as well as the exposure to long work hours, customer interaction, regulatory and disciplinary requirements, economic pressure, and other external factors affect in more than 50% of the cases in a negative matter the behavior of taxi drivers while they work.
7. Finally, the investigation revealed that the 60% of the taxi drivers manifest a conduct type N, unadjusted, high risked and danger attitude in the roads, which implies a negative influence of the subsystem taxis on the mobility of the city.
8. The increase in the specific regulations for public individual transport, also the sensitization, education, control and regulation of taxi drivers, can help decrease the behavioral pattern N type.

References:

Aldana, E.; Reyes A. 2004. *Disolver Problemas: Criterio para Formular Proyectos Sociale*s. Universidad de los Andes, Bogotá: 23-52

Cámara de Comercio de Bogotá. 2010. La demanda de transporte en Bogotá. Available from Internet: http://camara.ccb.org.co/contenido/contenido.aspx?catID=127&conID=6529

Cámara de Comercio de Bogotá. 2010. Observatorio de Movilidad, Nº 5: 22.

Duarte – Guterman y CiaLtda. 2003. Estudio para la Optimización Técnica y Organizacional de los Organismos de Tránsito y Transporte de las Entidades Territoriales.

Farber S.H. 2005. Is Tomorrow Another Day? The Labor Supply of New York City Cabdrivers. *Journal of Political Economy*, 113 (1): 46-82.

Fuller D.T.; Lightfood, P.; Kamnuansilpa, P. 1985/1986. Mobility Plans and Mobility Behavior: Convergences and Divergences in Thailand. *Population and Environment*, 8 (1/ 2): 15-40.
García, A. 2007. Una noche como taxista. Extraído el martes 04 de Octubre de 2011. Available from Internet: http://www.semana.com/on-line/noche-como-taxista/105214-3.aspx

Canavos, G.C. 2003. *Probabilidad y Estadística: Aplicaciones y Métodos*. España: Mc Graw Hill.
Instituto de Estudios Urbanos. 2011. Indicadores de Respuesta: Velocidad y tiempo de recorrido. Extraído el 19 de Julio de 2011. Available from Internet: http://www.institutodeestudiosurbanos.com/endatos/0200/02-050-transporte/02.05.01.01.03.htm

Martínez, C. (2007), Estadística y Muestro. Ecoe Ediciones, Bogotá, Colombia. Edición N° 13, Vol. 1

Ponce, D.C.; Aliaga, T.J.; Delgado, C.E.; Solís, N.R. (2006). Estudio Psicológico sobre los Patrones de Conducta en Contextos de Tráfico, en Grupos de Automovilistas Particulares y profesionales de lima metropolitana. *Revista IIPSI*, 9 (2): 33-64.

Poó, F.; Ledesma, R.; Montes, S. 2008. Rasgos de Personalidad y Agresión en Conductores. *Avaliacao Psicología*, 7 (3): 69-80.

Quijano, B.J. 2009. *Análisis del transporte público individual a partir del estudio operacional actual*. Proyecto de grado para optar por el Título de Ingeniero Ambiental, Departamento de Ingeniería Ambiental, Universidad de los Andes, Bogotá, Colombia.

Sáiz, V.E.; Chisvert, P.M.; Bañúls, E.R. 1997. Efectos psicológicos de la exposición al tráfico en conductores profesionales y noveles. *Anales de Psicología,* 13 (1): 57-65.

Secretaría de Movilidad de Bogotá. 2011. *Movilidad en Cifras 2010*: 1

Secretaría de Tránsito y Transporte. 2006. *Plan Maestro de Movilidad*. Resumen Ejecutivo: 3

Universidad de los Andes & Cámara de Comercio de Bogotá. 2008. *Observatorio de Movilidad de Bogotá*, 1: 13.

Universidad de los Andes & Cámara de Comercio de Bogotá. 2011. *Observatorio de Movilidad de Bogotá*, 6: 29.

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