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APPLICATION OF ARTIFICIAL NEURAL NETWORKS IN PAVEMENT MANAGEMENT

ABSTRACT

There has been much discussion about the impact and future of artificial intelligence (AI) in our lives and future generations. Many experts even believe that AI will "rule" the world. Artificial Neural Networks (ANN) have provided a convenient and often extremely accurate solution to problems within all fields (e.g., engineering, biology, medicine, chemistry), and can be seen as advanced general-purpose regression models that try to mimic the behaviour of the human brain. The only requirement for the suitability of this approach is the need of solving problems much quicker and/or more accurately as long as they involve large amounts of data. The adoption and use of ANN-based methods in the Mechanistic-Empirical Pavement Design Guide is a clear sign of the successful use of neural nets in geomechanical and pavement systems. This paper aims to highlight the main features and potential of ANN in general and in their application to pavement management – a summary of the actual state-of-the-art is presented. Hopefully this will serve as motivation to experts in any field within transportation engineering and planning to start taking advantage of what is probably the most powerful and disseminated machine learning technique worldwide.

KEY WORDS

Artificial Intelligence; Artificial Neural Networks (ANN); Pavement Management

1. INTRODUCTION

1.1 Artificial Neural Networks

Although Artificial Neural Networks (ANN) are the oldest artificial intelligence technique, it is still the leading application if one counts the number of practical applications [1], such as Civil Engineering, Bioinformatics, Chemistry, Finances, Internet, Medicine, Organization and Management, Robotics, Speech Processing or Meteorology, just to name a few. In its most general form, an ANN is a hardware or software "machine" designed to perform a particular task or function of interest based in the way the human brain processes information.

ANNs have been employed to perform several types of relevant "real-world" basic tasks, such as (i) classification, like (i_1) sequence / pattern recognition, (i_2) identification of new data, or (i_3) decision-making, where the goal is to map each input with an output class, (ii) functional approximation / forecasting, (iii) clustering (grouping data into classes by analysing the similarities or dissimilarities between input patterns), etc.

Furthermore, ANNs have proven to be very competitive when compared to more popular data analysis methods, usually based on explicit statistical modelling. Just like any nervous system, which need to evolve in order to adapt to the surrounding environment, ANNs need to go through an adaptation/learning process in order to perform well. Artificial neural networks can be seen as advanced general-purpose regression models that try to mimic the behaviour of the human brain, although at present no ANN is anywhere near to recreating the complexity of the brain [2]. However, the progress that has been made since their inception is remarkable, and it is certain that the development and applications of these algorithms will keep growing in the future [3, 4].

1.2 Application of ANN in Civil Engineering

Expert systems and ANN have been the most commonly used AI techniques in Civil Engineering since the latter's inception in mid-1980s [5]. ANN have provided a convenient and often highly accurate solution to problems within all branches, appearing from the statistics on publications to be one of the great successes of computing [3]. The first journal article on civil engineering applications of neural networks was published in [6]. Since then, many other applications of ANN within all fields of Civil Engineering have arisen with increased complexity and sophistication [7].

Areas like buckling and bearing capacity prediction, (ii) constitutive modelling, (iii) structural reliability and/or optimization (e.g., [8]), (iv) structural health monitoring (e.g., [9]), or (v) transportation engineering (e.g. [10-14]), have received special focus until today. The adoption and use of ANN-based methods in the Mechanistic-Empirical Pavement Design Guide [15] is a clear sign of the successful use of neural nets in geomechanical and pavement systems.

1.3 Application of ANN in Pavement Management

Due to (i) the extent of ANN-based applications to pavement engineering since the 1990´s, and (ii) the rising potential of neural nets to the performance of more accurate and efficient engineering, this work aims to provide an overview of the state-of-the-art application of ANN models in pavement management. Unlike previous review articles published on pavement engineering topics before 2014 [10-13], it is worth noting that the present work is far more descriptive and makes the review much more appealing to the reader by highlighting numerically and/or graphically the effectiveness and possible drawbacks of each ANN application [16].

A truly brief overview of ANN features and fundamentals is presented in the next section. The applications of neural nets to several types of pavement management problems is described in section 3.

2. BRIEF OVERVIEW OF ANN FEATURES AND FUNDAMENTALS

This section aims at addressing the main neural network features and giving a quite short overview about the main concepts inherent to the most typical ANN models employed in pavement engineering so far. Further details about virtually any topic regarding ANN can be found in well-known books like [2] or [17].

The general ANN structure (*Figure 1*) can be seen as several partially or fully connected processing units (neurons), which are disposed in several vertical layers (the input layer, hidden layers – if there are some, and the output layer). Associated to each neuron is a linear or nonlinear transfer function which receives an input and transmits an output – a typical neuron's model is described in 2.1. Each connection (link between two nodes in the network) is associated to a synaptic weight, which is a typical example of a network unknown to be determined during the network design process. The way in which the neurons of a neural net are structured and linked define what is known as the network architecture. In sub-section 2.2, the multi-layer perceptron (MLP) is briefly addressed since it is the most commonly used network type in pavement applications.

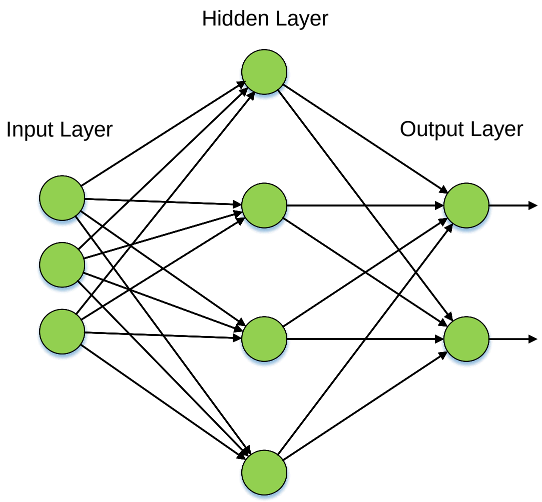


Figure 1 – Example of a Multi-Layer Feedforward Network

The ANN's computing power, making them suitable to efficiently solve complex (small to large-scale) intractable problems, can be attributed to their (i) massively parallel distributed structure and (ii) ability to learn and generalize, i.e, produce reasonably accurate outputs for inputs not used during the training phase. Besides, neural networks offer features like (i) nonlinearity, (ii) ability to handle imprecise/noisy and/or missing data [18], and (iii) input-output mapping – ANN-based solutions are frequently more accurate than the ones provided by traditional approaches (e.g., multi-variate nonlinear regression), despite not requiring a good knowledge of the function shape being modelled [3].

2.1 Model of a Neuron

Each processing unit of any ANN is called a neuron, and it plays a crucial role in the network's behaviour. There are three basic elements in a typical model of a neuron (*Figure 2*): (i) connecting links (also called synapses) between each "input" signal (x_j , j = 1,...,J) and the k_{th} neuron, which are characterized by their synaptic weights ($w_{jk} \in$ R), (ii) a summing junction ($s_k = x_j\ w_{jk}$) – Einstein summation convention employed, to add up the weighted input signals that converge to the neuron, and (iii) an activation (or transfer) function φ_k, which receives s_k plus neuron's bias ($b_k \in$ R) as input – also known as the induced local field, and provides neuron's output y_k. In ANN design, the activation functions are user-defined (e.g., logistic, linear).

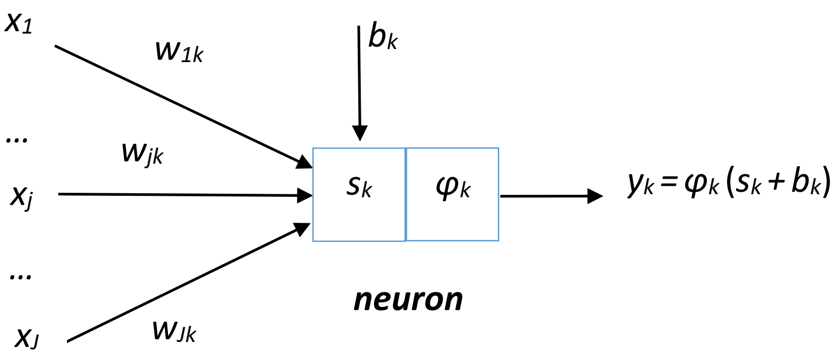


Figure 2 – A typical model of a neuron

2.2 The Multi-Layer Perceptron (MLP)

This is a feedforward ANN, i.e. the signal flow through the network progresses in a forward direction from left to right, and on a layer-by-layer basis, and exhibits at least two neuron-based layers and the input node layer. Each layer of neurons that is not the output layer is called a "hidden layer" and the corresponding units are called "hidden neurons". By adding one or more hidden layers, the network is enabled to extract higher-order statistics from its input [2]. *Figure 1* represents a 3-layer feedforward network, also referred to as 3-4-2 (3 input nodes, 4 hidden neurons in the single hidden layer, and 2 output neurons). As can be seen, each node in each layer links to every node in the next layer (typically called a fully-connected network), i.e. the output signals of the 2nd (hidden) layer will serve as input signals of the 3rd (output) layer – unless stated otherwise (e.g., PC - partially connected), all MLP networks referred in this paper are fully-connected. Nodes in each layer do not connect to each other and no connections across layers (between the input and output layers, in this case) are allowed. The synaptic weights and bias mentioned in 2.1 are network unknowns to be computed by a major task for any ANN, called Learning – the most used learning algorithms in pavement applications so far are called error Back-Propagation (BP) (the most popular) and Levenberg-Marquardt (LM).

2.3 The universal approximation theorem

For a nonlinear input-output mapping, this theorem states [2] that a single hidden layer MLP, with (i) any bounded, monotone-increasing and continuous activation function for the hidden neurons, and (ii) an identity (linear) transfer function for the output neurons, is sufficient to compute an arbitrarily good approximation of any continuous function in a general n-dimensional space – the absolute difference between any estimated and target outputs can be less than any $\varepsilon > 0$, for all input space values. However, it is worth recalling that this theorem does not guarantee great network behaviour concerning learning time and/or generalization.

3. ANN APPLICATIONS IN PAVEMENT MANAGEMENT

In this section, a quick overview over the state-of-the-art application of ANNs in pavement management is addressed. Although only one reference per problem type is described due to paper size limitations, the main ANN features used in the most relevant references addressed are presented in *Tables 1-2*.

3.1 Pavement Distresses

Roughness

A pavement profile (also called roughness) is one of the most effective pavement quality parameter that influences ride, handling, fatigue, fuel consumption, tire wear, maintenance costs and vehicle delay costs. Ziari *et al*. [19] proposed an ANN to predict international roughness index values in short- and long-term for flexible pavements. Sensitivity analysis using several LM-based MLP networks was performed and (i) the best performance regarding short-term was obtained for the topologies 9-80-50-30-1 and 9-3-1, whereas the 9-8-1 layout proved to be the best for long-term.

Skid Resistance

It is well known that weather and traffic influence the degradation of skid resistance between the tire and pavement surface over time. Bosurgi and Trifirò [20] developed a neural net-based "sideway force coefficient" prediction model to be applied on a motorway. A LM-based 2-3-1 MLP was adopted, yielding errors inferior to 7% in 91% and 86% of the cases in the training and validation phases, respectively.

Cracking

Paris' law, which is based on linear elastic fracture mechanics, has been adopted to analyse pavement cracking problems. However, one of the drawbacks of this model regards the quick and accurate computation of the stress intensity factors (SIF), a parameter that amplifies the magnitude of applied stress, at crack tips. Finite element analysis (FEA) is a powerful tool for that purpose, but the 3D pavement behaviour can only be accurately predicted through heavy (slow) FEA when using today's available resources in practical applications. Lee and Lee [21] presented three ANN to classify crack types from digital pavement images, as alternative to pixel-based ANN (higher processing time), namely designated as image-based (INN), histogram-based (HNN) and proximity-based (PNN). Each model has a different number of input nodes and each output neuron represents a crack type. The best performance was obtained with architectures 180-90-5 (INN), 27-60-5 (HNN) and 3-150-3 (PNN). The INN is similar to the pixel-based neural net except that it uses crack tiles. The matrix of crack tiles (1 if there is crack, 0 if there is not) is injected into the ANN input layer as an array with 180 binary values (12 rows x 15 columns in the "tiled" digital image) – inputs are read sequentially from the upper left corner tile to the bottom right corner tile. HNN networks inject two histogram arrays into input layer (27 nodes – 12 for the horizontal histogram and 15 for the vertical counterpart), as illustrated in Figure 3. PNN nets' input layer is defined by three variables, which, to be determined, requires computing the following quantities: (i) vertical proximity (Pv), defined by Equation (1); (ii) horizontal proximity (Ph), defined by Equation (2); and (iii) the number of cracked tiles in the image. The final results indicate that the PNN produced the best result, with a 95.2% accuracy on real validation images, despite its simpler structure with the lesser computing requirement (INN and HNN corresponding performances were 70.2% and 75%, respectively).

$$P_v = \sum_{i=1}^{Nc-1} \left| H_{v[i+1]} - H_{v[i]} \right| \tag{1}$$

where H_v is the vertical histogram and N_c the number of columns of the "tiled" image.

$$P_h = \sum_{i=1}^{Nr-1} \left| H_{h[i+1]} - H_{h[i]} \right| \tag{2}$$

where H_h is the horizontal histogram and N_r the number of rows of the "tiled" image.

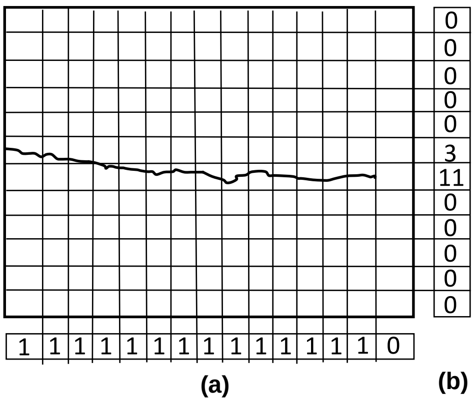


Figure 3 – HNN (a) vertical and (b) horizontal histogram
Source: [21]

Joint Faulting

Transverse joint faulting is one of the main types of distresses in jointed Portland cement pavements. It can be defined as the difference in elevation between adjacent slab edges at a transverse joint. Saghafi *et al*. [22] applied an ANN to estimate the effect of base layer conditions and pavement age on transverse joint faulting. Several BP-based MLP networks were assessed parametrically in order to find the optimal layout, which was 8-8-8-1. The proposed ANN was able to successfully predict the measured joint faulting with R^2 = 0.94 for the testing set.

3.2 Pavement Condition Indexes

Present Serviceability Index (PSI)

Prediction modelling of pavement deterioration (a stochastic and nonlinear phenomenon) is crucial for an effective PMS, where the goal is to find the appropriate period and method of rehabilitation. Tabatabaee *et al*. [23] proposed a two-stage soft computing model to properly classify (using a support vector classifier - SVC) and accurately predict pavement performance. A PC LM-based 8-5-1 RNN is used for the second stage to predict performance in terms of PSI, as illustrated in *Figure 4*. The two-stage model results were compared with those yielded from a RNN-based single model, and it was concluded that the latter was less effective in the prediction of PSI values (R^2 = 0.95 vs. R^2 = 0.98).

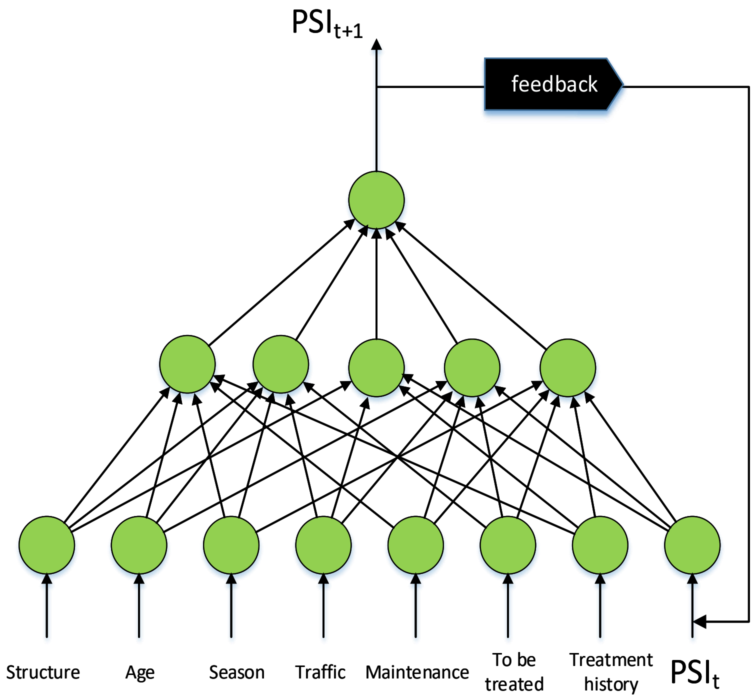


Figure 4 – The RNN used in a two-stage soft computing model for PSI estimation
Source: [23]

Condition Rating

One of the important activities of highway engineers is the determination of pavement condition ratings (PCR), i.e. assignment of relative weights to various levels of pavement distresses in order to obtain a combined score that indicates the current condition of a roadway section. Amin and Amador-Jiménez [24] applied BP-based 5-3-2-1 MLP networks to predict pavement condition index (PCI) values. The study categorizes road segments into four categories based on pavement types (e.g., flexible or rigid) and road hierarchies (e.g., arterial or collector), so four ANN models were developed. Concerning accuracy, the relative errors obtained in {training, validation, testing} subsets were approximately {5, 9, 9}%, {11, 23, 72}%, {3, 3, 4}% and {4, 4, 4}% for Arterial-Flexible, Arterial-Rigid, Collector-Flexible and Collector-Rigid road segments, respectively.

3.3 Maintenance

Traditionally, ranking of highway sections requiring maintenance is based on experience of qualified personnel. Mathematical decision-making criteria have been proposed through the so-called "aggregate condition index", which has shown several drawbacks [25].

Abdelrahim and George [26] evaluated the use of neural nets to predict the optimum maintenance strategy on the basis of realistic (i.e., noisy) data. A genetic adaptive algorithm is employed to train a 10-10-6 MLP network. Six outputs result from the fact that there are six different maintenance strategies to be considered – the selected strategy is coded 1 and the others 0. The proposed ANN was able to predict 83% of the validation examples.

3.4 Frequency of application of each ANN feature

In this final sub-section, *Tables 1-2* summarise the main ANN design features employed in some of the most remarkable pavement management applications found in the literature, so that the reader can decide much quicker which features to include in a neural net-based parametric analysis of similar problems.

Moreover, histograms based on all references addressed are presented in *Figures 5-7* and aim to give, for each pavement management field (1st column in *Tables 1-2*), a graphical insight of the frequency of use of each ANN feature in the final design.

From the analysis of *Tables 1-2* and *Figures 5-7*, it is possible to conclude that:

(i) The one hidden layer-MLP has been the most used neural net architecture by far in pavement management applications except distresses (75.0%), while it comes in second behind the two hidden layer-MLP (44.4%) for pavement distress studies.

(ii) The error backpropagation has been the most employed learning algorithm in any field addressed herein, having been used in more than 55% of the studies.

(iii) The logistic hidden node transfer function is by far (90.9%) the "winner" in pavement management applications except distresses. In the latter, it also takes the lead but by less than nine percent point difference over the hyperbolic tangent function.

(iv) For the output neurons, the logistic transfer function predominates except for pavement distresses, where the linear function was employed in 63.6% of the cases.

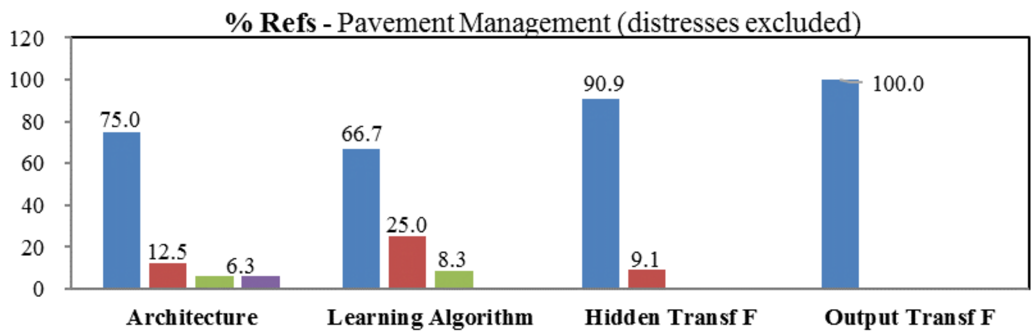
(v) *Figure 7* presents the distribution of the "ANN feature" in the fourth column of *Tables 1-2* for all the references analysed. That value represents the round of the constant amount of values (a) per input variable that needed to be considered if LD (total amount of learning data points) equalled the total number of input data combinations – "a" from a^{IV}=LD was computed and then rounded to the closest integer, where IV is the number of input variables.

Table 1 – ANN features employed in pavement management applications (distresses not covered)

Field	Problem	ANN Feature				Ref
		Architecture	Learning Algorithm	Hid./Out. Transfer Functions	$10^{\mathrm{Log(LD)/IV}}$	
Pavement Management	Skid Resistance	2-3-1 MLP	LM	-	27	[20]
	Maintenance	6-1-1 MLP	BP	Logistic	5	[25]
		12-22-5 MLP 12-28-5 MLP 12-34-5 MLP	BP	Logistic	1	[27]
	Condition Rating	5-3-2-1 MLP	BP	Logistic	-	[24]
	PSI	8-5-1 RNN	LM	Hyp. Tg / -	-	[23]

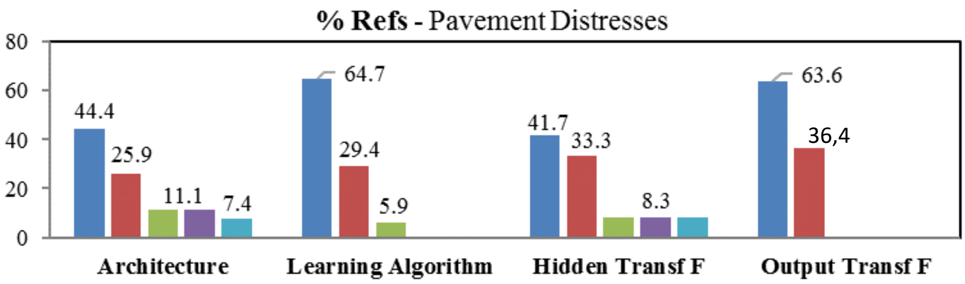
Table 2 – ANN features employed in pavement distress applications

Field	Problem	ANN Feature				Ref
		Architecture	Learning Algorithm	Hid./Out. Transfer Function	$10^{Log(LD)/IV}$	
Pavement Distresses	Roughness	x-15-4 WNN	BP	Mexican Hat Wavelet / Linear	-	[28]
		3-50-50-2 MLP	LM	Hyp. Tg / Linear	16	[29]
		9-80-50-30-1 MLP 9-3-1 MLP 9-8-1 MLP	LM	Hyp. Tg / Linear	2	[19]
	Cracking	3-150-3 MLP	BP	-	8	[21]
		8-40-40-1 MLP 9-40-40-1 MLP 7-40-40-1 MLP 9-40-40-1 MLP	BP	Logistic	3 2 3 2	[30]
		26-7-7-7-1 MLP 26-5-5-1 MLP 29-7-7-7-1 MLP 31-6-6-1 MLP	BP	Hyp. Tg / -	1 1 1 -	[31]
		4-7-2 MLP	BP	-	-	[32]
		8-12-8-2 MLP	BP	Logistic	3	[33]



Architecture	Learning Algorithm	Hidden Transf F	Output Transf F
1 Hidden Layer-MLP	BP	Logistic	Logistic
2 Hidden Layer-MLP	LM	Hyperbolic Tangent	-
1 Hidden Layer-RNN	Genetic Adaptive	-	-
MC-HARP	-	-	-

Figure 5 – Frequency of ANN features in pavement management applications (distresses not covered – Table 1)



Architecture	Learning Algorithm	Hidden Transf F	Output Transf F
2 Hidden Layer-MLP	BP	Logistic	Linear
1 Hidden Layer-MLP	LM	Hyperbolic Tangent	Logistic
3 Hidden Layer-MLP	Self-Organized	Mexican Hat Wavelet	-
RNN, WNN, Generalized Adaptive	-	Linear	-
1 Hid. Layer-RBFNN	-	Gaussian	-

Figure 6 – Frequency of ANN features in pavement distress applications (Table 2)

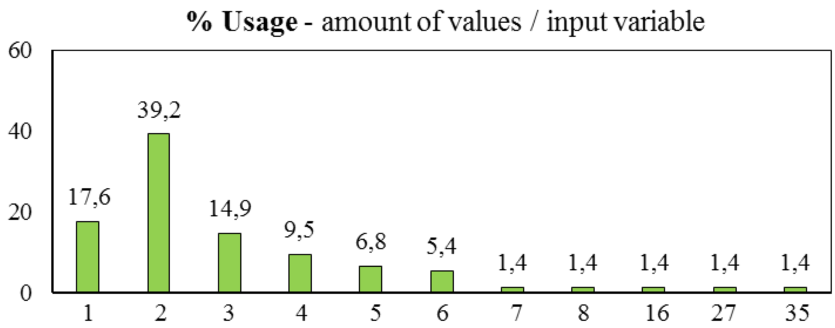


Figure 7 – Fictitious number of values per input variable according to the amount of learning data

4. FINAL REMARKS

An overview of the state-of-the-art application of ANNs in pavement management has been presented, covering fields like pavement distresses, pavement condition indexes, and maintenance. This work aims to motivate and support the related expert community in the use of neural nets in problems where there is abundant data but the solving methods usually adopted are too lengthy and/or inaccurate. It should be noted that despite the great amount of applications and quite satisfactory results found in the literature, there is a lack of utilization of more advanced techniques in the design of ANNs – in most cases, the more traditional architecture (MLP) and learning algorithms (BP, LM) were employed, and not much reference was made to special trimming and data pre-processing techniques for the improvement of the network generalization ability. The authors of this paper are currently working to make a contribution to change this scenario in the near future.

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SIMULATION OF ACTUAL NETWORK PERFORMANCE USING OPTIMIZATION ALGORITHM

ABSTRACT

Within the project GoSAFE RAIL, funded by the H2020 Shift2Rail programme with focus on achieving Single European Railway Area (SERA), one work package is dedicated to the development of an integrated rail network model that will incorporate both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement) data. Furthermore, the micro-level simulation tool OpenTrack will be used for enabling capacity optimisation in order to maximise the availability of the transport network and minimise environmental impacts. By employing algorithm for optimization and software's application programming interface (API) in the case study network Zagreb – Rijeka in Croatia, which is a part of the TEN-T network, the behaviour of actual network performance will be simulated as a proof of suitability of solutions provided by the provided optimization algorithm. Finally, an expected impact of the advanced traffic model using scheduling algorithm is a 40% reduction of delays in long-distance traffic.

KEY WORDS

rail traffic flow optimization; scheduling; Kronecker algebra; application programming interface

1. INTRODUCTION

Rail infrastructure managers are responsible for safety measures and planning within the infrastructure network. Although the railway transport mode is considered one of the safest modes of transport [1] with 0.16 fatalities per billion passenger km's there is a number of infrastructure failures that have happened in recent years. Unfortunately, the number is expected to rise in the future, mainly due to ageing railway network and stronger climate changes.

Consequently, the objective of the Shift2Rail project Global SAFEty Management Framework for RAIL Operations [2] is development of an evolutionary Decision Support Tool that self-learns (evolves) based on machine learning algorithms and artificial intelligence with the main goal of offering safer, reliable and efficient rail infrastructure. As already mentioned above, there is a low number in failures on the infrastructure network, which consequently leads to a lack of data crucial for machine learning. This will be solved by implementation of Near-Miss Concept; in other words, low-consequence events will be also included in the model and enable use of statistically significant data for model training. Furthermore, a new train mounted multiple sensor system for Object Detection will be developed.

Moreover, with OpenTrack micro-simulation modelling tool, traffic model will be developed that will use multi-criteria optimization algorithms to address complex requirements, for both passenger and freight transport. Using Kronecker algebra [3], which showed good results in dealing with optimization scenarios in railway traffic flow, especially avoidance of bottlenecks and conflicts, simulation of actual network performance on the line between Zagreb and Rijeka in Croatia will be performed.

2. MOTIVATION FOR SIMULATION

The main motivation behind dynamic rescheduling is avoidance of unnecessary and time consuming stops. Namely, enabling adaption of driving behaviour to constantly changing environment will bring avoidance of bottlenecks and hence, lower delays and consequently, increase capacity [4]. Dataflow in simulation of railway operation with today's production and operation with integrated real-time rescheduling is presented in Figure 1.

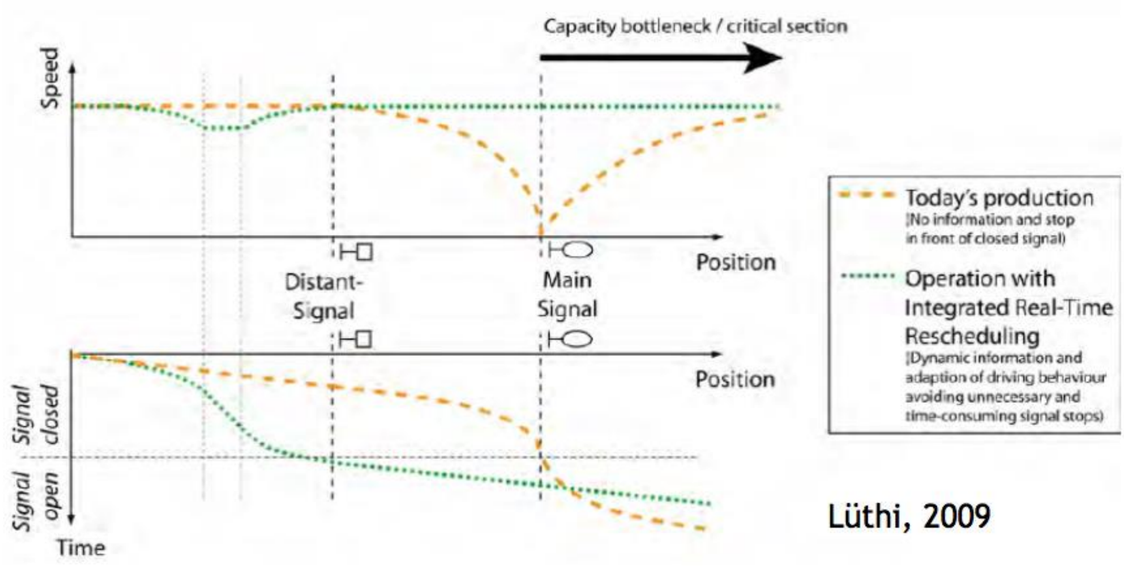

Figure 1 – Operational performance without and with real-time rescheduling
Source: [4]

The first step in using computer models in the railroad planning is to calibrate the base case model. This should accurately replicate observed railroad operations with the existing infrastructure, rolling stock, and schedules. Once the model has been calibrated it can be used to investigate many issues including estimating the stability of new timetables, determining the minimum infrastructure requirements for a given timetable, or evaluating the impact of rolling stock changes. A significant benefit of models is their ability to evaluate the impact of incidents or time-based network changes (e.g. maintenance) on railroad operations.

Computer simulation is especially valuable for railroad planning since, once developed and calibrated, models can be used for the comparison of the benefits, impacts, and costs of various different improvement packages. To analyse more than a few improvement packages by hand would be prohibitively time consuming. Thus, effective railroad simulation models enable planners to identify and evaluate more alternatives, ultimately leading to more creative and comprehensive problem solutions.

While computer simulation is an excellent tool for analysis and planning of railroads, railroad network simulation programs have the following limitations:

- Programs must be validated to actual conditions.
- Yard operations must be modelled separately.
- Resource constraints such as crew scheduling are largely ignored (although some specialized software does address resource constraints).
- Simulations only include the modelled study area.
- Simplifying assumptions generally create an inherent optimism about overall congestion, schedule adherence, and recoverability [5].

Given these limitations, especially the last one, it is critical that all simulation results be carefully reviewed, discussed and compared to reality.

3. OPENTRACK RAILWAY SIMULATION SOFTWARE

OpenTrack was developed at the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems (ETH IVT). The project's goal was development of a user-friendly railroad simulation program that could run on different computer platforms and could answer many different questions about railway operations [6]. Figure 2 illustrates the three main elements of OpenTrack: data input, simulation, and output.

OpenTrack is a microscopic synchronous railroad simulation model. As such it simulates the behaviour of all railway elements (infrastructure network, rolling stock, and timetable), as well as all processes between them. It can be easily used for many different types of projects, including testing the stability of a new timetable, evaluating the benefits of different long-term infrastructure improvement programs, and analysing the impacts of different rolling stock.

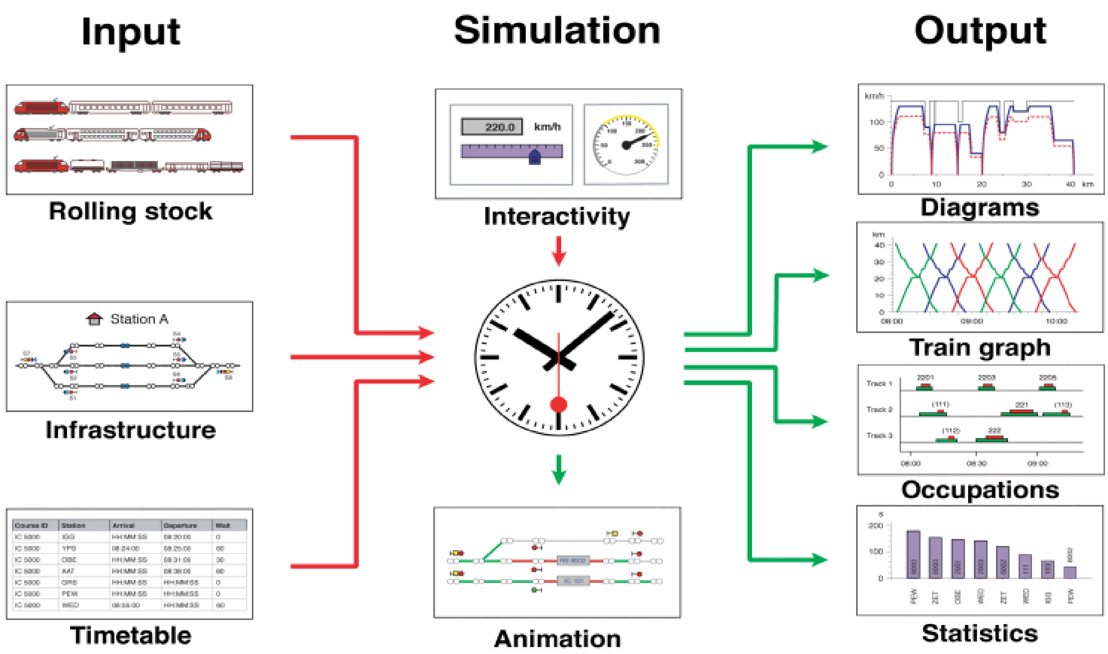

Figure 2 – Data flow in simulation of railway operation
Source: [7]

Input Data

OpenTrack manages input data in three modules: rolling stock (trains), infrastructure, and timetable. Users enter input information into these modules and OpenTrack stores it in a database structure. Once data has been entered into the program, it can be used in many different simulation projects. For example, once a certain locomotive type has been entered into the database, that locomotive can be used in any simulation performed with OpenTrack. Similarly, different segments of the infrastructure network can be entered separately into the database and then used individually to model operations on the particular segment or together to model larger networks.

Train data (locomotive and wagons) is entered into the OpenTrack database with easy to use forms displayed using pull down menus. Infrastructure data (e.g. track layout, signal type/location) is entered with a user-friendly graphical interface; quantitative infrastructure data (e.g. elevation) is added using input forms linked to the graphical elements. Following completion of the railML [8] data structure for rolling stock and infrastructure, OpenTrack is modified to enable train and infrastructure data to be directly imported from railML data files.

Timetable data is entered into the OpenTrack database using forms. These forms include shortcuts that enable data input to be completed efficiently. For example, users can designate hourly trains that follow the same station stopping pattern an hour later. Since OpenTrack uses the railML [8] structure for timetable data, timetable data can also be entered directly from various different program output files as well as database files. Furthermore, Figure 3 shows a short overview of different software programmes using railML interface.

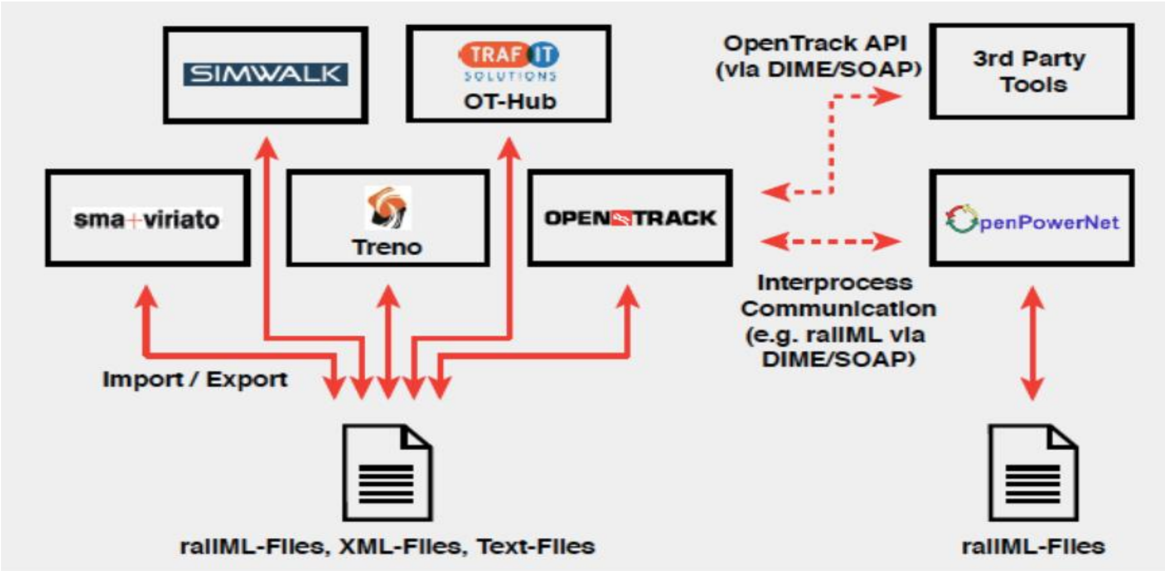

Figure 3 – Example of software tools already using railML
Source: [7]

One advantage of OpenTrack is that it enables users to adjust many variables that impact railroad operations. For example, users can simulate the impact of weather on traction by specifying the adhesion scenario (good, normal, bad). OpenTrack then estimates locomotive traction power using a percentage (also user-defined) of that calculated using the Curtius and Kniffler formula [6]. While OpenTrack provides standard default values for all variables, having the ability to adjust variables makes the program very useful.

Simulation

In order to run a simulation using OpenTrack the user specifies the trains, infrastructure and timetable to be modelled along with a series of simulation parameters (e.g. animation formats) on a preferences window. During the simulation, OpenTrack attempts to meet the user-defined timetable on the specified infrastructure network based on the train characteristics. OpenTrack uses a mixed continuous/discrete simulation process that allows a time driven running of all the continuous and discrete processes (of both the vehicles and the safety systems) under the conditions of the integrated dispatching rules.

The continuous simulation is dynamic calculation of train movements based on Newton's motion formulas. For each time step, the maximum force between the locomotive's wheels and the tracks is calculated and then used to calculate acceleration. Next, the acceleration function is integrated to provide the train's speed function and is integrated a second time to provide the train's position function [9].

The discrete simulation process models operation of the safety systems; in other words, train movements are governed by the track network's signals. Therefore, parameters including occupied track sections, signal switching times, and restrictive signal states all influence the train performance. OpenTrack supports traditional multi-aspect signalling systems as well as new moving block train control systems (e.g. European Train Control System – ETCS signalling).

OpenTrack is a dynamic rail simulation program. As such, the simulated operation of trains depends on the state of the system at each step in the process as well as the original user-defined objective data (e.g. desired schedule).

A simple way of describing dynamic rail simulation is that the program decides what routes trains use while the program is running. For example, when building the network, users identify various different routes that trains can use between two points; OpenTrack decides, during the simulation, which route the train will use by assigning the train the highest priority route available. If the first priority is not available, OpenTrack will assign the train the second highest priority route and so on.

OpenTrack's dynamic nature allows users to assign certain attributes to specified times in the simulation. Thus, users can assign a delay to a particular train at a given station and time, rather than being limited to assigning a delay at the start and using it through the entire simulation. Similarly, users can define other types of incidents (e.g. infrastructure failures, rolling stock breakdowns) for particular times and places.

Finally, dynamic simulation enables users to run OpenTrack in a step-by-step process and monitor results at each step. Users can also specify exactly what results are displayed on the screen. Running OpenTrack in a step-by-step mode with real time data presented on screen helps users to identify problems and develop alternative solutions.

Output

One of the major benefits of using an object-oriented language is the great variety of data types, presentation formats, and specifications that are available to the user. During the OpenTrack simulation each train feeds a virtual tachograph (output database), which stores data such as acceleration, speed, and distance covered. Storing the data in this way allows users to perform various different evaluations after the simulation has been completed.

OpenTrack allows users to present output data in many different formats including various forms of graphs (e.g. time-space diagrams), tables, and images. Similarly, users can choose to model the entire network or selected parts, depending on their needs. Output can be used either to document a particular simulation scenario or as an interim product designed to help users identify input modifications for another model run [7].

3.1 OpenTrack and API

The Open Track API (application programming interface) is able to communicate with a 3rd party application (over the internet). As in Figure 4 shown, OpenTrack accepts Commands (messages to OpenTrack) and sends Status Messages (Messages from OpenTrack). Most importantly, these messages are designed such that they correspond to those exchanged in a real-world railway system between trains, interlocking and dispatching units. For example, massages received from OpenTrack can be train, timetable and block/routes Messages, arrival and departure times at stations, interlocking messages and others. On the other hand, OpenTrack sends speed commands, timetable changes, dispatching decisions that resulted from dynamic simulation. Figure 4 shows an example of OpenTrack Dispatcher. In this case, OpenTrack acts as the replacement of the reality, since the same type of information is exchanged as in reality; namely, commands (messages) go to OpenTrack, whereas Status Messages come from OpenTrack [7].

OpenTrack API's application offers an unlimited number of possibilities, starting from implementation of customer-specific dispatching algorithms to in-depth evaluation of railway operations, connections between trains and circulation of train sets. However, for GoSAFE RAIL project is the possibility of development and analysis of new concepts in train control, such as optimization of energy consumption, reduction of delays and avoidance of bottlenecks and conflicts of greatest importance. This will provide support to IMs for achieving maximum amount of time slots for railway undertakings and for punctual operation. Finally, the goal is that simulation of the behaviour of the reality proves that the optimization algorithm provides suitable solutions within a short period of time.

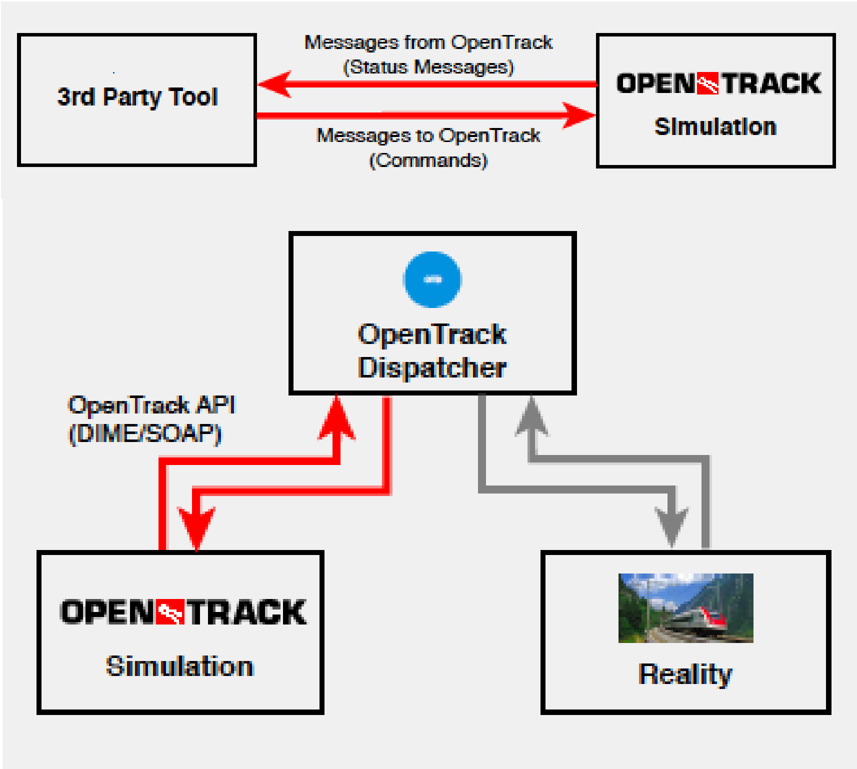

Figure 4 – Example for the application of the OpenTrack API
Source: [7]

4. CASE STUDY ZAGREB – RIJEKA LINE

As already mentioned, line Zagreb – Rijeka was chosen for the case in collaboration with Croatian Railways. First reason is its importance within domestic traffic network; second and more important reason, it being part of TEN-T corridor.

Figures 5 and 6 show examples of infrastructure from the case study. Infrastructure data has been successfully imported in OpenTrack, as it can be seen in these graphical representations of topology. For this paper, just few examples that best reflect the possibilities of OpenTrack were selected. This can be seen in Figure 5, where one can see a detailed presentation of the main railway station in Zagreb, Glavni Kolodvor, whereas the Figure 6 shows part of the preselected network for the case study Zagreb - Rijeka, namely from Hrvatski Leskovac, via Horvati, Mavracici, Zdencina, Desinec, Jastrebarsko, Domagovic, Lazina to Draganici.

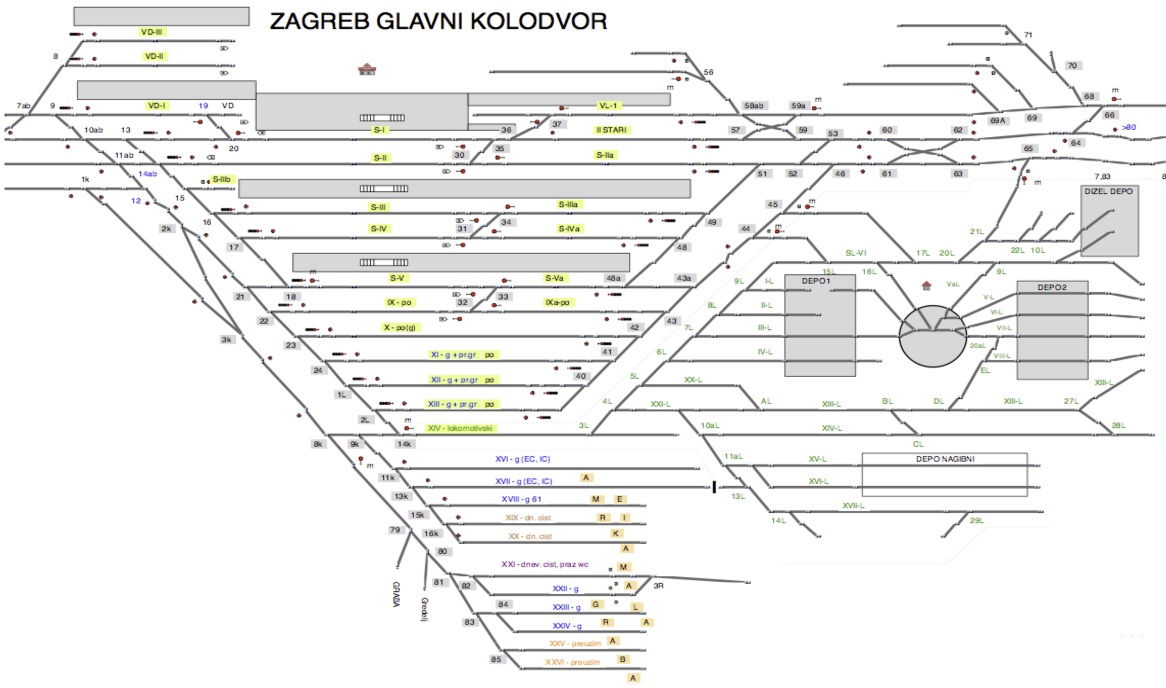

Figure 5 – Infrastructure in OpenTrack: Zagreb Glavni Kolodvor
Source: GoSAFE Rail Project Documentation

Infrastructure topology includes all signals, stations and information about radius, gradient and speed profile on every kilometre point.

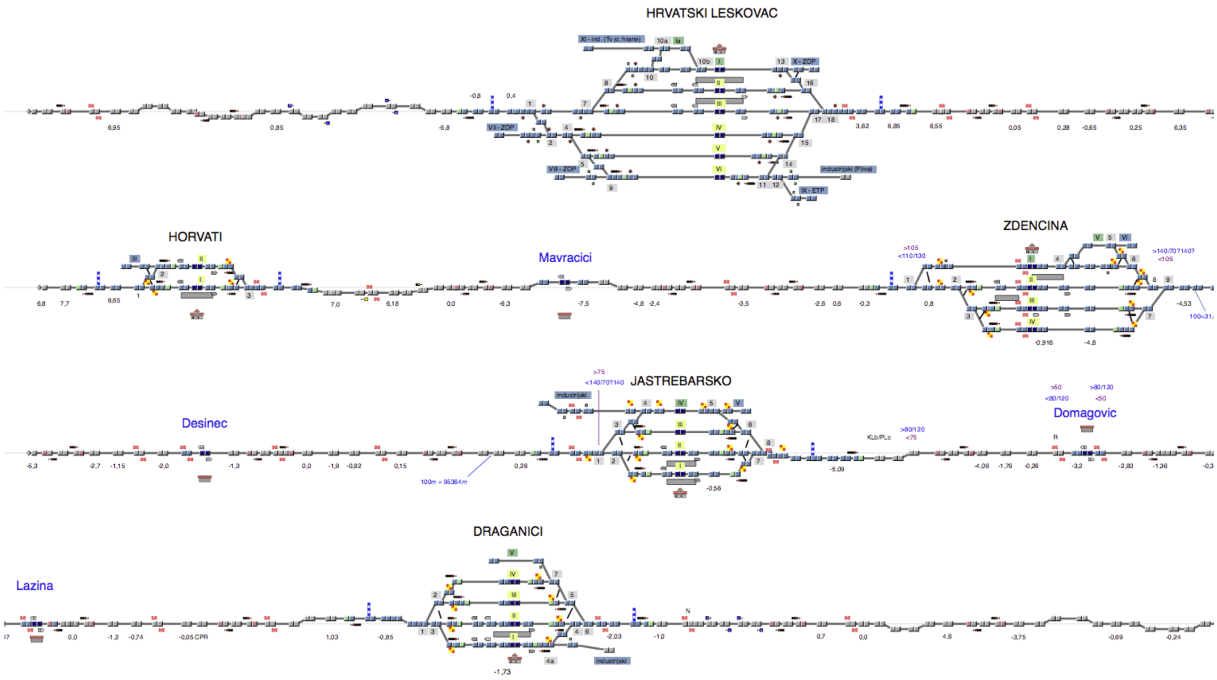

Figure 6 – Infrastructure in OpenTrack: Hrvatski Leskovac-Draganici
Source: GoSAFE Rail Project Documentation

Next steps include testing of integration of algorithm into micro-planning simulation and definition of a test scenario. These scenarios include track closure for maintenance in a certain time slot, or time slots, slow speed zone due to missing maintenance of any component

5. CONCLUSION

In conclusion, GoSAFE RAIL project will provide a means of virtually eradicating sudden infrastructure failures. OpenTrack, being a sophisticated micro-simulation model with API function, will allow the determination of impact of safety decisions on network capacity. Thus, by incorporating both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement), effective delivery of maintenance or new works while maximising the connectivity and adaptability of the overall surface system will be enabled. Finally, the maximization of the availability of the transport network leads to minimisation of environmental impacts, such as carbon emissions, and reduction of delays up to 40%.

ACKNOWLEGMENT

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ASSESSMENT OF PUBLIC PRIVATE PARTNERSHIP IN RAILWAY INFRASTRUCTURE PROJECTS AS A NEW DEVELOPMENT MODEL

ABSTRACT

Investment in railway sector can stimulate trade and link production sites to regional and international markets. A traditionally limited national budget for railway infrastructure in the Western Balkan region consequently lead to lower quality of railway services and permanently loses on transport market share. Based on European Union and global experience, public private partnership in railway infrastructure projects can be a great opportunity for further development of railway sector. Creating the public private partnership as a railway project implementation mechanism should define and allocate resources, responsibilities, risks and rewards on appropriate way in order to achieve 'win-win' effects and mutual benefits for both, public and private entity. Public private partnership in railway infrastructure projects in Bosnia and Herzegovina could be a vision of the new development.

KEY WORDS

railway; public private partnership; risks; assessment; development

1. INTRODUCTION

The growing demand for the more quality railway infrastructure and service and limited public budgets, as traditional resources of financing of the transport infrastructure projects, creating the new possibilities for involvement of private sector in the process of its financing.

Public private partnership (PPP) in its basic idea carries faster integration of new technologies, which stems from the fact that the private sector is more inclined to use new features than this is the case in the public sector. PPPs in railways bring opportunities for investment, operating efficiency and modern and clean technology. PPP railway projects providing for shared use of railway tracks may lead to efficiency gains and an increased revenue basis for states and private investors and make investment in PPP schemes more attractive [1].

Risks of a PPP railway project can arise from the complexity of regulatory framework, financing, taxation, and transport market conditions. Therefore they have to be managed on a proper way in order to achieve successful implementation of PPP project.

The aim of this paper is to assess the global and European experiences on implementation of PPP models in railway sector and to emphasise the risk management process, in order to create theoretical base for the future successfully implementation of PPP railway infrastructure projects in Bosnia and Herzegovina.

2. PUBLIC PRIVATE PARTNERSHIP IN TRANSPORT INFRASTRUCTURE PROJECTS

2.1. Theoretical consideration of PPP importance

Public-private partnership (PPP) is a mechanism for government to procure and implement public infrastructure and/or services using the resources and expertise of the private sector. Where governments are facing ageing or lack of infrastructure and require more efficient services, a partnership with the private sector can help foster new solutions and bring finance [1]. OECD defined that the PPP is an agreement between the government and private partners where the private partners provide the service in such a way that the service delivery objectives of the government are aligned with their profit objectives through a sufficient risk transferring to them [2].

Public private partnership combines the skills and resources of both the public and private sectors through sharing of risks and responsibilities. This enables governments to benefit from the expertise of the private sector, and allows them to focus instead on policy, planning and regulation by delegating day-to-day operations. In order to achieve a successful PPP, a careful analysis of the long-term development objectives and risk allocation is essential. The legal and institutional framework in the country also needs to support this new model of service delivery and provide effective governance and monitoring mechanisms for PPPs. A well-drafted PPP agreement for the project should clearly allocate risks and responsibilities [1].

In further considerations of PPPs, some authors [3] apostrophise some of the main aspects of PPP, as follow:

- PPP entails engaged private partners into public infrastructure projects, as far as their subjects and conceptions are generating a sufficient “contractor appetite”.
- PPP brings “fresh money” to the project, which may be spent and re-financed according to free agreements between the partners. When paid back to the private sector, this money is subject to interest rates on the capital market.
- PPP enables provision of necessary funding partly without or before it is fully available in the public budget (comparable to “off-balance” funding). This (private) part of the funding will have to be amortized either from future operation revenues (which regularly does not fully match in the field of infrastructure) or from future public budgets (comparable to “in-balance” funding).
- Properly executed planning and development of a project also allows better screening of options, and helps in deciding appropriate project structure and choice of technology considering cost over the whole life cycle of the project [4].

There are several reasons for the growing collaboration with the private sector in developing and providing infrastructure services, which include:

- Increased efficiency in project delivery, and operation and management;
- Availability of additional resources to meet the growing needs of investment in the sector; and
- Access to advanced technology (both hardware and software).

As an off-budget mechanism for transport infrastructure development, PPP is attractive for public sector due to the enhancing the supply of much needed transport infrastructure services, providing the relief from the burden of the design and construction costs and immediate cash spending, as well as allocation of risks on private sector.

2.2. Identification of Public Private Partnership models

PPP models have evaluated in wide spectrum determined by: capital assets ownership, responsibility for investment, assumption of risks and contract period duration. In general, PPP models could be classified in five categories (Figure 1), depending on level of involvement and risks assumption: (1) Supply and management contracts; (2) Turnkey contracts; (3) Leases; (4) Concessions, and (5) Private Finance Initiative (PFI) and Private ownership.

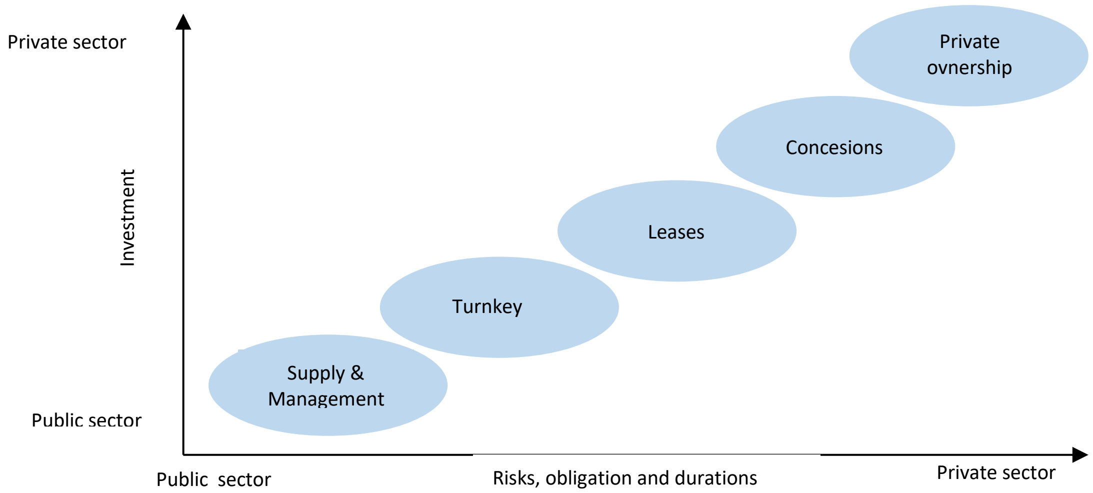


Figure 1 – Basic features of PPP models
Source: [4]

Each of these five categories has many variants, and in fact many recent PPP projects are combination of types. More specifically, the PPP and PFI have the same aim to improve mutual benefits in public services through allocation of resources and risks. However, since the PPP has no regular formation, the process and scheme of each country or project can be different. The PFI has formatted process to deliver the public service effectively [5].

Table 1 – Types of PPP models according to the stage of the project

PPP model	Design	Build	Finance	Manage	
				Operate	Maintain
DBO	Private	Private	Public	Private/Public	Private
DBFO	Private	Private	Private	Private/Public	Private
DBMO	Private	Private	Private/Public	Public	Private
DCMF	Private	Private	Private	Private	Private

Source: [6]

Forms and PPP schemes have evolved gradually and relatively for the long time period. Development and application form and schemes is subject to financial progress and legislation in different countries. Table 1 has summarised the types of PPP models by the stage of the project and identifies the private and/or public sector level of involvement in different phases of project: design, build, finance and manage.

PPP models separated by the ownership of the facility with identification of the main revenue sources are shown in the Table 2.

Table 2 – Identification of PPP models according to the ownership of the facilities

PPP model	Ownership	New/Existing	Operate	Main revenue source
BOT	Private/Public (Mostly private for a specified period)	New facility	Private	End users tariff
BTO	Public (Grant operation right)	New facility	Private	End users tariff
ROT	Private/Public	Existing facility	Private	End users tariff
BROT	Private/Public (Mostly private for a specified period)	Rehabilitation of existing faculty and new facility building	Private	End users tariff
BOOT	Private (For a specified period)	New Facility	Private	End users tariff
ROOT	Private (For a specified period)	Existing facility	Private	End users tariff
BLT	Private	New Facility	Private	Lease fee from the public sector
BTL	Public	New Facility	Private	Lease fee from the public sector
LDO (LBO)	Public	Existing facility	Private	Collect end users tariff and pay lease to public sector
BOO	Private	New Facility	Private	End users tariff
BBO	Private (Buy)	Existing facility	Private	End users tariff
LOO	Private (For the leasing period)	Existing facility	Private	End users tariff

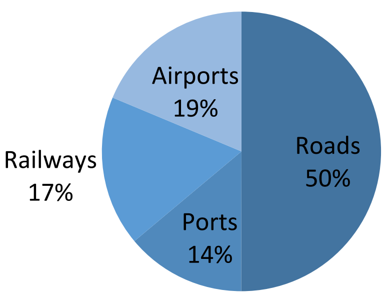
Source: [6]

3. ASSESSMENT OF THE PUBLIC PRIVATE PARTNERSHIP IN RAILWAY SECTOR

3.1. Analysis of PPP implementation in railway sector

Increased needs for efficiency of railway system, higher level of safety and reliability and increased need for growth in infrastructure, reducing government financial support creates the need for involvement of private capital in railway sector investment.

The railway sector is traditionally conservative regarding the PPP type of financing, compared with the other sectors infrastructure, like motorways and airports. Total investment in railway PPP projects for the period 1990-2016 amounted $ 93.314bn. For the same period trough PPP projects were invested $268.690bn in roads, and $100.507bn in airports and $74.569bn in ports [7].



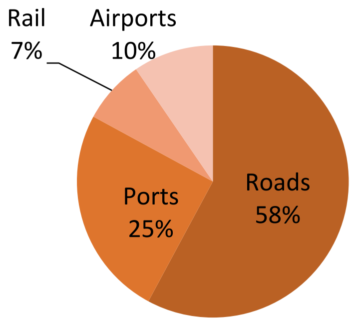


Figure 2 – Distribution of PPP projects in transport sectors in total investment value and number of projects for period (1990-2016)
Source: [7]

In sense of percentage share, railway PPP project value represent 17% of total amount what is almost three time less than share in roads which is 50%. The share in airports and ports are 19% and 14%, respectively (Figure 2).

Comparing the number of PPP projects in transport infrastructure it is evident that the share of 58% in roads is the biggest one, as a result of 938 PPP projects implemented for the period (1990-2016) on global level. The ports sector implemented 406 PPP projects and airports 155, what presents share of 25% and 10%, respectively. It is evident that the railway sector has implemented, in aforementioned period, the less number of PPP projects (122), what is just 7% of total share (Figure2).

Distribution according the number of PPP projects and the values of PPP railway projects in global level by the regions is shown in Figure 3 and Figure 4. The regions of Latin America and East Asia have recognised the significance and benefits of PPP projects for the railway sector improvement, what resulted with the highest number of PPP project.

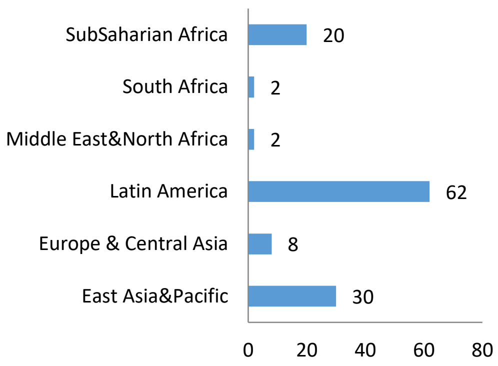


Figure 3 – Total number of PPP projects in railways on a global level (1990-2015)
Source: [7]

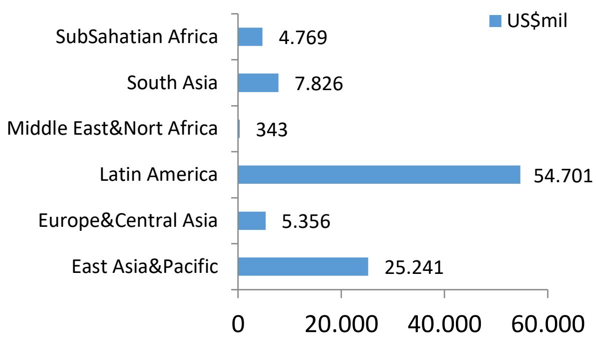


Figure 4 – Total investments of PPP projects in railways on global level (1990-2015)
Source: [7]

PPP projects in Asia have shown that railway and other infrastructure, can be developed mutually, opening specific synergies. In recent years, the investment on China's railways has been kept in an extremely large amount (i.e., 832.8 billion RMB in 2015). By the end of 2015, the length of express railway was 19 thousand km, which will reach 30 thousand km by 2020. China's railway construction in the past mainly relied on government investment, usually with a joint investment between the central and local governments. Nowadays, the government is keen to encourage the use of PPP. Currently, the number of transport infrastructure projects using PPP in China is 761, making up 10.9% of the total; the investment on the PPP projects in transport sector is about 2.23 trillion RMB, accounting for 27.47% of the total [6].

PPP projects in European railway sector focused on the improvement of railway infrastructure and extension of railway network. The railway PPP projects implemented, values, models, period of project implementation and PPP contracts duration are presented in Table 3. It is evident that majority PPP railway projects are in the segment of high speed lines. For high speed railway lines state co-funding is estimated on around 40%-60% of investment costs. French railway infrastructure manager RFF's portfolio of PPP projects in 2012 was estimated in amount of € 15 billion [8]. PPP for railways has already been successfully developed for various rail projects in the UK. The British rail market combines development of transport and infrastructure to comprehensive franchise systems, enabling specific forms of project organisation with corresponding results.

The most of railway PPP projects are of the DBFM (*Design-Build-Finance-Maintain*) type where traffic risks are borne by public sector, where track access charges are the main source of the public sector revenues. Remuneration is based on availability of the infrastructure capacity and other selected quality goals. A minority are BOT (*Build-Operate-Transfer*) types where traffic risk is borne by the private partner who obtains the revenue from track access charges plus some quality goals. PPP projects have also been applied to infrastructure rehabilitation, maintenance and operation projects in heavy railway (Chile, Mozambique) and metro (London underground).

Table 3 – PPP projects in railway infrastructure

Project	Design to completion time	Contract duration	Route length (km)	CAPEX	Public co-funding	PPP type
Stockholm-Arlanda Airport	1993-1999	41	39	SEK 4.1bn	SEK 2.4 bn	BOT
HS Channel Tunnel railway link	1996-2003(2007)	90	109	GBP 5.8bn	GBP 2.01bn	DBFM
Oresund road-railway link	1991-2000	20-30	38	EUR 2.0bn	NA	DBFM
HSL-Zuid	2000-2007	25	100	EUR 6.0bn	EUR0.11bn/ year	DBFM
Perpignan-Figueras HSL	2005-2009	50	45	EUR 1.1bn	EUR 0.6bn	DBFM
Diabolo railway link Brussels	2007-2012	35	3	EUR 0.54bn	EUR0.25bn	DBF
Leefkenhoek railway link Antwerp	2008-2013	38	16	EUR 0.84bn	EUR0.05bn/ year	DBFM
Tours-Bordeaux HSL SEA	2010-2016	50	340	EUR 7.8bn	EUR 4.0bn	BOT
GSMR-France	2009-2015	15	1400	EUR 1.5bn	EUR 0.16bn	DBFM
Lisbon-Madrid HS	2009-2013	40	165	EUR 7.8bn	NA	DBFM
Nimes-Montppellier HS	2011-2016	25	80	EUR 1.8bn	NA	DBFM
Bertagne-Pays de la Lorie HS	2011-?	25	182	EUR 3.4bn	NA	DBFM

Source: [9]

Even the PPP projects are mainly connected to the infrastructure (high speed lines, freight lines, metro lines, and railway and multi modal logistic terminals), PPPs are implemented also in the area of operations (container trains, passenger services and terminal operations) and area of services (catering and other on board services).

3.2. PPP railway projects risks management

Railway sector, especially, in the region of Western Balkan is intensive with the political, regulatory financial ant market risks. Therefore, it is needed for PPP railway projects success to identify, evaluate and manage risks throughout a project's life in order to achieve optimal risk allocation on the party best able to handle them.

Risk management is often seen as something intangible and theoretical. PPP railway project risk management concerns the identification, prioritization, and subsequent control of all eventualities that can endanger the projects' results dimensions: time, information, money, organization and quality (TIMOQ) [10]. Risk management follows a clearly identified process, which includes: risk identification, risk analysis, risk response planning (including transfer of risks to the private sector), risk monitoring, controlling, and reporting.

Risk management always starts with conducting a risk analysis. This is the process of identifying project risks, prioritizing them according to the level of impact to the project in terms of envisaged delays, adverse effect on communication, increasing of cost, poor management and organizational processes, or loss of quality of the required input/throughput/output [10]. A typical risk management structure, which could be used for railway PPP projects, is shown in Figure 5.

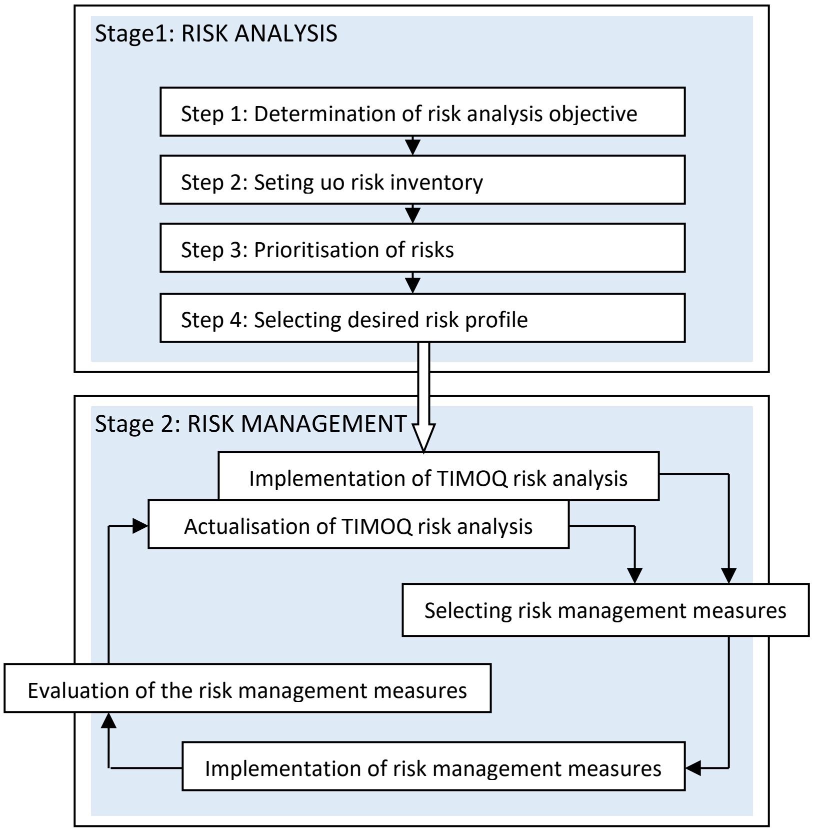


Figure 3 – Risk management algorithm
Source: [10]

Risk matrix is used to manage risks throughout all phases of the project, which includes:

1. Risk category – type of risk
2. Risk topic – identifying the specific risk;
3. Risk description – including a summary of the potential loss if the risk event occurs;
4. Risk probability – the likelihood of a risk occurring (e.g., high, moderate, low);
5. Potential consequence – impact of the risk, should it occur;
6. Allocation of risk –whether the risk will be transferred to the private sector, shared or retained;
7. Treatment options –actions that can reduce the likelihood or consequences of a particular risk (i.e., risk mitigation), and
8. Risk valuation – either a qualitative priority ranking or a quantitative estimate of the potential financial cost or "risk premium" based on the consequence and likelihood of a risk occurrence.

Table 4 – Identification of key types of risks in PPP railway projects partners

PPP project phase	Type of risks						
Development	Planning and environmental process	Political will	Regulatory	Site	Permitting	Procurement	Financing
Construction	Engineering and construction	Changes in market conditions	-	-	-	-	-
Operation	Railway traffic	Competing facilities	Operation and maintenance	Financial Default risk to public agency	Refinancing	Political and regulatory	Handback

Source: [11]

To make risk management efficient and meaningful, it is necessary to identify potential risks in PPP railway projects. The risks of the project arise at different stages of the project cycle, a different extent, a different place and have different sources of occurrence (Table 4).

Qualitative risk analysis includes methods for prioritizing the identified risks for further action. It assesses the priority of identified risks using their probability of occurrence, the corresponding impact on project objectives if the risks do occur, as well as other factors, such as the time frame and risk tolerance of the project. Many risk events are likely to have an impact on both cost and schedule. Schedule impact is quantified in units of time, but delays also have a cost associated with them.

			Cost Consequence				
			Greater than 25%	10% to 20%	3% to 10%	1% to 3%	Less than 1%
	Scale		5	4	3	2	1
Probability	Greater than 70%	5	Very High	High	High	Medium	Low
	40% to 70%	4	High	High	Medium	Medium	Low
	20% to 40%	3	High	Medium	Medium	Low	Low
	5% to 20%	2	Medium	Medium	Low	Low	Low
	0 to 5%	1	Low	Low	Low	Low	Very Low

			Schedule Consequence				
			Greater than 52 weeks	16 to52 weeks	4 to 16 weeks	1 to 4 weeks	0 to 1 week
	Scale		5	4	3	2	1
Probability	Greater than 70%	5	Very High	High	High	Medium	Low
	40% to 70%	4	High	High	Medium	Medium	Low
	20% to 40%	3	High	Medium	Medium	Low	Low
	5% to 20%	2	Medium	Medium	Low	Low	Low
	0 to 5%	1	Low	Low	Low	Low	Very Low

Figure 4 – Qualitative assessment of costs and schedule impact of risk
Source: [11]

Quantitative risk analysis is performed on risks that have been prioritized by the qualitative risk analysis process as potentially and substantially impacting the project. Quantitative risk analysis is conducted to quantify risks in terms of both cost and time impact. Two alternative levels of quantitative risk analysis may be undertaken:

1. Formula-based analysis using a simple formula to calculate average risk impact using minimum, maximum and most likely cost and schedule impacts [11]:

$$Risk\ Value = Probability\ x\ (Min + Max + 4x\ ML)/6 \qquad (1)$$

2. Monte Carlo simulation using specialized software for Monte Carlo simulation of expected cost and schedule impacts to get a range of aggregate risk values along with their probabilities.

The allocation of risk is one of the most important segments of preparing PPP railway project process. An entity that efficiently manages certain risks will have a minimal likelihood of its materialization. Risk allocation strategies strive to ensure that public sector achieve the lowest possible cost for taxpayers trough optimal allocation of risks achieving the added value, while private sector entities attempt to maximize their returns within the acceptable boundaries.

A small number of transferred risk or wrongly selected type of risk that is allocated will not result in the highest value for the public partner. On the other hand, bring you all the risks to the private partner, those risks which the private partner objectively cannot manage the transfer will be a return to the public partner through increased fee

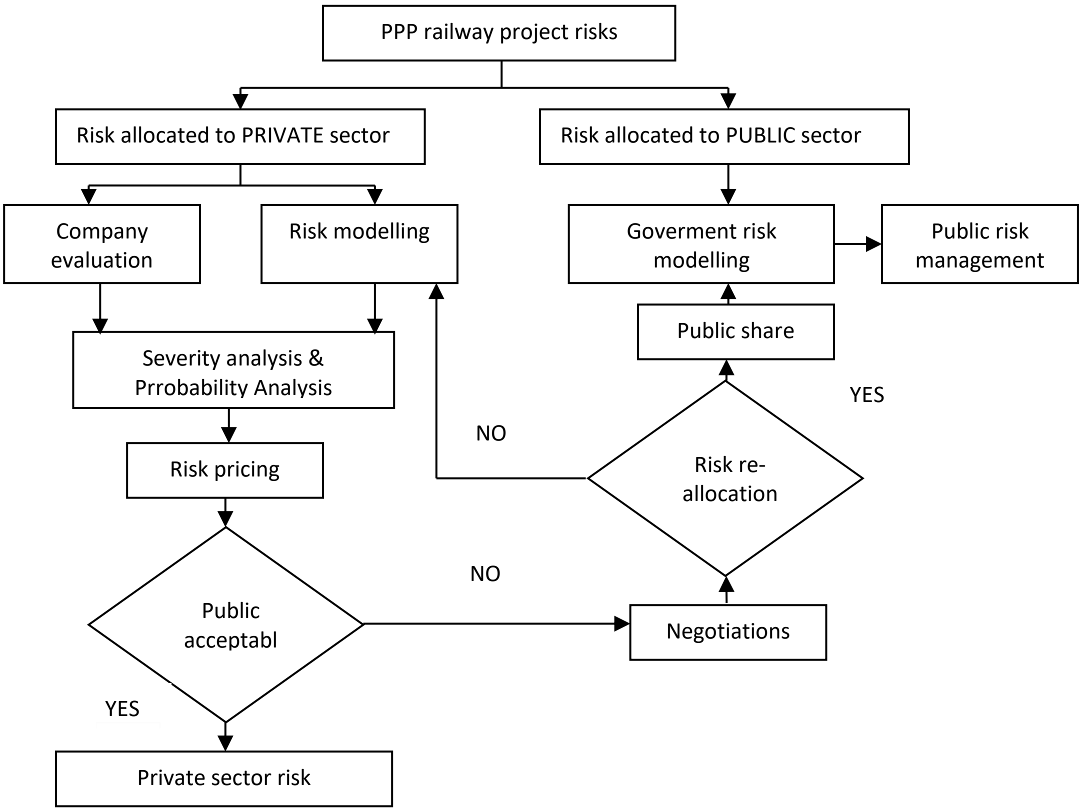


Figure 5 – Risk analysis and risk allocation in PPP projects
Source: [12]

Even though it is a starting point to transfer all permit risk to the private sector under a PPP, it is often a more complex risk allocation in practice – the public sector takes on the risk of the initial permits, but the private sector takes on the risk of any permit amendments associated with detailed design [11].

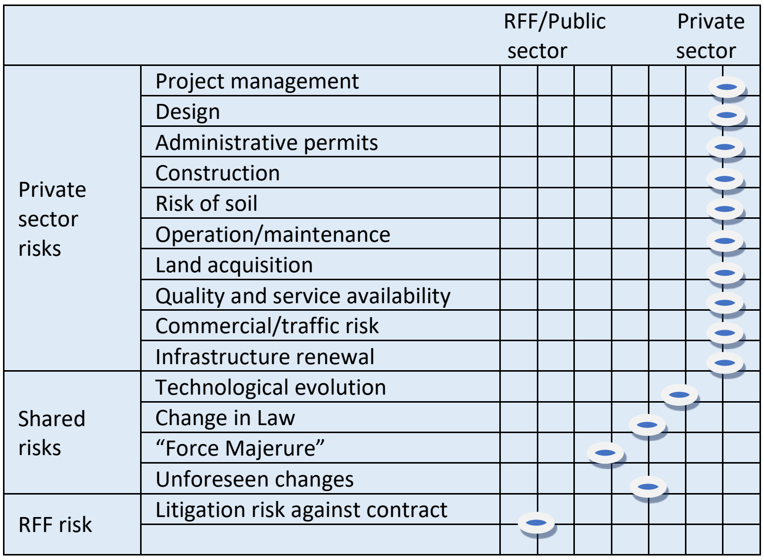


Figure 6 – Shared risks in railway infrastructure PPP project (France case)
Source: [8]

Risks identified in a risk matrix may be categorized in one of three ways: 1. Transferrable risks- risks fully transferrable to the private sector; 2. Retained risks- risks for which the government bears the costs, (e.g., the risk of delay in gaining project approvals), and 3. Shared risks- risks that are shared based on a combination of the above two allocations due to the nature of the risk (Figure 8).

A successful PPP arrangement in railway sector allocates risk in an optimal manner that is acceptable to the public and private sector. Each risk should be allocated to the party best suited to manage or mitigate it.

4. POSIBILITIES FOR PPP PROJECTS IMPLEMENTING IN BOSNIA AND HERCEGOVINA RAILWAY SECTOR

Although in recent years the investments in the reconstruction of the Bosnian railway infrastructure with significantly higher annual average per km of track compared to other networks of the Western Balkans, it is still not sufficient to prevent further deterioration of railway infrastructure capacity, and to bring them to full functionality [13]. Traditional way of financing of the railway infrastructure, based on accumulation and budget, can not provide sustainable financing of the railway infrastructure in Bosnia and Herzegovina what is is primarily a question of its future development.

So far, Bosnia and Herzegovina has no implemented PPP models in railway infrastructure development projects. In order to implement PPP models in Bosnia and Hezegovina railway infrastructure on proper way considering identification, allocation and elimination of possibile risks, few main precondidions on the state level should be defined: development policy including the PPP as required development segment, method and intensity to promote PPP models, legal framework, business framework and infrastructure sectors in which this model applies.

The consistent law framework on PPP in Bosnia and Herzegovina should regulate the terms and manner of drafting, proposing and approving PPPand determine entities competent or authorized for proposals and realization of PPP railway infrastructure projects, with clear rights and obligations of public and private partners, form and content of the agreement on PPP with or without elements and concessions. Creating the transparent, non-discriminatory and clear legal framework in order to stimulate foreign investment and legal protection of rights of participants in proceedings to public contracts, are essential in order to reduce or eliminate risks inherent to PPP models of financing the projects of the railway infrastructure.

In order to achieve the required attractiveness of railway projects for the involvement of the private sector through the PPP model of financing and security of investments, is essential for Bosnia and Herzegovina the clearly defined business framework, which should be based on three pillars: (1) economic regulations relating to prices, service levels and competitive policy, (2) non-economic regulations, relating to quality, safety and the environment, and (3) social regulations related to the structure of financial compensation.

The new national Strategy on transport has emhasises the railway network extension projects, shown in Figure 9, railwa line Čapljina-Trebinje-BiH border-Nikšić (Montenegro), in lenght of 230,4km

on the south, connecting BiH to the Port of Bar and railway line Vareš - Banovići with total lenght of about 50 km on the north, connecting Tuzla industrial region with the Port of Ploče and shortening distance Sarajevo-Belgrade attracting additional traffic flows to Corridor Vc and fostering regional cooperation.

From both comercial and socio-economic benefits points of view, these projects could be of a great potential for PPP models (BOT, DBFO) implementation.

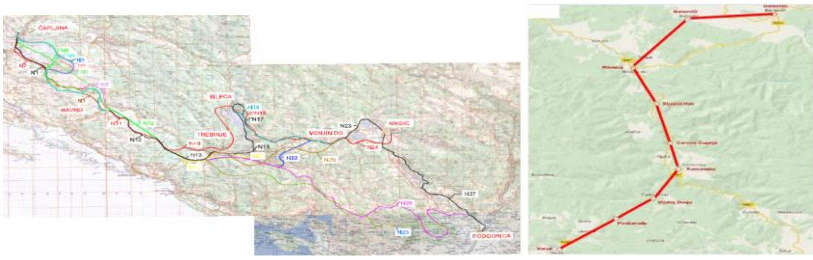


Figure 7 – Proposed railway lines: Čapljina-Trebinje-Nišić and Vareš-Banovići
Source: [13] and Authors

Also, rehabilitation of main railway station as a hubs of contemorary living and business centers (there has been prepared some preliminary design for the Sarajevo railway station, shown in the Figure 10), could be a great resource for involvement of private sector in railway facilities investment implementing ROT (*Rehabilitate-Operate-Transfer*) model of public private partnership.

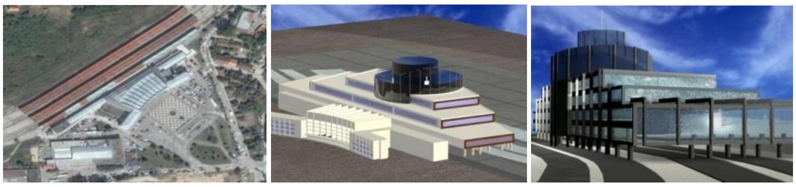


Figure 8 – Proposed design of Sarajevo railway station
Source: [17]

Proposed PPP projects can ensure the necessary competition in railway sector which improves the quality and attracts greater utilization and greater investments in these projects.

5. CONCLUSION

The complexity of PPP railway infrastructure projects implies the importance of the identification and allocation of risks in order to achieve the success of the project. The risks of a PPP project largely depend on the rating of the country and a concession environment, which implies greater attractiveness for financing and implementation of the project. Private sector cannot change the conditions in which it has implemented the project, but can, in partnership with the public sector to identify, mitigate or eliminate the risks resulting from poor rating of the country or concession environment.

Bearing in mind that the state is traditionally responsible for the railway infrastructure, it defines the forms and manner of introduction, and projects to be implemented through PPP model. It is therefore essential that Bosnia and Herzegovina create a regulatory and legal framework in accordance with EU legislation, which defines the planning, management and stimulating the implementation of PPP models. Beside commercial benefits, achieved socio-economic benefits from implementing those proposed railway projects as PPP models will improve regional development, economic growth and accessibility and stronger connection of Bosnia and Herzegovina with the wider region throughout developing the free movement of passengers and freights and significantly improve transport system for whole region. Expansion of railway transport system in Bosnia and Herzegovina using the public private partnership models in railway sector as a new development vision will accelerate its integration with the regional transport system and will develop transport operations within the region and with the European Union.

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OPTIMIZATION OF GOODS DISTRIBUTION IN RETAIL COMPANY "PREHRANA D.D."

ABSTRACT

In this paper, the authors will firstly analyse the current goods distribution solution for consumers in retail company "Prehrana d.d.". After the analysis, the authors will ponder and validate solutions related to distribution of goods in the company. The solutions will provide more effective vehicle usage (better vehicle capacity utilization), less operating costs of distribution, and better vehicle routing during the distribution.

KEY WORDS

distribution; goods; optimization; vehicle;

1. INTRODUCTION

The distribution of consumer goods represents one of the key problems for a successful and prosperous retail company. The average retail company in Croatia very often has its own fleet of vehicles and manages them to distribute goods to retail stores. Most of the retail stores are in the residential zones or in the combined residential-business zones. The situation is the same with the company "Prehrana d.d." - the company must provide goods for 94 retail stores, and almost all of them are in the central business district (CBD) of the City of Zagreb and the City of Samobor. Only a few retail places are in the suburban areas of the City of Zagreb and Zagreb County.

Therefore, the goal of this paper is to reduce delivery time, to save money for the company by more efficient vehicle usage, and to organize the delivery with the same number of vehicles to more stores. To achieve that goal, the authors will first analyse the current situation of goods distribution (number of vehicles, number of drivers, locations of retail stores and LDCs, etc.). After the analysis, new distribution concept for the company, including new LDC location, new vehicle routes, working time rearrangements for the staff, etc., will be given. In the conclusion, each solution will be presented.

The optimization problem that authors solve in the paper is known as VRPTW (vehicle routing problem with time windows). There has been many research on the subject. The papers studied to help the authors to propose solution are Masson et al. (2013), Phoung et al. (2012), and Chang and Chen (2007). Each paper shows that best method for solving these king of problems heuristics.

2. BASIC INFORMATION ABOUT THE COMPANY

The core business of the "Prehrana d.d." company is selling groceries in retail stores. The company itself is a retailer with 94 stores located in the City of Zagreb and Zagreb County. The retail stores have more than 30,000 consumers daily [1]. The majority owner of the company is "Klara d.d.", a company with bakeries in Zagreb. The company employs more than 410 people, such that fifteen workers are employed in the logistic department. The rest of the people in the company are employed in retail stores and company administration.

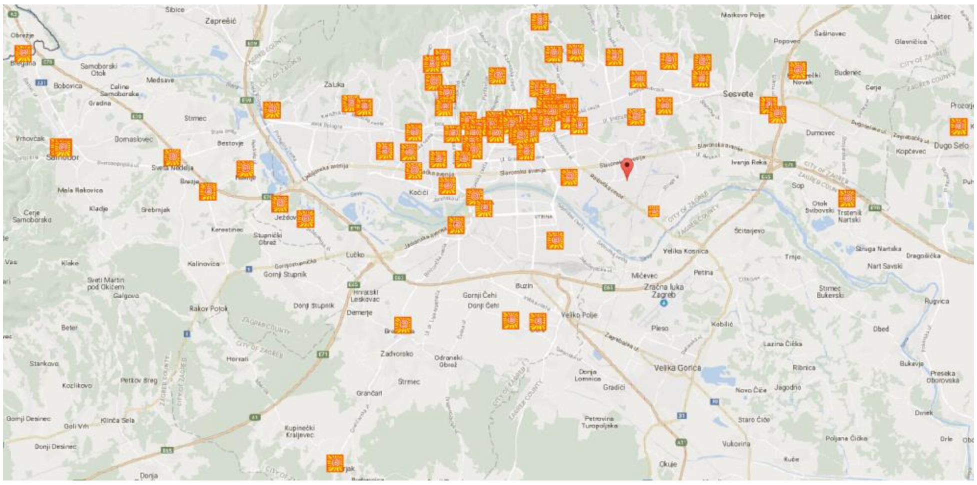

Figure 1 – Prehrana d.d. – retail store locations
Source: [http://prehrana.hr/prodajna-mjesta/]

Figure 1 shows the locations of company retail stores in the City Zagreb and Zagreb County. As it is visible, the largest store density is in the CBD of the City. The rest of the retail stores are in the suburban area or Zagreb County – mostly one per suburban district, and one per district near the City.

3. ANALYSIS OF CURRENT STATE OF DISTRIBUTION

The Analysis of the current state of distribution in the “Prehrana d.d.” company was conducted with data that have been gathered from the company employees.

The distribution in the “Prehrana d.d.” company is organized sporadically, i.e. the drivers decide which routes to use when delivering goods, and there is no assistance of any kind of software to the process itself. When drivers decide which route to use, experience is the key parameter for choosing the optimal route. If the drivers deliver goods to a smaller number of retailer places, the efficiency is relatively high; however, when the number of retailer stores increases, the solution is usually very far from the optimal one. Such case of distribution optimization requires more parameters for deciding which routes drivers will use to deliver goods to the stores. The parameters that are required for such case of optimization are shown in tables 2, 3 and 4.

3.1 Rolling stock

The rolling stock of the company consists of 4 vehicles. Three of them are N1 category (vehicles with maximum allowed mass below 3,500 kilograms), and one is N2 category (vehicles with maximum allowed mass below 7,500 kilograms). Table 1 shows the basic vehicle characteristics.

Table 1 – Rolling stock characteristics

Vehicles of the company			
Type of vehicle	N1 category	N1 category	N2 category
Brand and model	Citroen Jumper	Iveco daily	Renault Mascott
Maximum allowed mass	3,500 kg	6,500 kg	6,500 kg
Transport capacity	2,000 kg	3,300 kg	3,300 kg
Engine power	80 kW	114 kW	115 kW
Engine displacement	2,000 cm^3	2,000 cm^3	2,500 cm^3
Average fuel consumption	13.5/100 km	13.5/100 km	18.5/100 km

Source: by authors, based on [5]

3.2 Working staff of the company

The company employs more than 410 employees, and 15 of them are working in the logistics department of the company. Table 2 shows basic information of the logistics department employees.

Table 2 – Employees of the logistics department

Employees	
Total number of employees	15
The number of drivers	7
Working days per week	5
Working hours per week	40
Working hours per day	8
Driving hours per worker	6.5
Resting time per worker	30 minutes

Source: by authors, based on [5]

3.3 Demand for goods by the retail places

The data that are required for the distribution optimization are distances and retail store locations, demand for goods by the retail places in unit time (daily, weekly, annually) and vehicle utilization. Table 3 shows the information about mutual distances between retail stores and distances between LDC and retail stores.

Table 3 – Retail store distances

Distribution unit	
The number of retail stores	94
Total distance between LDC and retail stores	336 kilometres
Average distance between two retail stores	3.5 kilometres
Daily average mileage per shift	130 kilometres

Source: by authors, based on [5]

The data about total distance of the LDC to all retail stores was obtained by multiplying the average distance between two retail stores and the total number of retail stores. The daily average mileage per shift was calculated by data used from tachographs. Table 4 shows weekly demands for goods by each retail store.

Table 4 – Weekly store demands for merchandise

The amount of goods	
Weekly amount of goods necessary for distribution	47,500 kilograms
Weekly average amount of goods per retail store	500 kilograms

Source: by authors, based on [5]

4. RESEARCH METHODOLOGY

The authors have assumed that, by using heuristic method, a better solution than the current can be found for the problem. The method derived from heuristics that will be used in this paper is the empiric method by which authors, with the provided data, calculate how to maximize all resources (vehicles, working staff etc.) by using analytics, and without using new or replacing the existing resources. The optimization will be done on such way, that with exiting rolling stock and number of workers in logistics, respecting current legislative for working hours of mobile workers, the authors will try to find solution using simple analytics that will maximize vehicle's transport capacity and maximize allowed working hours for workers.

5. THE PROPOSED OPTIMIZATION SOLUTION

There are three kinds of solutions proposed to address the problem – efficient vehicle usage, new distribution centre location, and new distribution concept.

5.1 Optimization by efficient vehicle usage

Efficient vehicle usage can be achieved by a better goods rearrangement on every vehicle, so that every vehicle transports the maximum amount of goods able to fit into the vehicle. In the proposal of optimization by efficient vehicle usage, approximately 100 percent of cargo space was used in the fleet, as shown in Table 5.

Table 5 – Optimization by efficient vehicle usage

Prehrana d.d.				
Vehicle type	A (light-duty)	B (light-duty)	C (truck)	D (light-duty)
Transport capacity	2,000 kg	2,000 kg	3,300 kg	2,000 kg
The number of retail stores in the proposal area	20	20	33	20
Goods loaded per day	2 000 kilograms	2 000 kilograms	3 300 kilograms	2 000 kilograms
Driver shift	08:30 – 16:30	08:00 – 16:00	05:30 – 13:00	05:30 – 13:30
Daily average mileage per shift after the optimization	100 kilometres	120 kilometres	45 kilometres	35 kilometres

Source: by authors

5.2 New distribution centre location

The current distribution centre (LDC) location of the company is in the eastern part of the City of Zagreb. As visible on Figure 1, the retail stores are located western form the LDC. The current LDC location is rented, so another location would not increase costs – instead, it would lead to the reduction of the current operation costs.

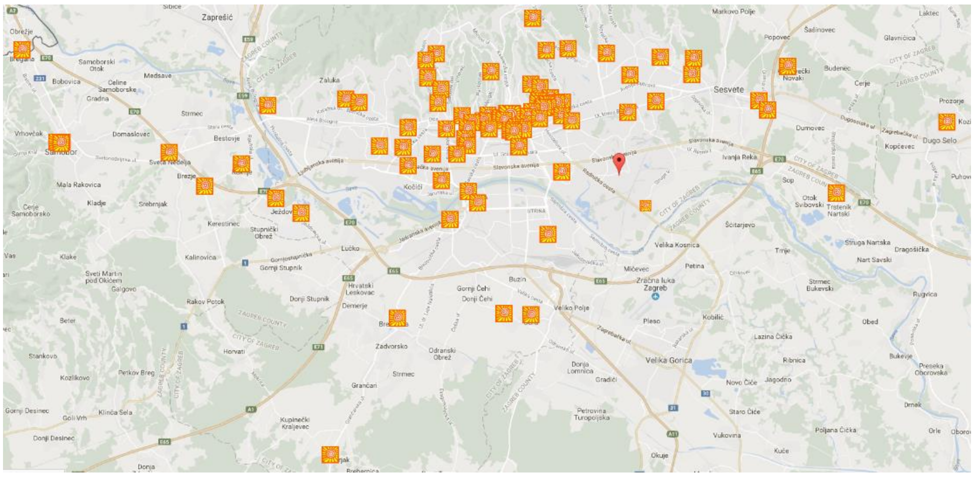

Figure 1 – The locations of the LDC and retail stores
Source: [http://prehrana.hr/prodajna-mjesta/]

5.3 New distribution concept

The new distribution concept for the company “Prehrana d.d.” is based on the following concept: when every vehicle leaves the distribution centre, it must submit all goods which needs to be delivered to retail stores in a single run. That concept can be achieved if each retail store, gets the necessary amount of goods every day. As seen from Table 4, the total weekly amount of goods required by the retail places is 47,500 kilograms. When these 47,500 kilograms are divided by the number of working days and the number of retail stores, the result is approximately 100 kilograms per store; therefore, each retail store has a daily demand for 100 kilograms of goods.

The new distribution concept would suggest 4 delivery zones. One vehicle would serve every retail store located in the zone (Figure 2). The proposal of new shifts would be done for each of zone separately. The shift for the Zone A (yellow) would start at 05:00, and the shift for the Zone B (green) at 05:30. The reason for such shifts are morning peak periods, in order not to increase delivery time due to traffic congestion. The shift for the Zone C (black) would start at 08:00, and the shift for the Zone D (red) would start at 08:30.

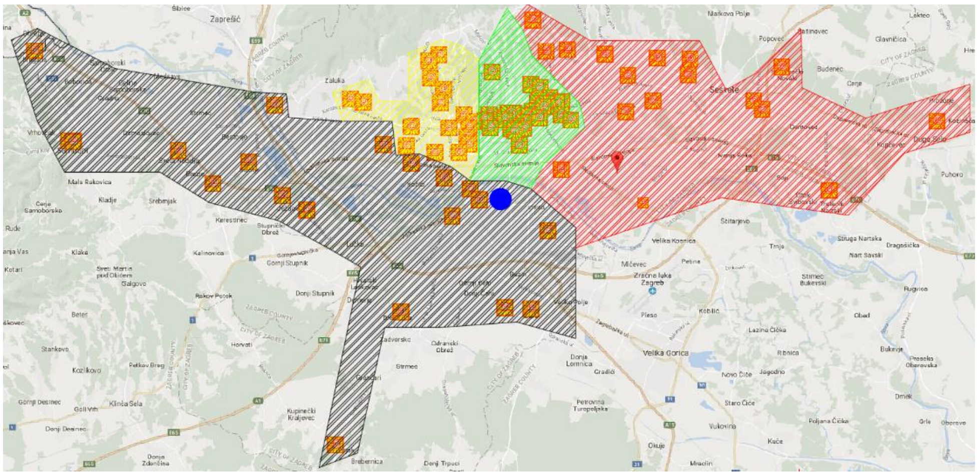

Figure 2 – Proposed delivery zones
Source: by authors

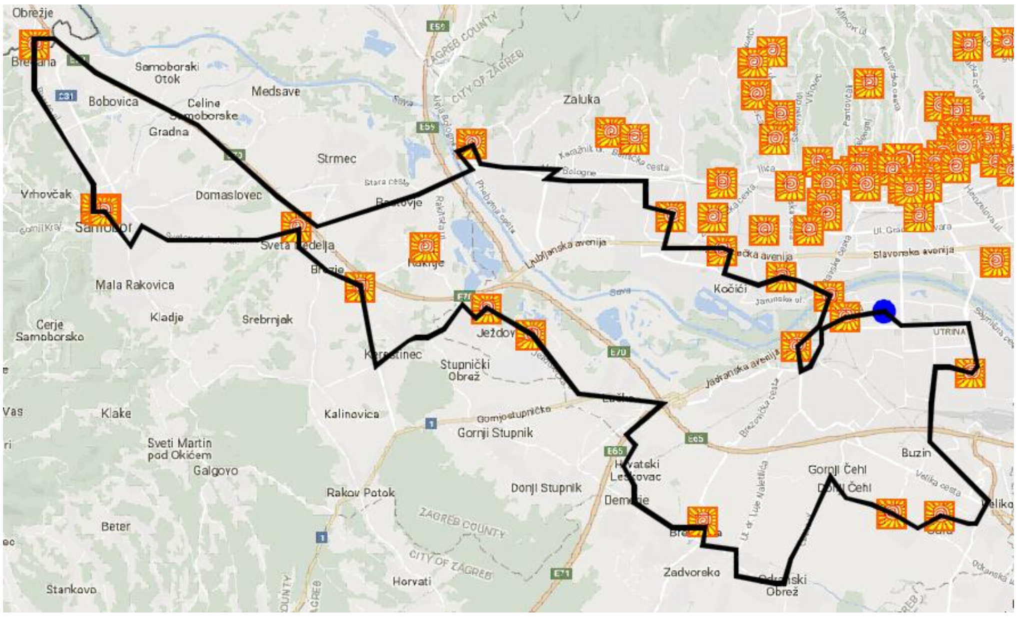

Figure 3 – New distribution concept - proposed Zone A
Source: by authors

Figure 3 shows proposed vehicle route for vehicle delivering in the Zone A (black in Figure 1). The proposed route length is approximately 100 kilometres, which is almost 25 percent less than the mileage per shift before the optimization. As seen in Table 1, If the average fuel consumption is 13.5 litres per 100 km, and the price of one litre is 9 HRK, the estimated daily saving per shift for the Zone A would be 35 HRK. Figure 4 also shows the proposed route for vehicle delivering goods to retail stores in the Zone B (red in Figure 1). The proposed length of the route is approximately 120 kilometres, because the same type vehicle is used to deliver, and the estimated daily saving per shift for the Zone B is 12 HRK.

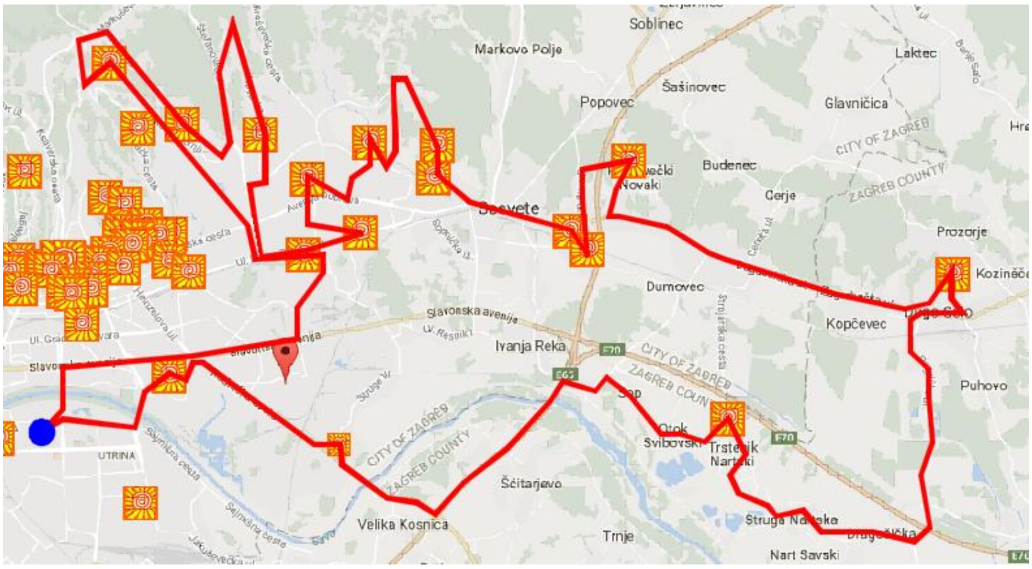

Figure 4 – New distribution concept - proposed Zone B
Source: by authors

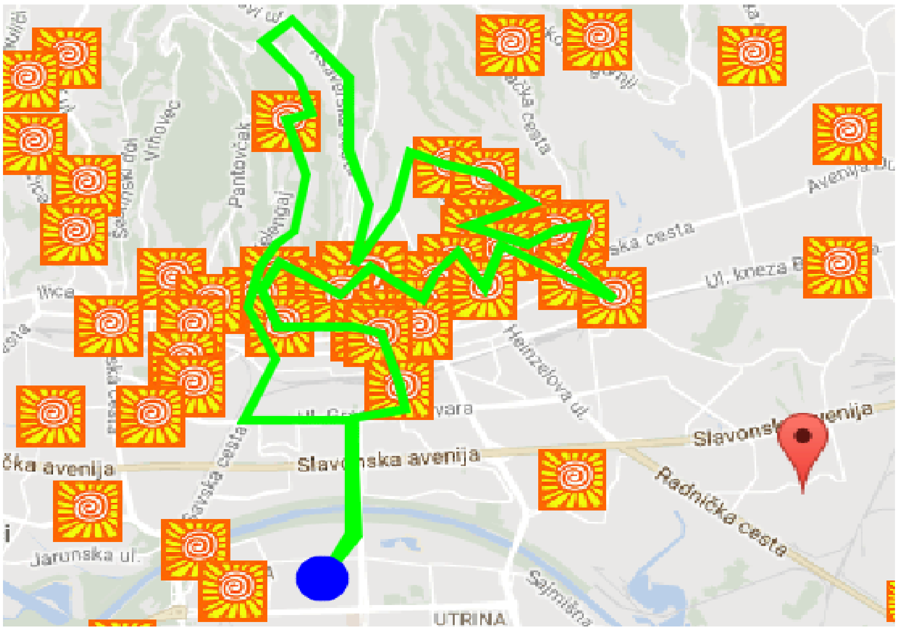

Figure 5 – New distribution concept - proposed Zone C
Source: made by authors

As seen in Figure 5, the proposed route length for the vehicle delivering goods to retail stores in the Zone C (green in Figure 1) is approximately 45 kilometres, which is almost 3 times less than the mileage per shift before optimization. As seen in the Table 1, If the average fuel consumption of 18.5 litres per 100 km and the price of one litre of fuel (9 HRK) were used, the estimated daily saving per shift for the Zone C is almost 140 HRK. Figure 6 also shows the proposed route for vehicle delivering goods to retail stores in the Zone D (red in the Figure1). The proposed length of the route is approximately 35 kilometres, which is almost 4 times less than the mileage per shift before optimization. The Estimated daily saving per shift for the Zone B (the average fuel consumption of the vehicle is 13.5 litres per 100 km) is almost 115 HRK.

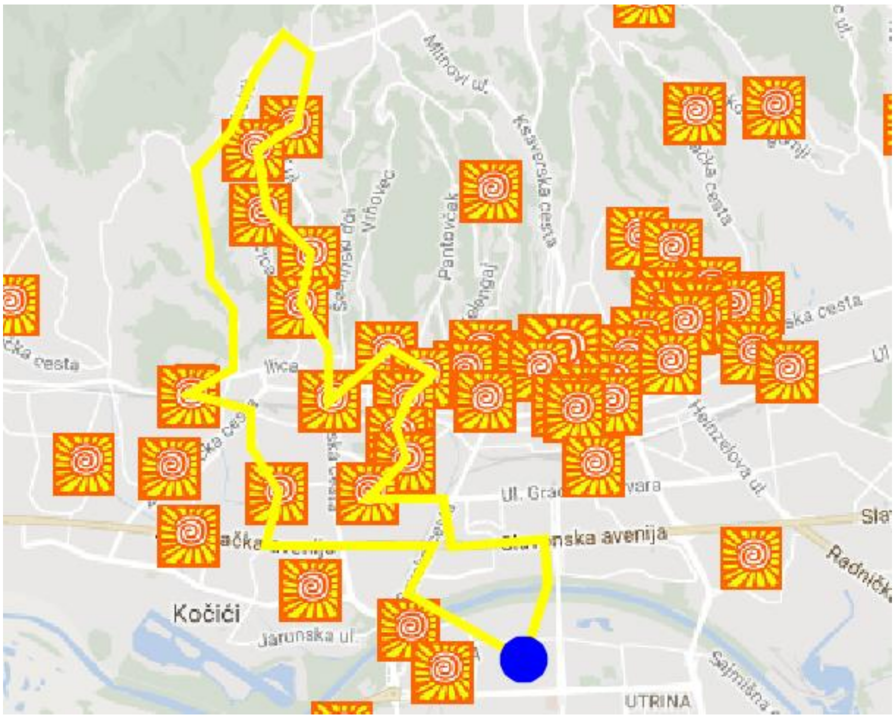

Figure 6 – New distribution concept - proposed Zone D
Source: made by authors

If the benefits for every zone were summarized, the estimated yearly operating cost saving becomes 80,000 HRK, vehicle capacity becomes used almost 100 percent, and the employees are utilized 100 % of their shifts (they do not have empty rides, except when returning to the distribution centre).

6. DISCUSION

The results shown in the chapter above suggest that a better solution using only empiric method can be achieved; however, the paper also shows that, if the optimal solution for the presented amount of demand in retail stores wants to be reached, programming tools (such as Paragon[1]) created especially for this type of problem, have to be used. The paper also shows that, for this kind of problem, working staff needs to be properly educated.

7. CONCLUSION

In this paper, the authors have been analysing the data obtained from the "Prehrana d.d." company. The analysis of the processed data showed that drivers tend to optimize goods distribution to retail stores by themselves (the management staff only provides drivers the information about the amount of goods to be delivered). In the offered solution of the distribution problem given in the paper, each driver would be assigned one zone, and each of them would have to deliver the required goods to the retail stores located in that zone. Also, the authors propose the new location of the distribution centre. If the proposed solutions were implemented, the company "Prehrana d.d." would have financial savings, better workforce utilization, and more efficient rolling stock.

The future research on this matter should include the analysis and the optimization by the programming tools used for these kind of problems, to achieve even more savings in time and operating costs. Also, the employees should take the adequate training to gain more needed knowledge, so they can execute tasks given to them more efficiently.

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ANALYSIS OF SELECTED DISTRACTING FACTORS INFLUENCING MOTORIC COMPONENT OF REACTION TIME USING ELECTROMYOGRAPHY

ABSTRACT

The aim of this article is to introduce the new methodology of driver's reaction time investigation in real traffic conditions. The investigation of reaction time was performed with the help of the biosignals' acquisition. The biosignals' acquisition enabled to penetrate into the biomechanics of the braking movement of the right lower limb. Furthermore, the effects of distracting stimuli to driver's reaction time were analysed to find the connection between the distraction and its effect to the right lower limb movement during the braking of the vehicle. Effect of selected distraction factors on movement time and also on muscle activation duration has been analysed.

KEY WORDS

Reaction time; electromyography; driver; distraction; muscle response time, movement time

1. INTRODUCTION

Human factor has been defined as the most common factor directly contributing to the accident causation (research papers defined the share of more than 90 %). One of the possible causes of road accidents might be a high density of information which may cause the driver misses a fact which is significant in a particular road traffic situation. The density of information affects the driver's ability to assess the situation as well as the driver's reaction time to external impulses.

The main characteristic of the driver is the duration of reaction time (RT). Reaction time has been defined as an interval between the time when an obstacle becomes visible firstly to driver or firstly acts in a way that could be perceived as hazardous to driver and time when the driver has initiated a response (typically touching the brake pedal) [1]. RT has been the most commonly divided into two stages – cognitive time and movement time. Cognitive time is a time required to the object noticing, recognition by the central nervous system (CNS) and time needed to muscle activation. Movement time is the duration between accelerator release time and brake pedal activation.

Reaction time could be affected by various elements. Driver´s ability to perceive risk is critical for traffic safety. Generally, the effects that negatively or positively affect the moment of initiative recognition have been known. The influences of selected distracting factors to brake reaction time have been included in many studies range from an interaction with in-vehicle devices (using GPS navigation system [2], conversing to a hand-held or a hands-free mobile phone [3], [4], [5], tuning the radio [6]) to a distraction of the driver´s attention by various elements in a road surrounding. Impact of many distractors on reaction time has been not quantified yet. Furthermore, an influence of these distractors on individual components of the reaction time has been examined rarely.

Recently, work fosused on the the driver's behavior has started to use an acqusition of biosignals. Primarily, biosignals' acquisition has been used in simulator studies, it has been used rarely in a real traffic. Electrical potential measurements have been frequently used for verifying or calibrating of alertness system – typically EEG or ECG [7], [8]. For active safety systems' development, not only analyzing of cognitive reaction time, but also analyzing of motoric component of reaction time should be important. Movement time and the influence of the selected distractive factors have been analyzed in many previous studies (for example [9], [10]). The usage of analysis of musculoskeletal system using EMG has been started currently.

The aim of this pilot study is to analyse how the selected distraction factors befall the motoric component of driver reaction time in detail. Using of electromyography have allowed the more accurate analysis of motoric component of reaction time. EMG recordings of the right limb provided an earlier indication of leg movement, i.e. it allowed a determination of time needed for muscle activation (muscle activation time - MAT), which have preceded the visible leg movement. Muscle response time (MRT) has been determined as the whole duration between the moment of muscle activation and activation of brake pedal (Figure 1).

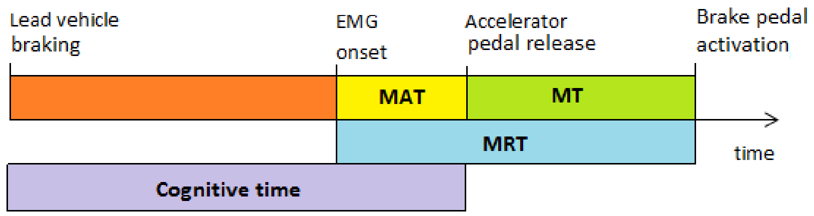

Figure 1 – Individual components of response time
Source: authors

This study was developed to investigate how these distraction factors affected movement time. As mentioned in [11], MRT values have been varied depending on how expected and sudden was the stimuli. In this pilot study, the effect of distraction on MRT has been investigated. Using combination of EMG and data from vehicle control unit has allowed to analyze motoric reaction time in detail.

2. METHODS

2.1 Methodology

Measurements were carried out with two following vehicles. The first vehicle was the Škoda Yeti with a training simulator - leading vehicle. Second towing vehicle Skoda Octavia was the measuring vehicle. Drivers have been exposed to critical incident – braking of leading car. Training simulator mounted on a modified towbar of vehicle Skoda Yeti was used because of safety reason (Figure 2). The simulator consists of a special flexible crash barrier with mounted taillights connected to the brake lights of the towing vehicle. The simulator was carried at a distance of 2 m behind the towing vehicle in order to minimize the possibility of a collision between leading and measuring vehicle. Measurement was carried out at low speeds because of the safety reason. Approximately constant velocity of all drivers (in the range of 30 to 40 kilometers per hour) quarantees elimination of the velocity influence on the reaction time. Testing drivers were asked to maintain approximately the constant distance between simulator which they considered as a safety distance. Seven men aged between 28 and 38 years (median 36 years) have participated in this study. Measurements were carried out on the road towards airport with the exclusion of other vehicles. Test segment had a total length of 516 m and an average width of 8 m. The road surface was without significant transversal or longitudinal inclinations and dry.

Figure 2 – Simulator with flexible crash barrier on vehicle Škoda Yeti and test vehicle Škoda Octavia
Source: authors

In the test track surrounding the objects that were intended to distract the driver while driving (billboards, dummy, etc.) have been deployed. Drivers attention have been also attacked during the drive by tasks associated with the operation of the vehicle, which limit the ability of the monitoring operation. Tasks related to control in – vehicle device and using mobile phone were also included.

2.2 Electromyography

One of the main aim of this study was to determine the MRT of drivers during the driver's braking intention. Next goal was to find the mutual relation between the type of stimulus and muscle response, or to establish the correct muscle timing. First of all, 14 muscles have been proposed for analysis. The group of the three principal muscles of the lower limb was established for the purposes of this study with the respect to kinematic rules of the ankle joint movements during the braking. As the most important part of the braking process the phase of the accelerator leaving and the phase of the brake pedal pressing were determined. Firstly the entire process is accompanied by dorsal flexion of the ankle joint, as the initial movement during the pedal changing; secondly the non-contact phase follows, which is replaced by the step on the brake pedal. Within this final full-contact phase the pronation of the forefoot was assumed as the earlier movement before the main plantar flexion of the entire foot.

As the most appropriate tracked muscles for these movements detection, these three muscles of the right lower limb has been found: musculus tibialis anterior as the primary mover of dorsal flexion of the ankle joint as well as supinator of the forefoot. As the primary mover of forefoot pronation the musculus peroneus longus has been established, and for plantar flexion detection the musculus triceps surae was recorded. The placement of electrodes was carried out in accordance with the SENIAM research group recommendations [12].

The sequence of the concentric contraction of the chosen muscles shows the quality of the muscle timing as well as quality of the postural stability of the driver’s ankle joint. In the case when the musculus peroneus longus does not start to work before the main plantar flexion provided by the strong musculus triceps surae the posture of the forefoot could be supposed as a supinated. In this supinated position of the forefoot the press on the brake pedal could have a different quality with unequal power transfer from the foot on the pedal.

In this study the muscle timing of the right lower limb was recorded by electromyography electrodes surface. For this purpose, the wireless EMG device Cometa was included to this measurement. EMG system Cometa consists of two main parts. First part is a set of 16 electrodes which can be placed on the human body and this set serves to biosignal acquisition. Second part of Cometa system is software for data processing.

For na objective determination of muscle response time value, automatic detection algorithm have been designed. The onset detection algorithm was based on the empirical mode decomposition (EMD) of EMG signal as the signal preprocessing [13]. The EMG signals acquired from three right lower limb muscles were decomposed into their intrinsic functions. The empirical mode decomposition was chosen instead of commonly used signal filtering to preprocess EMG signals without a need to create special filter for each signal separately. Figure 3 below shows the original EMG signal from m. tibialis anterior acquired during the driver's reaction to distracting stimulus and its first intrinsic function.

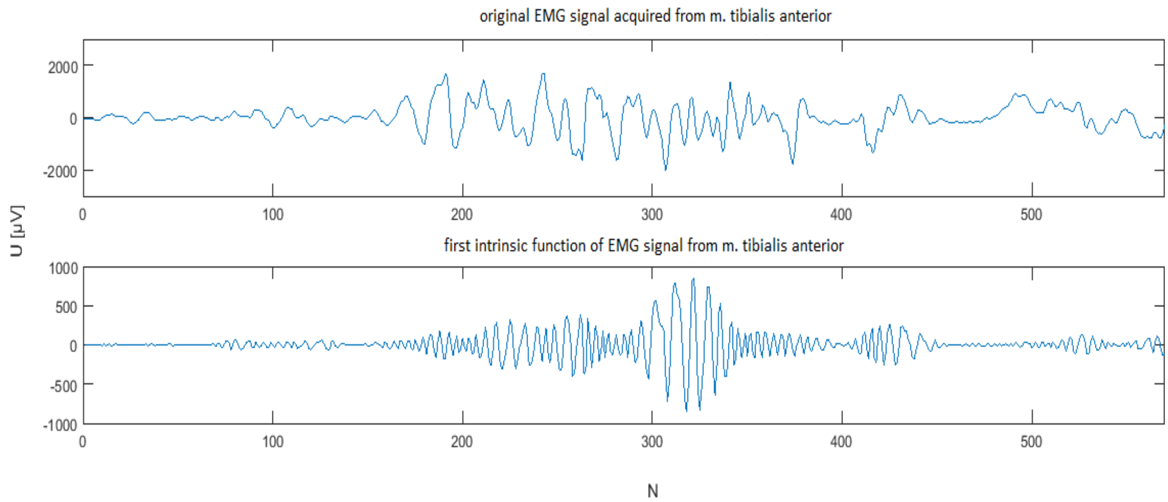

Figure 3 – EMD signal preprocessing of EMG signal acquired from m. tibialis anterior
Source: authors

The aim of the empirical mode decomposition of EMG signals was to emphasize the difference between the activation of muscles and resting state of muscles. Thus the empirical mode decomposition emphasized the difference between EMG spindle representing the active state of muscle and EMG baseline representing the resting state of muscle to detect the onset of the muscle activation [14], [15].

The last step of the signal preprocessing was represented by the application of Teager-Kaiser (TKEO) operator to the first intrinsic function of EMG signal obtained from the empirical mode decomposition [16]. The mathematic definition of TKEO operator is introduced below:

$$\psi[x(n)] = x^2(n) - x(n+1)x(n-1) \tag{1}$$

Application of TKEO to the first intrinsic function of EMG signal was used to highlight the extremes in signal. Basically, after TKEO application the origin high signal values were even magnified and origin signal values close to zero were reduced. This fact led to the more straightforward detection of the muscle's activation onsets [17].

Figure 4 shows the first intrinsic function of EMG signal obtained from m. tibialis anterior and the first intrinsic function of EMG signal after TKEO application. As mentioned above, TKEO application helps to magnify the high origin signal value and reduce the origin signal values close to zero. The first intrinsic function of EMG signal entered to the detection of muscle's activation onsets.

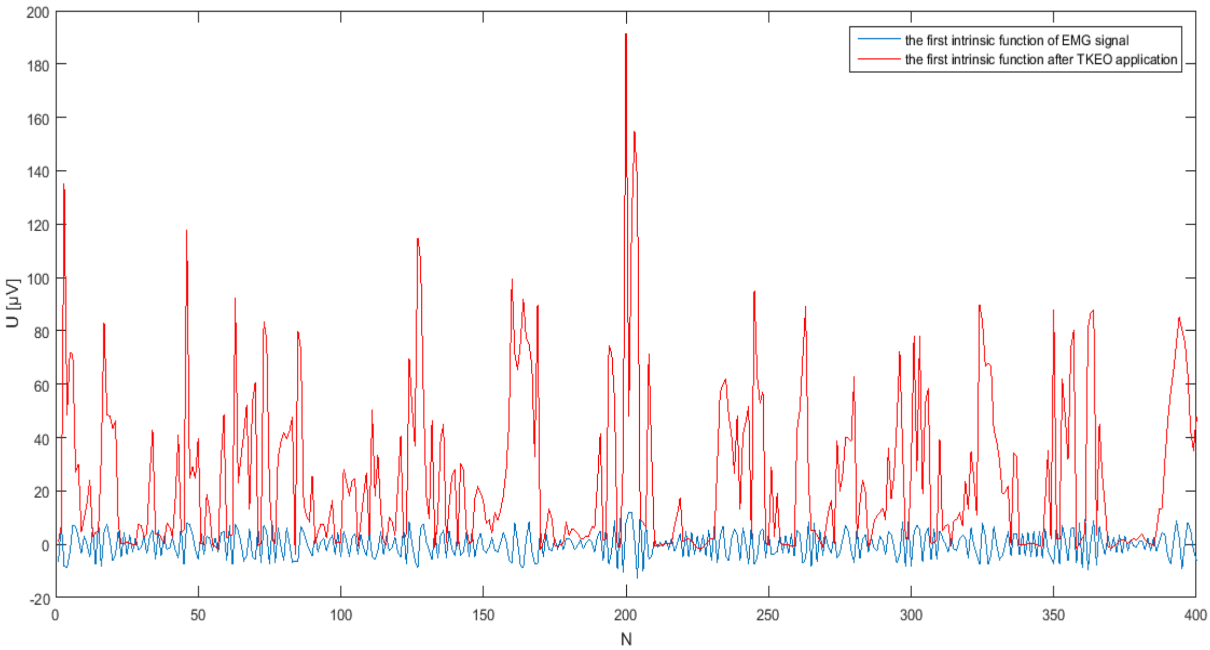

Figure 4 – First intrinsic function of EMG signal and its variant after TKEO application
Source: authors

After EMG signal preprocessing performance the detection of muscle activation onset was carried out. Onset detection was based on thresholding of preprocessed EMG signal. Threshold was derived from standard deviation of EMG baseline. The standard deviation of EMG baseline was estimated and its quintuple was used as the detection threshold. Own program passed through the entire EMG signal and higher signal values than the threshold were sought. The value of threshold should have been exceeded in fifty-milisecond signal window in order to declare that the onset of this signal window was the onset of the muscle's activation as well.

Detected onset of the muscle's activation is lower limit of MRT. The overhead limit of MRT should have been investigated in order to find out the whole duration of MRT of drivers. The overhead limit was found out from footswitch sensors which were placed directly on the brake pedal.

Figure 5 represents the duration of the driver's MRT obtained during the driver's reaction to the one of stimuli. The detected onset of muscle's activation represents the start of MRT and non-zero footswitch signal (the rising edge of the footswitch signal) represents the end of MRT.

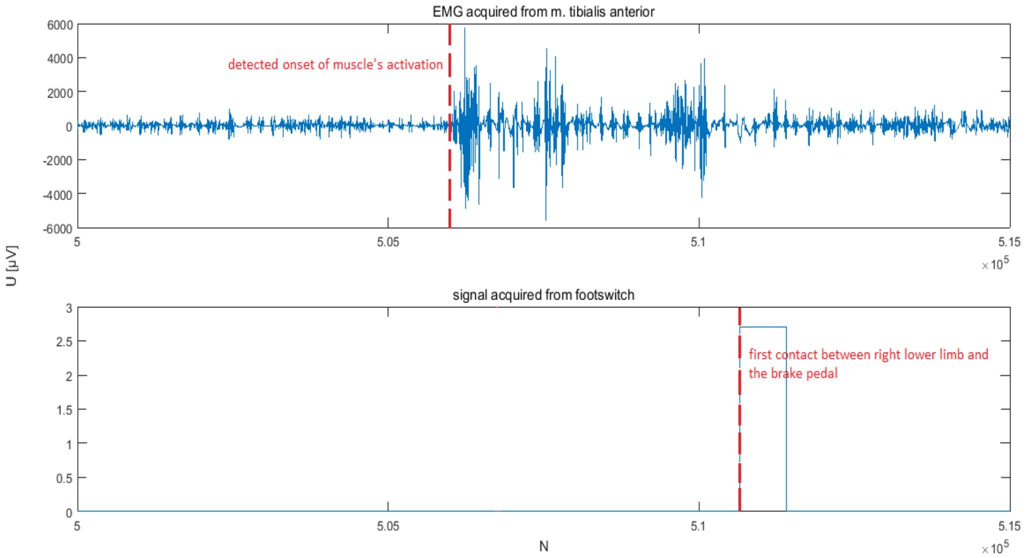

Figure 5 – EMG signal with detected onset of muscle's activation and footswitch signal
Source: authors

3. RESULTS

In the course of experiment each driver was exposed to two different types of distraction. All drivers were instructed to write and send a text message and using mobile phone during driving. Tasks related to control in – vehicle device were also included (tuning radio, interior temperature setting, etc).

As mentioned above, RT has been most commonly divided into two main parts: cognitive time and movement time (Figure 1). The start of the movement time was measured by accelerator pedal displacement. Movement time ends when brake pedal have been activated (starting of brake pedal depressing). Box plot in Figure 6 provided the results of leg movement response time. Analysis of variance denoted no significantly differences in movement time investigated with or without driver distraction ($p > .05$).

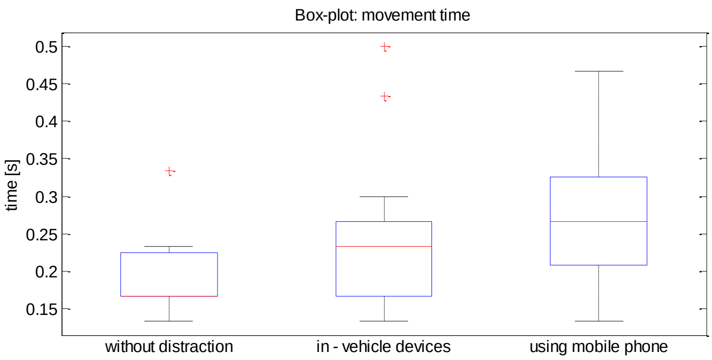

Figure 6 – Movement time (red line: median, blue box: 1. a 3. quartile, black lines: 5 – 95%, red cross: outliners)
Source: authors

Box plots (Figure 7) provided the results of muscle response time of the monitored muscles. As the most appropriate tracked muscles for muscle response time analysis musculus tibialis anterior, musculus peroneus longus, musculus triceps surae have been found.

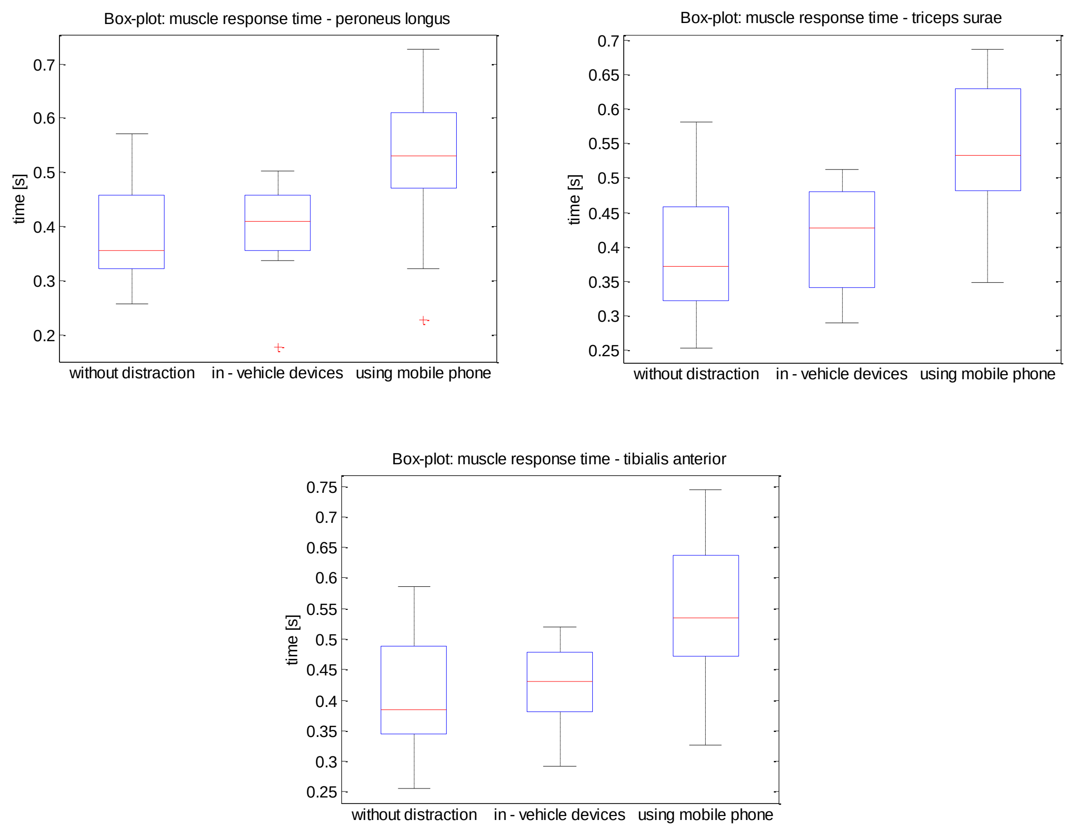

Figure 7 – Muscle response time of all three sensed muscles (red line: median, blue box: 1. a 3. quartile, black lines: 5 – 95%, red cross: outliners)
Source: authors

As found out in [11], these three muscles were activated gradually in the case of expected stimulus unlike in the case of unexpected stimulus these three muscles were activated almost simultaneously. In published studies (for example [18], [19], [20]), musculus tibialis anterior have been considered as the muscle that firstly reacts in emergency situation. Within the study the assumed timing of the muscle contraction with the sequence of the m. tibialis anterior – m. peroneus longus – m. triceps surae was confirmed only in roughly 50% of all reactions. Musculus tibialis anterior was the initial mover during the pedal changing in approximately 70% of reactions, therefore it has been found that m. tibialis anterior does not have to be the initial mover. About 75% cases the contraction of the m. peroneus longus preceded the contraction of the m. triceps surae, what means that in the time of brake pedal pressing the forefoot was in the full contact with the pedal and the transfer of the power was more effective. The relation between type of stimulus and the muscle response has not been found. Despite median values of MRT of all muscles during using mobile phone have been bigger then median values of MRT in situations without cognitive distraction, analysis of variance denoted no significantly differences in muscle response time with or without driver distraction ($p > .05$) at all three recorded muscle.

Using the combination of electromyography with data acquisition from vehicle unists has allowed more accurate analysis of motoric component of reaction time. Furthermore, the part of this study has been oriented on the determination of time needed for muscle activation (Figure 8), which have preceded the visible leg movement and have been commonly analysed as a part of cognitive time. ANOVA indicated that there are no significant differences between situation when driver attention has been affected and situation without cognitive distraction.

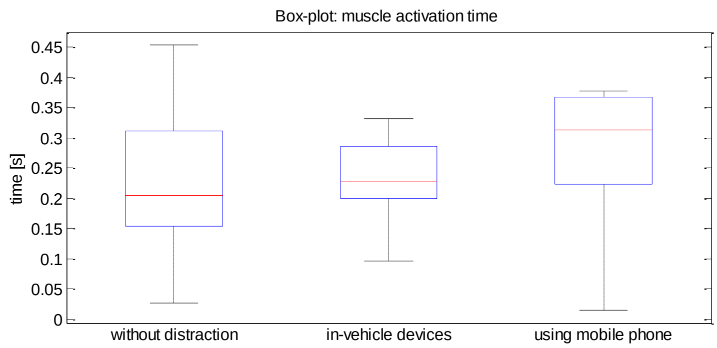

Figure 8 – Muscle activation time (red line: median, blue box: 1. a 3. quartile, black lines: 5 – 95%)
Source: authors

4. DISCUSSION

Total brake – response time has been most commonly subdivided into two main stages – cognitive and movement time. Effect of cognitive distraction on motoric component of reaction time has been analyzed in this study. There were no significantly differences in movement time through all three task conditions, which mean that cognitive distraction did not affect leg movement. Similar results have been published in [9], [20]. Compared with obtained results, the significant average decrease of leg movement during hands – free mobile phone conversation have been found in [10], but there have not been specified how exactly the onset of movement time were measured.

Using of EMG allowed an earlier approximation of the onset of leg movement as compared to accelerator pedal motion and it allowed determination of time needed for muscle activation, which have preceded the visible leg movement. For the purposes of this study the group of the three principal muscles of the right lower limb was established with the respect to kinematic rules of the ankle joint movements during the braking. As the most appropriate tracked muscles for these movements detection musculus tibialis anterior, musculus peroneus longus and musculus triceps surae have been found. In published studies ([18], [19], [20]), musculus tibialis anterior have been considered as the muscle that firstly reacts in emergency situation. In this study it has been found that m. tibialis anterior does not have to be the initial mover. Analysis of variance denoted no significantly difference in case of muscle response time and also in case of time needed for muscle activation during cognitive distraction tasks.

High values (especially outliners) of individual components of motoric reaction time during cognitive distraction have potentially suggested some compensatory behaviour. These values could be typically for the defensive drive and reflected situations when drivers did not react straight to the stimulus but try to anticipate the upcoming situation in real traffic.

5. CONCLUSION

The biosignals' acquisition can be viewed as a new approach how to analyze driver's behaviour. Using EMG allowed an earlier approximation of the onset of leg movement as compared to accelerator pedal motion. Obtained results have proved that cognitive distraction did not affect motoric part of reaction time. There were no significant differences in case of movement time and also in case of muscle response through all three task conditions. Efforts to reducing of distraction effect to movement time and muscle activation have not been relevant. For generalizability of these outcomes, future research should include a larger sample size, as well as consideration of more types of distractive stimuli. The main contribution of this study is the fact that unlike the majority of published studies using acquisition of biosignals, it was carried out under the conditions closed to real traffic.

Drivers were exposed to critical situations where they had to actually avoid the collision with a leading vehicle.

ACKNOWLEDGEMENT:

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DURABILITY OF WATERBORNE ROAD MARKING SYSTEMS WITH VARIOUS GLASS BEADS

ABSTRACT

Horizontal road markings belong to ubiquitous safety features on all roads. Based on scientific evidence, markings with higher retroreflectivity lead to a meaningful drop in the number of accidents. Hence, the recently proposed by the European Road Federation 150×150 formula to maintain lines 150 mm wide and with retroreflectivity at all times above 150 mcd/m²/lx (35 mcd/m²/lx under wet conditions) on every European highway ought to increase road safety. To propose the optimum waterborne road marking system for the 150×150 formula, durability of systems consisting of three types of paints reflectorised with three types of glass beads was assessed.

After ±1.4 million vehicle passes (the period included winter road maintenance), drop in retroreflectivity was measured in all systems. The drop was highest in case of a quick-dry paint and lowest with high-performance paint. In all of the cases, selection of glass beads also played critical role and markings reflectorised with high-performance glass beads showed highest retroreflectivity under dry and wet conditions both initially and after the test – such system should be the first choice to maintain the 150×150 formula. The systems where other glass beads types were utilised performed satisfactorily or very good. Since failures after one year were measured with only a few systems, the testing continues with hopes to furnish a two-year paint-based road marking system.

KEY WORDS

Road marking; glass beads; retroreflectivity; durability; waterborne paint; 150×150 formula

1. INTRODUCTION

Increasing road safety is an important aim of European Union countries. An ambitious programme started in 2010 with a goal to reduce the number of fatalities by 50% before the end of the decade. Statistical data demonstrate that the programme is so far on track, even though in 2014 on European Union roads occurred over 1 million vehicular accidents, resulting in about 1,4 million people injured and over 26 thousand dead [1].

One of the main causes of traffic accidents is failure to scan the road [2]. Since driving belongs to visual input-depending cognitive processes, clearly visible travel path should lead to lesser number of drivers' errors and thus improved safety. For that purpose, horizontal road markings, which guide the drivers and help them in maintaining their vehicles within a set travel path are commonly used feature.

Indeed, since the first line was marked in 1911 horizontal road markings became present on almost all roads. Analysis has shown that horizontal road markings are one of the most effective and inexpensive safety features that can bring up to 60:1 in benefit: cost ratio [3].

1.1 Horizontal road markings and safety

Almost half of the occurring vehicular accidents were reported to take place between dusk and dawn. After adjusting for the driven distances, the fatality rates are significantly higher at night as compared to daytime and their severity is higher [4]. Since line markings are poorly visible in darkness, their visibility is enhanced by incorporation of retroreflective elements, most frequently glass beads.

Research has shown that during night-time driving retroreflectivity (R_L) of road markings becomes a natural focus point for all drivers [5]. It is therefore obvious that high R_L of road markings is considered by road users as one of the factors increasing their safety and confidence [6]. Particularly, elderly drivers benefit from road markings with enhanced R_L, because they tend to fixate almost exclusively on the edge line while detecting the end of pavement markings [7]. Subjective perception of safety on clearly marked roads has only quite recently been statistically validated by finding a correlation between the number of single-vehicle night-time accidents and R_L: Based on a multi-year complex analysis of accidents that occurred in autumn (high R_L of freshly renewed markings) and in late spring (low R_L of markings after winter), it was found that the number of single-vehicle accidents at night could drop by up to 23% with R_L increase of 100 mcd/m²/lx [8]. Equally strong effect on decreasing the number of collisions had line width: Reports analysing accidents has shown that the use of 15 cm width of edge lines on two-lane rural roads could lead to reduction in total crashes by up to 30% and fatal or injury crashes by even 38%, as compared to roads marked with lines 10 cm wide [9].

Based in part on these findings, as a measure to improve road safety, the European Road Federation proposed a **150 × 150 formula**: minimum line width of 150 mm and at all times R_L>150 mcd/m²/lx and wet night visibility (RW) above 35 mcd/m²/lx. The current R_L standards vary between countries and in majority of cases a drop to 100 mcd/m²/lx is permitted, while RW applies in many cases only to the initial measurements (if it is demanded at all). Similarly, the current line widths can be as narrow as 100 mm in some countries.

The purpose of our evaluation was selection of the most suitable waterborne paint-based road marking system for the proposed 150×150 formula. Particular attention was given to a confirmation of the possibility of obtaining a two-year system by combining a high-end waterborne paint with appropriately selected high-end glass beads, which we recently measured and reported [10]. Such durable road marking systems would have the lowest environmental impact based on cradle-to-grave life cycle assessment, because analysis demonstrated that **system durability** is the main impactor [11].

1.2 Horizontal road markings materials

Horizontal road markings are **systems** that consist of the paint layer (paint, coldplastic, thermoplastic, plural component materials, or others) and reflective materials (most frequently glass beads). In a „symbiotic" relationship, the paint layer furnishes the desired colour, surface for retroreflection, and retains the glass beads, while appropriately embedded glass beads provide R_L and simultaneously protect the paint from abrasion caused by passing vehicles' tyres or snow ploughs. Various materials used for road markings were recently summarised [12].

Paints remain the most common, inexpensive, versatile, and easily applied road marking materials. In our previous experiments, solventborne paints were proved as materials of lower durability and lesser environmental friendliness, so we evaluated only waterborne paints [11][13][14]. Waterborne road marking paints of various qualities are widely available throughout the world from numerous manufacturers. Thick-layer systems were beyond the scope of this experiment, because they require more complex application techniques not readily available to us at the time.

1.3 Glass beads

Glass beads are inalienable components of almost every road marking systems. Their appropriate selection, quality, size, coating, and embedment in the paint play profound role in R_L and RW — and thus affect durability of the system. Standard glass beads have diameter between 100 and 850 µm; they are prepared from finely ground recycled float glass by flame attenuation at temperature approximately 1200 °C. Production of larger glass beads, with diameters reaching even up to 2000 µm, requires melting of virgin glass and its atomising. Such larger glass beads are used for Type II markings, designed to furnish retroreflectivity under rainy condition. Processing conditions during production of glass beads play a meaningful role in their quality and later the performance on the road.

Standard glass beads have refractive index 1.5 and can provide R_L of about 400 mcd/m²/lx in the field. Much higher R_L can be readily obtained with glass beads of higher refractive index, but such beads tend to be prone to scratching and, due to production process and required raw materials, are prohibitively expensive [10]. A proprietary SOLIDPLUS technology developed at SWARCO (Wattens, Austria) permits for increasing R_L to even 1000 mcd/m²/lx with the refractive index of just 1.6. These high-performance glass beads have improved resistance to scratching and furnish exceptional surface quality as compared to the standard products. SOLIDPLUS glass beads can be intermixed with standard beads to improve the properties for warranty-based performance contracts. Glass beads are available from numerous manufacturers; alternatives to SOLIDPLUS do exist on the market as well.

2. METHODOLOGY

Testing of road marking systems is quite difficult because of a plethora of variables that include not only different number of dissimilar vehicle passes at different speeds, but also weather conditions during application and usage, road surface type and quality, agricultural and construction activities in the neighbourhood, solar insolation, presence of trees or buildings, and other factors – not mentioning the differences in application. Therefore, the ultimate test shall always remain the durability on the road under normal usage conditions.

2.1 Testing: Materials and application

For our purposes, we applied lines perpendicularly to the traffic flow to assure that the number of vehicle passing on them would be known. The selected two-lane road near Zagreb, Croatia carry annually averaged daily traffic (AADT) of 7346 vehicles (including about 8% articulated lorries). The asphalt quality can be described as good, but we observed signs of ruts starting to form. Markings were applied in a 50 km/h speed limit zone where passing was not permitted.

The selected waterborne paints were commercially available materials: a quick-dry paint LIMBOROUTE® AQUA W13, a high-performance paint LIMBOROUTE® AQUA W15, and an improved-quality paint LIMBOROUTE® AQUA W16 (Swarco Limburger Lackfabrik GmbH; Diez, Germany). These paints were reflectorised with drop-on glass beads: standard SWARCOFLEX and high-performance SOLIDPLUS (M. Swarovski GmbH; Amstetten, Austria) and with MEGALUX-BEADS® (Swarco Reflex LLC; Mexia, Texas, the United States). All of the applied glass beads were coated appropriately and were sieved to 200-800 µm. For the purpose of this test, no anti-skid materials were incorporated.

Application was done by handheld spraying by a very experienced professional crew (Chemosignal d.o.o.; Zagreb, Croatia) in early Autumn of 2015, using application machine LineLazer IV 250SPS (Graco Inc.; Minneapolis, Minnesota, the United States). Glass beads were injected under pressure, also by a handheld nozzle. The applied material quantities were 550-650 g/m² of paint and 350-450 g/m² glass beads. Such spreads in the applied masses are typical and it is assumed herein that they did not play meaningful role in the overall performance. The applied lines were renewal markings, in all cases 15 cm wide. The application procedure and the arrangement of the lines is shown in Figure 1.

Weather conditions during application were rather poor for waterborne systems, with receding fog, air and road surface temperature 18-19 °C, relative humidity 70-80%, and no wind. In all cases, the road was opened to vehicular traffic within 1,5 h after application. Even with the high humidity, all of the applied paints were dry and paints achieved washout within less than 30 minutes [12].

Figure 1 – Application of paint and glass beads by handheld spraying.
Source: Authors.

2.3 Measurements

We have done the measurements using handheld retroreflectometer ZRM-6013 (Zehntner GmbH; Sissach, Switzerland). Thirteen data points per line were collected and the measured R_L and RW were averaged. Testing of RW was done according to ISO1436 norm. For our purposes, failures are considered as drop of R_L below 150 mcd/m²/lx and drop of RW below 35 mcd/m²/lx, according to the proposed 150×150 formula. In several cases, two lines per system were applied; since statistical analyses were not our goal for this paper, results from the repeats were simply averaged to maintain the clarity of message.

The number of passing vehicles was assumed to be constant every day and equal to the reported AADT, even though differences were quite likely; traffic load in both directions was assumed to be equal. Measurements were done after: ±0.1 million vehicle passes (initial measurements), ±0.8 million vehicle passes (after winter exposure – sadly, the number of snow plough passes is not known), and ±1.4 million vehicle passes (after about one-year exposure). Where needed, the numbers of vehicle passes to failure were estimated using second-degree polynomial line fit, which was found most suitable here (furnished lowest R^2). For lines that did not fail, the road exposure continues for another winter period. One ought to note here that the actual number of tyre passes (as is reported in German laboratory roundtable test) is more than double of the number of vehicle passes.

3. RESULTS

3.1 Retroreflectivity under dry conditions (R_L)

R_L measurements results are provided in Table 1; standard deviations are given in parentheses. Initial results are consistent with the expectations, demonstrating very high R_L (±1000 mcd/m²/lx) obtained with SOLIDPLUS glass beads. Improved quality MEGALUX-BEADS® furnished R_L (±430-540 mcd/m²/lx), which was mildly higher than we measured for the standard SWARCOFLEX beads (R_L ±300-400 mcd/m²/lx). The differences between the paints were most likely caused by variations in beads embedment, paint type, and the aforementioned plethora of factors that affect the performance.

After the winter exposure (±0.8 million vehicle passes), R_L expectedly dropped in all cases. Equally expectedly, standard deviations increased due to difference of tyres action in more and less used areas of each line. Only system based on quick-dry paint W13 with the standard glass beads failed; extrapolation indicated that the failure occurred at approximately 0.6 million vehicle passes. W13 reflectorised with MEGALUX-BEADS® was at the border of failure. It is somewhat lesser durability than we expected based on previous experiences with this paint and the reasons for the inconsistency are at present unknown [10][11]. W13 reflectorised with SOLIDPLUS glass beads was passing, as were all of the other tested systems.

Summer exposure, for a total of ±1.4 million vehicle passes, lead to further deterioration of R_L. Paint W13 with SOLIDPLUS beads was still passing (the obtained R_L of 316 mcd/m²/lx was higher than initial R_L measured with the standard beads), but R_L retention was quite low at only 32%. Paint W16 reflectorised with the standard glass beads was reaching its usable life for the 150×150 formula. All other systems were passing, with retention of 39% to 66% of the initial R_L. Especially high R_L was measured in systems based on high-performance paint W15.

Standard deviations were highest in case of SOLIDPLUS glass beads, which was attributed to their loss under vehicles tyres. Analysis under magnifying glass revealed that this was the case, indeed. Close-up pictures of least and most used areas of a line marked with paint W15 and SOLIDPLUS glass beads after ±0.8 million vehicle passes are provided in Figure 2: While the most used area is practically devoid of glass beads, the least used area remained rather intact. After ±1.4 million vehicle passes, the number of beads remaining in the most used area dropped to almost nil. Despite large standard deviations, superior results obtained with SOLIDPLUS glass beads are statistically valid.

Table 1 – Retroreflectivity (R_L) with various road marking systems.

Paint	Glass beads	R_L (Initial) [mcd/m²/lx]	R_L (±0.8 million vehicle passes) [mcd/m²/lx]	R_L (±1.4 million vehicle passes) [mcd/m²/lx]	Retained R_L
W13 (Quick-dry)	SWARCOFLEX	306 (48)	120 (59)	93 (30)	30%
	MEGALUX	430 (40)	151 (88)	110 (84)	26%
	SOLIDPLUS	1003(60)	393 (129)	316 (132)	32%
W16 (Improved quality)	SWARCOFLEX	393 (34)	231 (72)	155 (76)	39%
	MEGALUX	539 (116)	372 (115)	356 (113)	66%
	SOLIDPLUS	990 (48)	780 (135)	465 (206)	47%
W15 (High-performance)	SWARCOFLEX	436(31)	260 (64)	202 (76)	46%
	MEGALUX	539 (19)	269 (111)	213 (155)	39%
	SOLIDPLUS	1062 (51)	575 (281)	509 (338)	48%

Source: Authors.

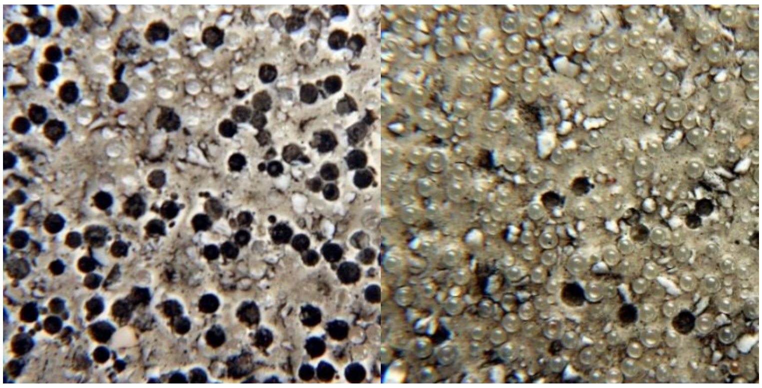

Figure 2 – Close-up images of line marked with paint W15 and SOLIDPLUS beads after ±0.8 million vehicle passes. Most used area (left) and least used area (right).
Source: Authors.

3.1 Retroreflectivity under wet conditions (RW)

Obtaining high RW is quite difficult with the standard road marking systems. In the areas where it is required (Type II road markings), thick-layer structured markings are applied. Such materials, most frequently coldplastics, are providing rough surface facilitating water drainage. In addition, glass beads in diameters typically reaching 1400 µm are being used. In our experiments, such systems were not tested and the results provided below are for standard lines and glass beads 200-800 µm, i.e. Type I markings.

The results from measurements of RW are provided in Table 2; standard deviations are given in parentheses. According to the expectations, SOLIDPLUS glass beads furnished exceptional initial RW, while SWARCOFLEX and MEGALUX-BEADS® provided very good results. The results obtained after the winter exposure (±0.8 million vehicle passes) were poor, with only three tested systems passing: W16 with MEGALUX-BEADS®, W16 with SOLIDPLUS, and W15 with SOLIDPLUS. Further exposure caused failure of all of the tested systems, which was expected.

The best overall performance was measured with SOLIDPLUS glass beads, which furnished not only the highest initial RW, but also provided the most durable systems. While systems reflectorised with the standard glass beads failed (RW dropped below 35 mcd/m²/lx) within ±0.1-0.6 million vehicle passes and those with MEGALUX-BEADS® lasted for about 0.3-0.9 million passes, SOLIDPLUS provided satisfactory wet night visibility until they were exposed to the impact of approximately 0.8-1.1 million vehicles. Relatively large standard deviations and minor inconsistencies in case of RW measurements were caused not only by the loss of glass beads, but also by uneven road; in a few cases, water did not appear to be draining properly, which skewed the results. Nevertheless, the overall values appropriately indicate the trends.

Table 2 – Wet night retroreflectivity (RW) with various road marking systems.

Paint	Glass beads	RW (Initial) [mcd/m²/lx]	RW (±0.8 million vehicle passes) [mcd/m²/lx]	RW (±1.4 million vehicle passes) [mcd/m²/lx]	Failure estimate [million vehicle passes]
W13 (Quick-dry)	SWARCOFLEX	36 (20)	9 (7)	9 (6)	0.1
	MEGALUX	74 (42)	9 (10)	20 (16)	0.3
	SOLIDPLUS	247 (46)	30 (25)	13 (9)	0.8
W16 (Improved quality)	SWARCOFLEX	93 (24)	11 (8)	6 (2)	0.5
	MEGALUX	178 (42)	56 (44)	27 (13)	0.9
	SOLIDPLUS	245 (77)	85 (43)	21 (17)	1.1
W15 (High-performance)	SWARCOFLEX	130 (23)	13 (12)	26 (36)	0.6
	MEGALUX	177 (35)	21 (13)	22 (19)	0.7
	SOLIDPLUS	275 (118)	62 (42)	23 (15)	1.0

Source: Authors.

4. DISCUSSION

Results from this road trial unequivocally demonstrate that utilisation of high-performance paint reflectorised with matching high-performance glass beads gives the most durable system for waterborne paint-based horizontal road marking. The primary role played the paint selection and the secondary – glass beads, which is consistent with our previous experiences [10][11]. Achieving a two-year paint-based system may be feasible and our research is in progress.

In terms of paints selection, high-performance W15 was almost matched by improved-properties W16 whereas quick-dry paint W13 was the least durable. This difference we believe to be caused by somewhat different chemistry of the acrylic binders. However, it has to be noted that the binder selection translates to the speed of drying and achieving washout resistance, which are critical parameters for the applicators: Paint W13 dries quickest amongst the tested materials. Unfortunately, the binder that is required for the high performance paint W15 is generally more expensive than used for other tested paints, which may hamper its widespread usage despite good properties.

In terms of glass beads selection, SOLIDPLUS technology furnished exceptional R_L (initial ±1000 mcd/m²/lx and very high ±300-500 mcd/m²/lx after one year) and RW (initial ±250 mcd/m²/lx and still passing after half a year). Improved quality MEGALUX-BEADS® were also very good (initial R_L 430-540 mcd/m²/lx), but only slightly outperforming the standard glass beads, which provided the expected standard performance (initial R_L 300-430 mcd/m²/lx).

From a purely academic point of view, system consisting of paint W15 and SOLIDPLUS glass beads should be recommended for the 150×150 formula in areas where using structured markings is not desired. However, we must acknowledge that due other chosen properties (like very quick drying, occasional need for lesser performance, or financial considerations) it may not always be the optimum choice. Road administrators and/or applicators must decide what durability and retroreflectivity is required for particular area and application. From the environmental perspective, the match of high-performance paint with high-performance glass beads appears to be the best choice as well, because environmental impact of road marking systems depends on the system's durability [11]. Such highly durable system can be of particular value for performance contracts.

The superior retroreflectivity provided by SOLIDPLUS glass beads should lead to increasing road safety and also may improve the quality of life for elderly road users by helping to increase their mobility. Such effect is very important for the contemporary society which comprises constantly increasing number of community-living senior citizens. Similarly, road marking could be used by autonomously driven vehicles and its quality was reported to be very important [15].

The advantage for contractors could be the possibility of intermixing SOLIDPLUS glass beads with standard beads to meet the minimum requirements and to avoid warranty claims. Care must be taken to select glass beads with appropriate coating to assure their compatibility with the paint and thus longevity of the applied system. Unfortunately, due to dissimilar chemical nature of waterborne road marking paints, their mixing is not possible.

Maintenance of wet night retroreflectivity at levels above 35 mcd/m²/lx for longer periods could not be achieved with any of the tested systems based on small glass beads. Even with the best system tested herein, RW failed quickly after approximately 1.0 million vehicle passes. Structured markings or road marking tapes seem at the present state of the art the best choice. In addition, large glass beads would be required and we intend to perform appropriate evaluation.

While literature reports confirm that increasing R_L leads to lesser number of collisions, the analysis of very high R_L possible with SOLIDPLUS technology has not been done [8]. Such analysis could be very valuable, but it requires quite a large data pool, currently unavailable.

In this effort, we did not measure daytime luminance, Qd. Visual assessment indicated that it would meet the requirements, because in our other unpublished results with similar systems we measured no failures. Recently, a weak correlation between R_L and Qd was found and by application of the methodology and equation, we could expect passing Qd values [16].

5. CONCLUSIONS

In this experiment done under field exposure conditions we have demonstrated the advantage of using **high performance road marking systems** in terms of **durability and retroreflectivity**. Overall, waterborne paint LIMBOROUTE® AQUA W15 reflectorised with SOLIDPLUS glass beads provided the best results. The rate of retroreflectivity loss – and thus durability of the systems – depended much more on the selected paint than the glass beads.

Notwithstanding the results reported herein obtained with waterborne road marking paints, it must be noted that glass beads based on SOLIDPLUS technology are fully suitable and manufacturer-recommended for other road marking systems, particularly for structured markings and pedestrian crossings.

This effort was undertaken to provide a selection tool for road administrators who seek the optimum solution to maintain roads at high retroreflectivity and minimise the expenses associated with renewal of markings. The results not only furnish the indication, but also show chance of obtaining a two-year paint-based road marking system. The testing continues.

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MULTIMODAL TRANSPORT IN DEVELOPING WESTERN BALKANS ECONOMIES

ABSTRACT

By 2020, the European intermodal transport system, featuring also Multimodal and Combined Transport, is envisaged as accounting for 40% of the movement of goods, as the transport of freight, even bulk, will become increasingly unitized. However, in the SEE Region, the development of the intermodality is still at the very early stage. Transportation infrastructure is poor, underinvested, fragmented, and varies in terms of quality. From year 2004 till now the dominant investment orientation was represented mostly in road infrastructure projects (around 75% of total investments). Lack of modern intermodal and logistics infrastructure and legal background harmonized with EU standards directly affects the development of trade and international transport (import, export and transit) in the region. In order to attract inter-regional and international transport flows, it is of utmost importance to promote regional cooperation in removing existing barriers and bottlenecks in intermodal logistics chains, and thus improving regional connectivity. In order to ensure sustainability of transport in the region, the focus should be redirected to environmentally friendly modes of transport, railways and inland waterways. The proposed paper addresses *GAP assessment analysis of the main logistics corridors in Western Balkans countries, promoting multimodal capabilities within the region.*

KEY WORDS

intermodality; GAP assessment; corridors; network;

1. INTRODUCTION

Intermodal transport will be an industry with its own identity, its own strategy, and its own voice [1]. The need to enhance intermodal operations in the South East Europe (SEE) is widely recognized to be essential to encourage economic development and job creation. The favourable transit position of the region offers great potential for the development of intermodal transport, both internally among the countries and internationally. The main problems that the development of the intermodal transport in SEE region is facing refer to the following issues:

- Institutional issues such as weak institutions, inadequate organization, non-existence of relevant associations, limited strategic foresight;
- Planning process - insufficient support to the comprehensive and wide-ranging planning process in the logistics transport chains;
- Operational issues, which comprises weak coordination and cooperation among stakeholders in the transport chain, as well as a lack of policy initiatives by governments for intermodal transport organization;

- Lack of infrastructure facilities – inadequate and weakly developed suitable infrastructure or superstructure, old mechanization and equipment;
- Economic constrains – lack of the concentration of considerable transport volumes at a reduced number of terminals to enhance intermodality in the region;
- Tariff policy issues, which do not stimulate the use of intermodal transport;
- Awareness issues – underdeveloped awareness of the benefits which an intermodal transport system provides and inadequate marketing of the benefits;
- Policy questionnaires and check-lists - to enable better track the progress of the national transport reforms, to ensure greater visibility in front of EC and international stakeholders and to assess the capacities and needs for future assistance in the field of intermodal transport.

Local public or private companies do not recognize the advantages of intermodal and container transport due to the failure of regional state policies. Intermodal stimulation measures are well known in many EU countries - such stimulation measures provide subsidy to operators, stimulating fiscal and economy policies, tariff policy, simplifying border procedures (time, technicalities and costs), open access to the terminals, etc.

2. LEGAL AND INSTITUTIONAL FRAMEWORK FOR INTERMODALITY IN WESTERN BALKANS

The requirements for the operation of more efficient and more environmentally friendly transport systems - which would be able to link modal infrastructure and related services on one side, and the nodes of the national and European economy on the other – should be strengthened. In such a context, intermodal freight transport has been identified as a priority for support by the European Commission. Regarding to legal and institutional framework to intermodal transport it could be highlighting that:

- National/regional and European regulation is focused on protecting competition in the common market rather than facilitating the intermodal transport development;
- The existing regulation in transport sector is formulated and applied separately for air, maritime, rail and inland waterways rather than intermodal (particularly within the antitrust regulation);
- Intermodal arrangements must have separate approvals from each of the affected regulators which is perceived as a constraint by carriers, shippers and providers.

The White Paper on EU Transport Policy for 2010, which proposes specific measures to be taken at Community level under transport policy, recognizes a growing imbalance between modes of transport in the European Union. This persisting situation is leading to an uneven distribution of traffic, generating increasing congestion, particularly on the main trans-European corridors and in towns and cities. To solve this problem, two priority objectives need to be attained: regulated competition between modes and a link-up of modes for successful intermodality.

EU emphasizes that a strategically important place should be reserved for the development of integral transport as a more efficient way of delivering goods to the biggest EU centres. The REBIS study [3] recommends creating the initial conditions for an efficient development of combined transport in the Western Balkans, which include, in the short term, improving the knowledge of the market and the creation of a new, adequate and a more efficient regulatory, organizational and institutional framework.

In the mid- and long-term, the strategy for the Western Balkans transport system should enable the realisation of at least three strategic goals:

- Faster development and rising to a higher technical, technological and organisational level of the whole transport system, which creates preconditions for more efficient and rational meeting of transport needs as well as reaching European standards;

- Establishment of such a structure of transport system and a transport services market that correspond to the valorisation of competitive advantages of all transport modes on certain routes;
- Further integration of domestic into international transport tendencies, according to the existing harmonised corridors at the EU level. Therefore, development of intermodal transport terminals is a precondition for the development of modern transport and distribution technologies within the SEE region.

In Western Balkans countries there are no specific regulations refer to intermodal transport which addresses development of terminals and services. Moreover intermodal transport is a consequence from the needs regarding market demand, fastening traffic flows and goods manipulating process, etc. This produced variety of standards (for pallets, containers, etc.) rather than regulations which are dedicated by the requirements and specificities of certain transport mode aiming to adjustment to existing and projected trade flows. Western Balkans economies record insufficient trade flows able to generate intermodal transport thus this type of services are cost efficient with high freight flows and goods manipulating processes. Moreover, it is typical type of transport services for countries with higher standard, export import, GDP and similar economical parameters.

In most countries intermodal transport is considered a local issue, which implies that local authorities are responsible for the majority of the regulations in this area. To minimize the negative impacts of freight transport, local authorities try to control goods transport operations by using different regulations adjusted by different transport mode rather than uniform regulations for intermodal transport. Even more, many local authorities do not have an extensive freight transport policy which is also the case in Western Balkans countries.

In Europe, intermodal transport has an important role in the transport system, because Europe has realized long time ago the fact that the marine, rail, road and inland waterway transport should act as a unique system on the market, and not to be a competition to each other.

Sea ports are the main generators of cargo flows and intermodal transport, and as the most developed it could be mentioned the Netherlands, Germany, Belgium, France, Spain and Italy. The great advantage of northern European ports is a good rail connection with the hinterland and developed traffic on inland waterways. In this way, large amounts of cargo can be transported to the end user, with low transportation costs, while there is no congestion on the roads.

Therefore, Intermodal transport is promoted through policies that are addressed at all political levels. It directly or indirectly depends on several general factors, such as:

- The political stability of the region: Political stability is a prerequisite for prosperity, economic growth and the growth of trade and therefore has a huge influence on the development of intermodal transport in the participants of the WB;
- EU accession date of WB countries: Accession had a strong and positive impact on macroeconomic development and political stability of post-communist countries. Similar effects are likely to happen in WB countries;
- Macroeconomic development and stability in the Western Balkans and their neighbouring countries. Also a great impact on macroeconomic stability have other countries in the near neighbourhood of Western Balkans and the major western European trading partners (Austria, Germany, Italy, Hungary, Romania, Bulgaria, Greece etc.).

The policy maker's role in intermodal transport policies is to assure an environment for a smooth functioning market, maintain a complete and interoperable multimodal transport network and promote its optimized use to minimize environmental externalities. Intermodal transport policy in Europe is based on a co-modal approach, the efficient use of different modes on their own and in combination to achieve a high level of both mobility and of environmental protection. Various transport policies aim to initiate a modal shift of freight from unimodal road transport to modes that are environmentally more efficient. In 2007, the European Commission (EC) announced a European freight transport action plan. One of the concepts introduced is that of “green transport corridors”. Green transport corridors include shortsea shipping, rail, inland waterways and road transport combinations to enable environmentally friendly transport solutions for the European industry.

3. IDENTIFICATION OF INTERMODAL INDUSTRY STANDARDS

To utilise containerisation potential, Western Balkans countries are needed to increase the market share of intermodal transport. Such challenges require development of efficient network of intermodal terminals and easy access to intermodal services. Therefore, reliability and efficiency of intermodal systems and corresponding planning processes are getting in importance.

The following physical factors as the primary influences on the performance of intermodal terminals are defined by [4]:

- Geographical position of the terminal within the transport network (connectivity to rail, road and inland waterways);
- Size and length of the rail handling tracks; and
- Number and capabilities of the handling equipment (cranes and stackers).

In addition, successful implementation of intermodality concepts needs definition of clear standards intended to help actors in intermodal transport chains to measure the performance and quality of its systems, to understand their strengths and weaknesses and to contribute to the cost reduction in the chains. In other words, they should enable management of the most critical success factors of an intermodal operator. However, different authors claim that such standards or factors or indicators have not generally been agreed on European level [5].

Development of an intermodal terminal network should take into account existing standards or indicators for performance measurement and mutual comparison of terminals. Western Balkans countries belong to the group of developing countries, making them particularly suitable for application of these methodologies. However, such comparisons should not be the aim by itself. They are intended to indicate why the terminal is performing the way it is. Terminal decision makers should define the targets, the terminal is aiming to achieve, based on such own evaluations. It will provide comprehensive insights into the factors of primary importance for the achieved performance levels; the aspects of performance which should be improved further and identify future development trends of the terminal.

The performance measurements are aimed to indicate how certain terminal operations affect the results. Therefore, these measurements should be performed in a standardized and widely accepted way. The flowing benefits coming from the application of harmonized and standardized measurements in intermodal transport defined by [4] are:

- Comparability of performance between all transport modes;
- Standardized method for data collection and editing;
- Common basis of comparable data on performance;
- More transparency in reporting on performance;
- Increased quality and attractiveness of intermodal transport;
- Timely feedback for users that ensures action on time.

The same authors [4] have identified the potential areas for performance measures in intermodal transport research. These areas are assigned to one or more of the main components of the intermodal transport system. The main components include road transport, rail transport, inland navigation and intermodal terminals. Our particular focus is on terminal performance measures and we can see from (*Figure 1*), corresponding 14 different categories.

In addition, [6] argues that any reliable performance measurement study should incorporate factors controllability issues. Therefore, there is a need to differentiate between controllable and uncontrollable factors at the intermodal terminals (*Table 1*) i.e. improvement of efficiency and effectiveness may be or is not within the control of the terminal operator. The authors claim that only controllable factors should be included in the benchmarking analysis, while the extent to which uncontrollable factors influence port efficiency should also be considered.

It is well-known from the literature that it is not possible to identify one single holistic benchmark which would be applicable for the whole intermodal terminal or for any port. Analysis of the terminal's performance can only be made after handling, processing and elaborating all values assigned to any of the terminal performance factors. It will enable identification of the terminal's strengths and weaknesses. These weaknesses can be tackled and improved by analysis how and what the other terminals, with higher benchmark scores, are doing in a different way. So, this process is very helpful in identifying how utilization of existing equipment may be improved before making and realizing a decision to invest in new equipment and infrastructure at the terminal.

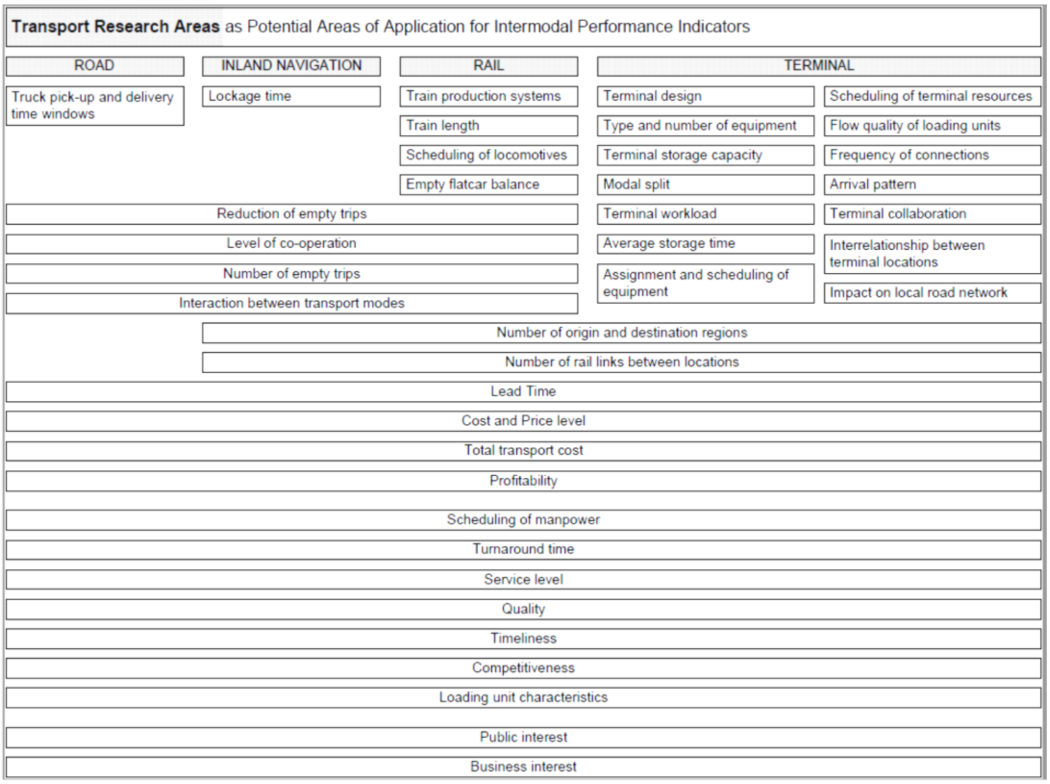

Figure 1 – Potential Areas for Performance Measures in Intermodal Transport Research

Table 1 – Controllable and Uncontrollable Factors at the Intermodal Terminals

Controllable factors	**Uncontrollable factors**
Service and waiting time	Tidal and weather restrictions
Dedicated/priority berthing arrangements	Other physical and technical constraints
Capacity development and expansion	Trade pattern, traffic type and mix
Terminal layout and configuration	Container status, type, and dimensions
Terminal procedures	Vessel size and type
Working hours, shift/labour arrangements	Pattern/frequency of shipping service
Terminal and handling charges	Arrival pattern of ships, trucks and trains
Type, size and maintenance of equipment	Stowage and by-plan
Routing and stacking of containers	Landside and intermodal connections
Equipment allocation and deployment	Customs and trade related procedures
Berth and yard management systems	Healthy and safety requirements
ICT and TOS modules	Other regulatory requirements
Reliability and level of customer service	

Benchmarks for the intermodal terminals in the Western Balkans countries should be set against a range of terminals in the nearby as well as competing regions and countries. Higher level benchmarks would encompass wider geographical areas and more developed intermodal terminals. Thus set benchmarks would also constitute objectives the terminals should aspire to in their development phases. However, in any stage, local conditions and characteristics of the terminals, such as size, connections with main corridors, available equipment, should always be taken into account. The paper [7] clearly presents differentiates between vessel[1], yard[2], gate[3] and equipment[4] measurement for the intermodal terminal productivity benchmarks. Among them, there are four types of more commonly used benchmarks:

- Workforce productivity (TEU/employee/year) – may indicate a need for implementation of better training, review of working practices and optimisation of staff utilisation;
- Crane productivity (TEU/crane/hour) – indicates the efficiency of systems operating around the crane rather than the crane itself;
- Berth productivity (TEU/m of berth length);
- Yard productivity (TEU/hectare of yard) – may be used for assessment of competitor terminal yard productivity levels as well as needs for improvements of yard operations or investments in expensive additional land for stacking areas.

In addition, less commonly used benchmarks may include [7]:

- Yard Equipment Productivity (TEU/Unit/hour);
- Vessel Turnaround (hours) – may indicate needs for simultaneous bunkering or re-provisioning and unloading activities;
- Berth Occupancy (% age) – important for avoiding vessel waiting time delays;
- Dwell time in Yard (days) – point out the efficiency of clearance procedures, needs for different policies on daily storage charges as well as needs for capital expenditure for additional equipment, area increase, improvement to pavements, etc;
- Vehicle turnaround time within the terminal (minutes) – measure of the efficiency of the gatehouse and the yard procedures;
- Loss or damage (per 1000TEU) – indicate whether or not the container handling is complying with International Standards and/or whether insufficient resources are being applied to the security of containers within the terminal and those being released from the terminal.

All these industry standards usually do not exist as data for relevant intermodal terminals may not be available. It particularly relates to the terminals in developing regions like Western Balkans countries with lot of space for further improvements of intermodal services. However, lack of availability of all required data should be not prevent researchers to try to conduct the benchmarking exercise by using information that can be found from the terminals and other sources.

Determination of this data is intended to enable comparison with accepted industry norms and existing best practice in other intermodal terminals of similar size or even slightly larger. Any identified underperformance at the terminal needs to be linked with definition of what measures have been implemented at the “best practice” terminals [7]. Application of these measures at the elaborated terminal should be considered and analysed. It will clearly indicate the growth potential of certain

[1] *Vessel measurements*: number of lifts per crane operating hour; average delay per vessel departure; number of lifts per vessel hour; number of lifts per quay labourer hour;

[2] *Yard measurements*: average truck cycle time; no. lifts per “yard crane” operating hour; net container lifts per gross container lifts; TEUs stored per hectare of terminal; mean storage dwell time; mean stack height; number of lifts per yard labourer hour;

[3] *Gate measurements*: entry gate delay per arriving truck; exit gate delay per departing truck; trucks per gate per operating hour; trucks per gate labourer hour;

[4] *Equipment measurements*: equipment availability – available/required; mean time between failures; mean time to repair per failure.

systems within the terminal. Obviously, all these analysis may efficiently be used in the planning processes at intermodal terminals both in case of expansion or development of intermodal terminal.

4. GAP ASSESSMENT ANALYSIS OF THE MAIN LOGISTICS CORRIDORS IN WESTERN BALKANS ECONOMIES

Western Balkans countries are characterized with different levels of transport infrastructure development. The state of intermodal facilities varies among the participants as well. Intermodal transport corridors in the Western Balkans region may use maritime, inland waterway, rail and road modes for freight transportation. Process of selecting and evaluating intermodal transport corridors in the Western Balkans countries should be based on the identified most important players in the intermodal transport services in the region, infrastructure and operational possibilities and existing networks. By following this approach, several potential intermodal transport corridors (ITC) have been identified, i.e.:

- IWW (Novi Sad – Belgrade – Šamac) – rail (Šamac – Sarajevo – Ploče) – maritime (Ploče – overseas destinations);
- IWW (Novi Sad – Belgrade – Brčko) – rail (Brčko – Tuzla);
- Rail/IWW/Road (Hungarian border – Novi Sad – Belgrade) – Road/Rail (Belgrade – Niš – Skopje – Greece border);
- Rail/IWW/Road (Hungarian border – Novi Sad – Belgrade) – (1° Road/Rail (Belgrade – Podgorica – Bar) – maritime (Bar – overseas destinations); – 2° Road/Rail (Belgrade – Podgorica – Durres) – maritime (Durres – overseas destinations));
- Rail/IWW/Road (Hungarian border – Novi Sad – Belgrade) – Road (Belgrade – Niš – Pristine – Durres) – maritime (Durres – overseas destinations);
- Rail/Road (Durres – Tirana – Skopje – Bulgarian border);
- (1° Road/Rail (Bar – Podgorica) – road (Podgorica – Pristine – Niš); 2° road (Durres – Pristine – Niš)) – road/rail (Niš – Bulgarian border).

Identified transport corridors are intermodal and include railways, roads, inland waterways, maritime transport, ports, intermodal transfer points and border crossing facilities. They link key points in the Western Balkans countries and are intended to increase the level of intermodal connectivity and speed up the cargo and passenger flows in this region. The corridors are expected to play very important role in the transport systems of all countries.

This chapter assesses selected intermodal transport corridors in the Western Balkans countries from the infrastructural and operational perspectives. Particular attention is paid to the impact of existing freight flows, transportation costs, transport times, environmental impacts, use of information and communication technologies (ICT), managing and monitoring of transport activities on potentials for development of intermodal transport. The overall goal of this chapter is to identify gaps and needs for development of those intermodal transport corridors in the region. The applied approach enables comparison of these corridors, identification of development barriers and problems and suggestion of appropriate policy measures.

All identified corridors in the Western Balkans countries can be classified as international and transit corridors. They involve at least one border crossing but also give the resource to speeding up the transport of goods and passengers across borders and to facilitation of trade flows in-between and outside the region. The corridors are defined so as to provide for consolidation of cargo flows into larger units and therefore to achieve more efficient utilisation of available transportation resources. Directing existing and future transport flows on these corridors will for sure have effect of advancement of cargo transfer processes among barges, railcars and trucks, reducing transport time and operating costs.

Existing freight flows in the Western Balkans countries are often considered as one of the major barriers for the extensive development of intermodal transport. As an example of the required annual freight flow, we analysed the corridors involving inland waterway transportation. We decided to present this analysis as container-on-barge activities are currently almost non-existing, so it clearly indicates the efforts that should be invested in promoting and developing intermodal transportation in the region. Therefore, development of selected intermodal logistics centres and defined network of intermodal corridors may contribute to the consolidation of freight flows for both internal and international markets in quantities sufficient to trigger further growth of intermodal activities within the region.

4.1 Required annual transport volume in intermodal transport corridors incorporating inland waterway transportation

Identified corridors ITC 1 and ITC 2 runs through the Sava River in both Serbia and Bosnia and Herzegovina. The total amount of freight carried on the Sava River in 1990 amounted to 5.2 million tons of primarily bulk freight. However, in recent years, the Sava River has been neglected and annual traffic volumes have been modest, amounting to less than 400,000 tons on the entire waterway.

According to the CEMT and UNECE classification of waterways, sections of the Sava River belong to either class III or class IV. Classification is based on the existing state of Sava River and takes into account its economical importance for international inland waterway transport. From the Sava River mouth (rkm 0.0) up to Šamac port, there are three river sections, with total length of 29.8 km, belonging to the CEMT class III. Other sections are classified as CEMT IV class. However, rehabilitation and improvement of the Sava river waterway (recognized as one of the SEETO priority projects) will upgrade it to a minimum navigability class IV and class Vb. Therefore, for the purpose of this study, class IV of all sections up to Šamac port will be included now on.

Class IV waterways are considered as European inland waterways of international importance. Minimum required draught is 2.5 m, and allows navigation of vessels with carrying capacity between 1250 and 1450 t. In addition, minimal technical characteristics for the CEMT class IV waterway require passage of a vessel 80 to 85 m long and 9.50 m wide. Furthermore, [8] gives an overview of the container capacity of vessels for different waterway classes (*Table 2*).

Table 2 – Relation Between Waterway Class and Container Capacity of Vessels

Waterway class - type of vessel	Container capacity (in TEU) length x width x height
II/III	6 x 2 x 2 = 24
IV	10 x 3 x 3 = 90
V	13 x 4 x 4 = 208
VI	17 x 5 x 4 = 340

Source: [8]

Inland shipping companies estimate the break-even loading degree to be 75%. Such estimation takes into account current practice of barge operations, characterized with rather long vessel turn-around times. If these times are improved the break-even loading degree will decrease [8]. The same author also explains the relation between vessel sizes, annual transport volumes and transport frequencies – services per week (*Figure 2*).

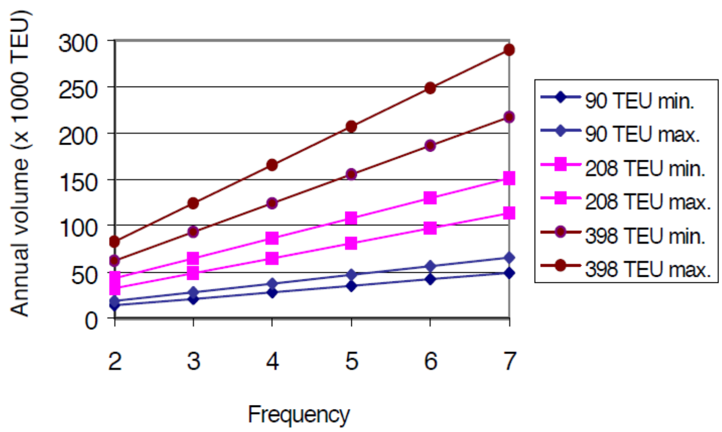

Figure 2 Relationship between vessel sizes, annual transport volumes and transport frequencies (75% loading degree = minimum; 100% loading degree =maximum)
Source: [8]

Obviously, based on (*Table 2*), navigation of container vessels with up to 90 TEUs may be allowed on Sava river waterway. In order to take advantage of foreseen increased scale of operations and vessel size, inland container vessels with such capacity should be utilised, particularly for transport of containers up to Belgrade. Therefore, (*Figure 2*) and break-even point of 75 %, with service frequency of 2 or 3 services per week, indicate a required annual transport volume on this transport direction to be between 15000 and 20000 TEUs. Smaller container barge vessels would lead to the reduced required annual transport volume, but to the increased transport costs due to economy of scale.

Through development of intermodal transport, utilisation of railways and inland waterways, as more efficient modes, will be increased leading to the reduced costs of international transport activities. Transportation costs will be affected by the level of cargo flows, punctuality of transport services, availability of containers in the region, business relationships between transport operators and shippers, etc. Since suggested corridors are intermodal and international, special attention is to be paid to the specific cost categories like transhipment costs, cross border costs, cost of return of empty containers, handling in ports, road tools, locomotive operation costs, etc.

By analysing existing situation within the Western Balkans countries, it may be concluded that several policy and operational measures may be implemented that will lead to the reduced transportation costs. These measures include establishing regular container train and barge services with satisfying operational frequencies, incentives to promote intermodal transport among shippers in the region, support to the further development of freight forwarding industry, facilitating cross-border procedures, etc. Promotion and support activities are aimed to ensure sufficient cargo flows along corridors and therefore avoidance of empty container transportation, i.e. availability of cargo for only one-way trip. Border crossing or any other loss of time, impacts not only transport costs, but trade flows and value of goods as well. In order to achieve the expected effects, all these measures will require improvement and maintenance of existing rail, road and inland waterways infrastructure and modernization of vehicle fleets.

Development of intermodal transport activities in the Western Balkans countries may impose longer transport times and it will particularly affects land-locked regional participants (Kosovo*, the Former Yugoslav Republic of Macedonia or Serbia) or other areas distant from seaports. Therefore, cooperation between countries is taken as crucial to provide for transit and market accesses for remote areas within Western Balkans region and accordingly to contribute to the increased efficiency of the transport system.

Environmental impacts have also been taken into account in defining the suggested intermodal transport corridors. It is well known that emissions and energy intensity of road transport is comparatively higher than other modes. In an effort to reduce the emissions of pollutants from transport operations in the Western Balkans region, these corridors are intended to enable modal shift from road-only to intermodal transport, i.e. options which include railway and barge transport activities. [9] reports that improved logistics organization and corridor route planning could reduce CO_2 emissions by 10-20 %. Therefore, defined corridors allow for transport of cargoes and passengers using a combination of modes and minimize environmental impacts along these corridors.

Globalization and the trend of increasing global trade and container transport encourage the growth of intermodal transport. Excluding disruptions to trade flows that have occurred 2008th and 2009th as a result of the global economic crisis, there has been significant growth in container flows. The total annual growth of container flows (in TEU) is about 10% in the period since 1997 by 2007 year. This growth is the logical consequence of increasing goods flows and processes of globalization [10].

Use of information and communication technology (ICT) is often considered as a tool for improvement of intermodal transport activities. Streamlining and speeding up of transportation process may be achieved through application of electronic data interchange (EDI) protocols, container tracking using GPS technology, implementation of emerging paperless trade concepts. All these technologies are aimed to enable advanced and real-time provision of numerous data on cargos, consignments or vehicles, increased security and reduced pilferages along the corridors, improved clearance procedures at cross-bordering, etc. ICT will reduce both transportation time and cost. Logistics infrastructure and services will gain importance but will also require various kinds of improvements (e.g. decision support tools assisting logistics service providers to select optimal intermodal route) in the existing logistics practice and industry. Therefore, adequate implementation and utilisation of ICT technologies in transport processes within the Western Balkans countries would require capacity building and training of staff dealing with transport service and infrastructure.

Defined intermodal transport corridors, affecting Western Balkans countries, are structured to follow the SEETO Comprehensive network. On the other side, efficiency of corridors operation would, for sure, arise as an issue of managing transport activities along them. Management of transport corridors, as usual, may lie within national government. Such an approach, applied within the Western Balkans region context, will require investing lot of efforts to ensure efficient cooperation among various stakeholders from both public and private sector. Increased level of cooperation and coordination between stakeholders, leading to reduced procedural impediments, is often seen as a way to improve the performance of any intermodal transport chain [11]. In that sense, EC nominated a European Coordinator for each of the nine TEN-T core corridors. They are, among other things, in charge of drawing up the relevant corridor work plan, highlighting difficulties in implementing this work plan, making recommendations in areas such as transport development along corridors or access to financing / funding sources, reporting to the European Parliament, Council, Commission and the Member States concerned on the progress achieved, etc. It may be concluded that corridor-based management, instead of national, would be needed in the Western Balkans region as well. Obviously, regional organizations in charge of transport will have an important role to play in managing development of such intermodal transport corridors.

Development of identified intermodal transport corridors would require constant monitoring of time and cost of transportation processes along them. Periodic studies on the cost and time levels would be, obviously, needed in that context [12]. In addition, in-depth assessments of required infrastructural and operational improvements, as well as benchmarking studies to set performance targets for the corridors would be performed regularly. All these activities would require identification, regular collection and monitoring of key performance indicators related to the defined ITCs. As a conclusion, the following gaps and needs should be taken into account and considered in an effort to improve intermodal transport infrastructure and operational services within the Western Balkans countries:

- Development of selected intermodal logistics centres and network of intermodal corridors, as well as improvements of the existing logistics practice is needed for the consolidation of freight flows in quantities sufficient to trigger further growth of intermodal activities within the region;

- Efforts are needed to direct existing and future transport flows on these corridors as it will advance cargo transfer processes among barges, railcars and trucks and reduce transport time and operating costs;
- Incentives to promote intermodal transport among shippers in the region are required;
- Governmental support to the further development of freight forwarding industry is missing;
- Establishment of regular container train services;
- Establishment of regular container barge services;
- Cooperation between countries, providing for transit and market accesses for land-locked countries and remote areas within Western Balkans countries and contributing to the increased efficiency of the transport system, is needed;
- Increased level of cooperation and coordination between stakeholders, leading to reduced procedural impediments and therefore improving the performance of any intermodal transport chain, is required;
- Facilitation and streamlining of cross-border procedures;
- Use of ICT (electronic data interchange (EDI) protocols, container tracking using GPS technology, implementation of emerging paperless trade concepts);
- ICT capacity building and training of logistics service providers and transport staff;
- Implementation of corridor-based management, instead of national;
- Periodic studies on the transport cost and time levels along identified intermodal transport corridors;
- Assessment studies of required infrastructural and operational improvements on the corridors;
- Benchmarking studies to set performance targets for the corridors.

5. CONCLUSIONS

Based on analysis of the existing situation it can be concluded that the intermodal transport in Western Balkans countries is underdeveloped. Total TEU traffic for all Western Balkans countries in 2013 was around 210,000TEU/year. The biggest TEU traffic was achieved in the Port of Durres, which today amounts to about 110,000TEU/year. But comparing the values of achieved TEU traffic of this port with a distinctive ports in the Mediterranean region (Koper, Rijeka, Trieste, Thessaloniki, Constanta, Piraeus) and wider (Barcelona, Rotterdam, Hamburg, Antwerp), it can be concluded inferior role in the intermodal of port of Durres in intermodal transport in Europe.

Improving of intermodal transport involves the implementation of a large number of different measures which are listed as: legislative, regulatory, administrative, organisational, technical and technological, monitoring procedures, educating and qualifying of personnel.

According to provided GAP assessment analysis, certain fast-implemented measures are identified as very high priority measures:

- Making planning documents (intermodal studies, strategies, national programs-apply to those participants whose do not possess these documents);
- Establishing the status of intermodal transport as an activity of special economic importance;
- Immediately start creating the project of information system, database and statistics of intermodal transport;
- The obligation of submitting the data to create statistical reports and databases and procedures of information flow;
- Liberalization of the railway sector;
- Include the intermodal projects in the priority projects for the use of pre-accession EU funds;
- Internal transport-Transhipment places must be ready for accepting of TEU units;

- Adaptation of handling (reloading) facilities and entities (users of transport services) for handling of TEU units (City Logistics aspect);
- Solutions for border crossing: a) Improving the cooperation between the national Customs Authorities; b) Submission of preliminary information, finalisation of the complete electronic data exchange; c) Harmonisation of the control procedures and organisation of joint control with the neighbouring countries;
- The use of modern IT equipment (hardware and software).

The provided research presents the global overview of the state of art and possible interventions for intermodality improvement within the Western Balkans countries.

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PRICE ELASTICITY IN PUBLIC TRANSPORT – A CASE STUDY OF THE CITY OF ZAGREB

ABSTRACT

A tariff policy with sound-based guidelines for ticket pricing in public transport is essential for shifting passengers from their private cars to public transport, and thus, for making urban mobility sustainable. The price elasticity is an important indicator of transport demand management in public transport that should be mandatory for every tariff policy; therefore, it is important to have the public opinion on the prices. This paper will present the current state of ticket pricing in public transport in the City of Zagreb; furthermore, it will present the results of the research related to price elasticity in public transport conducted on public transport users; and finally, it will provide the most important conclusions related to ticket pricing, providing further recommendations for improving the current tariff system in public transport.

KEY WORDS

City of Zagreb; price elasticity; public transport; tariff policy; transport demand management

1. INTRODUCTION

The price elasticity is defined as the percentage change in consumption caused by each one-percent change in its price of other characteristics such as travel speed or transit service. A negative sign indicates the effect is opposite from the cause (e.g. service-price relationship), and the positive sign indicates that the effect is positive (e.g. service-frequency relationship) [1]. Several methods have been used to calculate price elasticities, and the precision of the method depends on the situation. The most familiar are: shrinkage ratio (based on linear changes, useful for shorter changes) and arc elasticity (based on logarithmic changes, useful for wider range of changes) [2].

In recent years, there has been an increasing interest in transportation demand management, including pricing reforms, to achieve planning objectives such as congestion, accidents and pollution reductions. Critics sometimes claim that vehicle travel is insensitive to pricing, citing studies of declining price elasticities and examples of fuel or toll price increases that caused little reduction in vehicle travel. This implies that pricing reforms are ineffective at achieving planning objectives and significantly harm consumers [1]. Bresson et al. (2003), combining economic determinants with structural determinants showed that price elasticity of public transport is mostly related to the motorisation rate, making the financial equilibrium of the industry problematic [3].

As well as considering the direct effects of a change in fares, it is often important to consider the effects of fare changes on other modes. The usual method to consider the effect that other modes have on the demand for a mode of public transport is to use cross-elasticities, estimating the demand elasticity for a competing mode with respect to the change in the given mode [4]. The cross-elasticities should therefore be mandatory for observing the changes in demand, considering every mode of transport in the urban area. Holmgren (2007) used meta-regression to emphasize the importance of level of service, income, price of petrol and car ownership to be added to the price elasticity [5].

To help analyse cross-elasticities, it is useful to estimate mode substitution factors, such as the change in automobile trips resulting from a change in transit trips. These factors vary depending on circumstances. Other trips will shift from non-motorized modes, ridesharing (which consists of vehicle trips that will be made anyway), or be induced travel (including chauffeured automobile travel, in which a driver makes a special trip to carry a passenger). Conversely, when a disincentive, such as parking fees or road tolls, causes automobile trips to decline, there is generally a 20 to 60 percent shift to transit, depending on conditions [6].

Price elasticities have many applications in transportation planning. They can be used to predict the ridership and revenue effects of changes in transit fares; they are used in modelling to predict how changes in transit service will affect vehicle traffic volumes and pollution emissions; and they can help evaluate the impacts and benefits of mobility management strategies such as new transit services, road tolls, and parking fees [6]. Matas (2004) used aggregate demand function to obtain demand elasticities to observe long-term impacts of introducing travel-card scheme, to conclude that passengers are most sensitive to price and quality variables [7].

2. BACKGROUND

The City of Zagreb is the capital and the largest city of the Republic of Croatia, with population of an estimated 0.8 million [8], and a population density of 1,200 residents per square metre. The metropolitan area of the City has the population of 1.1 million. The City itself is located on the southern slopes of Medvednica mountain, divided by the Sava river, with rough terrain only in the northern peripheral parts of the City. It consists of 17 municipalities, divided into 70 neighbourhoods.

The road traffic in the City is characterized by local streets, higher priority streets, and city avenues. Most of the city avenues stretch from east to west, making the current state of traffic subject to the capacity of roads connecting northern and southern parts. Since motorisation rate is 430 vehicles per 1000 inhabitants, and passengers are used to their private cars, traffic congestion is usual in the morning and the afternoon peak periods on each main road and avenue.

Public transport in the City is organized mostly by trams and buses. Passengers ride on 140 bus lines and 15 tram lines, with approximately 740,000 daily trips, and the public transport vehicles record very high passenger densities in morning and afternoon peak periods. Public transport network is stretched throughout the City, covering every significant part of the City, resulting in 10-minute walks in the city centre and 15-minute to 20-minute walks in the periphery. Although the fare charging scheme offers different price plans for public transport users, the dynamic performance represents the weak link, with 12 km h^{-1} operating speed unsatisfactory for passengers.

The mobility in the City of Zagreb is highly related on purchasing power, comfort provided by the private cars, and a poor transport policy by the city administration. Due to the financial crisis starting in 2008, one third of people use private cars, one third use public transport, and the remaining third is divided into pedestrians and cyclists, with a continuous increase of bicycle traffic in the past several years. Although public transport has become financially more acceptable than private car, it still does not represent an acceptable choice for passengers.

The city public transport authority, Zagreb Electric Tram (ZET), offers different types of tickets (paper and electronic) – single tickets, daily tickets, multiple daily tickets, monthly tickets, and yearly tickets [9]. With the increase of the validity period, the tickets become cheaper per unit period. Also, long-period tickets are cheaper for the privileged passenger groups, such as students or elderly people. At the time, the single ticket cost 10 HRK, and its validation was limited to 90 minutes. Ticket control is conducted by ZET officials in vehicles, usually randomly considering time and vehicles. The fare charging system is zonal (Figure 1), with the first zone covering the urban area, and the second zone covering suburban areas of Zagreb County (such as Zaprešić and Velika Gorica). The cost of the single ticket is constant in both zones; however, the transfer between zones cancels the validity of the current single ticket, and an another one should be bought to legally continue the ride.

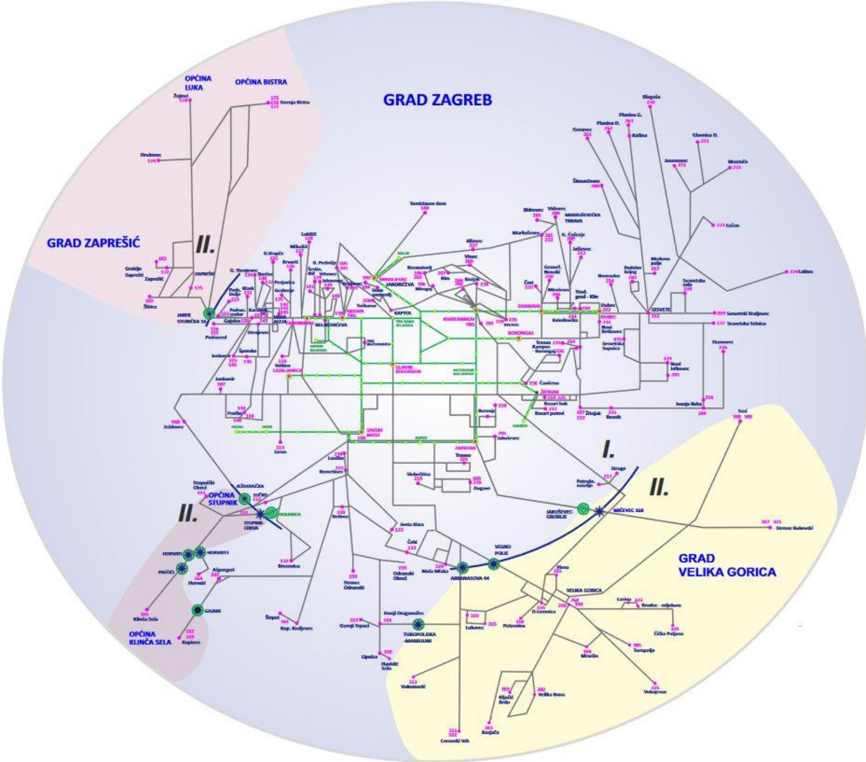

Figure 1 – The City of Zagreb – fare charging zones in public transport
Source: [10]

The research described in the paper was a part of the scientific research project "Evaluating the effects of measures and strategies of sustainable transport in cities", carried out by the Faculty of Transport and Traffic Sciences of the University of Zagreb. The goal of the project was to analyse the efficiency of the planned and applied sustainable transport measures and strategies, by observing cost efficiency, and implementing cost-benefit analysis. The planned project methodology was used to analyse the current progress on implementing sustainable urban mobility plans, and, by collecting relevant data, to analyse the current state regarding sustainable urban mobility plans in the Republic of Croatia. A great amount of the project focused on understanding user behaviour in transport system in the urban environment by analysing price elasticity in public transport and car parking management.

3. METHODOLOGY

The research on this paper is focused on public transport users, considering both public transport modes (tram and bus), since the single ticket is valid for the entire tram and bus network (as stated in the previous chapter, only the interchange between zones causes single tickets to expire).

The input data for the research was gathered by a survey on public transport users (Figure 2) in the City of Zagreb (the questionnaire used was originally in Croatian). The main purpose of the collected data was to get the information about price elasticity of the single ticket. The survey was conducted during October and November 2016 by the students of the Faculty of Transport and Traffic Sciences in Zagreb. The reference sample had the following characteristics:

- time periods: workdays (Tuesday, Wednesday, Thursday) at morning peak periods
- locations: 25 tram and bus stops with high transport demand
- data: 790 samples

Location:	
Date:	
Time:	
Surveyor:	

SURVEY ON PUBLIC TRANSPORT ELASTICITY

Sex?	*M*	*F*			
Profession?	*pupil*	*student*	*employed*	*unemployed*	*retired*
Private car ownership?	*YES*	*NO*			
Purpose of the journey?	*work*	*school, university*	*residence*	*other (recreation)*	

On-vehicle travel time in public transport (one direction), minutes:

What ticket type do you use in public transport?	*no ticket*	*single (electronic)*	*single (paper)*	*daily (one day)*	*daily (more than one day)*	*monthly*	*yearly*

Are you satisfied with ticket prices?	*YES*	*NO*

Your satisfaction regarding public transport service (1 – very unsatisfied, 2 – unsatisfied, 3 – cannot decide, 4 – satisfied, 5 – very satisfied)?

Speed:	*1*	*2*	*3*	*4*	*5*
Comfort:	*1*	*2*	*3*	*4*	*5*
Punctuality and regularity:	*1*	*2*	*3*	*4*	*5*

In case of an improved public transport service, what price of a single ticket would you agree upon?	*8 HRK*	*9 HRK*	*11 HRK*	*12 HRK*	
Should a 45-minute single ticket in daily traffic be introduced?	*no*	*yes, 6 HRK*	*yes, 5 HRK*	*yes, 4 HRK*	*yes, 3 HRK*
Monthly income in HRK??	*no income*	*below 2800*	*2801-5000*	*5001-9999*	*more than 10000*

Comments:

Figure 2 – The questionnaire form used in the research
Source: authors

The data was then input manually using the Microsoft Excel and processed according to the type of questions and answers provided to get the insights. The elasticity mandatory for the research was the linear elasticity, as described in [11]:

$$E = \frac{P}{Q} \frac{\Delta Q}{\Delta P} \tag{1}$$

, where $\Delta Q \ Q^{-1}$ is the percentage change of demand, and $\Delta P \ P^{-1}$ is the percentage change in price. Since the price elasticity in this paper is observed on single-ticket pricing, it is obvious that higher prices should result with less transport demand, and lower prices could attract more passengers to the public transport – the price elasticity will then always be negative, evaluated as [11]:

- Below minus one: elastic (the demand changes faster compared to the price)
- Minus one: unit elasticity (any price changes result in equal demand changes)

- Between minus one and zero: inelastic (the demand changes slower compared to the price)
- Zero: no elasticity (the change in price does not have any effect on the demand)

In this case, the information about the price elasticity was extracted from the question asked to the participants, related to a hypothetical scenario in which the ticket price changes from the current 10 HRK to possible 8 HRK (-20 %), 9 HRK (-10 %), 11 HRK (+10 %), and 12 HRK (+20 %). The elasticity was calculated as a linear function, with 8, 9, 11, and 12 HRK as independent variables, for two types of categories:

- private car ownership: two cases (yes; no)
- income in HRK: four cases (below 2,800; 2,801 – 5,000; 5,001 – 9,999; above 10,000)

Besides the price elasticity, the research results were divided into three additional groups, due to the importance of these additional results to the elasticity itself:

- The percentages of passengers for each ticket category (including illegal rides)
- User satisfaction
- The opinion about introducing the 45-minute single ticket

4. RESULTS

The results regarding the percentages of passengers for each of the ticket categories are shown in Figure 3, indicating approximately one third of active people. Single tickets (paper and electronic combined) belong only to one fifth of the total number of passengers. The interesting is also the fact that one fifth of total passengers ride illegally (no ticket).

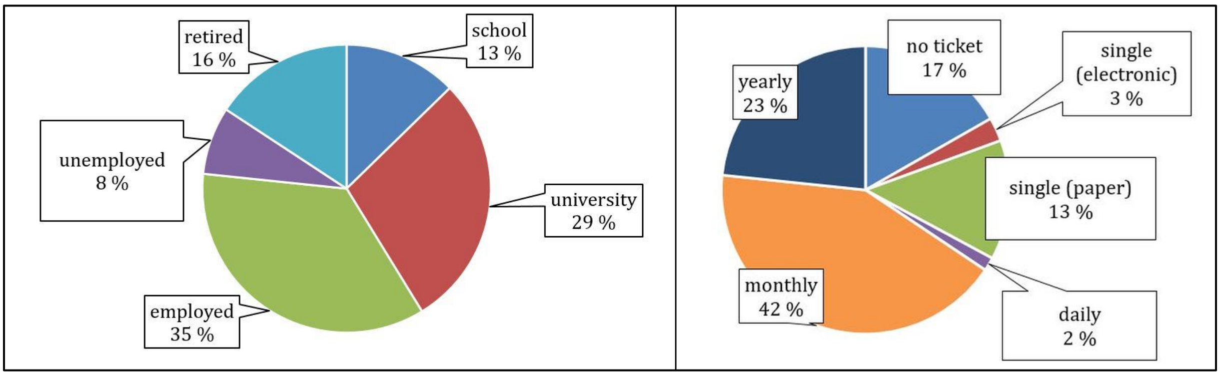

Figure 3 – Passenger categories – per occupation (left) and per type of ticket (right)
Source: authors

Regarding the user satisfaction, 54 % of passengers claimed that ticket prices are satisfactory. The satisfaction was also measured in three categories on the scale from one to five, and the results were:

- for the punctuality and regularity: 3.2
- for the comfort: 3.4
- for the speed: 3.2

The results regarding the most common passenger complaints are shown on Figure 4, with the following explanations:

- operating speed: vehicles running too slow, or their priority is neglected,
- information: passengers are poorly informed (pre-trip and on-trip)
- network: poor network density and stop accessibility
- personnel: inconsiderate drivers
- tariffs, fare charging schemes: fare charging schemes that do not meet the passenger requirements
- punctuality and regularity: vehicle departures not synchronized with the timetable

- prices: tickets inadequately expensive
- vehicles: poor cleanness and interior configuration
- timetables: insufficient vehicle scheduling

The most common passenger complaints can be summarized into two main categories:

- complaints about the quality of service (operating speed, information, network, personnel, punctuality and regularity, vehicles, timetables): approximately two thirds of passengers
- complaints about ticket pricing (tariffs, prices): approximately one third of passengers

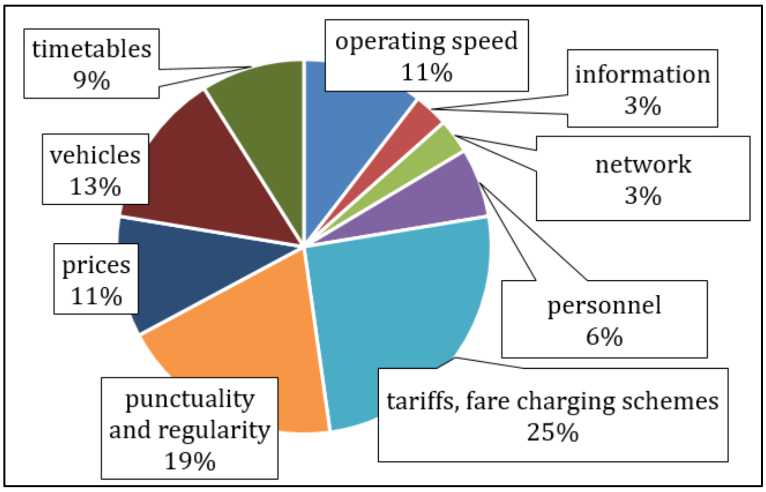

Figure 4 – The most common passenger complaints
Source: authors

Regarding the possibility to introduce the 45-minute single ticket, the results are shown in Figure 5. Approximately two thirds of passengers agree on introducing the ticket, with the majority opting out for the cheapest variant (3 HRK), and the variant in which the price was the half (5 HRK) compared to the current situation. Also, most passengers ride shortly: approximately two thirds under 30 minutes, and approximately four fifths under 45 minutes.

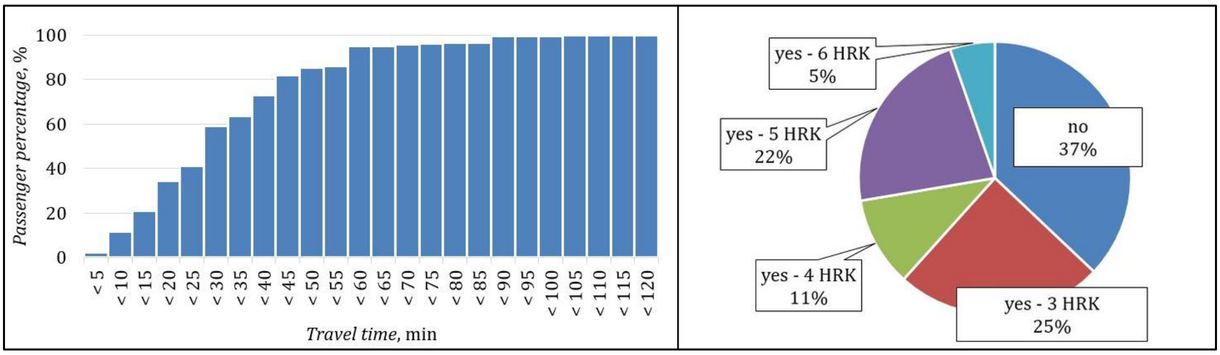

Figure 5 – The 45-minute single ticket – passenger percentage per travel time (left) and opinion about introducing the ticket (right)
Source: authors

The price elasticity per private car ownership is shown in Figure 6. For approximately one third of passengers who own a private car, the elasticity of -0.92 suggests mildly inelastic transport demand, and for the rest, the demand is mildly elastic (-1.09).

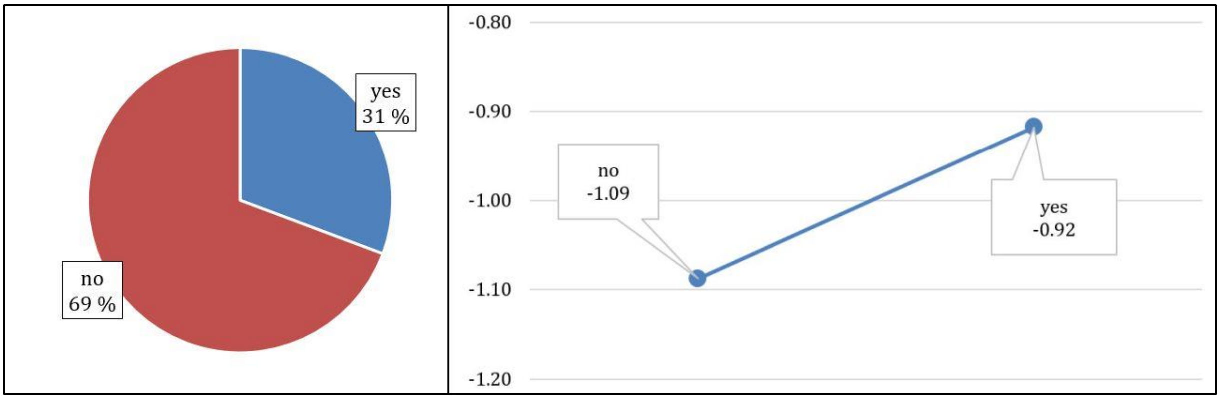

Figure 6 – Price elasticity per private car ownership: sample percentages (left) and the values (right)
Source: authors

The price elasticity per income in HRK is shown in Figure 7:

- For approximately two thirds of passengers who belong to the lowest-ranked income categories (no income, below 2,800), the joint elasticity of -1.10 suggests mildly inelastic transport demand
- For approximately one third of passengers who belong to the middle-ranked income categories (2,801 – 5,000, 5,001 – 9,999), the elasticities of -0.96 and -0.93, respectively, suggest mildly inelastic transport demand
- For a very few passengers, who belong to the more than 10,000 category, the demand is inelastic (-0.61)

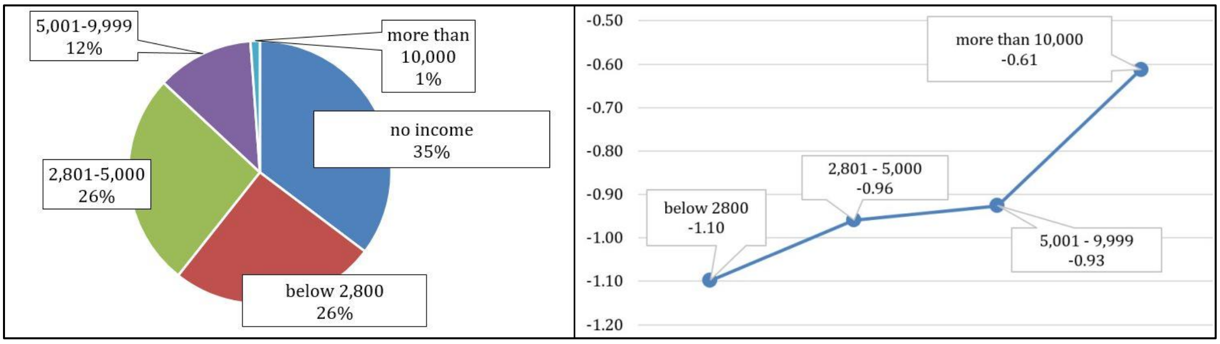

Figure 7 – Price elasticity per income category in HRK: sample percentages (left) and the values (right)
Source: authors

5. DISCUSSION

The paper focuses on passengers who use single tickets on their trips (one fifth of the sample). However, for a high-resolution analysis, the price elasticity should be observed for the rest three fifths, which use monthly or yearly tickets. The concerning illegal rides suggest that the existing ticket control should be improved. Also, most illegal passengers are more likely to become potential single-ticket users, making the research results more relevant.

The passengers were mostly complaining about the quality of service (two thirds). Therefore, the minority of passengers complaining about the pricing are directly connected to the mildly inelastic transport demand, regarding both private car usage and usual income categories. In other words, passengers put the problems related to the quality of service on top of the problems related to ticket pricing. This is also supported by the results on average opinion (comfort better than speed, punctuality and regularity).

Although the passengers were asked about the hypothetical scenario in which the quality of service would be improved, the majority (two thirds) would agree on introducing 45-minute single ticket, which is consistent with the two thirds of passengers traveling under 30 minutes (passengers tend to have spare 15 minutes, to cover almost every journey). The choice on the minimum offered price of 3 HRK for most passengers (25 %) could be merely a psychological effect – every passenger would like to ride more cheaply. In practice, the 45-minute single ticket, which would have exactly a half validity period compared to the existing single ticket, could cover even four fifths of the current journeys. In practice, two benefits arise from introducing such a ticket – less illegal rides, and possible modal shift from private car to public transport for some passengers; both resulting in higher income for the public transport operator. However, for the mentioned four fifths of passengers, 45-minute single tickets monthly (2 rides a day, average 22 workdays in a month) could become a cheaper option if compared to the existing monthly ticket price of 280 HRK or yearly tickets, so the higher incomes for the operator cannot be guaranteed long-term.

The results for the price elasticity suggest the usual mindset among the passengers – for the ones who do not own a private car (and therefore, not having the private car option), the demand is naturally more elastic, because they rely much more on public transport for crossing longer distances. Considering the incomes, the situation is similar – the higher the income, the demand becomes less elastic, because the purchasing power determines whether the users will rely on public transport.

At the project dissemination, the representatives of the Zagreb Electric Tram were present as well, and they were informed about the research results regarding price elasticity in public transport. Approximately one month after the project dissemination, the City of Zagreb (the local administration body in charge of Zagreb Electric Tram) decided on introducing 30-minute single tickets for 4 HRK. The response of the public was satisfactory, and ZET has compared single-ticket revenues in February 2017 (14.8 million HRK) with the ones in February 2016 (9.0 million HRK) – a 64 % revenue increase [12].

6. CONCLUSIONS AND RECOMMENDATIONS

Regarding the price demand elasticity in public transport of the City of Zagreb, the research resulted with the following conclusions:

- the observed one fifth of citizens who use single (plus the additional fifth of illegal rides) are considerable for the observation, especially when the newly-introduced 30-minute single ticket could attract passengers who use monthly or yearly tickets – nevertheless, the research should be expanded to the entire passenger sample
- mildly elastic and mildly inelastic transport demand suggest that passengers prioritize the quality of service over the pricing in scope of the possible improvements
- the introduction of the 45-minute single ticket could cut down the illegal rides and shift some passengers from private car to public transport (at least for short-term) – this has been proven by the introduction of the 30-minute single ticket at the beginning of February 2017

Price elasticity can be an important indicator for creating an efficient tariff policy which could be able to manipulate the existing transport demand, and make modal shift from private cars to public transport for a considerable number of passengers. The future research would have to include a comprehensive price elasticity analysis, not only in public transport, but for the entire urban transport system, involving each mode. Only this kind of analysis would indicate how a sound-based tariff policy should be designed, contributing to the integration of the fare-charging schemes and more sustainable urban mobility in the City of Zagreb and its gravitational area.

ACKNOWLEDGEMENTS

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AIR CARGO HANDLING PROCESS

ABSTRACT

Air cargo business is a very important business for the global air transport market. This means that air cargo handling process is important for any airport or cargo handling agent who provides cargo handling services. This also means competent cargo staff, procedures, cargo information system, developed infrastructure and process management. The objective of research presented in this paper is air cargo handling process and its complex structure. Using scientific methods of cognition, the author explores the structure of air cargo handling process and causality of its structure elements. The result of this research is that process approach to air cargo handling services can improve these services in general and allow providing of complex air cargo handling services and fulfilment of customer requirements. In these circumstances the process approach makes contribution to competitiveness.

KEY WORDS

air cargo; handling process; process approach; handling services; air cargo handling process;

1. INTRODUCTION

As per the IATA (International Air Transport Association) data, 52 million tons of air cargo was transported in 2016 in the world. According to the mass, it is less than 1% of the world trade, however, it presents more than 35% of the world trade value, accounting for the value of around 6.8 US$ billion daily. Air cargo transport realizes 9% of total aircraft operators' income, being twice the income resulting from first class passengers. Directly and indirectly, air cargo business provides around 32 million of work places around the word.

Air Cargo Handling Process at airports may be rendered by airports themselves, as the case was for instance at Zagreb Airport before it was taken over by the Concessionaire, or by a daughter company founded solely for provisions of airport ground handling services, the case of Zagreb Airport after takeover by the Concessionaire. Pursuant to the Ordinance on Provision of Ground Handling Services (Official Gazette 39/10), when cargo traffic in an airport reaches 50,000 ton annually and exceeds it, the market of these service should be liberalized so that other service providers are enabled to provide services of air cargo handling process under the conditions of the Ordinance and within market competition. In Croatia, but also in the surrounding countries (Slovenia, Bosnia and Herzegovina, Serbia, Macedonia, Kosovo, Montenegro) there are no airports with annual traffic of 50,000 t and more [1].

When it comes to air cargo transport, competition among airports is very strong, especially in relation to intercontinental traffic. Airports winning in this market competition are the ones having: competent staff, appropriate cargo infrastructure, developed route network, good traffic links of the airport with the railway, technology implementing latest developments, quality based on ISO standards, IATA projects such as Cargo 2000 (C2K) management system [2], e-freight technology [3], iQ and the like. Cargo iQ is an IATA interest group with the mission of creating and implementing quality standards for the worldwide air cargo industry. For that reasons every handling agent, or air cargo handling service provider, makes efforts to improve quality of the process in all elements, in order to be competitive in the market.

2. AIR CARGO HANDLING PROCESS

Air Cargo Handling Process belongs to core business processes regardless if the airport itself conducts it or it is managed by a specialized organization in the liberalized market conditions.

2.1 Definition of the Process

The word process originates from Latin word *processus*, meaning ... flow, the way in which something becomes or is, development, procedure... [4]. Process is set of interrelated or interacting activities that use inputs to deliver an intended result [5]. Further on, process means transforming or reshaping input values to output ones, however, not in any way but within the framework of set rules and controls and with application of defined mechanisms, or resources, as shown in Figure 1.

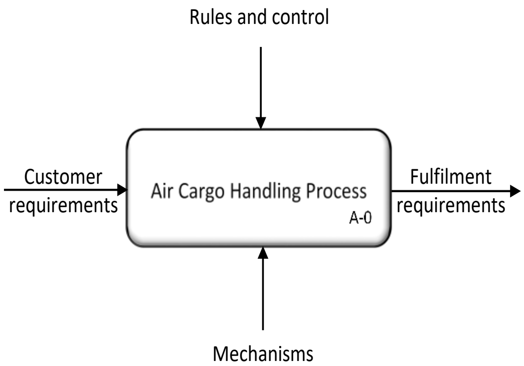

Figure 1 – Context diagram of Air Cargo Handling Process

Process input is always a requirement of customer/user, regardless in which form it is presented (contract, specification, order, etc.). Process output is a product or service with characteristics (quality) that fulfil the customer/user requirements defined at the process input. Rules and controls that must be observed when transforming inputs into outputs can be: international standards, laws and other regulations, contracts, specifications, procedures, work instructions, methodologies and the like. Mechanisms or resources needed for process running can be: competent staff, infrastructure, equipment, financial means, work environment, hardware, software, partners, etc.

2.2 Hierarchy of Air Cargo Handling Process

Any process has its hierarchy, as shown in Figure 2. The Air Cargo Handling Process is a very complex process for several reasons:

- cargo handling activities at arrival (receipt) and departure (dispatch) run simultaneously, so that this process has two sub-processes: 1) air cargo handling sub-process – arrivals and 2) air cargo handling sub-process – departures;
- airside and landside activities run simultaneously;
- physical and documentary receipt and dispatch activities (handling) run simultaneously.

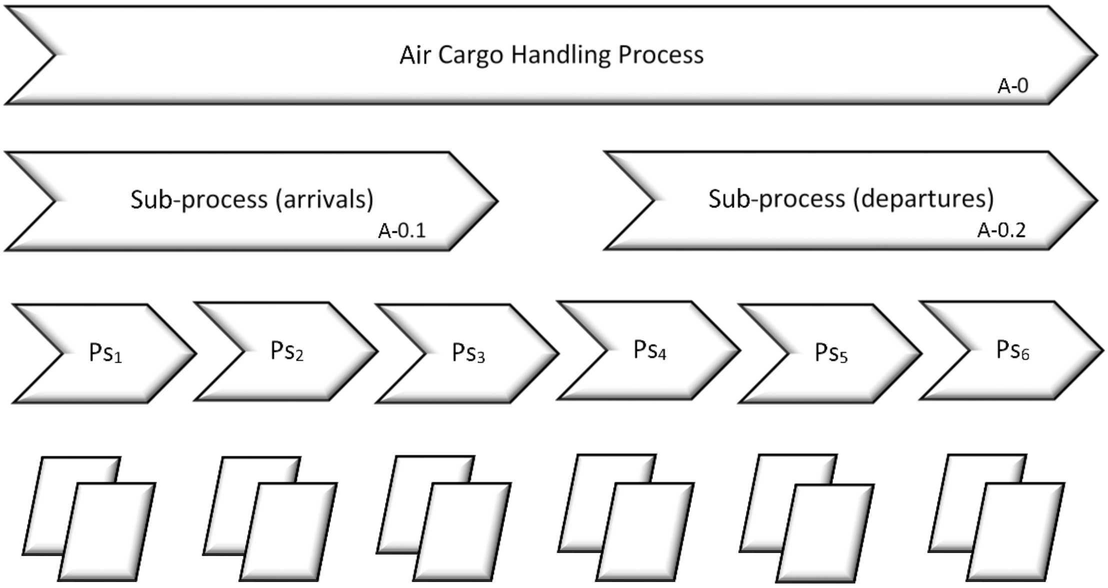

Figure 2 – Hierarchy of Air Cargo Handling Process

Each of the listed sub-processes encompasses several process steps consisting of numerous activities to be carried out to complete all actions within that process step. In this way prerequisites for transition from one process step to the next are created, in such a way that at least one output from the previous process step is also the input to the following process step, as shown in Figures 3, 4, 5. It is not possible to start activities in a process step unless all activities within the previous process step have been completed.

What activities from individual process steps is defined by written procedures representing documented basis of each process step. Procedures define and describe each activity, according to the sequence of execution. Control points are also defined at which something is measured, evaluated, controlled, or at which it is decided if the activity has been performed in compliance with the requirements or not. If the answer is YES, the process may continue, if the answer is NO, certain activities are repeated until the requested quality level has been achieved. Control points serve to manage the process, so that it does not happen that the final results, in this case the service, does not comply with user requirements. In such case, it would be too late for any improvement, and only a conclusion could be made that a non-compliant service has been provided, with all consequences such as non-quality costs, loss of reputation, fall of competitiveness, etc.

A procedure clearly specifies the responsibility for carrying out and the responsibility for control for each activity by indicating a work position, not a name, because work positions are relatively constant, and the specific responsible person can change in line with work allocation.

How many written procedures are needed for documenting a process step depends on complexity of the process, or the process step in question. However, at least one written procedure should be used to define the flow of activities within a process step.

2.3 Air Cargo Handling Process Decomposition

When talking about the Air Cargo Handling Process, the input is the requirement of the cargo owner or its agent, to carry out the air cargo transport from point A to point B, in a safe way and in good time. The process output should be completion of the air transport service from point A to point B, in accordance with the requirements set by the cargo owner or its agent. Rules and controls for running the process are: international documents regulating air traffic and aircraft cargo transport, customs regulations, security regulations, special regulations for individual cargo types such as for instance the IATA – Dangerous Goods Regulation (DGR) for transport of hazardous substances, cargo handling contracts with aircraft operators, contracts with customers and their agents or forwarders, national laws and regulations, internal quality procedures, work instructions, methodologies, etc. Mechanisms or resources needed for conducting this process can be: competent workers possessing all required licenses for handling certain cargo types or managing special equipment, infrastructure including storage area with all necessary types of special sections (cold chambers, security vaults, storage rooms under temperature regime, area for DGR goods, human remains storage (HUM), live animals storage (Live Animals Regulation – LAR), special equipment (forklifts, weighing devices, pallets, dollies, thermometers, refrigerators, security screening equipment, etc.

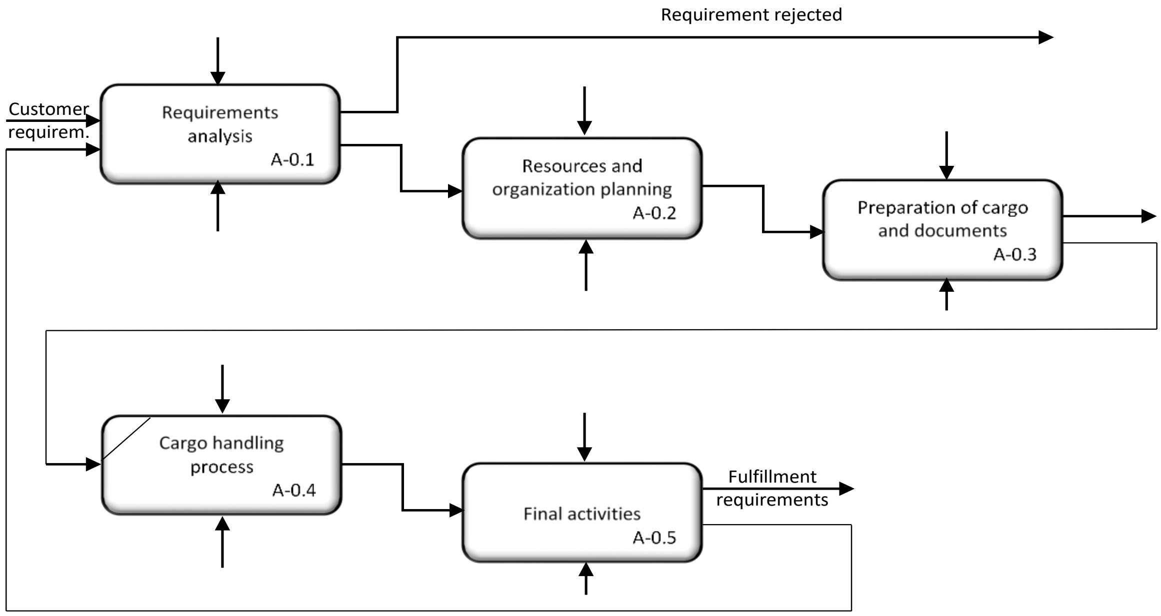

Figure 3 – Diagram of Air Cargo Handling Process decomposition

Figure 3 shows a diagram of Air Cargo Handling Process decomposition. Process input is the customer requirement. In the first process step *Requirement analysis (A-0.1)* the customer requirements are analysed, or the capability of the process to meet these requirements. If the analysis shows that the process is not capable to meet these requirements for any reason, the requirement is rejected and the customer officially informed about this. If the requirement can be fulfilled, the next process step *Resources and organization planning (A-0.2)* starts. In this process step resources for carrying out the Air Cargo Handling Process in compliance with the customer requirements are planned. The work is organized so that the process can run without setbacks. After all activities in this process step have been completed, it is possible to proceed to the next process step, *Preparation of cargo and documents (A-0.3).* Preparations for physical handling and documents handling is carried out within this process step. Preparation for physical handling includes preparing necessary equipment units and storage positions for later physical manipulation of the cargo, forming ULD (Unit Load Devices), loading onto dollies and the like. Preparation of documentary handling includes planning of documentation and issuance of documents accompanying the shipment, such as for instance Cargo Manifest, Air Waybill, UCD (Unified Customs Declaration) and some other documents accompanying individual types of shipment or cargo (DGR, perishable goods, live animals, etc.). Upon physical and documentary preparation of the cargo, the process step *Cargo handling process (A-0.4)* follows. Air cargo handling is carried out in this process step, meaning physical and documentary handling, running simultaneously on the airside and landside. This process step is therefore complex and needs to be further decomposed (marked with a slanted line in the upper left corner of the graph in Figure 3).

2.3.1 Air Cargo Handling Sub-process (Arrivals) – Airside

On the airside, upon aircraft (AC) arrival, the *Unloading cargo from aircraft (A-4.1.1)*, as shown in Figure 4, is carried out. Shipments, either in containers, on pallets, in bags, in cages or loose, are unloaded onto dollies located beside the AC.

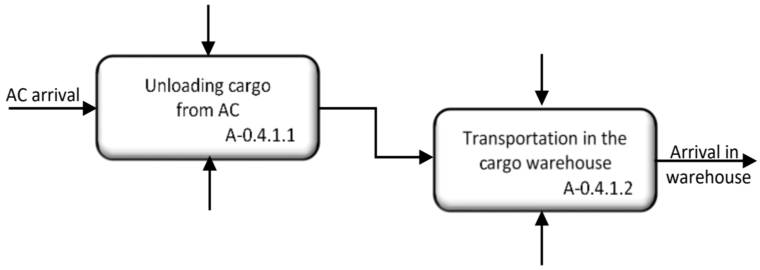

Figure 4 – Further decomposition –air cargo handling sub-process (arrivals) – airside

After all shipments have been unloaded and loaded on the dollies, and after the AC crew has taken over the accompanying documents, cargo is transported to the cargo warehouse by special tractors. The transport is performed on the base of appropriate procedures. The transport enters the cargo warehouse.

2.3.2 Air Cargo Handling Sub-process (Arrivals - Departures) – Landside

On the landside in the cargo warehouse and at the forwarder's, handling activities (arrivals) and handling activities (departures) run in parallel, as shown in Figure 5. Upon arrival of transport with shipments from the AC in the cargo warehouse, activities contained in the *Breakdown ULD's (A-0.4.2.1)* process step are carried out. It is determined which shipments are issued to end users or their forwarders at the concrete airport, and which continue their way further on, to other destinations. After that, activities within the second process step *Incoming checks and administration (A-0.4.2.2)* begin. Entry control of received shipments is carried out, or alignment with the accompanying documentation. It is established if there are damaged deliveries, packaging or the like. If such shipments are found a Record on Defective Cargo (complaint) is made. The next process step follows, named *Sorting and documentation (A-0.4.2.3)*. In this process step activities related to arrivals and departures run simultaneously. Shipments having the relevant airport as the ultimate destination are placed on storage positions or immediately taken out from the warehouse and issued to end users or their forwarders. At the same time, in the same warehouse and at the same forwarders, sorting and preparation of documents related to departure are carried out. Preparation and *Outgoing checks and administration (A-0.4.2.4)* are completed. Shipments are checked, possible damages determined, and issuance of all required documents to accompany the shipments confirmed. Customs formalities are performed if applicable.

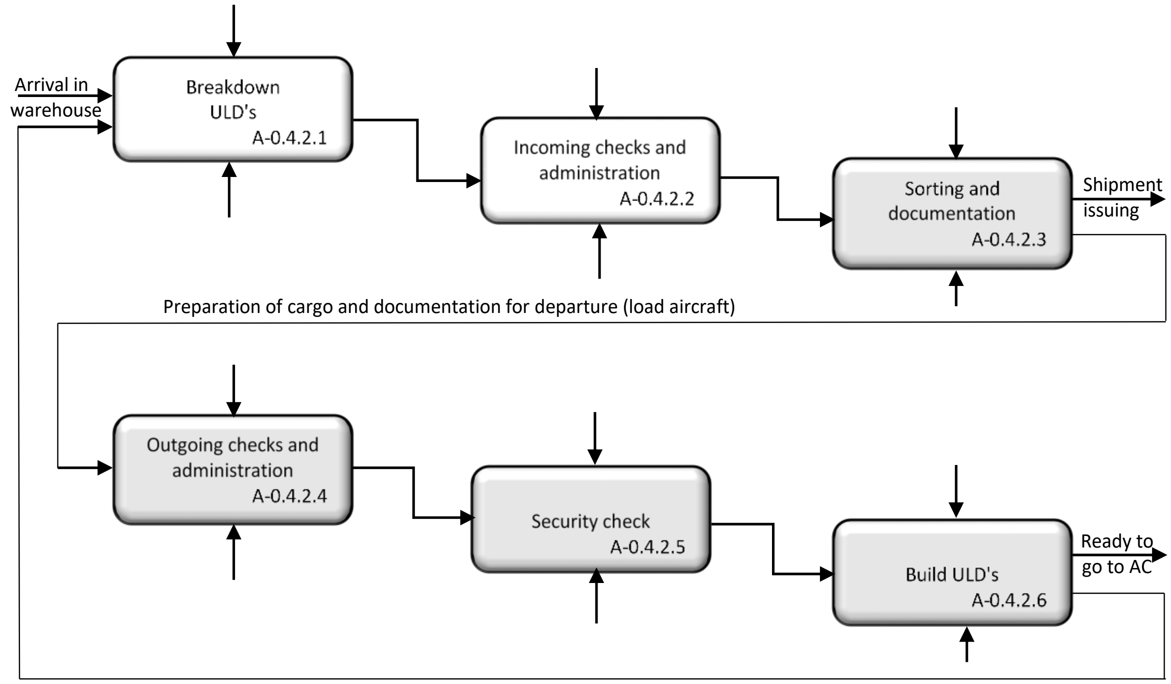

Figure 5 – Further decomposition – cargo handling sub-process – (arrivals-departures) - landside

This is followed by the process step *Security check (A-0.4.2.5.).* The security check of shipments is carried out in compliance with procedures prescribed by international organizations regulating air traffic security, but also with procedures adopted by individual countries or airports, depending on risk assessment. Upon the security check activities of the *Build ULD's (A-0.4.2.6)* process step are started, and in this step unit load devices are formed, weighing and loading onto dollies carried out to prepare the cargo for transport to the AC.

2.3.3 Air Cargo Handling Sub-process (Departure) – Airside

After the transport is prepared, activities from the process step *Transportation to aircraft (A-0.4.3.1)* take place*.* As in case of arrival, transport is performed according to a special procedure. Loading cargo into AC is also carried out in accordance with a special procedure. Loading is supervised by responsible persons all the time. When loading is completed, the documentation accompanying the cargo is submitted to the AC crew.

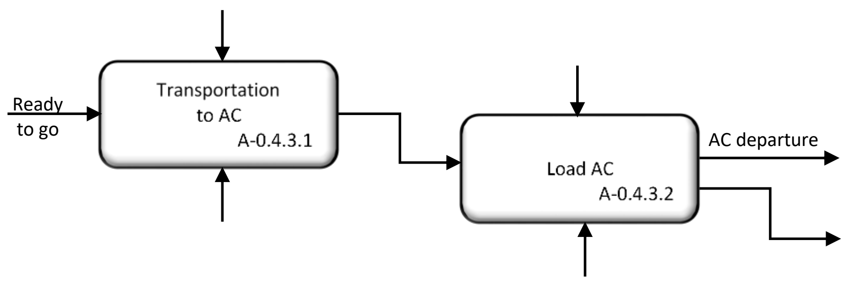

Figure 6 – Further decomposition – air cargo handling sub-process (departures) – airside

Upon successful completion of this process step, it is possible to go on to the final process step, as shown in Figure 3, *Final activities (A-0.5).* Activities such as document distribution, report making, communication among process participants, records, preparing invoices for the provided services, etc. are conducted within this process step. The process output is air cargo handling service, with its characteristics or quality fulfilling customer requirements received as process inputs.

3. TYPES OF CARGO AND DOCUMENTATION

It is considered that air transport is used for higher value goods that withstand the transport price, generally higher for air transport than for other modes of transport. This is mostly true, as already explained in the introduction of this paper.

3.1 Air Cargo Types

In exceptional situations, due to various circumstances, such as: delivery time, contract penalties, urgency or other contract obligations, goods that would in usual circumstances be transported in another way (truck, ship, railway) are also transported by AC. For this reason, various goods are transported by air, as for instance: IT components, other technical goods, perishable goods (food and agricultural products); weapons, explosives, dangerous goods, but also goods such as: construction joinery, metal elements and assemblies, live animals, animals for zoos, transformers, cars, pesticides, machines and devices, human remains, value shipments (gold, money, noble metals), human organs for transplantation, etc. For individual types of cargo special rooms are provided in warehouses, and the air cargo handling process for such types of goods runs under special procedures. Equally, workers manipulating certain cargo types, either at the forwarder's or in the organization providing handling services, should be trained and licensed for manipulation of that cargo type.

3.2 Cargo Documentation

Each cargo shipment in air traffic is accompanied by appropriate documents. Cargo Manifest and Air Waybill are documents accompanying every type of shipment. These are unified forms applied in the whole world, containing information on the shipment and other data related to participants in the process, such as data relating to the point of departure and destination. Beside the mentioned ones, other documents can be issued if needed, to accompany a shipment: Mail Manifest (for mail), UCD – Unified Customs Declaration, Record on Defective Cargo, NOTOC – Notification to Captain (Special Load), Unit Load Device - ULD, Request for sanitary examination of imported shipment, DGR – Dangerous Goods Checklist, Live Animals Acceptance Checklist, etc.

4. CONCLUSION

Air Cargo Handling Process is a core business process at airports regardless if they provide ground handling services themselves or engage special cargo handling companies. This is a complex process due to activities running simultaneously: in arrival and departure, in airside and landside, physical handling and documentary handling. This process forms integral part of the process structure of the organization managing it, the structure consisting of: management processes, core business processes, support processes and measurement, analysis and improvement processes. Certain assumptions must be fulfilled for managing this process in the required manner: 1) name, model, document and implement business processes in the management system; 2) establish process oriented organization; 3) have competent staff; 4) be integrated in the global cargo business network since it is a global air traffic activity. The objective is to fulfil customer requirements, meaning that the objective is service quality as the process output. The reason for this is that today there is competition among airports and cargo handling companies and the selection criterion is primarily their quality. The position of a handling company in the global market depends on this. The task of the air cargo handling process management is therefore to reach the level of management that guarantees process reliability and fulfilment of customer requirements in all elements of quality (safety, punctuality, conscientiousness, courtesy, transparency, innovation). Meeting the listed requirements contributes to increase of competitiveness. By establishing and implementing process approach it is possible to perform the most complex cargo handling even in situations when it looks impossible at first sight.

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ANALYSIS OF TERRITORIAL ACCESSIBILITY BASED ON TRANSPORT INFRASTRUCTURES OF COMPANIES THAT PROCESS TROPICAL FRUITS IN CALDAS - COLOMBIA

ABSTRACT

This research paper evaluates the geospatial position of farms and companies that produce and process fruits. The aim is to determine the relationship between the geospatial location of activity nodes and the Gross Domestic Product GDP at the municipal level of the area under study through the application of a territorial accessibility analysis. The results show that in the mid- west of the Caldas Department there are enough farms producing the fruits of interest of this research, but to the east the production is very low. Results also show that here is a direct relationship between the location of processing companies and the areas that refer higher GDP. This was not observed in the analysis of production at the municipal level and of the transport infrastructures in general and it shows that either these processing companies take advantage of the possibility of being in a geostrategic location or they drive the production of the areas and sectors with which they have more expeditious communication. Then, municipalities with higher GDP get better benefits from the processing companies, which drive production in sectors where products are easily delivered.

KEY WORDS

Accessibility; Average travel time; Coverage; Geostatistical analysis; Gross Domestic Product; Processing companies.

1. INTRODUCTION

This research paper is part of the project "Model of a platform of integral use, value adding and competitiveness of commercial Andean fruit trees" (Modelo de plataforma de aprovechamiento integral, adición de valor y competitividad de frutales comerciales andinos), which is financed by the Inter-American Development Bank (IDB) and carried out by Universidad Nacional de Colombia, Manizales Branch. The objective of this project is to determine the geospatial relationship of farms producing five different fruits of interest (tree tomato, guava, blackberry, passion fruit and lulo) and the processing companies (Frugy S.A. Company, Alpina S.A. and FLP Procesados S.A.S) and also to find the relationship between the geospatial location of both the production farms and the processing companies and the Gross Domestic Product - GDP at the municipal level of the area under study. This is done through an analysis of territorial accessibility based on the collection of operational data from the transport infrastructure network and the application of a geostatistical model. The production farms, 21 in total, are concentrated mostly in the Caldas Department at an altitude between 1,240 and

2,710 masl. Only two of these farms produce two of the fruits of interest simultaneously. The area under study is located in the central western region of Colombia, on the central mountain range in the area known as the "coffee axis" (Eje Cafetero) (See Figure 1). The farms that are part of this research are a sample of a total of 300 production farms that fulfilled the specific requirements of the fruits of interest.

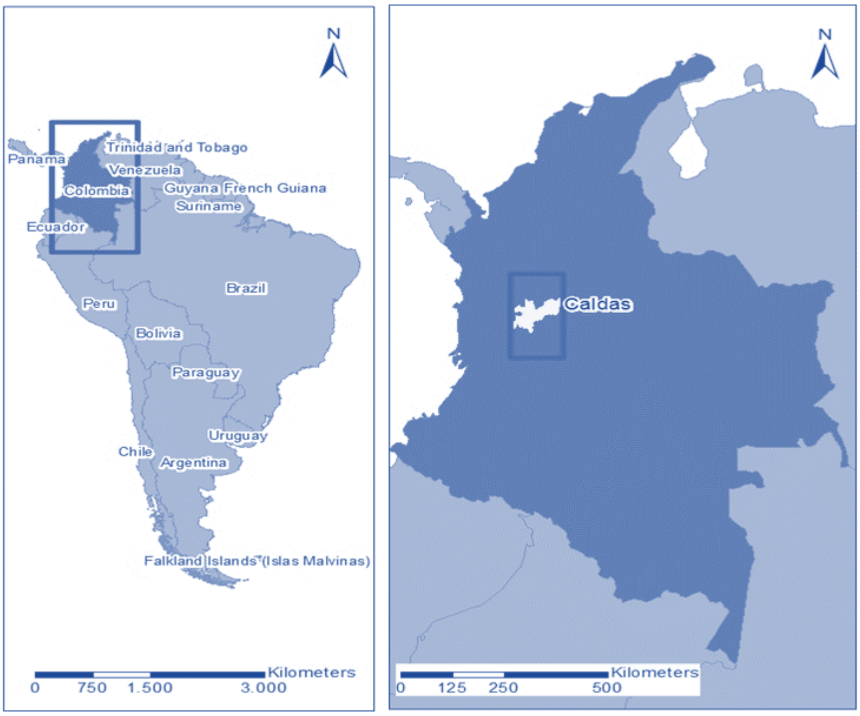

Figure 1 – Geographic location of the area under study.
Source: Own elaboration.

The term "accessibility" might have different interpretations from the transport point of view. In some environments, it is related to the possibility of having adequate infrastructure for people with reduced mobility [1, 2, 3]. In contexts such as territorial planning, it is related to the analysis of the availability of infrastructures that allow communities to access goods and services [4].

Hansen (1959) [5] introduced the first technical definition of the concept of "accessibility" in terms of territorial planning as: "the potential of opportunities for interaction". Currently, it is recognized that the basis of adequate territorial planning is the clear identification of the sectors or areas of a region with the least opportunity to reach a specific activity. It is possible to initially achieve this identification through the application of the graph theory [6] to study the networks in order to determine the condition of the structure, which should be taken into consideration when implementing regional territorial models using equitable and sustainable concepts [7].

An analysis of territorial accessibility seeks to understand the relationship between the various human activities and the availability of physical infrastructures to carry out activities such as transporting products or raw material from a source to a specific destination. It also aims to analyze the impact of investments in infrastructure and in general the impact of such activities on the economy [8]. Transport infrastructures are invaluable components for the promotion and application of territorial development policies [9, 10]. Infrastructures, location of activities, organizational structure of communities and economic structures are the 4 most determining variables in regional development [9, 11]. Different applications of the term have been identified in topics such as modes of transport operation [12], geospatial analysis of economic activities [13], marketing [14], location of services [15, 16], sustainability [17], and altitude zonal altitude models [18], among others.

Research has shown a relationship between GDP and spatial analysis [19] and spatio-temporal analyzes comparing this economic indicator among several regions [20, 21] and transport infrastructures [22]. In addition to this, there are research studies that address this issue in an indirect way and are related to geographic and spatial analysis.

Gross Domestic Product - GDP is the monetary value of all finished goods and services produced in a country or region in a set period of time, usually one year [23]. It is possible to use this value to compare productivity of several regions or countries [24], which is related to economic growth and common well-being [25]. The first GDP analysis carried out in the world date back to 1940 [26], however, the first calculation of this indicator in Colombia was introduced by McGreevey (1975) [27] even though some estimates were proposed in 1955 by Ospina [24, 28]. Studies have shown the relationship between GDP and spatial analysis [19] and temporo-spatial analyzes comparing this economic indicator among several regions [20]. In addition, there are research studies that indirectly address this subject and are related to geographic and spatial analysis and transport infrastructures [22].

On the other hand, there is research that directly relates the conditions of accessibility of a territory to its economic growth. Other research studies have used potential accessibility analyses based on GDP [29] to conclude that the variables accessibility and GDP show a significantly high correlation in the European region and that there is direct connection to transport infrastructure, logistics and economic development [30].

Finally, in the last decades, planning instruments have improved their computing characteristics allowing the analysis of spatial distribution of geographic phenomena, which can be modeled using statistical techniques for data analysis and prediction of variables [31]. It is also possible to relate several geographic databases [32], which is precisely what was intended to be done in this research. The operational characteristics of the transport infrastructure network were related to the GDP values at the municipal level, based on the location of production farms and processing companies through the application of the concepts of territorial accessibility.

2. METHODOLOGY

The methodology is composed of four main stages that follows the diagram shown in Figure 2.

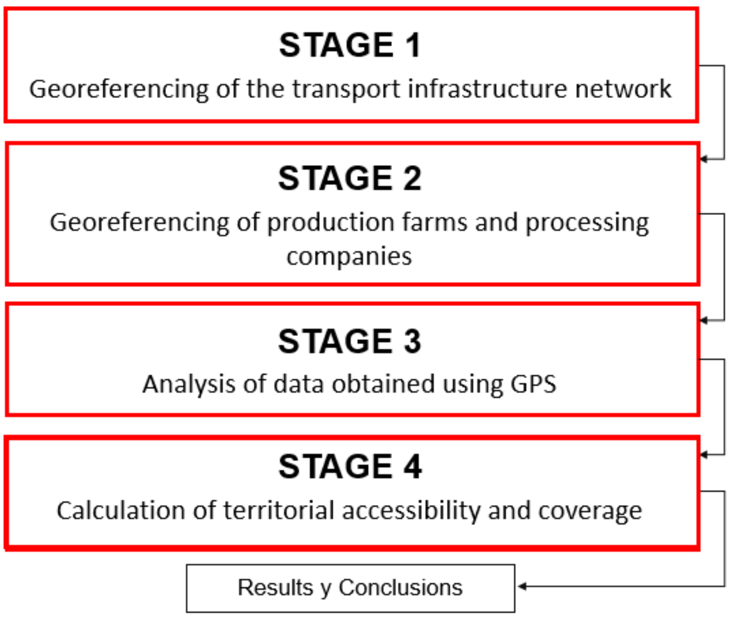

Figure 2 – Methodology flow chart.
Source: Own elaboration.

2.1 Georeferencing of the transport infrastructure network

In this stage, the transportation infrastructure network of the Caldas Department is adjusted taking as a starting point the Regional Road Plan for 2009 [32]. The road layout was rectified by using updated information, and by verifying the data through field trips supported by GPS equipment and the new data was loaded to the Geographic Information System - GIS. There are 7,558 km of roads in the area under study; 390 km (5.2%) are primary roads, 1,394 km (18.4%) are secondary roads and 5,775 km (76.4%) are tertiary roads. A road network index of 0.9 Km / Km2 is calculated using these values. This figure is lower than the established national average of 1.2 Km / Km2. The geographic database used for the accessibility and geostatistical analysis model was consolidated using the previous information.

2.2 Georeferencing of production farms and processing companies

21 production farms located in the mid-west of Caldas and part of Risaralda to the south of the municipality of Villamaría were identified and georeferenced. Only 7 of the 30 municipalities (21%) that make up the area under study have production farms involved in this research. Only one of the 21 farms produces tree tomatos, 4 produce guava, 8 produce blackberry, 3 produce passion fruit and 7 produce lulo. Taiwan and La Judea are two of the 21 farms that produce two types of fruits.

Three fruit processing companies located in two municipalities were analyzed as part of this research. Both municipalities, Manizales and Chinchina, are considered important axes for the regional economy. The processing companies are:

- Frugy S.A.: This Company is located in Manizales and uses the five fruits of interest (tree tomato, guava, blackberry, passion fruit and lulo).
- Alpina S.A.: This Company is located in the village of El Edén in the municipality of Chinchiná and processes blackberry, passion fruit and lulo.
- FLP Procesados S.A.S.: This Company is located in Km 2 via Palestina in the municipality of Chinchiná and uses in its processes four of the five fruits of interest (guava, blackberry, passion fruit and lulo).

2.3 Analysis of data obtained using GPS

Officials of the Colombian Agricultural Research Corporation - CORPOICA visited 21 farms of interest that were initially part of the research and assisted with field data collection related to the operational characteristics of the infrastructure network. Data of the routes were gathered and speeds in the different access roads were estimated. A total of 130,451 points were collected (see Figure 3).

The percentile 85 of the data of each arc was used to calculate operating speeds because there are different factors on the road which are not part of the correct daily operation. The results show that primary roads refer an average speed of 62 km/h, secondary roads 39 km/h and tertiary roads 37 km/h, which makes the relationship between the road category and the reached average speed coherent. However, the speed in the tertiary road network is high because the access points to several farms are close to primary roads. The transport infrastructure network that lacked speed data from GPS equipment was loaded with functional network speeds from the road category.

2.4 Calculation of territorial accessibility and coverage

The speeds obtained through the GPS and the functional speeds were used to calculate territorial accessibility in order to find average travel times and load them into the minimum path algorithm as the impedance variable. The transport infrastructure network used for the calculations consists of 10,866 nodes and 11,749 arcs. The average travel time vector (See Equation (1)) was obtained by generating the impedance matrix and the minimum average travel time matrix, where Tvi= average minimum travel time between node i and the other nodes in the network and n = number of nodes in the network.

$$\overline{T_{vi}} = \frac{\sum_{j=1}^{n} t_{vi}}{(n-1)} \qquad i = 1,2,3,\dots,n\,;\, j = 1,2,3,\dots,\mathrm{n} \tag{1}$$

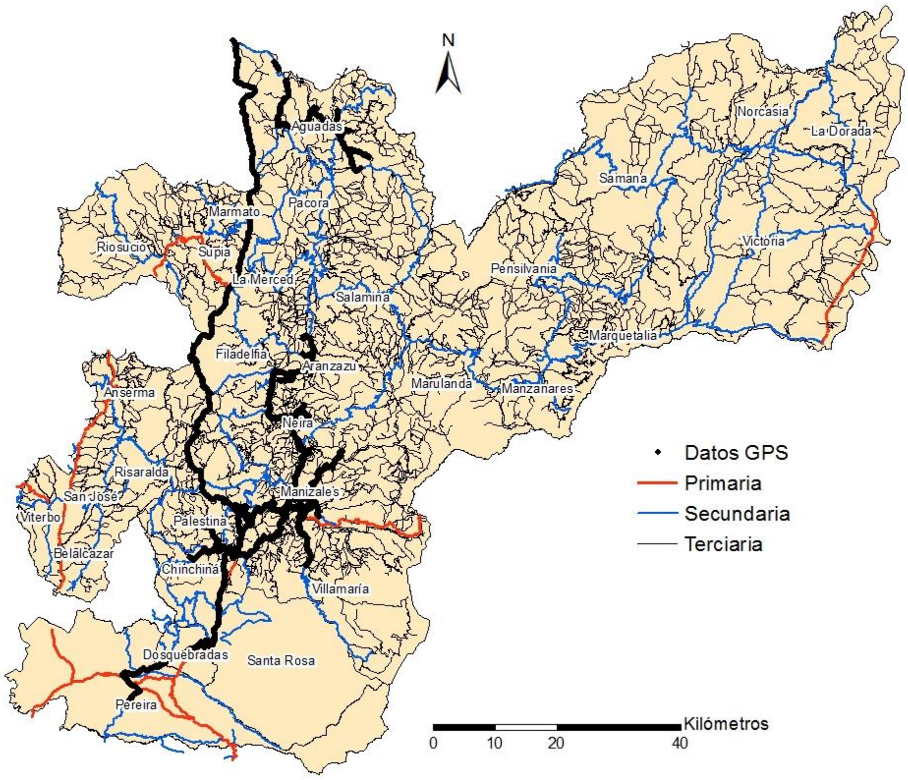

Figure 3 – Data gathered using GPS systems
Source: Own elaboration.

The average travel time vector obtained (n x 1) is related to the geographical coordinates (length and latitude) of each node in order to calculate the isochronous curves of average travel time of the entire area under study. The general formulation used to solve a spatial interpolation problem, as in this case, can be defined as [31, 33]: Given N average travel time values zj (j=1,2,3,…,n) measured in the points rj = xj[1],xj[2], ... , xj[d]) (j=1,2,3,…,n), within a dimensional space d. The search is for a variability function of d F(r) that solves the known points, that is that satisfies the condition present in equation (2).

$$F(\boldsymbol{r}_j) = z_j \quad j = 1, \dots, N \tag{2}$$

This research applies geostatistical and interpolation principles by applying the Kriging model, of which there is detailed description in literature [34, 35]. Still, the basic notions of this model are presented below [31]. The semivariogram γ(h) (equation(3)) can be estimated given data z(ri) and considering as a hyphotesis the existence of stationary, which is related to spatial covariance (equation (4)), where C(0) is the value of the semivariogram tending to infinity (chair). It is possible to choose various functions as theoretical semivariograms (Spherical, exponential, Gaussian, Besse, linear and others) [36]. The quality of the forecasts and the spatial distribution prediction ability become the main strength of the Kriging model, in which it is possible to take the average travel time variable as an additional dimension with zonal or geometric anisotropy or as a combination of the correlation time space with stationarity hypothesis [37, 38].

$$\gamma(\boldsymbol{h}) = \frac{1}{2Var[\{z(\boldsymbol{r}+\boldsymbol{h})-z(\boldsymbol{r})\}]} \approx \frac{1}{(2N_h)\sum_{(ij)}^{N_h}[z(\boldsymbol{r}_i)-z(\boldsymbol{r}_j)]^2} \tag{3}$$

$$\gamma(\boldsymbol{h}) = C(0) - C(\boldsymbol{h}) \tag{4}$$

Three types of analysis applying the Kriging model were carried out in this research. The first analysis was performed from each node to each node to obtain the most accessible place in the area under study. The other two were from each node to the production farms to learn how the community was connected to producers. And the third analysis was performed from each of the nodes to the processing companies evaluating the sites with better accessibility for the delivery of fruits and also the farms with better location regarding these companies. These analyses were subsequently evaluated in relation to the coverage that each isochronous curve refer of the GDP variable of the municipalities, getting GDP1 (for municipalities in lower GDP in the area under study) and GDP6 (for the municipality with the highest GDP in the area under study).

3. RESULTS AND DISCUSSION

3.1. General territorial accessibility analysis

Figure 4 shows the results of territorial accessibility of the area under study obtained after applying the procedure outlined in the methodology. The results show that the most accessible place of the area under study is between the municipalities of La Merced and Salamina with an average time of 2.25 hours to access any other point of the area. The east of Caldas is the sector that refers lower conditions of territorial accessibility with a minimum average travel time of 5.5 hours.

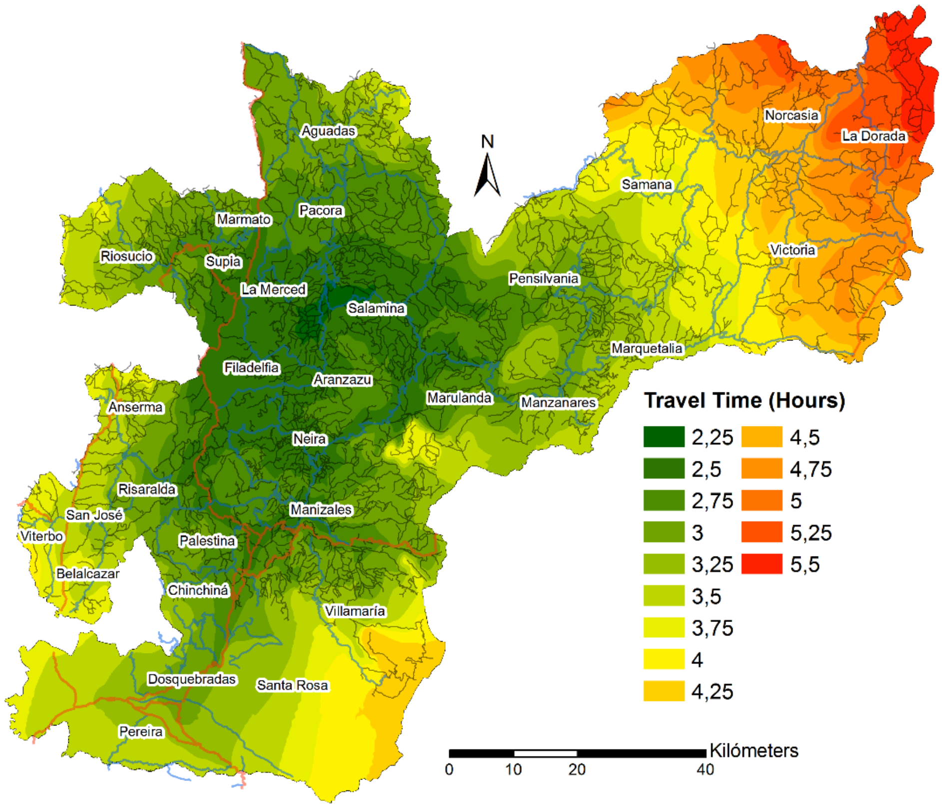

Figure 4 – Analysis of territorial accessibility of the area under study
Source: Own elaboration.

Analysing the relationship between the isochronous curves and the gross domestic product data at the municipal level, it is observed that the municipalities of Manizales, Pereira and Dosquebradas do not have the best territorial accessibility conditions even though they refer the highest GDP value. However, the coverage calculation is performed through a more detailed analysis according to a classification of municipal GDP.

Figure 5 shows the coverage of the GDP ranges analysed. It showed that due to their geographic location, the municipalities to the east of the department, in a GDP1 range, refer the lowest accessibility conditions. On the other hand, the municipalities to the northwest, in a GDP3 range, refer the best accessibility conditions of the area under study.

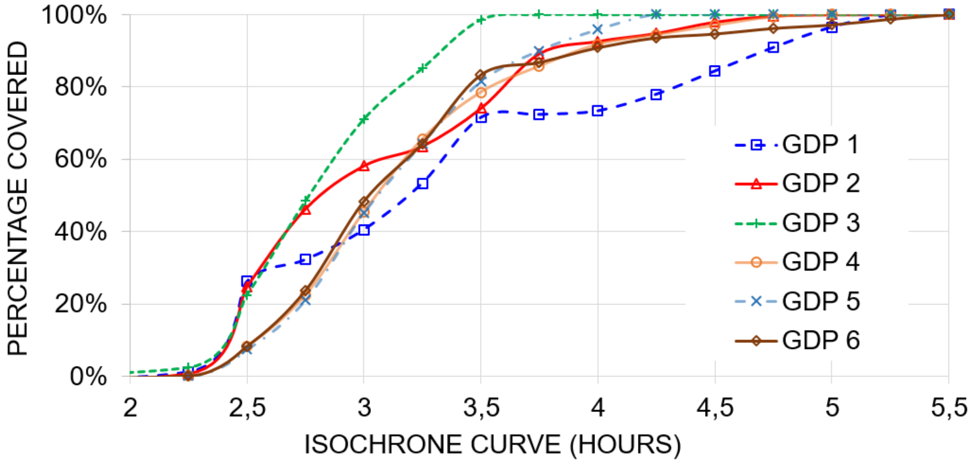

Figure 5 – Coverage GDP ranges of the area under study regarding the isochronous curves of the territorial accessibility analysis.
Source: Own elaboration.

3.2. Analysis of territorial accessibility of production farms

The territorial accessibility of every transport infrastructure network node of the area under study to the production farms of interest was analysed in this stage of the research. The calculation of isochronous curves shows that the sectors with the best accessibility conditions are located in the vicinity of the production farms (see Figure 6), exactly in the mid-west zone. However, the eastern part of the Department of Caldas refers the worst conditions of territorial accessibility to the production farms.

However, it should be noted that La Dorada is a municipality that has economic potential in relation to the Magdalena River and the activities associated with warm weather and low heights, while the dynamics developed in the sector with the best accessibility presents another type of activities. Figure 6 shows the results of coverage of municipal GDP values and the isochronous curves towards the production farms. In general terms, municipalities in the GDP3, GDP5 and GDP6 ranges refer better accessibility conditions.

This situation is contrary to the one found in the general territorial accessibility analysis of the area under study, where GDP5 and GDP6 did not refer adequate accessibility conditions for at least average travel times of up to 3.5 hours. On the other hand, it is observed that GDP4 and GDP1 refer the worst accessibility conditions. This situation is similar to the one found in the global territorial accessibility analysis.

3.3. Accessibility analysis of the processing companies

The location of the three fruit processing companies of interest and their relationship with the transport infrastructure network was evaluated. Figure 7 shows the isochronous curves resulting from the analysis of average travel times of the territory towards the processing companies. It can be observed that the production farms and the areas surrounding the processing companies have the best location regarding the transport network characteristics because the routes are shorter. This is further evidence that the east of the Caldas Department refers the worst conditions of territorial accessibility in relation to the location of the three processing companies.

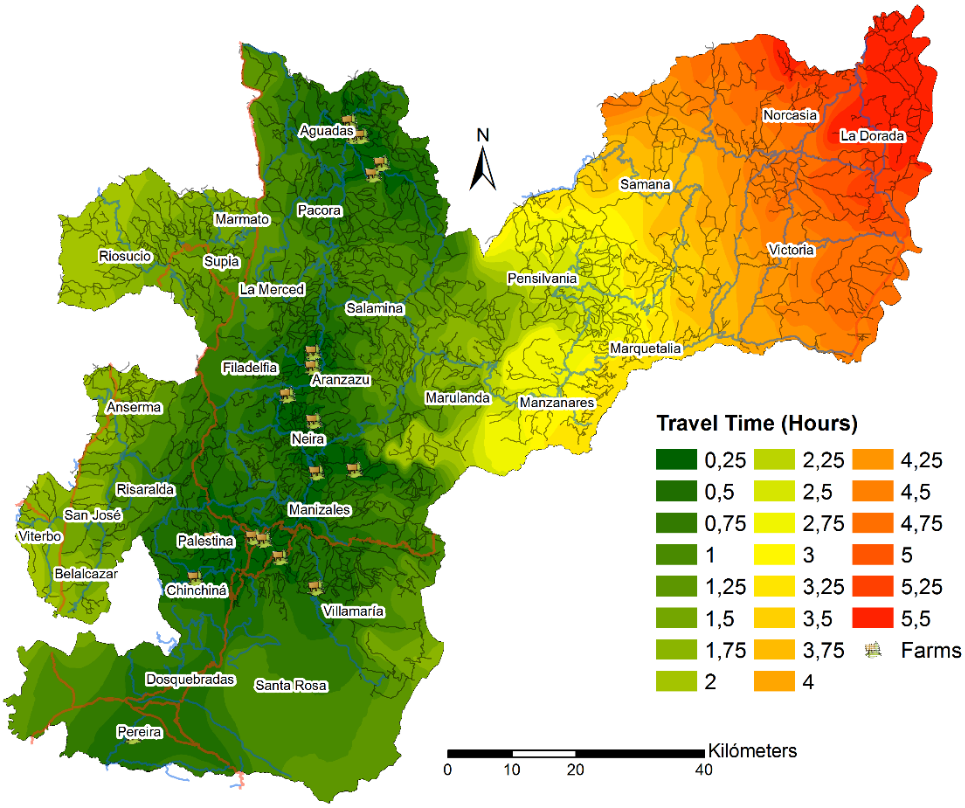

Figure 6 – Analysis of accessibility to the production farms in the area under study.
Source: Own elaboration.

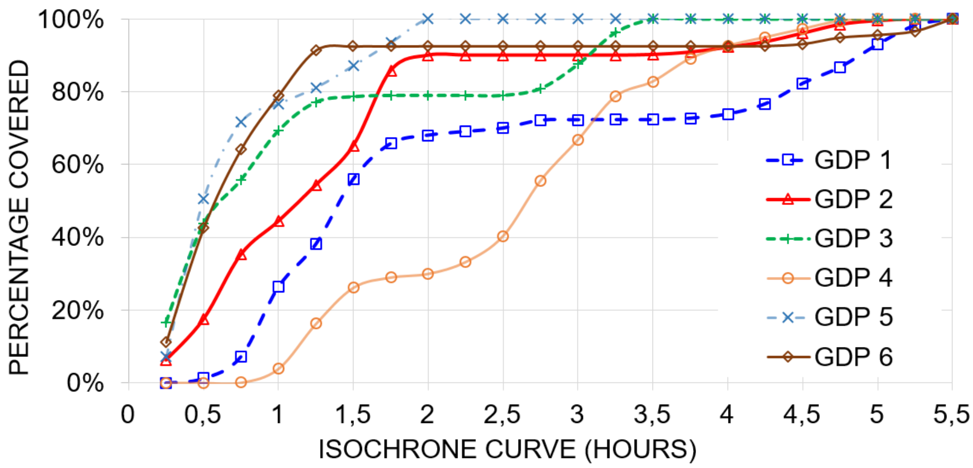

Figure 7 – Coverage per ranges of the GPD of the area under study regarding the isochronous curves of the accessibility analysis of production farms.
Source: Own elaboration.

Figure 8 shows the coverage results of the municipal GDP values and the isochronous curves towards the processing companies. Similar to the results found in the analysis towards the production farms, the municipalities in the ranges of GDP5 and GDP6 refer the best accessibility conditions with the exception of GDP3, which for this particular case, refers more unfavorable accessibility conditions than in the previous analyzed case. Likewise, the GDP4 and GDP1 also refer the worst accessibility conditions. This situation is similar in the analysis of global territorial accessibility. It is evident that the zones of greater production are those that refer better accessibility conditions due to the fact that it takes 5.5 hours to cover 75% of the areas in GDP1 and less than 1.25 hours to cover the same percentage in GDP5 and GDP6.

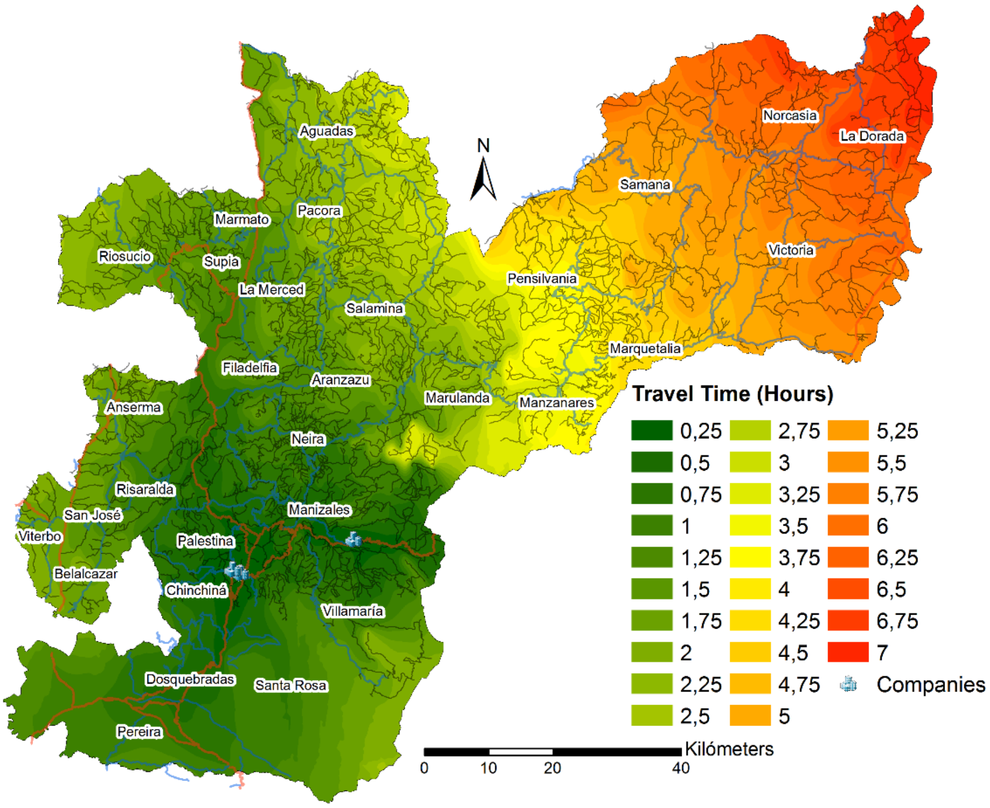

Figure 2 – Accessibility analysis of the processing companies in the area of study
Source: Own elaboration.

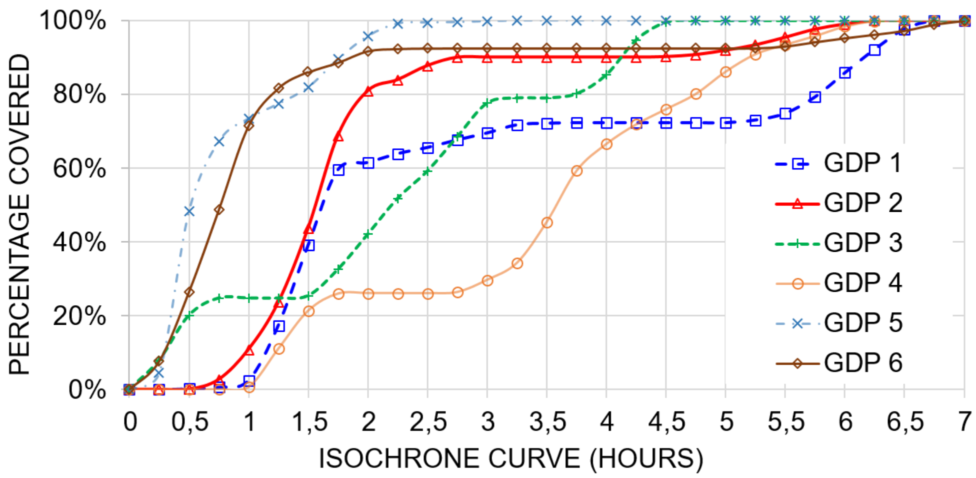

Figure 3 – Coverage by GDP ranges of the area under study regarding the isochronous curves of the accessibility analysis of processing companies.
Source: Own elaboration.

4. CONCLUSIONS

The results show that in the mid- west of the Caldas Department there are enough farms producing the fruits of interest of this research, but to the east the production is very low. Results also show that here is a direct relationship between the location of processing companies and the areas that refer higher GDP. This was not observed in the analysis of production at the municipal level and of the transport infrastructures in general and it shows that either these processing companies take advantage of the possibility of being in a geostrategic location or they drive the production of the areas and sectors with which they have more expeditious communication.

Then, it is reflected that the municipalities with higher GDP get better benefits in relation to the processing companies and to the production farms, because both are located near Manizales and Pereira; the main cities of the area under study. Nevertheless, the government and private companies must ensure a process of inclusion in areas of less production and lower GDP with the aim of improving the quality of life and the access to work of the people residing in these municipalities.

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THE INFLUENCE OF DRYING OF THE ROAD MARKING MATERIALS ON TRAFFIC DURING THE APPLICATION OF MARKINGS

ABSTRACT

The markings on the roadway are one of the most important components of traffic signalization because their position is in the driver's center of attention. They consist of a set of longitudinal and transversal lines, inscriptions and symbols, and are usually made of paint (solvent borne or waterborne), thermoplastic or cold plastic. Previous research focused on the study of the impacts of markings on the driver's behaviour, traffic safety, visibility and durability of the markings and their environmental impact. The goal of this research is to analyse the effects of the drying of material from which the markings are made of on the traffic flow, and thus the traffic safety during the execution, and as such, as known to the authors, it is the first research of that kind focused on the mentioned problematic. The research was carried out by simulating a real traffic situation while renewing the transverse markings in the PTV Vissim simulation tool. The simulation results show the correlation between vehicle flow and the drying time of each material. Also, the flow during the execution of transverse marking with waterborne paint showed to be the highest relative to other materials used (solvent borne paint, cold plastic and thermoplastic).

KEY WORDS

materials for roadway markings making; drying time; traffic safety; traffic flow

1. INTRODUCTION

Road markings represent unique traffic management tools that continuously transmit information about the direction of the traffic movement, the center and edges of the roadway, and general traffic-related information without making the driver turn his attention away from the road [1]. They consist of lines, inscriptions and symbols whose combinations form the surfaces of the traffic infrastructure and provide the driver with visual guidance, especially in conditions of reduced visibility.

The quality of the visual guidance of the driver, in addition to the presence of the markings themselves, is affected by its visibility that determines the life of the markings, which is the function of the material type and a number of other factors related to the geographic-climatic-traffic conditions in which the marking is located. Although there is a number of materials for marking making, which differ between application, lifespan, cost, structural characteristics, etc., the most commonly used is the usage of paints and plastic materials. For this reason, the influence of color and plastic materials on the traffic flow during the application of markings is simulated in this study.

Colors are liquid materials that belong to a group of thin layer materials, and consist of pigments, binders, fillers and solvents. Due to the type of binder, they are divided into solvent-based paints and water-based paints. Solvent based paints use different types of solvents to ensure drying and fixing of the material after application. While packed in the packaging, the solvent-based paint is in liquid state just because of the solvent. After the application of the marking on the roadway, the solvent breaks down (dissolves) the binder and thereby dries the marking that goes into solid state. The speed rate of the binder dissolving affects the drying speed of the marking which usually lasts for 30-40 minutes. Solvents evaporate into the atmosphere as harmful compounds or Volatile Organic Compound (VOC) during the drying process. Typically, the level of VOC paint based on solvent is between 400 and 500 g / L (~ 25%) [2].

On the other hand, water-based paints are very similar to solvent-based paints, although the process itself is somewhat more complicated. For solvent-based paints, by evaporating the solvent, the material is dried and strengthened while in water-based paint the same process is based on water vaporization. The main advantages of water-based paints are related to their low cost and good stability during storage. On the other hand, their main disadvantage is the time it takes for the material to become washout resilient (washout time). Namely, as the mentioned material is water-based, if in a certain time after the material is applied it comes into contact with water, it simply becomes diluted and discolored. Color becomes flush-proof when it is no longer affected by rain, and the time it takes to become so depends largely on the chemical composition, i.e. the binder and additive employed [2]. Depending on the parameters listed above, the paint drying speed varies between 8 and 15 minutes.

Plastic materials are multicomponent and are usually made of synthetic binders, natural and artificial resins, pigments, fillers and pearls [3]. They belong to a group of thick-band markers, and can be placed on a roadway of cold or elevated temperature, and can therefore be divided into two basic groups: cold plastics and thermoplastics.

Cold plastic is a liquid state material to which various thickening additives, depending on the manufacturer, are added. After the initial smoothing, it is applied onto the roadway, where it is solidifying for twenty minutes and can be driven over it afterwards [3].

Thermoplastic is a material that needs to warm up to about 180 ° C before applying. After 15 to 20 minutes of laying on the roadway, the mass hardens and it can normally be ridden over it. Due to the increased material strength and the thickness of the application, the thermoplastic markings have a significantly longer life span than the paint markings. Although the number of factors influences the lifespan of the marking, the typical duration of the thermoplastic marking (thickness of 3 mm) is between two and four years, often longer. In addition to all the above mentioned, a very important feature of thermoplastic materials is that they do not contain solvents, nor do they require their use during application. Also, certain binders used to make thermoplastic materials are from renewable sources making these materials ecologically acceptable.

Most of the current research was focused on the effects of retroreflection (night visibility) of markings on the roadway and their presence on the number of traffic accidents and traffic safety. In the study conducted in Texas, the influence of roadway edge markings on road traffic safety was investigated. On the basis of the comparison of the number of before and after traffic accidents, it has been concluded that in places where there are no boundary markings, there is an increase in the number of traffic accidents [4]. The authors [5] conducted a study on the effect of retroreflection of markings on roadways on the occurrence of traffic accidents during night conditions. According to the collected data, it has been proven that places with a larger retroreflection on the roadway reduce the possibility of traffic accidents during night conditions. In a study published in 2013, the authors analyzed the traffic accidents that occurred during the night: those involving only one vehicle without injured or fatalities, those with fatalities and injuries, and accidents involving a vehicle with fatalities and injuries. The results of the research emphasize the positive influence of the retroreflection of markings on the roadway on general traffic safety [6]. Also, the research done in 2016 shows the persistence of a statistically significant correlation between the retroreflection of markings and the number of traffic accidents. The results of this research, as the authors point out, point to the need of maintenance of the markings on the roadway, because the expected number of traffic accidents is significantly reduced by increasing the retroreflection of the white and yellow fringes [7].

The aim of this research is to analyze the effect on the traffic flow of drying of the material from which the markings are made, and thus on the safety of traffic during the execution. As it is known to the authors, as such, this is the first research focused on the above-mentioned problem. The research was conducted in two parts. The first part is related to the field tests involving the recording of data on the time required for drying of a single material from which transverse markings are made in potentially hazardous locations on the DC 30 state road. The second part of the survey refers to the processing of the data obtained from the field test using the specialized PTV Vissim simulation tool. The PTV Vissim is a microscopic simulation tool for modelling city traffic networks and public transport operations and pedestrian flows [8]. The accuracy and credibility of the simulation model depends mostly on the modelling quality of the vehicle's behaviour in the simulated transport network.

2. METHODOLOGY

The study of the influence on the traffic flow of the drying time of the material for the applying of markings on the roadway was carried out in two parts. In the first part, field tests were conducted to collect data on the drying times of individual materials. As noted above, given the frequency of usage, the study involved four materials: solvent based paint, water-based paints, thermoplastics and cold plastics. The collecting of this data was carried out during the renewal of the transverse markings on two potentially hazardous places on the DC 30 state road. During the application of the markings the weather conditions were satisfactory with relative humidity of 55-75%, air temperature of 11-16 ° C, road temperature 11-18 ° C, wind speeds of 0.5-1.5 m / s, while the application lasted about 6 hours.

The drying time of individual materials was between 2100 and 600 s. The longest drying time was for solvent-based paint (2100 s), then cold plastic and thermoplastics, while the shortest time was recorded for water-based paint (600 s) as shown in Figure 1. The recorded results are consistent with the current knowledge of drying times [9] [10].

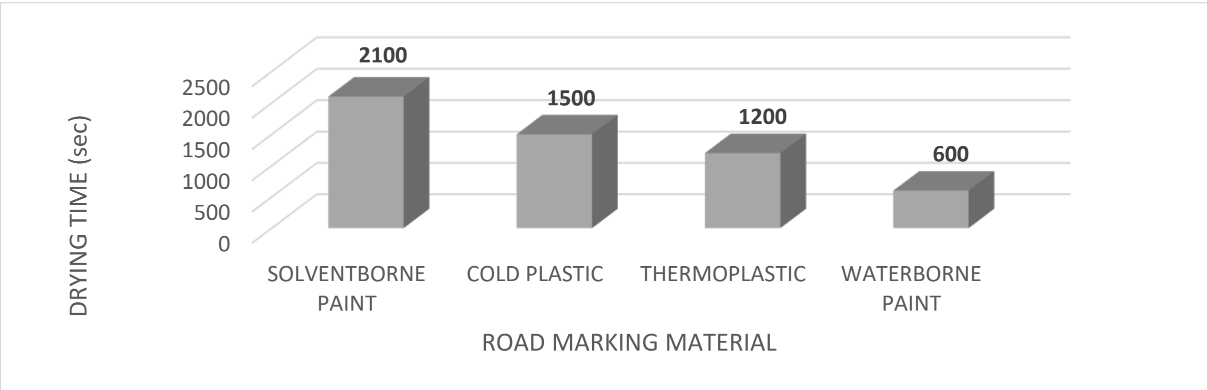

Figure 1 – Drying times of individual materials for driveway markings

The second part of the survey refers to the processing of data obtained from the field, using a specially crafted simulation tool: PTV Vissim. Apart from the drying time of individual materials, the input parameter for the simulation was the amount of traffic on the observed part of the road. According to the statistical data from [11], the average annual daily traffic (PGDP) and average daily traffic for the two locations as well as data on the structure of the traffic flow were obtained. Based on the obtained data, it was established that the traffic load for the first location was 2000 rpm, and the load of 600 rpm was for the second location.

Based on the mentioned, a simulation of the actual locations where data was collected was made as shown in Figure 2.

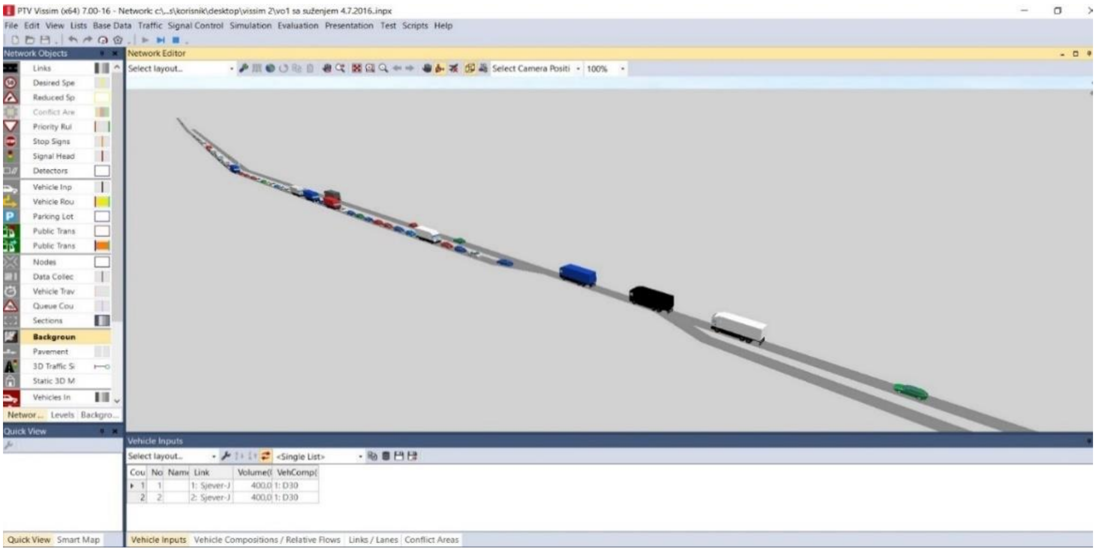

Figure 2 – Simulation performance display

3. SIMULATION RESULTS

After the setting of all parameters of the traffic flow, two potentially dangerous places were simulated on the state road DC 30. The overall simulation process was set to the longest time necessary (40 min) for drying of the material, which is in this case solvent-based paint. The simulation process for each material starts by "warming up" the network which moves in the range from 0 to 3600 seconds. After the initial "warming up" of the network, the closing of one traffic lane is simulated for the time required for each material to dry. The entire simulation process during which vehicle flow is measured ranges from 3600 to 6000 seconds. The vehicle flow was measured on each location separately in both directions (North-South and South-North). The given results for both locations are shown in Tables 1 and 2 as the vehicle flow through the observed section in a 40-minute time period (Vehicles / 40 min). The vehicle flow for a given type of material is shown graphically in Figures 3 (first test site) and 4 (second test site).

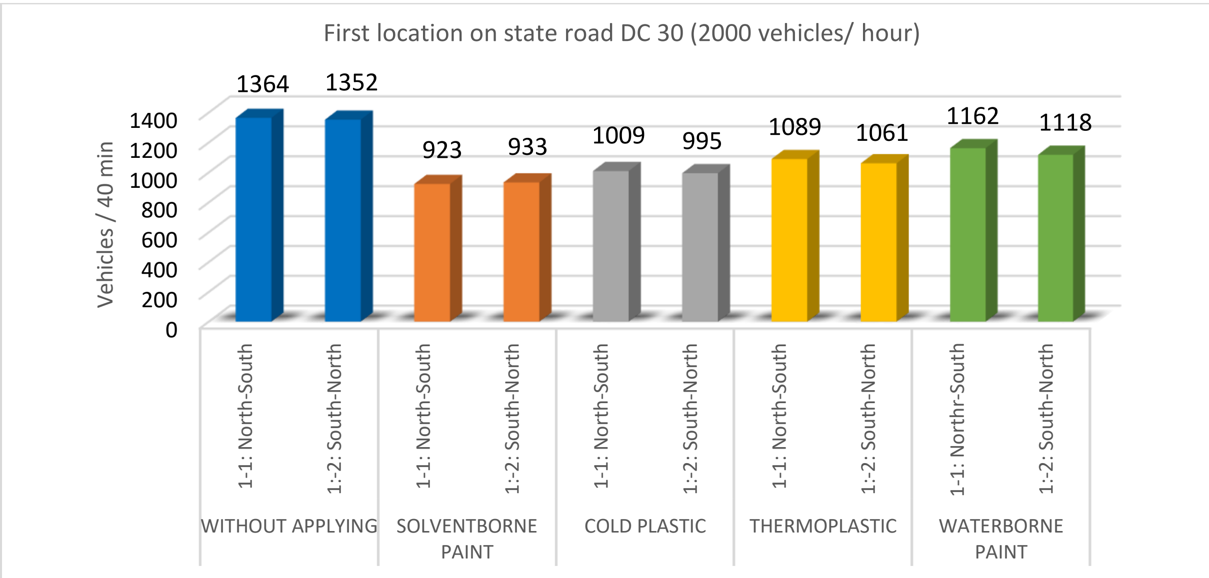

Figure 3 – Vehicle flow depending on the time necessary for the drying of a certain driveway marking material (first test site)

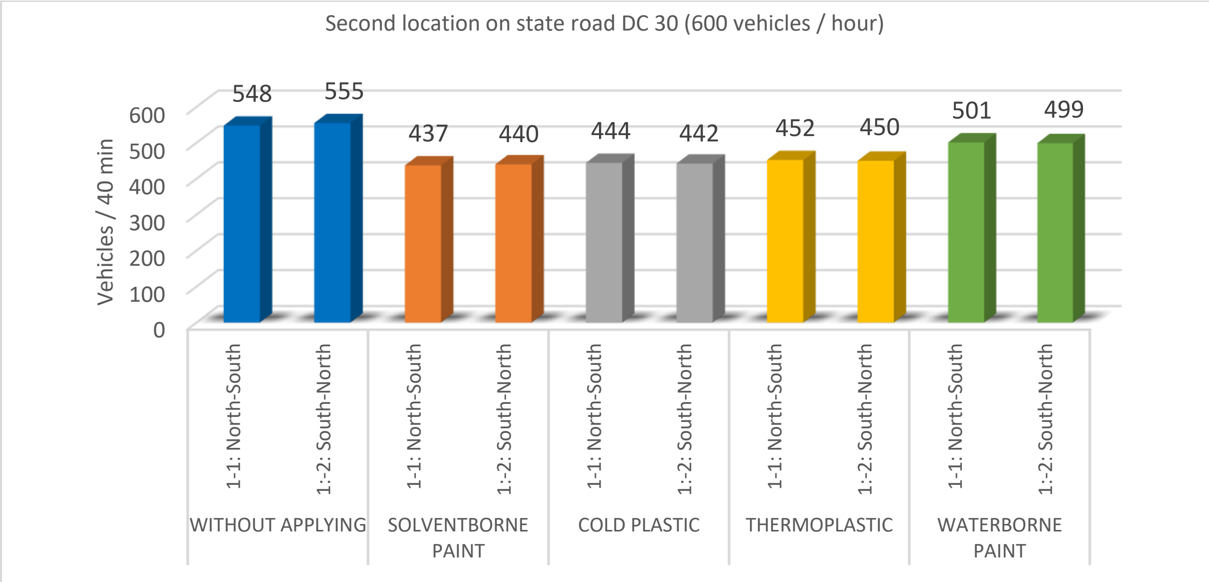

Figure 4 – Vehicle flow depending on the time necessary for the drying of a certain driveway marking material (second test site)

Based on the obtained data, it is apparent that the flow of vehicles at the second testing location depended on the time required for each material to dry is almost equable. A slight deviation was observed with water-based paint, used as the material used to make the markings on the roadway, where the vehicle flow recorded was slightly higher than with previous materials. By analyzing the data obtained at the first location, it can be seen that the movement of vehicles during the execution of the markings depends not only on the time required for the drying of the individual material but also on the number of vehicles which constitute the traffic load on the observed part in a unit of time. As the number of vehicles rises and the drying time of the material is longer, the vehicle flow in the unit of time is smaller with the appearance of larger waiting periods. The usage of water-based showed as an optimal solution in situations with increased vehicle flow on the observed part, with which the flow of vehicles was considerably higher than with the other materials. The difference in vehicle flow at the first site relative to the time of drying of each material is shown in Figure 5 (the percentage for each material represents the realized vehicle flow in relation to the flow obtained without barriers). According to the data, there is a difference in the vehicle flow compared to the applied material and by applying the water-based paint markings the vehicle flow, compared to the other observed materials, increases by an average of almost 15%. The flow with water-based paint is lower by 16%, with thermoplastic 21%, with cold plastics 26%, and with solvent-based color by as much as 32% versus the barrier-free flow.

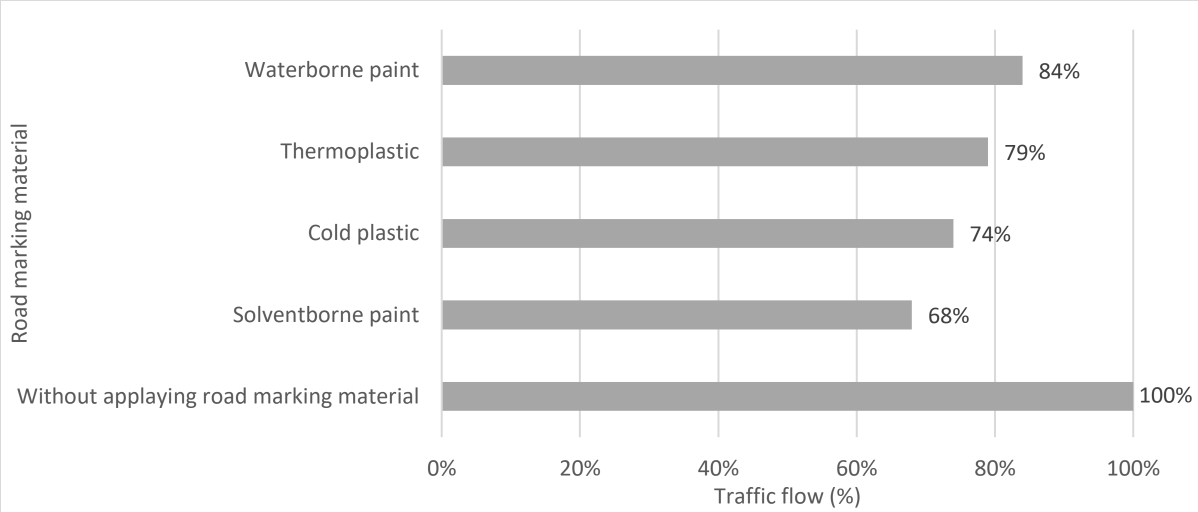

Figure 5 – Vehicle flow at the first site (percentage) in relation to the drying time for each individual material

The vehicle flow ratio obtained on the basis of each applied material is shown in Figure 6. Solvent-based paint was found to be the worst with an 8% lower flow rate compared to cold plastics, 16% thermoplastic and even 23% compared to water-based paint. Thermoplastics turned out to be, with water-based paint, the best material with a 7% higher flow compared to cold plastics and 21% lower flow compared to no barriers flow, and 6% less than water-based paint.

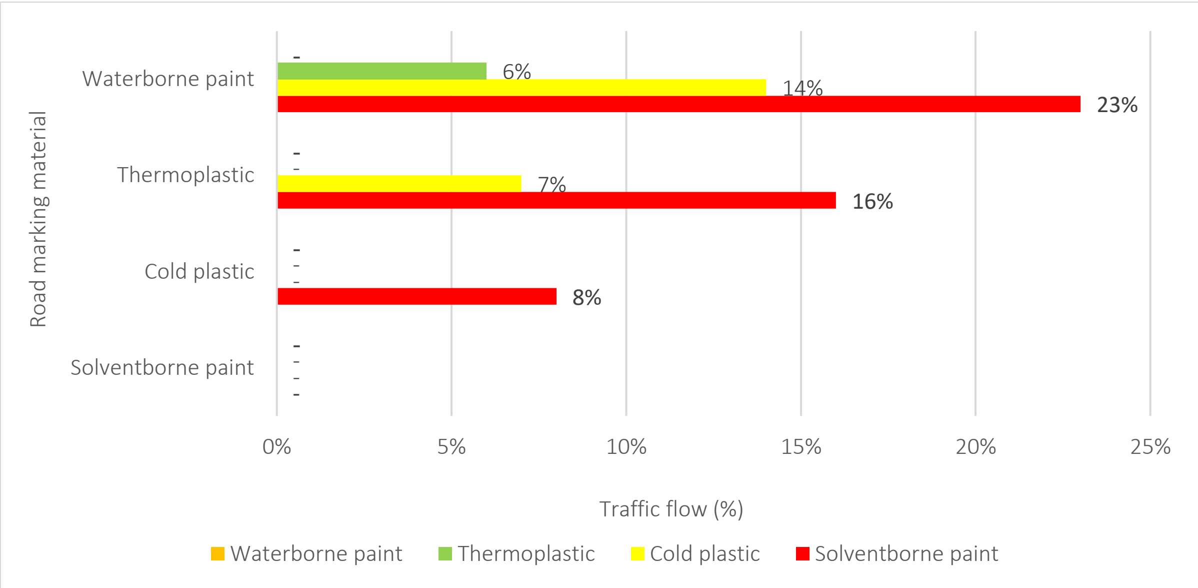

Figure 6 – Vehicle flow at the first test site (percentage) in relation to the used material

The difference in vehicle flow at the second location relative to the time of drying of each material is shown in Figure 7. The analysis of the data obtained can be used to determine almost the same flow for solvent-based paint, cold plastics and thermoplastic, which is 80%. Again, the highest flow was obtained by applying water-based paint, 91% in comparison to the flow obtained without the barrier simulation. It is characteristic for this location that due to reduced traffic loads (600 vehicles / h), solvent-based paint, cold plastics and thermoplastics (although the drying time of the material is different) have almost the same vehicle flows, while water-based paint gives better results.

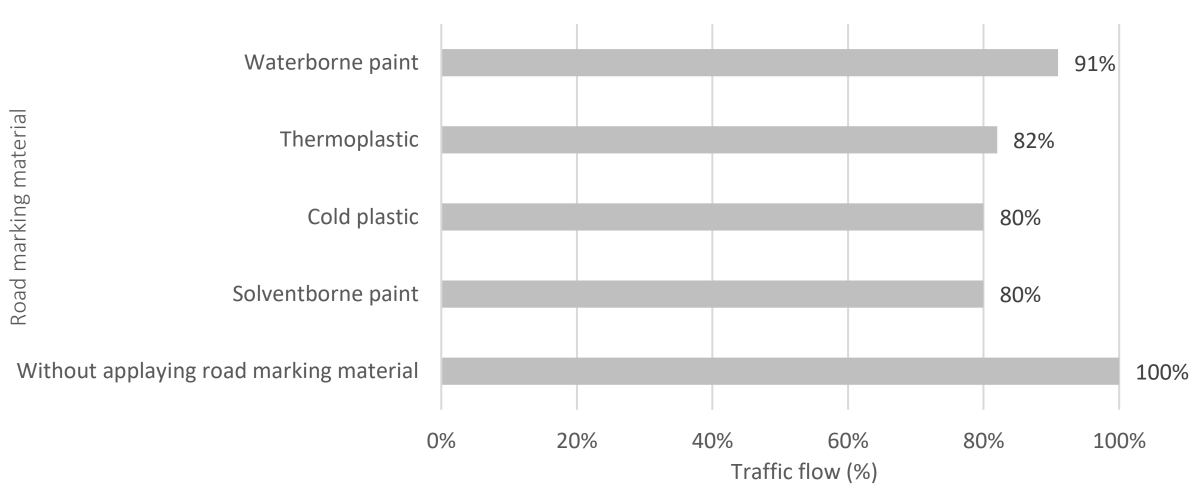

Figure 7 – Vehicle flow at the second site (percentage) in relation to the drying time for each individual material

The flow rate of vehicles at the second location for the testing of each applied material is shown in Figure 8. The solvent-based paint still represents the material with the smallest vehicle flow, with a difference of 14% compared to the water-based paint. Thermoplastic shows an 11% lower vehicle flow compared to water-based paint, but a 2% higher flow compared to cold plastic and 3% compared to solvent-based paint. Cold plastic has a vehicle flow rate of 1% higher than the solvent-based color.

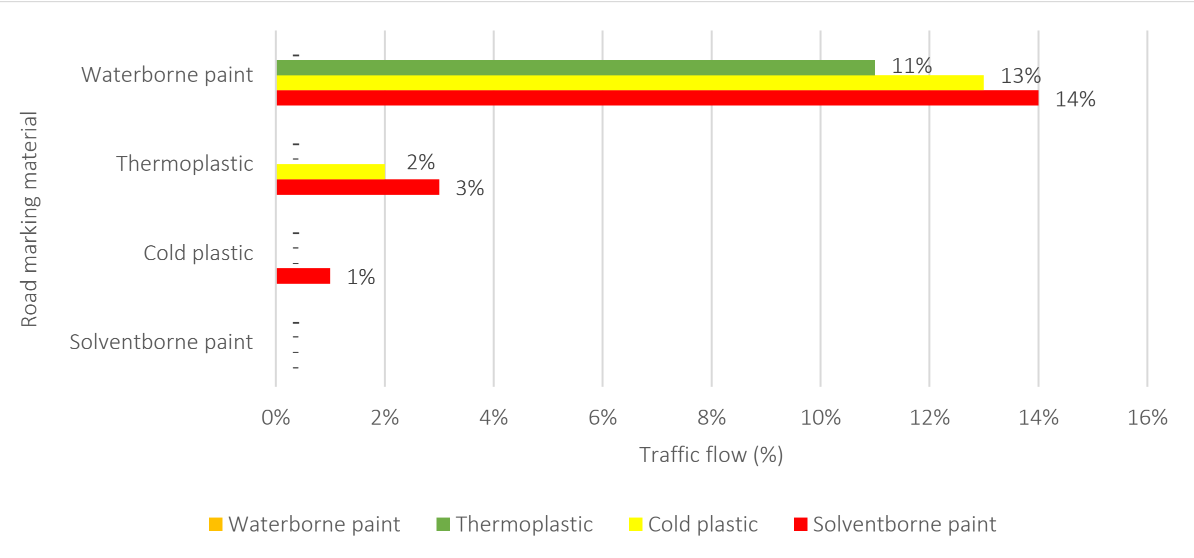

Figure 8 – Vehicle flow at the second test site (percentage) in relation to the used material

4. CONCLUSION

Experience and science confirm that high-quality traffic signalling with high reliability can be achieved with small resources thanks to the modern technology of creating traffic signalization. The effective solving of certain local traffic problems can have a significant qualitative impact on the flow of the entire traffic network, on the increasing of security in the narrower and broader zone, and on motivating the participants in traffic to cooperate [1].

This paper analyzes the influence on the traffic flow of the time required for drying of individual materials for marking on the roadway. By simulating at two potentially hazardous locations on the state road DC 30, transverse markings of different types of materials were applied along with the known drying time for each material and with the traffic load for each tested location. The results obtained by simulation confirm the correlation between the vehicle flow and the drying time of the individual material at a higher traffic intensity.

By comparing materials at both locations, it can be concluded that water-based paint ensures, in comparison to other materials, the best traffic flow during application due to shorter drying times. At the first test site (2000 vehicles/h), vehicle flow is higher by 6% than with thermoplastics, 14% compared to cold plastics and 23% compared to solvent-based paint. At the second test site (600 vehicles / h) water-based paint shows a vehicle flow higher by 11% than with thermoplastics, 13% compared to cold plastics and 14% compared to solvent-based paint. In other words, applying water-based markings causes the least disturbance in the traffic flow, and thus increases the traffic safety when applying the markings. On the other hand, solvent-based paint had the greatest disturbance of traffic flow. Cold and thermoplastics had relatively similar results with the mild advantage of thermoplastics.

From all of the mentioned, it can be concluded that water-based paint affects and obstructs traffic flow the least during application. In addition, with their modernization over the last decade, the durability of water-based paint has been prolonged considerably and recent studies have found that the durability of these markings is over 2 years with high levels of night visibility [12]. Although slightly shorter in durability compared to plastic materials, water-based paint compared to cold and thermoplastic is considerably cheaper. Also, since they are water based, water-based paints represent the most environmentally friendly material for roadway marking with a reduction of harmful VOC emissions to 93% [13].

By comparing all the mentioned facts, water-based paint is shown to be an efficient material for marking the roadway with the material's satisfactory durability and cost-effectiveness, providing satisfactory negative impact on the traffic flow during application and by minimizing at the same time the adverse environmental impact, which makes them a worthy substitution and competition to plastic materials.

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A SURVEY OF NETWORK SIMULATION TOOLS IN THE FUNCTION OF INFORMATION AND COMMUNICATIONS NETWORKS

ABSTRACT

Nowadays, the network simulation tools represent an inevitable tool in studying the area of information and communication networks (ICN) and network technologies (ICNT). Network simulation tools make it possible to test complex networks and network devices and to validate the data links and to check certain network protocols or specific network algorithms. In this paper, a comprehensive survey on current relevant network simulation tools is presented. Focus has been placed on the cumulative analysis of the past research and the application of network simulation tools for the scientific needs from a wider area of ICNT. The analysis included relevant network simulation tools (ns-2, ns-3, GNS3, OMNET++, OpenStack, Mininet, Riverbed Modeler, QualNet and J-Sim) and the available research related to ICNT. Several available relevant science bases served as the research space. The contribution of this paper is reflected in the positioning of the network simulation tools regarding the purpose, subareas of research and practical requirements.

KEY WORDS

network simulation; network simulation tools; information and communication networks; network technologies;

1. INTRODUCTION

Basically, network simulators represent a software which serves to forecast the operation of different types of information and communications networks (ICN). The main motivation behind the development of network simulators lies in the improvement of reliability and reduction of costs in developing new network technologies. Simulation is a term that describes any process used to imitate or represent the real process in a certain controlled environment, usually in a simplified manner. A simulator is the term for an application or any other mechanism representing an actual process. Since it is often difficult or practically impossible to purchase a sufficient quantity of high-quality and advanced network equipment for the research needs, the network simulators are used.

Network simulation is the most commonly used methodology to estimate different network topologies not needing implementation in the actual environment. Network simulation is used in different areas, by academic researchers, industrial development, to analyse, design, simulate and verify the performance of different network theories and hypotheses [1].

The aim of the research was to determine the applicability of single analysed network simulator according to independently defined topical groups (areas i.e. key words), for which available science bases were used. The motive to study this topic is related to the lack of availability of the taxonomy of network simulators, i.e. clear classification and applicability of network simulators for different areas of research within the information and communication network technologies. The background for data collection and decision-making on the applicability of certain network simulators was in the relevant available science bases (four bases): Elsevier's Scopus, IEEE Xplore Digital Library, Science Direct and Web of Science Thomson Reuters. The frame of research is related to network simulators that have been recognized as the most applicable ones: ns-2, n2-3, GNS3, OMNET++, OpenStack, Mininet, Riverbed Modeler, QualNet and J-Sim. In this paper, the purpose was not to analyse all the available network simulators, but rather only those that are mostly used i.e. those that are characteristic for the studied area. When analysing the available scientific papers, the areas from the information and communication network technologies have been recognised. These are most researched by the authors using selected network simulators. In this way the following terms have been highlighted: QoS, VoIP, Wireless, Security, IoT, SDN, Cloud and LTE. It is with special consideration that the quantity of the published scientific papers has been analysed, according to the years of publication (from the first publication of the topical work to 31 December 2016).

Section 2 gives an overview and review of the current research from the analysed area and a functional description of the carried-out research. Section 3 provides an overview of the selected network simulators with their brief descriptions. Section 4 contains an analysis of using network simulators regarding areas / key words based on the available science bases. The conclusion (Section 5) synthesizes all knowledge acquired by the carried-out research and gives guidelines and plans for further research.

2. OVERVIEW OF CURRENT RESEARCH AND DESCRIPTION OF THE CARRIED-OUT RESEARCH

The studies about network simulators at the world level are numerous, particularly in the last decade [1], [2], [3], [4]. They study various types of network simulators and their characteristics that affect the analysis of different types of ICN. Network simulators can be compared on the basis of different characteristics: range (from the very simple to the very complex), specifying the nodes and the links between those nodes and the traffic between the nodes, specify everything about the protocols used to handle traffic in a network, graphical applications (allow users to easily visualize the workings of their simulated environment), text-based applications (permit more advanced forms of customization) and programming-oriented tools (providing a programming framework that is customized to create an application that simulates the networking environment to be tested) [2], [5]. Network simulators can also be compared according to the following features: language supported, platform, cost & licenses, network support type, user interface, CPU utilization, memory usage, computational time, scalability, Application Programming Interface (API), interaction with real-time system, etc.

According to the characteristics of network simulators different authors consider their advantages and drawbacks [1], [3], [5]. The study of advantages and drawbacks is most often partial for a certain group [5], [6], [7] or several simulators [8], [9], [10].

A large number of studies are available, which use a certain network simulator or several ones in order to analyse and compare different segments in the area of information and communications networks (e.g. wired and wireless computer networks, etc.) [11], [12]. Currently, there are many network simulators that have different features in different aspects.

By studying the mentioned science bases and carried-out analysis, eight fields were isolated that were recognized as being significantly represented within the used science bases: QoS (Quality of service), VoIP (Voice over Internet Protocol), Wireless, Security, IoT (Internet of Things), SDN (Software-Defined Networking), Cloud computing and LTE (Long Term Evolution). While searching the science bases, apart from the mentioned areas – key words, other synonyms or similar key words were also used, that are used in a certain area, e.g. Wireless – Wi-Fi, IoT – IoE (Internet of Everything), etc. In searching the papers, data processing and interpreting the obtained results it is necessary to take into consideration the overlapping of the papers regarding the use of more key words in the same scientific paper. Figure 1 shows the analysed elements of the carried out research (through three connected steps).

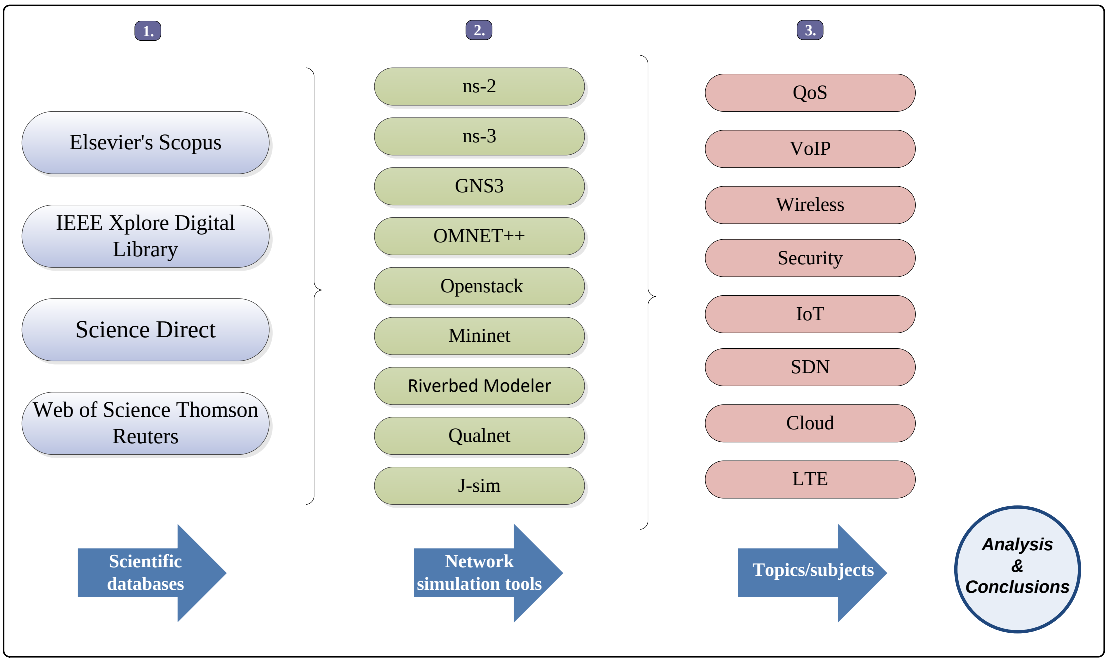

Figure 1 – Selected elements of the carried-out research

Further in the text a brief overview of the analysed network simulators and a comparative analysis of their main features is given.

3. OVERVIEW OF NETWORK SIMULATORS

For the requirements of this research an analysis has been previously made on the current network simulators and nine most represented network simulators in the field of information and communications network technologies have been isolated. Further in the text the analysed network simulators are briefly described.

3.1 ns-2

Ns-2 (network simulator-2) [13] is a simulator designed for research in computer communication networks. Ns-2 is the second version of ns (Network Simulator), originally based on REAL network simulator. It is an open source, discrete event network simulator. Ns-2 is used for the simulation of network protocols with different network topologies. It is capable of simulating wired as well as wireless networks. Ns-2 was built in C++ and provides the simulation interface through OTcl, an object-oriented dialect of Tcl. The user describes a network topology by writing OTcl scripts, and then the main NS program simulates that topology with specified parameters. In ns-2, network animator (NAM) is used for the graphical view of the network. Ns-2 is the most common and widely used network simulator for research work [1], [13].

3.2 ns-3

Ns-3 (network simulator-3) is a simulator similar to ns-2 that is primarily used for research and education. Development of ns-3 began in July 2006 and the first public version was released in June 2008. Ns-3 is built using C++ and Python scripting as its core languages. Ns-3 is supported by three primary platforms (Linux, macOS and FreeBSD). Ns-3 is open-source discrete-event network simulator that encourages the development of simulation models which are sufficiently realistic to allow ns-3 to be used as a real-time network emulators. Ns-3 supports research on both IP and non-IP based networks, but mostly Wi-Fi, WiMAX, or LTE models and a variety of static or dynamic routing protocols. Ns-3 also has network animator (nam) and emulation mode for integration of real networks, which ns-2 does not have. Ns-3 is made to replace the current ns-2; however, ns-3 is not an updated version of ns-2 since that ns-3 is a new simulator and it is not backward-compatible with ns-2 [14].

3.3 GNS3

GNS3 (Graphical Network Simulator 3) is used to emulate, configure, test and troubleshoot virtual and real networks. It is a network software emulator first released in 2008. It supports simulation from simple and small networks to big and complex networks. The number of virtualized network devices is growing and includes e.g.: Cisco virtual switches, Brocade vRouters and Cumulus Linux Switches. GNS3 allows you to visualize, plan, test and troubleshoot network environments across any vendor platform at scale - without the need to directly interact with the network hardware. With the intuitive graphical interface, users can seamlessly connect all types of virtual interfaces to compose a real representation of networks [15].

3.4 OMNET++ (Optical Micro-Networks Plus Plus)

OMNeT++ is a public-source, component-based network simulator with GUI support. Its primary application area is communication networks. OMNeT++ has generic and flexible architecture which makes it successful also in other areas like the IT systems, queuing networks, hardware architectures, or even business processes as well. Since OMNeT++ is designed to provide a component-based architecture, the models or modules of OMNeT++ are assembled from reusable components. Modules are reusable and can be combined in various ways which is one of the main features of OMNeT++. As the key feature of OMNeT++, the simulation kernel C++ class library consists of the simulation kernel and utility classes which are used to create simulation components. The library also includes the infrastructure to assemble simulations from different components. Beside these, there are also runtime user interfaces or environments for simulations, and tools to facilitate and manage simulations [3], [16].

3.5 OpenStack

OpenStack software controls large pools of compute, storage, and networking resources throughout a data centre, managed through a dashboard or via the OpenStack API. OpenStack works with popular enterprise and open source technologies making it ideal for heterogeneous infrastructure. OpenStack began in 2010 as a joint project of Rackspace Hosting and NASA. It is a free and open-source software platform for cloud computing, mostly deployed as an infrastructure-as-a-service (IaaS). The software platform consists of interrelated components that control diverse, multi-vendor hardware pools of processing, storage, and networking resources throughout a data centre [17].

3.6 Mininet

Mininet is a network emulator which creates a network of virtual hosts, switches, controllers, and links. Mininet hosts run standard Linux network software, and its switches support OpenFlow for highly flexible custom routing and Software-Defined Networking. Mininet supports research, development, learning, prototyping, testing, debugging, and any other tasks that could benefit from having a complete experimental network on a laptop/other PC. Mininet creates a realistic virtual network, running real kernel, switch and application code, on a single machine (VM, cloud or native). It provides an easy way to get correct system behaviour (and, to the extent supported by your hardware, performance) and to experiment with topologies [18].

3.7 Riverbed Modeler (Opnet Modeler)

Riverbed Modeler was formerly referred to as Opnet Modeler Suite (Optimized Network Engineering Tools). This simulator is developed by OPNET technologies, Inc. Opnet had been originally developed at the Massachusetts Institute of Technology (MIT). In October 2012, Opnet was acquired by Riverbed Technology. It is extensive and powerful enthusiasm software bearing in mind broad variety of possibilities to simulate entire heterogeneous networks past various protocols. Riverbed Modeler comprises a suite of protocols and technologies with a sophisticated development environment. By modelling all network types and technologies (including VoIP, TCP, OSPFv3, MPLS, IPv6, and more), Riverbed Modeler analyses networks to compare the impact of different technology designs on end-to-end behaviour. Modeler lets you test and demonstrate technology designs before production; increase network R&D productivity; develop proprietary wireless protocols and technologies; and evaluate enhancements to standard-based protocols [19].

3.8 QualNet

The QualNet communications simulation platform is a planning, testing and training tool that "mimics" the behaviour of a real communications network. Simulation is a cost-effective method for developing, deploying and managing network-centric systems throughout their entire lifecycle. Users can evaluate the basic behaviour of a network, and test combinations of network features that are likely to work. Network simulator software tool provides a comprehensive environment for designing protocols, creating and animating network scenarios, and analysing their performance [20].

3.9 J-Sim

J-Sim, a Java-based simulation and animation environment supporting Web-Based Simulation, a rapidly emerging area of simulation research and development. J-Sim provides a loosely-coupled component architecture, i.e., a component can be individually designed, implemented and tested independently. OpenStack is a free and open-source software platform for cloud computing, mostly deployed as an infrastructure-as-a-service (IaaS). The software platform consists of interrelated components that control diverse, multi-vendor hardware pools of processing, storage, and networking resources throughout a data centre. Users either manage it through a web-based dashboard, through command-line tools, or through a RESTful API [21].

Table 1 shows a comparison of analysed Network Simulation tools based on the main features.

Table 1 – Comparison of analysed Network simulation tools

Network Simulation tools / Main features	Released at	Language supported	Platform	Availability	User interface
ns-2	1996	C++, Otcl, Tcl script	Linux, Unix, Windows, Cygwin	Open source	Command Line Interface
ns-3	2008	C++, Python	Linux, Unix, Windows	Open source	Command Line Interface
GNS-3	2008	Python	Linux, Windows, MAC OS	Open source	Command Line Interface, Graphical User Interface
OMnet++	1997	C++	Linux, Unix, Windows, MAC OS	Open source	Graphical User Interface
OpenStack	2010	Python, Kombu, SQLAlchemy	Linux, Windows, MAC OS	Open source	Command Line Interface, Graphical User Interface
Mininet	2011	Python	Linux, Unix	Open Source	Command Line Interface
Riverbed Modeler	1987	C (C++)	Linux, Solaris, Windows	Commercial	Graphical User Interface, Command Line Interface
QualNet	2001.	Parsec C++	Linux, DOS, Unix, MAC OS, Windows, Solaris	Commercial	Graphical User Interface, Command Line Interface
J-Sim	2001	Java, Tcl	Windows, Linux, Matlab	Open source	Graphical User Interface, Command line interface on Linux

Source: Made by the authors according to [1], [13], [14] and [15]

Section four provides an analysis of using network simulators according to the analysed science bases.

4. ANALYSIS OF THE USAGE OF NETWORK SIMULATORS

By analysing the available science bases the number of scientific papers that use certain network simulators (first and second step of research) has been determined. Figure 2 shows the number of scientific papers related to the application of network simulators in the wider information and communication technology (ICT) area in the science base of papers Elsevier's Scopus, from 2000 to 2016. The network simulator ns-2 has been represented in 6,224 scientific papers, Riverbed Modeler in 3,056 papers, and ns-3 in 1,300 papers.

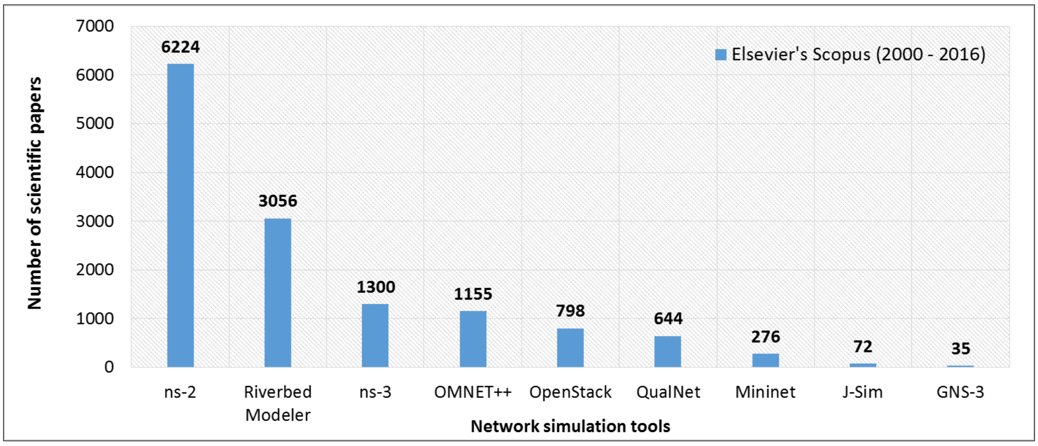

Figure 2 – The number of scientific papers related to the application of network simulators in the ICT area in publications of Elsevier's Scopus from 2001 to 2016. Source: [22]

Figure 3 shows the number of scientific papers related to the application of network simulators in ICT area in the science base of papers IEEE[1] Xplore Digital Library, from 1995 to 2016. Network simulator ns-2 has been represented in 3,206 scientific papers, Riverbed Modeler in 1,885 papers, and ns-3 in 667 papers.

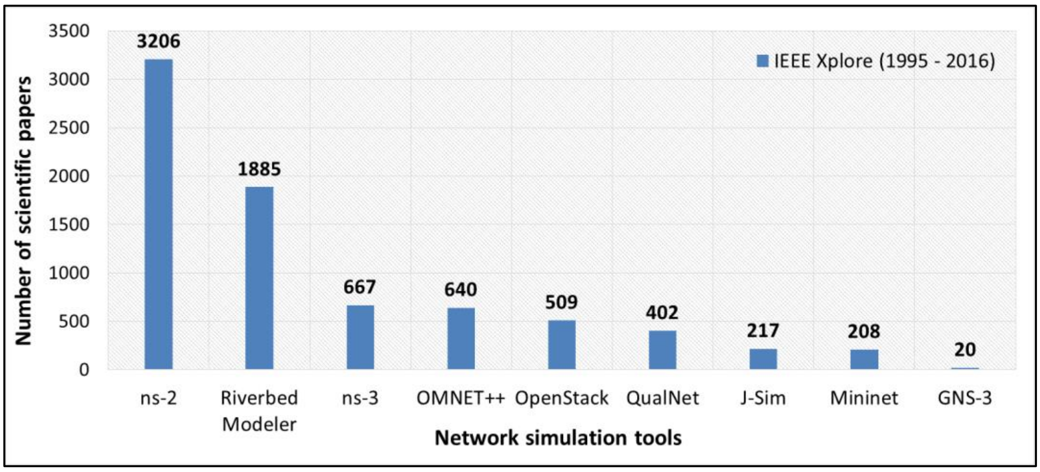

Figure 3 – The number of scientific papers related to the application of network simulators in ICT area in publications IEEE Xplore Digital Library from 1995 to 2016. Source: [23]

Figure 4 presents the number of scientific papers related to the application of the network simulators in the area of ICT in publications of Science Direct, from 2000 to 2016. Network simulator ns-2 uses 877 scientific papers, Riverbed Modeler 873 papers, and OMNET++ 605 papers.

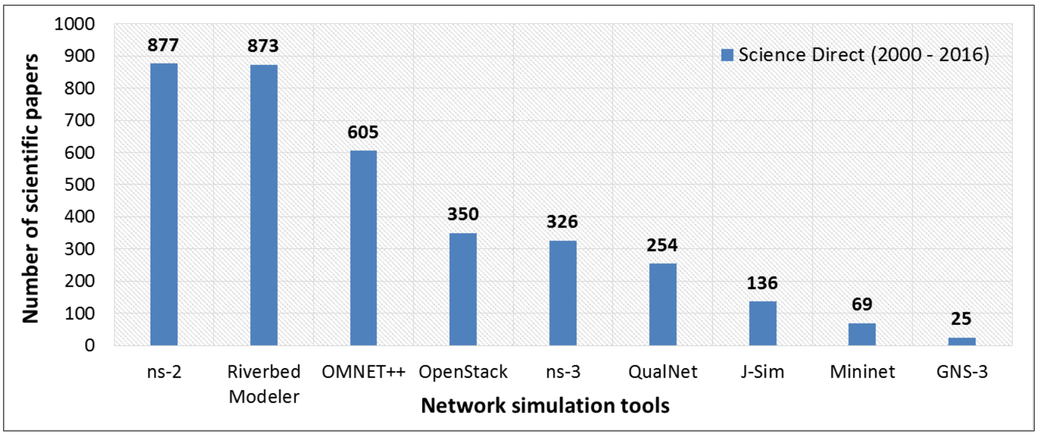

Figure 4 – The number of scientific papers related to the application of network simulation tools in the field of ICT in the publications Science Direct from 2000 to 2016; Source: [24]

Figure 5 shows the number of scientific papers related to the application of network simulation tools in the area of ICT in the science bases of Web of Science Thomson Reuters, from 1996 to 2016. Network simulation tool ns-2 is represented in 3,589 scientific papers, Riverbed Modeler in 1,909 papers, and OMNET++ in 695 papers.

[1] *Institute of Electrical and Electronics Engineers*

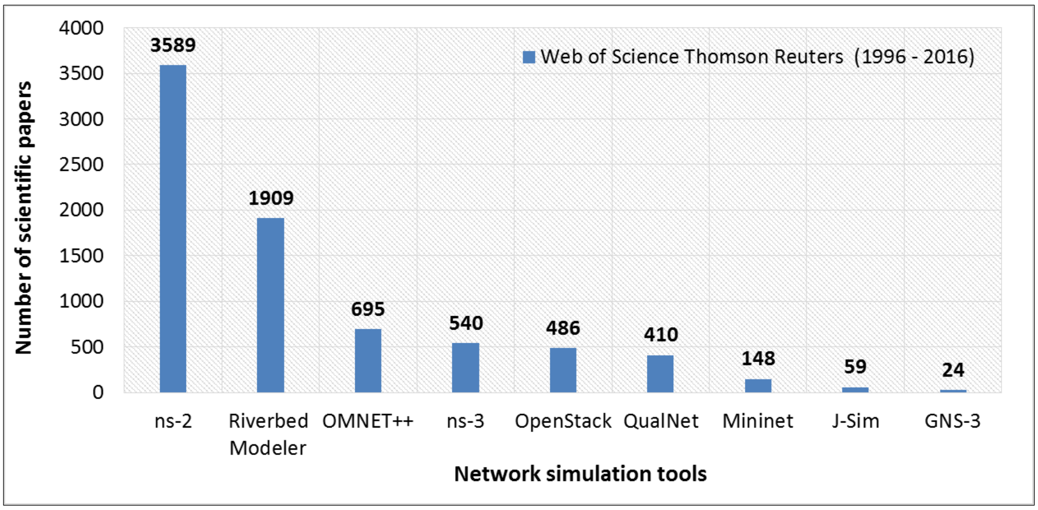

Figure 5 – The number of scientific papers related to the application of network simulation tools in the area of ICT in the publications of Web of Science Thomson Reuters from 1996 to 2016; Source: [25]

Figures 6 a), b), c) and d) show the number of scientific papers related to the application of individual network simulation tools in the area of ICNT according to the analysed science bases (according to the criterion of the highest total number of papers – four network simulation tools). Network simulation tool ns-2 has been represented in the largest number of scientific papers (6,224, Elsevier's Scopus), followed by Riverbed Modeler in 3,056 papers (Elsevier's Scopus), and ns-3 in 1,300 papers (Elsevier's Scopus).

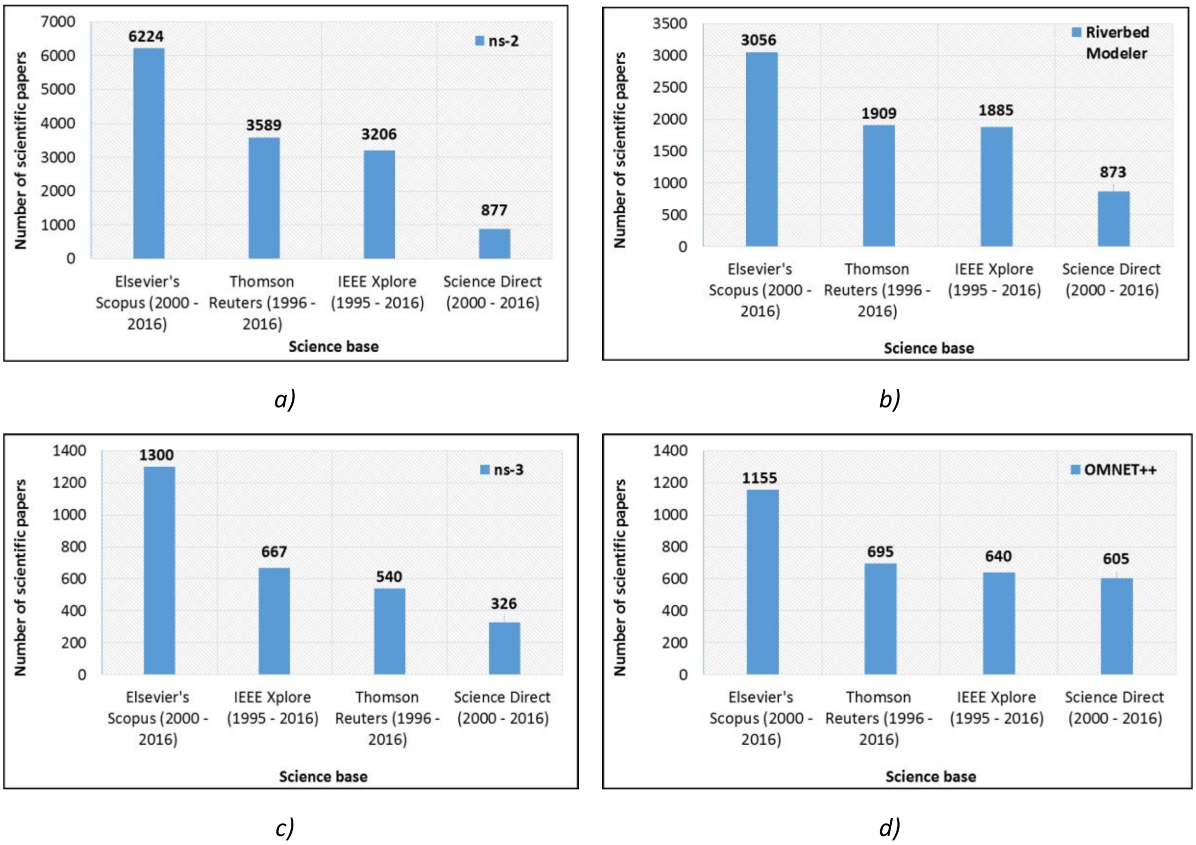

Figure 6 – The number of scientific papers related to the application of certain network simulation tools in the area of ICT according to the analysed science bases; a) ns-2, b) Riverbed Modeler, c) ns-3 and d) OMNET++. Source: [22], [23], [24] and [25]

Network simulation tool GNS-3 has been represented in the lowest number of disseminated studies, i.e. scientific papers (35 in Elsevier's Scopus; 25 in Science Direct, 24 in Web of Science Thomson Reuters and 20 in IEEE Xplore). GNS3 is widely used for preparation of network professional certification exams, especially for Cisco certification exams (CCNA, CCNP, CCIE, etc.). It could be said that GNS3 is more used/popular between network professionals and less used for academic research.

Table 2 shows the cumulative number of scientific papers according to the selected science bases (step 1), areas/key words (step 3) and recognized network simulation tools (step 2).

In the science base Elsevier's Scopus the largest number of papers is for the area/key word “Wireless” related to network simulation tool ns-2 (3,396 papers), followed also by “Wireless“ in Riverbed Modeler (1,038 papers) and “QoS“ in ns-2 (890 papers).

The science base IEEE Xplore Digital Library the largest number of papers belongs to the area/key word “Wireless“ related to network simulation tool ns-2 (2,044 papers), followed by “Wireless“ in Riverbed Modeler (964 papers) and “Cloud“ in network simulation tool OpenStack (480 papers).

In the base Science Direct the largest number of papers in in the area related to wireless networks (“Wireless“) in network simulation tool Riverbed Modeler (548 papers) and ns-2 (306 papers) as well as “Wireless“ in OMNET++ (232 papers).

Table 2 – The number of published papers in the area of ICT

1	3	2								
Science base	Key words (QoS, VoIP, Wireless, Security, IoT, SDN, Cloud and LTE)	Network simulation tools								
		ns-2	ns-3	GNS-3	OMNET++	OpenStack	Mininet	Riverbed Modeler	QualNet	J-Sim
Elsevier's Scopus	Total number of papers acc. to selected key words	5,058	940	11	933	862	244	1,900	544	53
	Total number of papers per all areas	6,224	1,300	35	1,155	798	276	3,056	644	72
IEEE Xplore Digital Library	Total number of papers acc. to selected key words	2,943	688	13	543	718	281	1,738	414	49
	Total number of papers per all areas	3,206	667	20	640	509	208	1,885	402	217
Science Direct	Total number of papers acc. to selected key words	790	240	23	378	348	87	682	434	131
	Total number of papers per all areas	877	326	25	605	350	69	873	254	136
Web of Science Thomson Reuters	Total number of papers acc. to selected key words	2,591	517	5	468	609	188	1,377	334	44
	Total number of papers per all areas	3,589	540	24	695	486	148	1,909	410	59

Source: Made by the authors according to [22], [23], [24] and [25]

As shown in table 2, it is possible that “total number of papers acc. to selected key words” exceeds “total number of papers per all areas”, reasoning behind that is some of the published papers have both key words. It's near to impossible to avoid these kind of results while searching different key words numerous times.

In the science base Web of Science Thomson Reuters the largest number of papers is from the area/key word “Wireless” related to network simulation tool ns-2 (1,765 papers), followed also by “Wireless“ in case of Riverbed Modeler (743 papers) and “QoS“ in case of ns-2 (518 papers).

5. CONCLUSIONS

This paper contains a comprehensive survey of the different types of network simulation tools used for standard network simulation. Network analysers taken into consideration through the science bases include: ns-2, ns-3, GNS3, OMNET++, OpenStack, Mininet, Riverbed Modeler, QualNet and J-Sim.

By analysing the science bases it has been determined that the network simulation tool ns-2 is the most used tools for the simulation needs of the information and communications network technologies (on the first place in all four included science bases; a total of 13,896 papers). It is followed by Riverbed Modeler (occupying the second place in all four analysed science bases, a total of 7,723 papers), OMNET++ (3,095 papers) and ns-3 (2,833 papers). By analysing the network simulation tools by selecting the key words from the area of ICNT and available science bases, a connection between the simulation tool and the area of research has been determined. Network simulation tool ns-2 is the most used software related to the wider problems of wireless networks (7,511 papers) and the quality of service (QoS, 2,009 papers), while Riverbed Modeler is usually related to wireless networks (3,383 papers). The largest number of available papers in network simulation tool OpenStack is thematically related to Cloud computing (1,801 papers).

Plans for future research and dissemination are related to individual analyses of the selected network simulation tools and areas of research, and determining of differences between the results without key words and with key words. When expanding the research it would be good to consult also other science bases of papers and open scientific resources such as e.g. social network service for scientists ResearchGate, Google Scholar's bibliographic database, CiteSeerX, getCITED, etc. Regarding development, dynamicity and application of application simulation tools in the area of information and communication networks and network technologies it is suggested to make at least once a year similar studies. We hope that this paper will help other authors in selecting the appropriate network simulation tool for their research.

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DEMAND FORECASTING IN PHARMACEUTICAL INDUSTRY

ABSTRACT

Demand forecasting in pharmaceutical industry has a great importance because it deals with products that have high cost and are subject to a limited shelf life. Other than that, it is crucial to have pharmaceutical products available at any time for end users because it has direct impact on human life. Therefore, it is important to select and implement appropriate forecasting method to improve procurement and efficient inventory management. This article demonstrates the use of different forecasting methods (Moving Average, Simple Exponential Smoothing, Winter's Method) in forecasting demand of pharmaceuticals products wholesalers. Forecasting methods have been applied by using Minitab tool, based on real historical data on demand of two products, for three wholesalers.

KEY WORDS

Pharmaceutical products; forecasting methods; wholesalers; Minitab tool

1. INTRODUCTION

Demand forecasting is an area of predictive analytics dedicated to understanding consumer demand for goods or services [5]. Its objective is to determine which products are purchased, where, when, and in what quantities. Pharmaceutical manufacturers are affected by the political and economic relations of incomplete forecasting techniques. Balanced market power and valuable information are seen on developed markets. In other sectors, gathering of the forecasting methods condition, sharing available information systematically and demanding scenarios develop independently from political conditions with greatest accuracy [1]. Therefore, in this article, forecasting methods are evaluated and ranked based on their accuracy, in cases of actual demand for two products, at three wholesalers.

2. DEMAND STRUCTURE OF THE PHARMACEUTICAL INDUSTRY

Demand in the pharmaceutical market is a complex combination of push and pull driven demand and regulatory and pricing pressures. Third parties decide on formalities that influence prescription behavior, while pharmaceutical companies use lawyers, managed care, detailing, and direct to consumer campaigns to influence the FDA[1], pharmacy benefit providers, doctors and patients to prolong the patent, promote on formulary, prescribe and request their products.

[1] Food and Drug Administration is a federal agency of the United States Department of Health and Human Services.

Pharmaceutical companies are closely related to doctors, patients, pharmacies and lawyers, while the manufacturing processes must comply with the regulations such as FDA and GMP[2]. A complex structure of demand and supply within the pharmaceutical market is shown in *Figure 1*.

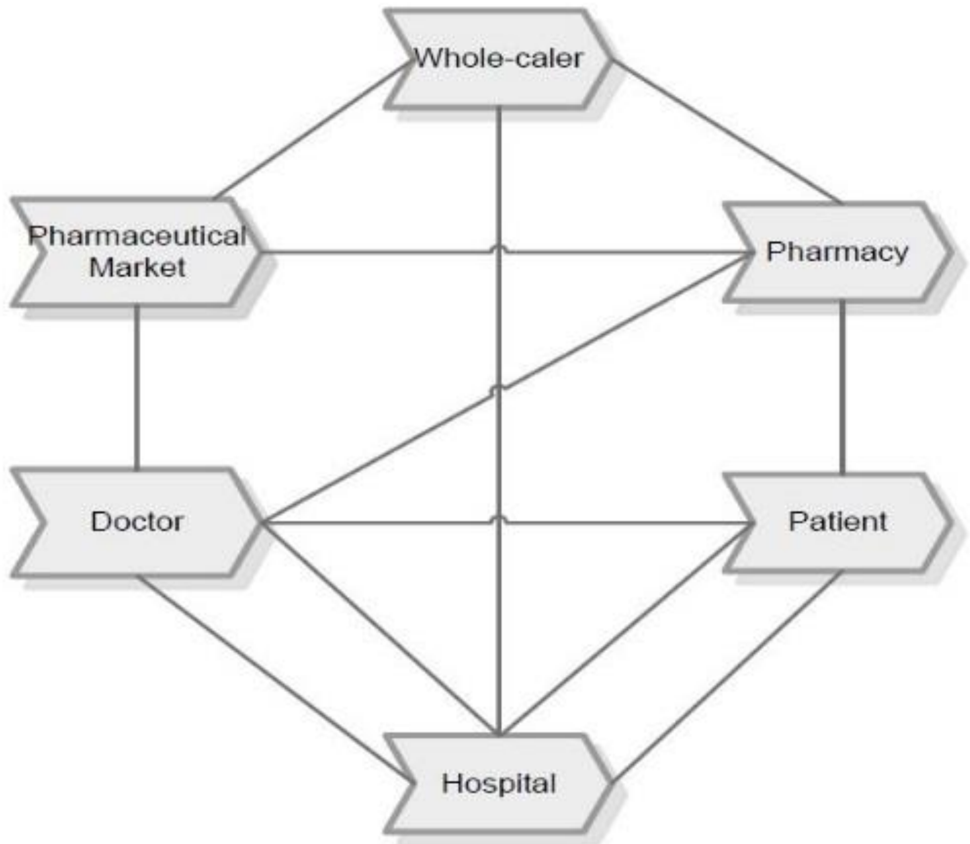

Figure 1 – Complex Structure of Pharmaceutical Market
Source: [1]

3. FORECASTING MODELS IN PHARMACEUTICAL INDUSTRY

There are three types of models used in pharmaceutical industry: Time Series, Cause-and-Effect and Judgmental. In Time Series models, we extrapolate data by using suitable technique. In Cause-And-Effect, there is a cause and there is an effect. We develop relationships between them by using the historical data, and then make a forecast by using those relationships. In Judgmental models, judgment is predominant. They are used particularly in the case of new product forecasting where historical data are not available.

Among all the models, Time Series models are the easiest, and the most often used (52%). Whereas, cause-and-effect is used 24% and judgmental 19%. The remaining 5% represents homegrown models. In some cases, they use more than one type of models [2]. In this article the focus is on time series methods: single exponential smoothing, Winter's method and simple moving average. Within the time series the models that are often used in pharmaceutical industry are shown in *Figure 2*.

[2] Good Manufacturing Process is a system for ensuring that products are consistently produced and controlled according to quality standards.

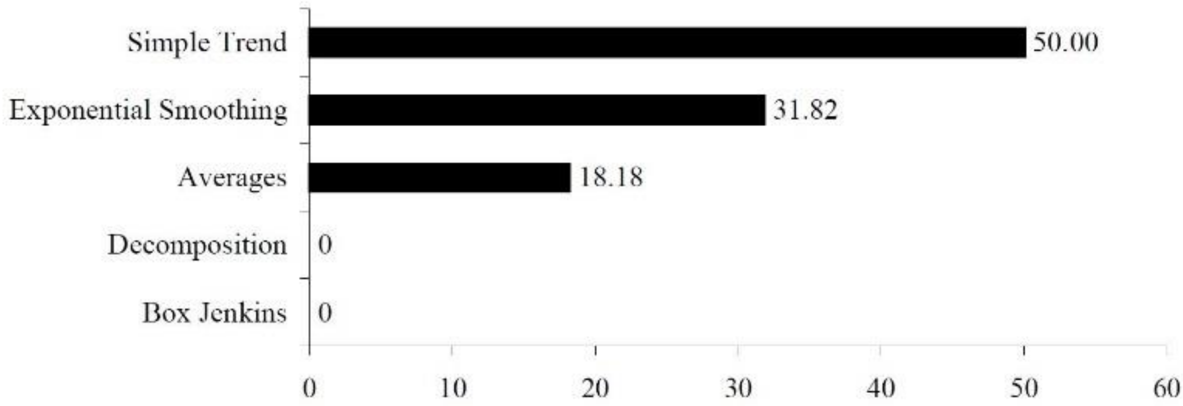

Figure 2 – Time series models used in the pharmaceutical industry (percentage)
Source: [2]

4. MEASURING FORECAST ACCURACY

A forecast is never completely accurate. The principle objective of forecasting is that there is as small deviation from actual demand as possible. Forecast error measures also allow comparing forecasts and help to determine the better technique. The measures of forecast error used in the study are Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE) and Mean squared error (MSE). MAD measures the average of difference between the forecast and actual demand. It is the simplest determinant of forecast error. A smaller value of MAD represents a more accurate forecast. The MAD is given by equation (1):

$$MAD = \frac{1}{n}\sum|\Delta_t| \quad (1)$$

Where: $\Delta_t = y_t - F_t$
y_t = Actual demand value at time t
F_t = Forecast demand value at time t
n = Number of time periods

Another popular accuracy measure is the Mean Absolute Percentage Error (MAPE). The MAPE is scale independent. However, MAPE was criticized for the problem of asymmetry and instability when the original value is small. MAPE as accuracy measure is affected by four problems: Equal errors above the actual value result in a greater MAPE. Large percentage errors occur when the value of the original series is small and outliers may distort the comparisons in empirical studies [4]. The MAPE compares the error in terms of percentages. The MAPE gives an indication of average relative magnitude of forecast errors in comparison to actual forecast error. MAPE is pertinent across different time series methods. For this reason it is included in this study. The MAPE is given by equation (2):

$$MAPE = \frac{1}{n}\sum\frac{|\Delta t|}{y_t}\cdot 100\% \quad (2)$$

Where: $\Delta_t = y_t - F_t$
y_t = Actual demand value at time t
F_t = Forecast demand value at time t
n = Number of time periods

The MSE is similar to the MAD, except that each residual is squared. In this way, larger forecast errors are more heavily penalized. The MSE is given by equation (3):

$$MSE = \frac{1}{n}\sum{\Delta_t}^2 \quad (3)$$

Where: $\Delta_t = y_t - F_t$

y_t = Actual demand value at time t

F_t = Forecast demand value at time t

n = Number of time periods

5. FORECASTING METHODS FOR WHOLESALERS DEMAND

Demand is the amount of some goods or service that the customer wants to buy. Forecasting demand serves as a tool to efficiently plan production in this case and to reduce losses and costs. Therefore, it is crucial for a production company to forecast demand because the production volume is determined according to the annual plan. The data that is processed within the study outlined in this paper is confidential, therefore no company names nor product names are specified. It refers to the demand of the three wholesalers in Croatia that are being supplied with pharmaceutical products from the foreign manufacturer. This study is based on past demand data and explained by quantitative methods. The forecasting methods selected in this paper are simple moving average, single exponential smoothing, and winter’s method.

The simple moving average technique is simple and easy to understand and implement. The single exponential smoothing technique takes into account the weighting factor/smoothing factor and this helps in reacting more strongly to recent changes in demand. The winter’s exponential smoothing uses seasonal component in addition to the trend component [3].

The chosen forecasting models were applied into Minitab tool and are evaluated and ranked based on their accuracy in forecasting by parameters MAPE, MAD and MSE on actual demand data. The objective of this article is to identify the most suitable forecast model for the chosen product and for all three wholesalers, by using real demand data based on years 2013. and 2014. Demand of all three wholesalers for product A is presented in *Figure 3* for the time period from 2013 to 2014.

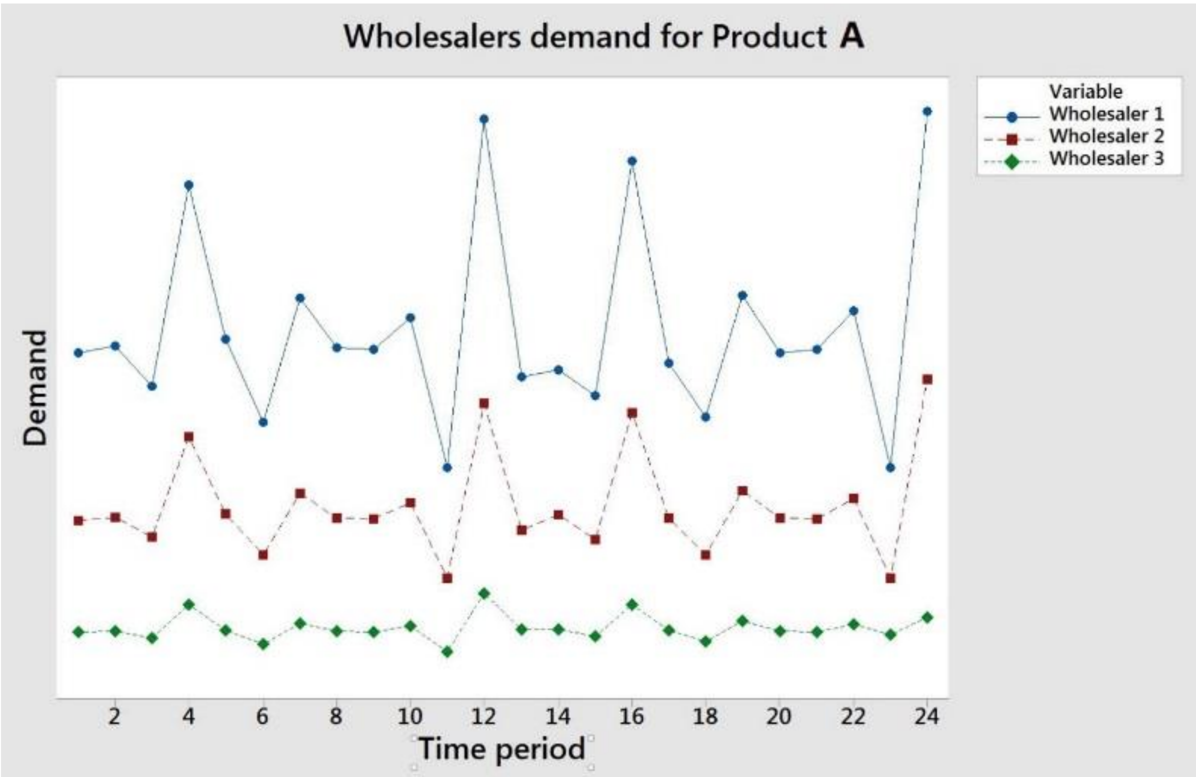

Figure 3 – Wholesalers demand for product A

Source: Made by the authors

A big difference can be noticed in the amount of demand for certain wholesaler, but oscillations are quite the same. Seasonality is evident in the demand for product A, which peaks in December and April which can represent medicines for cold or flu. In order to determine the method that best suits the demand of individual wholesalers, the software tool that was used is Minitab. Ranking of the forecasting methods for the demand of product A is shown in *Tables 1, 2* and *3*.

Table 1 – Ranking of forecasting methods for product A at wholesaler 1

Wholesaler 1	MAPE	MAD	MSE	Rank
Winter's method	6	596	489318	1
Single exp. smoothing	19	2848	15187866	2
Moving average	20	2939	19277840	3

Source: Made by the authors

Table 2 – Ranking of forecasting methods for product A at wholesaler 2

Wholesaler 2	MAPE	MAD	MSE	Rank
Winter's method	5	274	278195	1
Single exp. smoothing	18	1447	3633469	2
Moving average	21	1511	4373170	3

Source: Made by the authors

Table 3 – Ranking of forecasting methods for product A at wholesaler 3

Wholesaler 3	MAPE	MAD	MSE	Rank
Winter's method	5,6	139	38746,9	1
Single exp. smoothing	19	459	547203	2
Moving average	21	476	725824	3

Source: Made by the authors

Parameter MAPE represents the size of the error percentage, while MAD presents how much a certain method over predicts on average and MSE measures the average of the squares of the errors or deviations.

As mentioned earlier, Winter's Method captures the seasonality in demand of product A. Seasonality is evident in the demand volume of product A, which peaks in December and April. *Figure 4* shows the demand for all three wholesalers for product B in the time period from 2013. to 2014. like in the previous one.

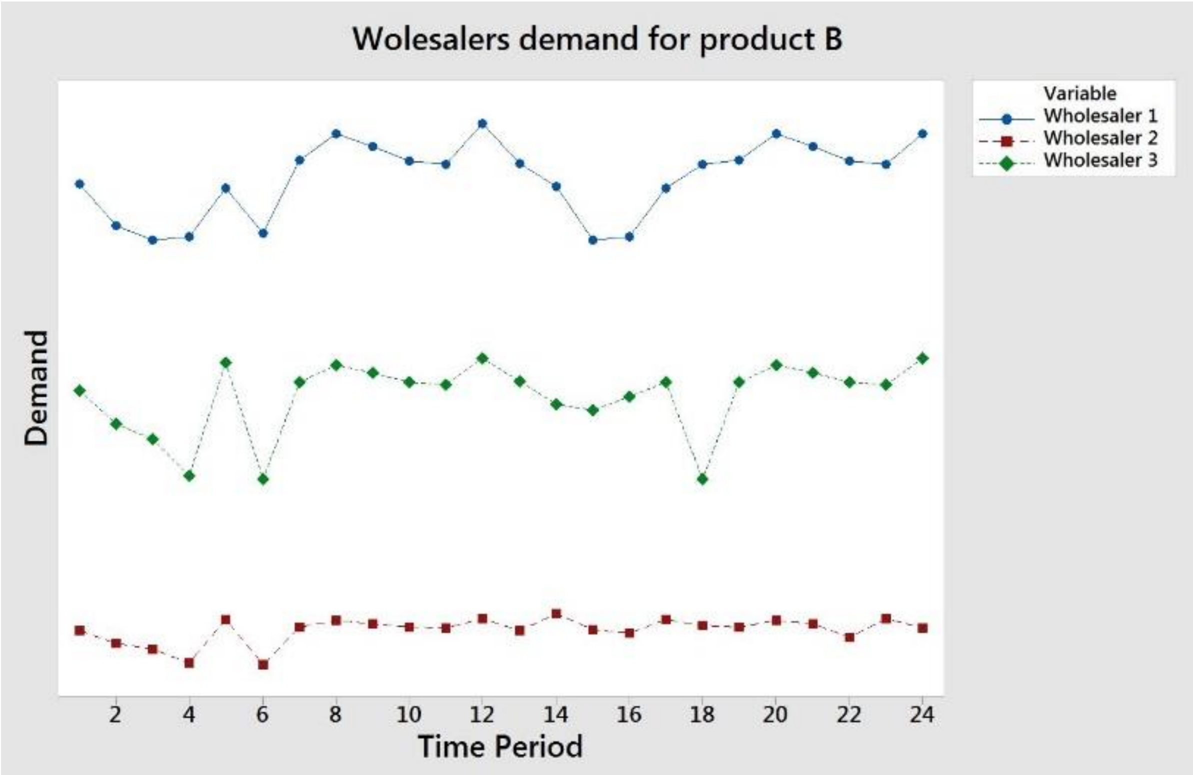

Figure 4 – Wholesalers demand for product B
Source: Made by the authors

Graphs are different from the first case because there are no large fluctuations, as in the first case there is an obvious seasonality in the demand. Ranking of the forecasting methods for the demand of product B is shown in *Tables 4, 5* and *6*.

Table 4 – Ranking of forecasting methods for product B at wholesaler 1

Wholesaler 1	MAPE	MAD	MSE	Rank
Single exp. smoothing	9	3115	10474303	1
Winter's method	12	3971	17075881	2
Moving average	8	3772	20484828	3

Source: Made by the authors

Table 5 – Ranking of forecasting methods for product B at wholesaler 2

Wholesaler 1	MAPE	MAD	MSE	Rank
Moving average	5	861	1140559	1
Single exp. smoothing	7	1032	1635665	2
Winter's method	8	1098	19893122	3

Source: Made by the authors

Table 6 – Ranking of forecasting methods for product B at wholesaler 3

Wholesaler 1	MAPE	MAD	MSE	Rank
Moving average	8	3118	14357697	1
Single exp. smoothing	8	3137	14441955	2
Winter's method	10	3964	19893122	3

Source: Made by the authors

Tables 4, 5 and *6* show that six-month moving average best predicts the demand for product B, which has a relatively stable demand during an entire year or the time-period in question with some exceptional fluctuations for the wholesaler 1.

6. CONCLUSION

The purpose of the study outlined in this paper was to determine the demand structure in the pharmaceutical industry. For this purpose, different forecasting methods for wholesalers demand are applied, in order to select the most adequate one by evaluating the forecast accuracy. Forecasting was based on 24 month demand of the three wholesalers in Croatia that are being supplied with pharmaceutical products from the manufacturer.

This method of forecasting by using Minitab tool can help to define strategies for procurement and efficient inventory management based on product characteristics and seasonality as shown in this paper. The analysis of the wholesalers demand can provide manufacturer with better information about market situation and to help develop a more accurate annual production plan. Without using adequate forecasting method it is hard to determine future demand pattern and can lead to incorrect assessments and unnecessary expenses.

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THE CHALENGES OF GOOD DISTRIBUTION PRACTICE IN THE PHARMACEUTICAL INDUSTRY

ABSTRACT

The distribution of pharmaceutical products is very complex as it is subject to various strict laws and regulations. All partners involved in the distribution chain of pharmaceutical products need to ensure the quality of products and the coherence of the distribution chain from the point of manufacture to the final consumers. Distribution of pharmaceutical products is an activity within the temperature controlled supply chain, known as the "cold chain" which represents an uninterrupted series of activities and equipment that enables one to maintain a certain temperature regime during production, storage and transportation. This paper reviews the increased importance of cold chain management in the pharmaceutical industry, and logistic standards of good storage and distribution practices. With reference to the above, the distribution of pharmaceutical products is analysed within the case study of the pharmacy distribution network.

KEY WORDS

Distribution; pharmaceutical products; cold chain; case study

1. INTRODUCTION

Distribution is an important logistics service in the pharmaceutical supply chain management. Various companies are responsible for the whole or for certain elements of the distribution process (manipulation, storage and transport) of such products [1]. Pharmaceuticals is one of the most sensitive and major industries which deals with human and animal life. To ensure the quality of pharmaceutical products, every partner of the pharmaceutical distribution chain must consider the legislation and every single activity in the distribution logistics needs to be provided according to the principles of good manufacturing, storage and distribution practice [1],[2]. This article explains the specifics of pharmaceutical product distribution in terms of regulations, documentation, packing and labelling of products. It also deals with the distribution problems due to additional testing of drugs in production.

2. DISTRIBUTION OF PHARMACEUTICAL PRODUCTS

The pharmaceutical distribution chain include many manufacturers, distributors, wholesalers and retailers as shown in Figure 1. The pharmaceutical distribution chains in a developed countries are regulated and able to improve the availability of medicines as well as the level of service. The distribution chains in a medium-developed countries are not regulated which creates the problem of the availability of medicine products. 'At every point in the chain, precautions should be taken to minimize the effect of external conditions on the quality and stability of the product. It is mandatory that records should provide reliable up-to-date evidence of compliance, in case of audits and investigations. Before setting up a storage facility, transport system or taking on a new range of products, it is advisable that distributors carry out a risk analysis' [3], [4].

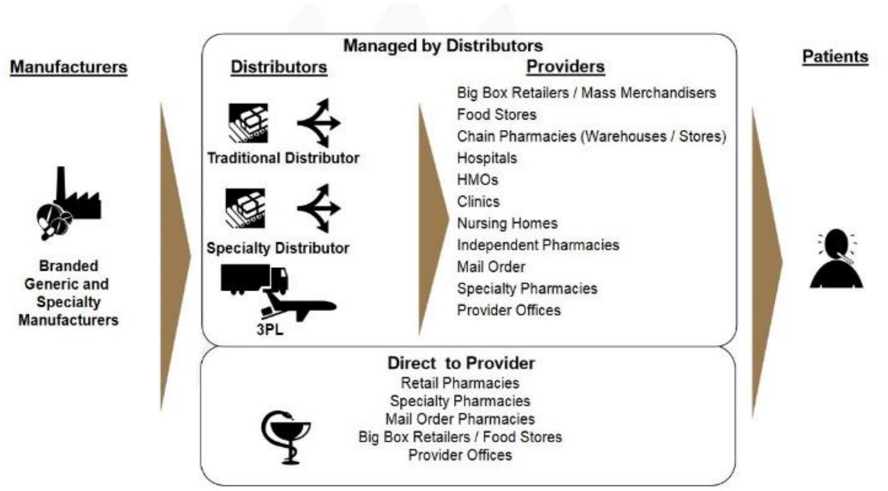

Figure 1 – Distribution chain in pharmaceutical industry
Source: [8]

2.1 Good distribution practices for pharmaceutical products

All partners of the pharmaceutical distribution chain need to ensure the quality of pharmaceutical products from the manufacturer till the end user (patient). To establish minimum quality standards, the principles of GDP[1] should be included in national legislation or guidelines for the distribution of pharmaceutical products should be established [1].

The principles of GDP should be applicable to: (1) pharmaceutical products moving forward in the distribution chain, (2) pharmaceutical products moving backwards in the chain and (3) pharmaceutical products which are donated [1].

All partners included in the distribution activities should 'apply due diligence with adherence to the principles of GDP, for example, in procedures relating to traceability and in recognition of security risks' [1]. Moreover, every partner should have an adequate organizational structure with clearly defined and understood responsibilities and duties of all employees. Employees should also be very well trained in their duties and responsibilities [1]. Partners must also be able to maintain a quality of the activities and should react in case of deviations.

[1] GDP (good distribution practises) - That part of quality assurance that ensures that the quality of a pharmaceutical product is maintained by means of adequate control of the numerous activities which occur during the distribution process as well as providing a tool to secure the distribution system from counterfeits, unapproved, illegally imported, stolen, counterfeit, substandard, adulterated, and/or misbranded pharmaceutical products

2.2 Regulation of distribution of pharmaceutical products

The distributor should only be the company that is authorized and has appropriate license to import or export pharmaceutical products. Such a distributors may only distribute a product to a country that has an authorization to use that pharmaceutical product [1].

Distributors should purchase pharmaceutical products only from suppliers which are authorized to supply such products. Some duties of the distributor may only be transferred to companies that are suitably authorized. An agreement needs to be signed in this case. The Internet sale of pharmaceutical products may be provided by the authorized mail-order company [1].

2.3 Transportation of pharmaceutical products

Transportation of pharmaceutical products is done through a cold chain. It is a temperature-controlled supply chain that requires controlled temperature storage from the producer's point to the end customer. 'In some circumstances (such as the manufacture of a product containing a temperature-sensitive active ingredient), the cold chain may also include the storage and shipping of active pharmaceutical ingredients used in the manufacture of the product' [9], [5].

Vehicles used to distribute pharmaceutical products need to be appropriately equipped and need to allow effective cleaning to prevent exposure and contamination of the products or any other risk. Special attention should be given to the use of information and communication technologies, such as transport management system, which would increase the security of products during the driving process. Also the equipment used to store and manipulate pharmaceutical products should be suitable for their purpose to prevent exposure and contamination [1].

Distributors that don't have their own fleet should have written agreements with logistics service providers to ensure that appropriate measures are taken and appropriate documentations and records are maintained. All records need to be kept for the whole shelf-life of the product distributed plus one year or as required by national legislation [1].

2.3.1 Temperature-controlled vehicles

Temperature-controlled vehicles are vans and trucks that have an insulated thermostatically controlled cargo space which keep the declared temperature of the transported products [6]. 'Vans and small trucks have refrigeration/heating units powered by the vehicle's engine. Larger vehicles and semi-trailers have independent diesel-powered refrigeration/heating units' [6]. Small and large vehicles could also have electrical back-up so that they can be mains-powered whilst parked [6]. All temperature-controlled vehicles need to have also an on-board electronic temperature monitoring and event logger system. The temperature-controlled vehicle can also be used 'to extend the autonomy of the passive shipping system and protect the product from temperature extremes' [6].

2.3.3 Passive shipping systems

A key advantage of passive systems is that they allow safe transport of TTSPPs[2] over poor roads. Passive shipping systems contains a disposable insulated material, a temperature stabilizing media and a finite amount of refrigerant energy [6]. In some cases also 'advanced phase change materials PCMs[3] instead of water-based gel packs or simple water-packs' is used [6]. Such a combination of material allows 'a specified temperature for a pre-defined period of transport without reliance on mechanical

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[2] Time and temperature sensitive pharmaceutical product (TTSPP): Any pharmaceutical good or product which, when not stored or transported within predefined environmental conditions and/or within pre-defined time limits, is degraded to the extent that it no longer performs as originally intended.

[3] Advanced Phase Change Materials (PCMs): Temperature stabilizing media (sometimes referred to as refrigerants), chemically engineered so that their latent heat of fusion occurs at a temperature other than zero ° C, phasing from one state of matter to another (i.e. liquid to solid) at a pre-formulated temperature. Such materials are typically comprised of oils, salts, or paraffin.

assistance' [6]. Passive shipping systems could be reusable or for one-time use (Figure 2). They can also be used for air transport.

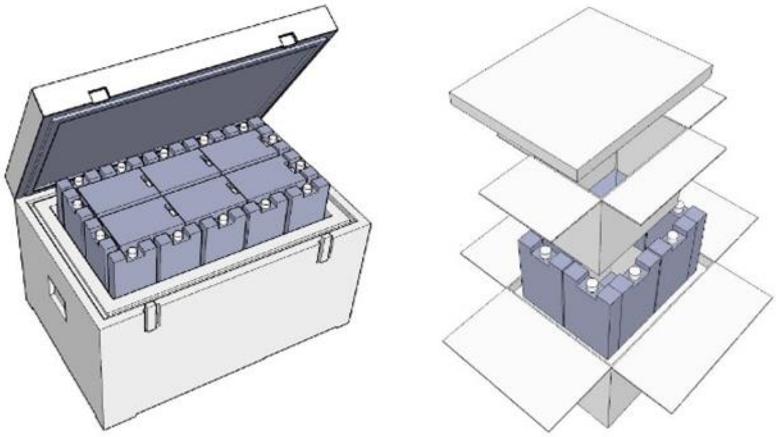

Figure 2 – Generic passive containers with coolant packs
Source: [5]

2.3.4 Active shipping systems for air transport

The active shipping systems are dedicated containers used in air transport (Figure 3). They could allow cooling or heating and cooling. The temperature stabilizing medium in active shipping systems that allow cooling is dry ice. The temperature stabilizing medium in active shipping systems that allow cooling and heating are phase change materials. Compressor-driven cooling systems could also be used [6].

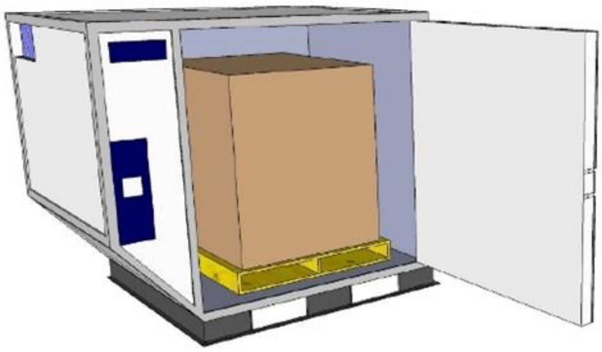

Figure 3 – Active air transport container – type LD3
Source: [6]

2.3.5 Active shipping systems for ocean transport

High performance ocean containers specifically designed for transport of TTSPPs have recently been developed. These use a refrigeration and air circulation system running off the ship's on-board power supply and incorporate integrated satellite tracking.

The pharmaceutical industry avoids the ocean transport because of long delivery times, 'environmental exposure at sea and in port before loading and unloading, loss at sea and port security concerns' [6].

2.4 Documentation

Written records with all activities relating to the distribution of pharmaceutical products, receipts and invoices need to be available and kept for seven years by the distributor. At least date, name of the product, quantity and name of supplier need to be written on records [1].

'Procedures should be established and maintained for the preparation review, approval, use of and control of changes to all documents relating to the distribution process. Procedures must be in place for both internally generated documents and those from external sources. All records must be readily retrievable and be stored and retained using facilities safeguarded against unauthorized modification, damage, deterioration and/or loss of documentation. Mechanisms should exist to allow for transfer of information, including quality or regulatory information, between a manufacturer and a customer as well as the transfer of information to the relevant regulatory authority as required. Permanent records, written or electronic, should exist for each stored product indicating recommended storage conditions, any precautions to be observed and retest dates. Procedures should be in place for temperature mapping, security services to prevent theft or tampering with goods at the storage facilities, destruction of unsaleable or unusable stocks and on retention of the records. Where the records are generated and kept in electronic form, backups should be maintained to prevent any accidental data loss' [1].

2.5 Repackaging and relabelling

Repackaging and relabelling of pharmaceutical products should be avoided and only be provided by companies that are authorized for this kind of activities. They need to be performed in accordance with national and international guidelines and with GMP[4] principles [1]. 'In the event of repackaging by companies other than the original manufacturer, these operations should result in at least equivalent means of identification and authentication of the products. Procedures should be in place for the secure disposal of original packaging' [1].

Relabelling can occur when products need to be sold on a different market with different regulations and guidelines. This is due to the fact that every product gets labelled according to the country that is being sent to. The use of relabelling will be further explained in this article on a case study.

3. DISTRIBUTION OF PHARMACEUTICAL PRODUCTS - A CASE STUDY

The production of the case study is located in the Netherlands in town of Breda where the inventory management and the distribution for wholesalers is planned according to the manufacturer. It therefore means that logisticians in Croatia need to plan their orders for wholesalers according to annual production plan of the company.

Every month production additionally informs of the exact dates of finished products and possible deviations so that logisticians can determine the exact date for transport. Logisticians can see finished products in the information system only when the goods arrive at the distribution centre (DC), which is located in another city in the Netherlands and only then they can organize transportation of goods. The very organization of transport is carried out by two partners; one partner is used for groupage shipment such as consolidating shipments for Croatia with other countries.

[4] GMP (good manufacturing practices) - That part of quality assurance which ensures that pharmaceutical products are consistently produced and controlled to the quality standards appropriate to their intended use and as required by the marketing authorization.

The second partner is used for large shipments with FTL[5] transport straight to Croatia. The manufacturer does not have its own warehouse in Croatia so the goods are sent directly to wholesalers in their warehouse. The distribution of pharmaceutical products can be seen in Figure 4.

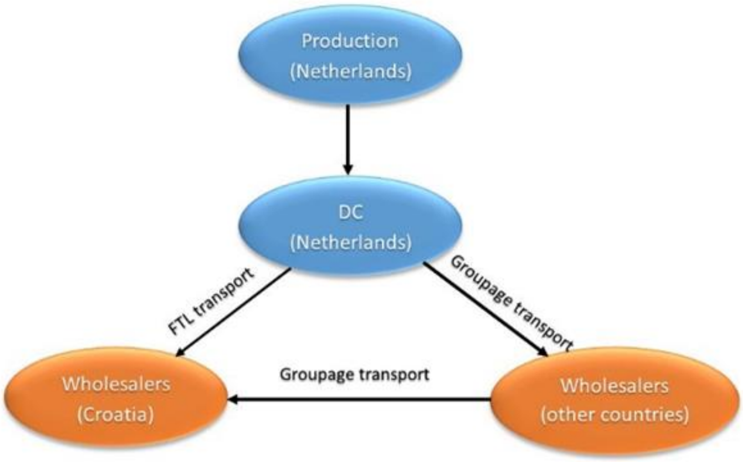

Figure 4 – Distribution chain of a case study

As the company produces medicines and nutritional products, they must go through various tests, safety checks and must comply with international standards. In addition, production of pharmaceutical products must be on high security level and must pass almost daily inspections of the quality and safety.

One of the common problems in production is additional testing of drugs, by various mistakes that can happen in the middle of production. This problem extends the production of drugs by 5-20 days and thus causes problems to logisticians who have scheduled transport according to production plan. Logisticians use two methods to solve this problem, the first is simple and includes ordering goods capacity for 45 days. This means that logisticians need to order enough goods to cover the time period until the next order which is every month so that wholesalers do not run out of important products. So the logisticians order goods for an additional 15-20 days to ensure the supply of wholesalers. In this case they do not need to take into account the costs of storage as it is at the expense of wholesalers.

The second method involves good communication with other partner companies across Europe. The company produces products for the whole European market so when the products arrive in the distribution centre it is available for all countries, not just for Croatian market. But when the products arrive in the DC they are labelled according to the laws of the country to which the products are being dispatched. We have already stated that when products arrive in the DC they become available in the information system so the logisticians can organize transport. However, if a product labelled for the Croatian market is not in stock in DC, it does not mean that the product is completely out of stock in the DC. This is because the product can be in stock for other countries but is labelled according to the laws of that country. For example, if Croatia doesn't have a product in stock because it is undergoing additional testing the logisticians can contact logisticians in Austria if they can give theirs. In that case if Austria approves the transaction, additional documents need to be filled due to changes in the declaration before transport. The duration of transport is 5-7 days and in that time papers can be filled for declaration change and goods can safely arrive on time to the wholesaler as shown in Figure 5.

[5] FTL – Full truck load

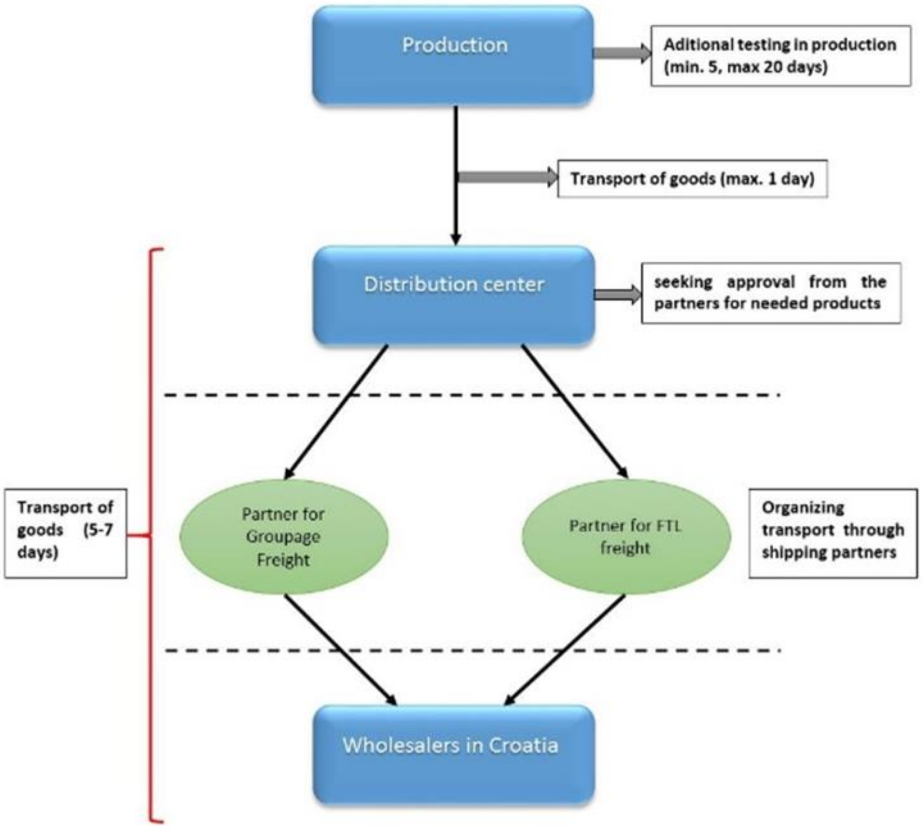

Figure 5 – Distribution solution for additional testing of drugs in production

4. CONCLUSION

The pharmaceutical industry is one of the most complex industry in terms of logistics because of transport and handling regulations, temperature controlled systems, laws, and documentation. Therefore, it is crucial that all subjects are dedicated to preserve the pharmaceutical products quality and thus contribute to the safety and effectiveness of the medicines. This article outlines the challenges in distribution of pharmaceutical products and discusses possible solutions for problems that may occur due to specific logistic requirements involved.

Further research should be focused on developing advanced distribution systems that can assure uninterrupted flows of products in the controlled environment, while minimizing risks and distribution costs.

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WAREHOUSE PROCESSES OPERATOR'S PERFORMANCE EVALUATION LITERATURE OVERVIEW

ABSTRACT

The ways in which the warehouse processes are performed directly affects the efficiency of the flow of goods in the supply chain. This paper will explore the basic features of warehouse processes, from technical and technological, organizational and the warehouse processes operator effectiveness point.

Paper provides recent research in the field, specified methods of operator's performance evaluation, enhanced impact on the efficiency on the supply chain performance and describes the analysis of human resources utilization in warehouse processes.

KEY WORDS

warehouse processes; warehouse operator; work efficiency; literature overview

1. INTRODUCTION

Human resources management in the supply chain represents commonly significant factor in the success of business companies. Competence and quality structure of employees directly influences the increased competitiveness of business, reduces costs and achieves lower price levels for services provided within the supply chain [1].

Successful and competitive qualified companies in the global environment give the increasing importance to human resources management with a variety of methods including the selection of employees, continuing education and training, professional seminars, training courses, team building and other forms of raising the level of knowledge and motivation of employees. From the foregoing it follows that the essential function of human resources in the supply chain is to quickly and efficiently find optimal solutions for connecting different transport modes in a continuous process of transport, warehouse operations and other operations from the initial to the final point of goods delivery [1].

Human resources management, as a category in company's business, gets more important because it encourages the development of production, warehouse process operations, distribution and marketing activities. Existing and planned level of employment should be managed in a way to achieve maximum effect in the business with minimum cost and a high level of satisfaction of all participants in the production, transport and distribution process as well as meeting the needs and desires of consumers [2].

Processes which occur in warehouses are of large importance for the circulation of goods throughout the supply chain. Warehousing itself refers to taking care, transportation, loading, unloading, packing and processing of goods between the production and consumption for commodity and other various functions. According to authors Bartholdi and Hackman [3], the warehouse process of order picking takes 70% of time and 55% of costs which makes it a significant process in a warehouse.

The aim of this paper is recent research review of reference authors in the field of operator's performance evaluation, and models that are applied in this area at the global level. A review of research will include the, overview of terms and settings related to the specific characteristics and problems of managing warehouse process operations primarily with technical, technological and organizational point of view, and will state the final guidelines for further research.

2. KEY FUNCTIONS OF HUMAN RESOURCES IN THE SUPPLY CHAIN

According to [1] and [4] one of the key factors for optimal performance of the transport operations, transshipment, storage and delivery of goods to the consumer are the employees who carry out these operations. The fundamentals of management and human resources planning are:

- well-organized supply chain
- uniformity of procedures
- recruitment
- level of education
- motivation
- remuneration for work

Human resources planning in the supply chain is a complex process due to the dynamic and spatial dimension realization of transport process. Authors [5] stated that planning is an integral part of the overall business of the company, and it can be seen as a long-term (strategic), medium term (tactical) and short term (operational planning).

For the concept of human resource management authors [4] used different terms, such as human capital, intellectual capital etc. According to [2] the link between human resources management in the supply chain system, reflects in order to increase the total created value of the product or service while success in achieving this goal is the difference between the value that the product or service has to the customer and the value of resources spent.

Authors [6] state that in the supply chain system and connecting all its components, human resources have one of the key roles because they realize the set tasks, and this affects the organization of the process, uniformity of procedures, level of education, motivation, teamwork, and a host of other factors. According to [7] and [8] in Republic of Croatia many companies give the increasing importance to human resources management because in line with scientific and technical research the quality staff contributes competitiveness and business performance.

The key functions of human resources in the supply chain according to [1] and [6] can be divided into several stages where in each of them the human factor affects the dynamics and the way the logistic processes work:

Collection and processing of offers for transportation represents the administrative tasks of communication with various operators at local, regional or national level.

Organization of transport requires knowledge of the capacity and performance of vehicles, and the choice of transport routes.

Transport process requires highly qualified and trained staff for handling and managing the transport vehicles.

Delivery or goods to the end user represents administrative chores and physical delivery of goods.

At the global level specific research in field of human resources were carried out mainly in the industrial sector, while the research of these issues in the transport field were carried out as part of general research. For the research of the human resources problem different methods and models are structured with the largest portion oriented towards top management and managers. The authors [9] describe the possible application of mathematical methods in human resources management. They propose business analysis based on the dynamics, the existing procedures and environment dynamic that continuously affects the business flow. The choice of mathematical models essentially depends on the input parameters and the narrow field of research and includes Markov chains, stochastic, linear and goal programming. Unlike purely mathematical modeling approach, the authors in [10] describe that human resources management should be observed from an organizational aspect, segmented into modules, and suggest the need for measuring the outcomes in the various systems on the market. The proposed model of human resource management is viewed from two aspects, unique and pluralistic approach defined by interest groups.

Further studies included the proposal of the authors in [11] for the implementation of information systems for human resources management in the supply chain in the form of modules ERP (Enterprise Resource Planning). ERP systems are information systems that consist of integrated software applications and include modules for planning, sales and production.

Research related to human resources management in businesses that are participants in supply chains include those of the authors in [12], which highlight the need for the identification and selection of qualified professionals in supply chain managing. They propose different methods of evaluating competence, optimization possibilities in organizing their own business structure and function within the supply chain, creating procedures, and development of criteria based on the analysis of the observed business structure.

Authors in [13] examine market changes in terms of the demand increase, and the impact and uncertainty of goods delivery from the suppliers. They expand the issues of responsibility of certain functions within the supply chain, and propose strategic and long-term relationships with subjects within the supply chain. The paper presents four case studies with the benefits of the application of human resource management on four levels, including the resources utilization.

By using a comparative method, the authors in [14] represent the specificity of differently successful supply chains in different markets in terms of resource planning.

3. WAREHOUSE PROCESSING

The warehouse process involves activities: receiving, storage, order picking and shipping of goods. Each activity consists of actions executed by the operator, they are in its basic form: receiving (receiving transport means, preparation of transport means for unloading,); storage (stock keeping unit (SKU) positioning at the storage location,); order picking (taking orders, collecting SKUs, positioning the cargo in the shipping zone), shipping (control of consolidated orders, positioning the cargo on the transport means). Depending on the function of individual warehouse systems, warehouse work may include additional activities such as labeling, value-added services, packing, cross docking and similar [15] [16] [17], and it is shown in Figure below.

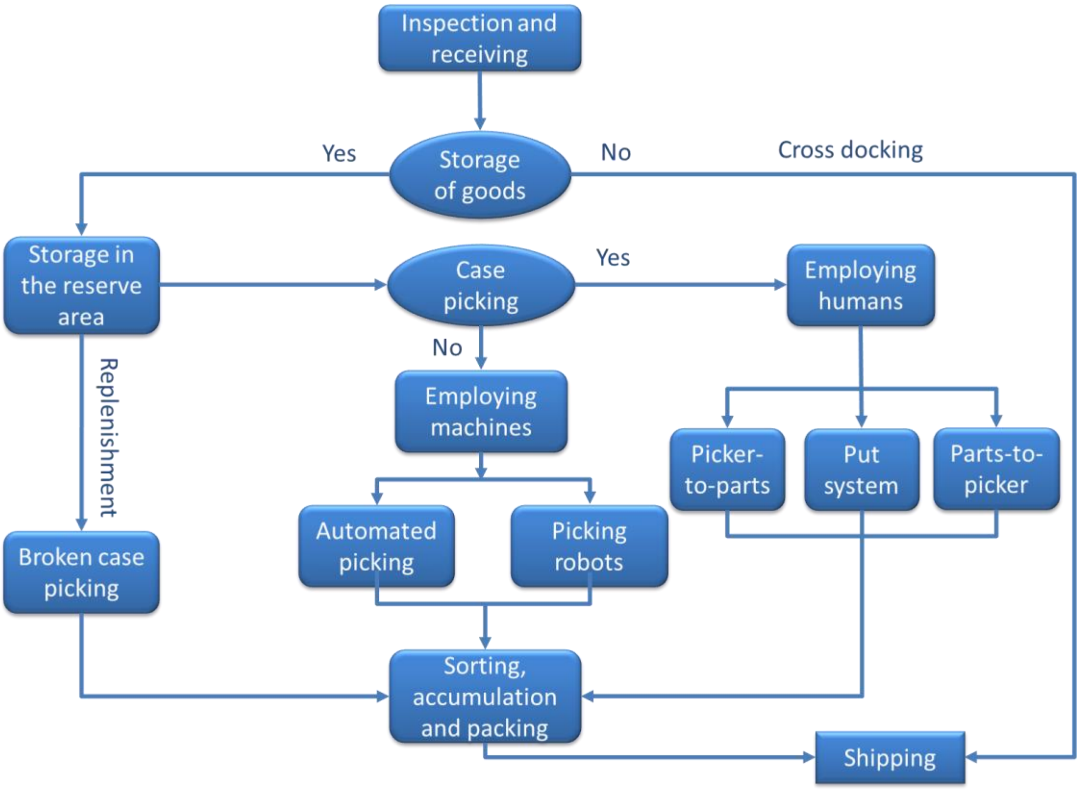

Figure 1 – Typical warehouse processes
Source: [15]

Goods which usually enter as units of a larger scale, go through reorganization submitted to repackaging that results with units of a smaller scale.

In this kind of warehouses, operations which are done daily are tied with human performance and greatly depend on it. The smaller the handling unit, the greater the handling cost. Smaller units require more labour and much more processing to be delivered. Precisely, pallet manipulation at a warehouse directly influences the time used for picking. This results with accurately collected units which are then forwarded to the next process [18].

3.1. Receiving

First in line of warehouse processes is receiving of goods. This process does not take as much time as picking, which is shown onwards, but it is as relevant as any. Especially, if incorrect put-away occurs and causes errors in further processing [19]. The process of receiving can begin with the notice of the goods arrival. This permits the warehouse to prepare, to schedule inbound operations so there are no uncoordinated events. With arrival, unloading begins after which units are put away with accurate documenting before.

If there is necessity for labelling, this process occurs before goods are put away. In every warehouse a place must be preordained for these actions. If there is no such place, but it is known that some of the arriving products must be labelled, a temporary place must be determined.

Products typically arrive in a warehouse in larger units, as it has been mentioned before, on pallets. If pallets are not arranged homogeneously they have to be broken down into separate cartons [3]. It is necessary for receiving that the method of delivery is compatible with the unloading equipment in the receiving warehouse. Otherwise, the need for additional equipment arises [18]. Altogether, the process of receiving accounts for only 10% of the operating costs in a typical warehouse, but it is supposed to be reduced by the use of Radio-frequency Identification (RFID) [3].

3.2. Put-away

Every SKU in a warehouse has its own location, determined in advance, whether the positioning is predefined or random. Precisely, there are several storage policies. A predefined storage policy prescribes a particular location for SKU to be stored, but random policy leaves the decision to the operator. Both of these storage policies can be used in some warehouses. Furthermore, a class-based storage system allocates zones to specific product which is based upon products turnover rate as ABC zoning. Another storage policy includes correlated storage of family groups, that is, storing products at nearby positions if they are often required simultaneously [20].

This step in the process is of large importance. It can reduce time defined for picking and in the end decrease total duration of outbound processes. For put-away the inventory management needs to be correct and up to date. It must be known at all times what storage locations are available, how much weight they can bear, etc. In this case, the secondary inventory management must be managed, not of products, but of locations in order to know everything mentioned. After the product is placed on its location, the storage location should also be scanned to record where the unit has been placed. This kind of information will be of use when it is needed to pick orders [3].

There are several options for inbound SKU. First is inbound into high-density storage like drive-in racking, next is inbound into standard wide aisle reserve slots such as upper levels. The last is inbound into pick slots which are ground-level wide aisle racking. The latter is represented in a small amount of products with no current stock [19].

Put-away process may require a large amount of work because SKUs must be moved over significant distances to their storage position. Put-away accounts for approximately 15% of warehouse operating costs [3].

3.3. Order picking

The process of order picking in a warehouse involves selecting and gathering specified amount of right SKUs in accordance with the order and it is composed of lifting, moving, picking, putting, packing, and other related activities [21].

During the order picking process, the orders are generally assigned to several pickers or picked by individual warehouse worker. Further, order picking can be manual or automated. In manual order picking, the picker gathers units from their locations and then transports them to a packing area.

In the case of automated picking, that is, automated storage and retrieval systems, system retrieves one or more unit loads and places them to a picking station. After that, the picker takes products on orders, and the remaining items on the unit loads are transferred to storage again [21]. The picking systems classification is also shown in Figure 1.

3.4. Packing

The process of packing can be demanding because every previously picked unit is generally handled separately. At this time, the process of checking the picked order is also required and convenient and there is less chance for errors to occur. Order accuracy is a crucial measure of service to a customer. If inaccurate orders make it to the customer, there will appear new expenses such as returns, which are expensive to handle. This process must be dealt with caution and awareness. The basic task of packing is to prepare goods for further transportation by any carrier in a way that does not affect shipping costs in a negative manner. If there is a complication with picking orders, there will be complication with packing. Precisely, if all items from the order are not positioned at the same time at a packing area, it is likely that the shipment will be delayed or/and costs will increase. The shipment can be sent partially resulting in higher costs [3].

3.5. Shipping

The process of shipping is the final process amongst warehouse processes. After packing and preparing units for shipping (consolidation), the first step is loading into transportation mean with the assumption that the shipping methods have been previously arranged. This process is not as complex and generally includes less labour than mentioned before, although there can be some additional activities if the product is being staged before being loaded [3]. Also outbound zone can include control, which will often occupy at least one warehouse worker to provide the activity. Depending on the warehouse information system, control can be done manually or using a scanner.

4. WAREHOUSE PROCESSES OPERATOR'S PERFORMANCE ANALYSIS LITERATURE OVERVIEW

Warehouse systems are objects intended for temporary and safe disposal, storage, preparation and issuing of goods. They are a part of the process of the supply chain which plans, implements and controls the efficient and effective flow of storage of goods, services activities added value and related information between the point of origin and the point of consumption in order to fulfill customer requirements. The capital and operating costs of warehouses represent about 22% in the USA and 25% in Europe of the logistics costs. Therefore, improvements in the planning and control of warehousing systems can contribute to the success of any supply chain [22].

The set of all manipulation of goods in the warehouse represents a warehouse process, and organizational activities and operations related to the fulfillment of the warehouse, represents a warehouse system.

The realization of activities is influenced by various parameters such as the resources organization (warehouse space, transportation/manipulative means and warehouse operators), the expected amount of inventory, value added services, user requirements, etc. [23] [24]. Organization of resources directly affects the effectiveness and efficiency of the supply chain [24]. The effectiveness implies the ability to meet the requirements of warehouse systems with pre-defined objective, which is the same rating achieved results in relation to its objectives. Terminology effectiveness is a term superior to efficiency and is measured by metrics (set of standardized measures, ways of measurement and interpretation of measurement results) of three categories objectives evaluation: (1) performance operations which according to [25] performance is a way of performing the observed action, including quantification of the same process; (2) the accuracy of order fulfillment and (3) utilization of warehouse space. Efficiency relates to evaluation of actions within the goals of effectiveness, and the data are obtainied by following analysis: performance operation (the number of received, order picked, stored and dispatched SKUs, the number of manipulations in a specified time period); accurate orders fulfillment (accuracy in the order picking of SKUs, accuracy in a given time delivery of orders); utilization of the warehouse area (the impact of SKU positioning on the activities of order picking, storage and replenishment). The effectiveness of a storage system from a financial aspect is by connecting labor cost with operations, the fourth category by the reference authors, substantially excluded from the primary analysis. The objective evaluation of resources is the optimal relationship of efficiency and effectiveness. the fourth category by the authors of reference substantially excluded from the primary analysis. The main objective of resources evaluation is the optimal relationship between efficiency and effectiveness [26].

The number of studies have been conducted a on the topic of warehouse performances evaluation, while most of the proposed models focuses on individual performance measures, such as the often analyzed period of order picking, especially in terms of shortening transport times. Integrated assessment models of overall warehouse performances are rare, and this area is processed in the form of preliminary research [27]. Subsequently the authors in [28] emphasize that the delivery on time, accurate order picking, labor turnover, inventory capacity, the neccesary time from recieving to storage and distribution costs are the key factors in analyzing warehouse performances in order to achieve efficient warehouse management performances. Baker and Canessa [29] as the efficiency criteria emphasize on time delivery of ordered goods, as soon as possible, delivery accuracy and delivery without damage. Tsui and Chang in [30] and [31] point out that the positioning of the transport means to a specific ramp determines the recieving and shipping efficiency. In their work they have developed a bilinear program to calculate/determine a sample for receiving and shipping, and the positioning of the transport means on entry and exit ramps to the obtained results. The result of the proposed model is time saving which allows the operator to determine the optimal solution for the transport means positioning. Model can also be modified as required. Gue [32] proposes a model based on the "look-ahead" algorithm for the scheduling of transport means positioning according to a ramp specification. The simulation program using look-ahead algorithm showed a 15% lower labor costs due to the time required for receiving and shipping. Bartholdi and Gue [33] discusse the problem of overloading the entry and exit ramps in crossdock warehouse in order to optimize the shortest time of order picking and waiting time. According to [34] the guidance are related to the definition of the optimal warehouse layout. In the paper they limit the decision variables and include the configuration of entry and exit ramps, pallets form, height of pallet racks, and the size and layout of shipping zones.

Previous studies related to the activity of receiving among others include [35] where the authors point out that a systematic approach to optimizing the warehouse system depends on the receiving. The reception mode may be that the person in receiving prints the actual amount of received goods regardless of the documentation, bar code (each packing is scanned by barcode reader), direct receiving (directly sending the received goods in the warehouse area) and cross docking (stacking goods and shippement without storage) [15] [16] [17]. Activity of recieving according to the authors is crucial for the effective functioning of the warehouse, where they point out the key criteria as the aim to increase the productivity: define periods for receipt of transportation means; abolish the control at the receiving point; plan and provide an accurate and efficient storage of inventory; use the cross docking method. Cross docking can be defined as a continuous flow of goods from receiving to shipment, which eliminates the need for conventional storage. The primary role of the warehouse is the coordination of input and output flows and not storage of goods. At the same time it means reducing the time and number of manipulations that goods pass between receiving at the cross docking terminal and shipping. In the cross docking system igoods are mostly shipped in larger quantities (one pallet to more) which minimizes the manipulation of individual unit, the use of forklift trucks and other transport-handling means.

5. WAREHOUSE OPERATORS WORK EFFICIENCY EVALUATION

The economy is stressing the need for resources evaluation because of the often limited capacity of resources and tight deadlines for orders delivery. Evaluation of resources in the warehouse system refers to the management of the warehouse operators and equipment according to the criteria: (1) cost control of resources; (2) provision of the necessary capacity of resources; (3) defining the time required to execute a specific action [36].

Referenced literature highlights the different approaches for evaluation of resources performance such as benchmarking, simulation modeling and analytical models [27]. According to the authors [37] the evaluation of resources in a particular warehouse system is carried out with the analysis of the observed warehouse system by processes recording and measuring the time required for the certain activities, which is determined by standardization.

By calculating the current resource efficiency of individual activities the optimal management of the observed system can be defined. When providing standard it is relevant that the action of the observed activity according to the norms can be defined by an average trained and average fast operator [25]. This is shown in Table 1. [38] where for e.g. order picking typically accounts for about 55% of warehouse operating costs; and order picking itself may be further broken into travelling, searching, extracting and additional activities such as paperwork. Measuring performance when watching a particular warehouse facility for e.g. for order picking process, should be systematically divided and measured within the working hours per warehouse operator for a specific activity within the process per order. When evaluating it is also necessary to define the reference sample.

Table 1 – Order picking time

Activity	Order picking time [%]
Traveling	55
Searching	15
Extracting	10
Paperwork and other activities	20

Source: Made by the authors according to [38]

Previous studies regarding warehouse operators work efficiency evaluation has been conducted by a number of authors, and this applies to the observation of a single process, while on the macro level this has not been observed. The author in [39] classifies around 130 indicators used to evaluate the effectiveness of the warehouse such as storage surface, the storage volume, pallet racks, number and characteristics of the ramps, number of pallets per hour, pallets per square meter and working hours. In their work, authors [40] represent a software tool that allows you to select the warehouse on the following criteria: the possibility to control temperature; the possibility of dangerous goods storage; distance from the main roads, railways and waterways; types and number of handling means. According to [41] the method for warehouse processes evaluation is performed according to the criteria: (1) Number of orders per hour (number of order picked/packaged orders in relation to the total number of working hours in the warehouse); (2) the number of lines per hour (number of order picked/packaged lines in relation to the total number of operating hours in the warehouse); (3) the number of units per hour (number of order picked/packed units in relation to the total number of running hours of the warehouse); (4) cost per order (total cost of storage in relation to total number of orders shipped); (5) cost of sales share (total storage costs in relation to the total number of orders shipped).

Research activities on which to focus research for warehouse operators work efficiency evaluation is in process of receiving because the existing models and methods of standardization on which they are based, have significant drawbacks and do not take into account all factors. In studies related to the above it is necessary to put the focus on:

- type of transport means,
- type of SKUs in receiving (box, pallet, single package)
- type of SKUs in storage,
- type of equipment in the warehouse,
- the type of SKUs for order picking and,
- shipping method that affect the performance of the entire warehouse process.

Methods for standardization referred to in the preceding considerations are not optimal for warehouse operators work efficiency evaluation in the field of receiving activity, and require systematic analysis of the present methods, or precision for receiving activities. Based on the results of analysis it should be noted which method will be best suited for performance evaluation with the processing of goods, it is necessary to explore the possibilities of processing and development of valuation models supplemented with criteria, which would allow the application for obtaining better results of performance evaluation.

6. CONCLUSION

In the global environment the business of the company requires certain approaches to management of processes in the supply chain, starting with the planning of each step of goods processing where warehouse processes are included.

Modern technologies condition the highest level of communication and implementation of information systems for the preparation and realization of supply chain.

Research of human resources management in warehouse processing, with particular emphasis on supply chains were carried out mainly in the context of general studies in scientific, industrial and service sectors but with no detailed methodology of warehouse performance evaluation for each warehouse process activity.

In order to achieve greater competitiveness and profitability of companies in the supply chain it is also necessary to develop a strategic research demonstrating operational plans and performance of each warehouse activity.

The general approaches and methodologies that are proposed and overviewed in paper lack user friendly implementation for evaluation of each warehouse worker or specific activity performance.

The application should be visible from:

- degree of organization,
- existing processes analysis,
- uniformity of procedures,
- measurement of the warehouse worker efficiency
- observed process efficiency

With systematic approach it is necessary to separate the key parameters that directly affect the flow of complete supply chain with the technological and organizational point of view, where technical and technological aspect includes evaluation of warehouse processes and operations.

The organizational aspect involves defining the existing procedures, documentation, supporting information systems, and the level of employees education. In two of these aspects it is necessary to establish a direct and measurable impact of warehouse worker at the efficiency of observed warehouse.

Also, from the aspect of human resources scientific research training of personnel involved in the supply chain primarily results also with the optimal organization of the flow of goods and reduces the number of working operations, thus achieving efficiency of the chain system directly increasing profits. Mentioned is applicable also on warehouse processing.

Research activities according literature review on which to pursuant further research on warehouse operators work efficiency evaluation due to the lack that existing methods have is to develop a methodology that will be on the macro aspect take into account criteria such as

- type of transport means,
- type of SKUs in receiving (box, pallet, single package)
- type of SKUs in storage,
- type of equipment in the warehouse,
- the type of SKUs for order picking and,
- shipping method that affect the performance of the entire warehouse process.

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MODELING OF THE GENERAL DEFINITION OF THE CUSTOMS SYSTEM

ABSTRACT

Customs system, generally speaking, represents an integrated subsystem of total system environment of one country (union), which, in the sense of relatively isolated unit, consists of elements and functions, and it has its defined goals that should be compatible to goals of the system environment; it functions according to the rules (legal norms and other standards) set from inside and outside and it is, in a functional sense, under the management of customs administration of the country. This paper, applying the concept of the general system theory, synthesizes and provides the general definition of the customs system with a developed process model. Considering explanations and definitions of the concept "customs system" given by relevant authors, which implies, also, the critical approach toward the same, and assuming that the customs system can be noted as an appearance which satisfies principles of general system theory, this paper shows definition of this notion along with its defined constituents. Also in this paper was carried modeling general definition of the customs system.

KEY WORDS

customs; customs system; modeling general definition of the customs system; systemic approach;

1. **INTRODUCTION**

In respect to definitions of concept "system" authors can also be found with different explanations of notion "customs system". Customs system is a part of certain system, a subsystem within a broader system environment. Functioning of subsystem as an independent part is connected with achieving the objectives defined in the total system where regulations concerning the development of domestic market are manifested. With regard to this, customs system represents a dialectical unity of certain scientifically established findings on basic parts and institutes (e.g. bonded goods, customs value, customs area, etc.) and certain number of instruments which are used for actual realization of its objectives (customs, levies, substitute exports etc.). Customs system as a subsystem of a broader system of international economic relations realizes its function in accordance with interests and goals of broader system of certain country. System of international economic relations achieves its defined goals through interactive and mutually restricted functioning not only of tariff but of foreign trade, foreign exchange and credit-monetary system as well. Observed in a more complex way, these systems represent integral parts of a broader economic system which is, however, a subsystem of total system of social-economic development of one country.[1]

According to many authors in the field of customs, it is not so rare that customs system is defined in its narrow sense, in the narrow sense of the word that is as customs systems which formally represents a group of regulations for the field of customs, bond (customs supervision) and customs clearance which is applied in the certain area.[2] Customs system of every country does not represent something that is isolated or imaginary to the economic system of respected country. Customs system of certain country represents an integral part of the country's economic system. One cannot imagine development of certain country's economic system without development of its customs system.[3] As an integral part of economic system in general, it defines the rules according to which domestic legal and natural persons that set economic relations with countries abroad in the field of customs protection of domestic production should act. Customs system, as an integral part of a country's economic system, has to be consistent with rights, obligations and responsibilities set by systemic solutions in other subsystems: foreign trade, foreign exchange, tax, monetary, system price, etc. Customs system is, basically, set of total legal regulations which are interconnected so that they regulate all relations and conditions referring exit and entry of persons in and out of state, as well as import and export goods.[4] Even though it represents rounded whole, entirety, customs system is only a subsystem of total fiscal system and depends on development policy of domestic market. Some authors, observing the customs system as the way of how customs, customs duties, customs goods, customs supervision, customs territory, customs tariff and other institutes and customs instruments are regulated, define customs system as "unity of institutes of customs policy, customs supervision and customs clearance that apply to one customs territory regardless of whether these are included in autonomously adopted regulations or predicted by international conventions and agreements which the respected country ratified." Much broader definition of the one given so far is that customs system represents customs sovereignty of certain country which is actually expressed through number of institutes, instruments, measures, actions and mechanisms set by laws and other legal regulations and that are used to realize the strategy and policy of passive and active protection of national economy in commodity exchanges with foreign countries.[5] Pavlinić S. has given the following explanation of the concept 'customs system': "For the concept of customs system it can be said that customs system is a system of interconnected subsystems and elements that with law regulations, material-technical means and human resources enable international transport of goods and passengers, that is, ensure the international exchange and unimpeded flow of goods, people, capital and information."[6]

2. MODELING OF THE GENERAL DEFINITION OF THE CUSTOMS SYSTEM BY APPLYING SYSTEM APPROACH

Taking into consideration previously given explanations or definitions of the concept customs system, which also includes a critical approach to the same, and given the assumption that customs system can be noted as a appearance that meets the principles of general systems theory, Jakupović S. has given the following definition of this concept along with its defined integral elements: "Customs system of a country represents a relatively isolated unity (subsystem) within its system environment, composed of structure which in the observed time period operates in accordance with defined criterions and has a synergetic control over the flow of goods, people, capital, ideas and information that are necessary for the realization of defined goals of respected customs system as well as the objectives of total system environment. "

Therefore, the above given definition includes complete categorical system of fundamental factors of a appearance noted as "customs system", that is, the following categories of these factors are included:

- Boundaries of the customs system as relatively isolated units, as well as the system environment of the customs system,
- The goals of the customs system and its system environment,
- The structure of the customs system, composed of elements and their interrelations,
- The criterion for performing the functions of the customs system, and
- The dimension of time observation of the customs system.

Following the given definition, in order to give better explanation of customs system as a relatively isolated unity (subsystem) in relation to its system environment, Jakupović.S has also shown a graphic model as following (Figure 1)

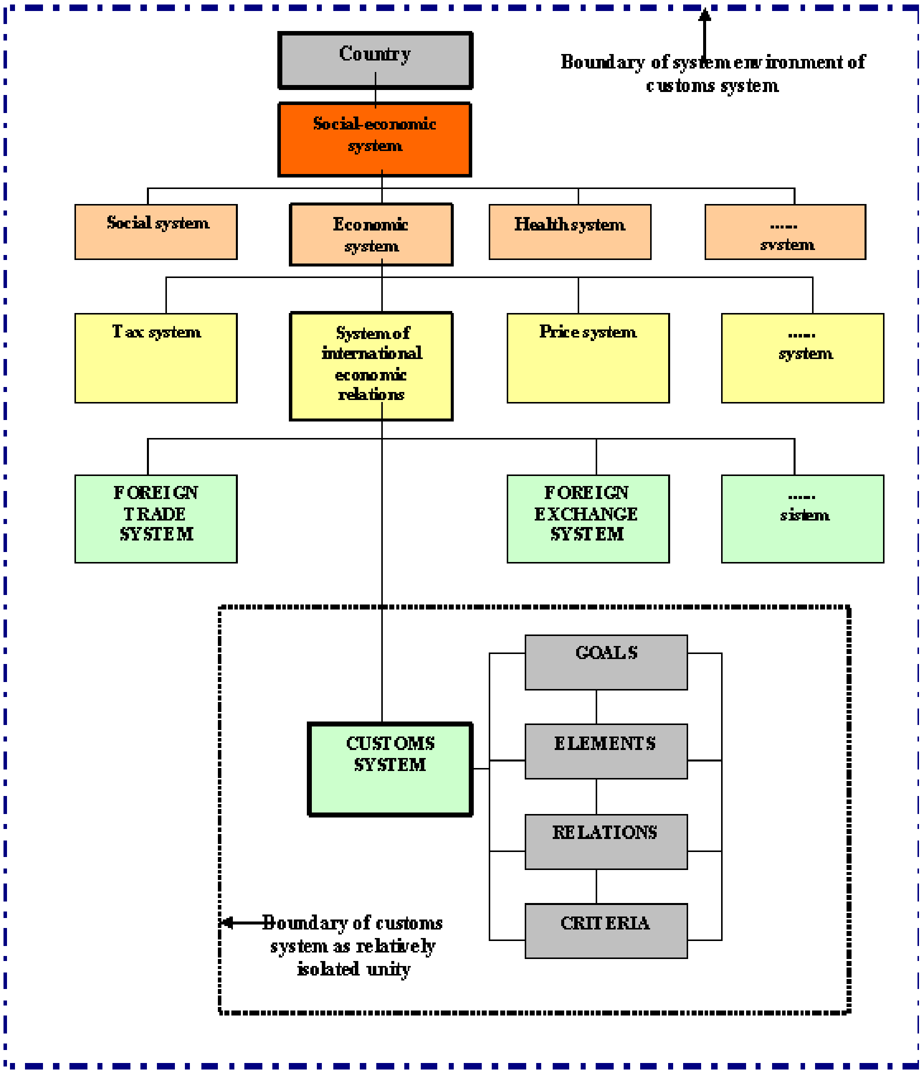

Figure 1 – Model of customs system as relatively isolated unit in relation to its system environment
Source: [7]

2.1 Integral elements of customs system (structure, function, criterions) – general process model

The structure of the system is composed of the elements of the system and their interrelations and connections. The structure has a fundamental meaning for the system and its properties, and this is understandable, given the fact that the system does not include simple, but complex composition of elements that are in mutual interaction, and it does not need to have the same properties as its constituent parts. The features of the system depend on the manner in which its elements are related, and that means of its structure.[8] Mutual interaction and operation of dynamic systems to each other, operation of the system's elements and operation of the system to its environment are realized through material, energetic and information flows. These flows have been enabled by the existence of the channels that represent the relations between the elements of the system. Each system must have channels through which the effect of the environment on the system is transmitted and the channels through which the system operates on its environment. Therefore, each system must have at least one input and one output.

The system's inputs represent the channels through which the effect of the environment on the system is transmitted, and the outputs represent the channels through which the system operates on its environment. The effects of the environment on the system that are transmitted by the system's input are called input values**,** and the operation of the system on its environment that is transmitted by its output is called output values. Each system that has at least one input and one output is called the active system, that is, each system can be seen as a part of the space that is in the active relation. Activity of the system is reflected in the constant transformation of its input to output. The number of inputs and outputs of the system depends on the extent of its activity and they do not have to be mutually equal. The system is more active if it has larger number of inputs or larger number of outputs, or even larger number of inputs and outputs altogether.[9]

Pavlinić S. starts from the following assumption: "For the structure of customs system it can be said that the structure of customs system represents an internal layout, that is, the internal formation (mechanism) of all parts that are connected by the relations of dependence. The structure of the customs system is complex, static, and nowadays dynamic as well, stochastic, and composed of the parts that are directly influenced by numerous external factors while, at the same time, the customs system itself operates on its environment. "

According to such given explanation, Pavlinić S. notes that the customs system consists of the following elements: regulations, organization, human potential, informational technology, risk management, the culture of organization and equipment. At the end of this explanation Pavlinić S. has noted that these elements of the customs system can be determined to belong to the customs system in narrow sense (micro customs system), while the element of logistic activity is a part of the customs system in wider sense (macro customs system) for numerous activities referring the customs service's operation can be included here such as the international forwarding agents, international agents, carriers, inspection services (phytosanitary, veterinary, business, etc.), police, and, widely speaking, even importers and exporters can be included here, that is all those that in any way participate in foreign trade activities.

Taking into consideration the above given theoretical explanations of the system's structure, however, partially respecting the opinion of the customs system's structure given by Pavlinić S., and starting from his own given general definition of the customs system, and applying the concept of systemic approach and process model, Jakupović S. concludes that the structure of the customs system (Rcs), in general, is composed of the following elements (E) and relations (T) – (Figure 2).

$$Rcs = \{E,T\} \tag{1}$$

(1) Elements of input values (E_{Xi}) – *goals, criterions, (regulations, rules), human resources, material resources, information, ideas, money;*

(2) Elements of output values (E_{Yo}) - *goals, criterions (rules), human resources, material resources, information, ideas, money;*

(3) Elements of transformation of input-output values (E_P) – *overall management subsystem (customs administration with all defined elements, structure and function), goals, criterions (regulations, rules).*

For realization of its functional role (goal function), all the above mentioned elements are connected by the relation channels (flows) ("feedback" principle), thus, comprising together the complete structure of the customs system. Considering the above defined elements of the customs system, the relations between them can be characterized as (Figure 2).

(1) flows of information (F_{in}),
(2) flows of ideas (F_{id}),
(3) flows of material resources – goods (F_r),

(4) flows of human resources (F_p),
(5) flows of money – capital (F_c).

The system environment of the customs system consists of its environment. The environment of the customs system is composed of constituent elements of so-called „input environment“ (Ei) and constituent elements of so-called „output environment“ (Eo).On one hand, input environment operates on the input values that further participate in the process of their transformation within the management (sub)systems, while, on the other hand, after the transformation is done, management subsystem (customs administration) operates on the output environment of the customs system through the so-called effects of the customs system, i.e. its output values.

The input and output environment of the customs system include constituent elements that satisfy their needs and requests (defined by their goals) by realizing the function of the customs system as a segment of total system environment of one country. Input-output environment of the customs system primarily includes the following factors:

- Economic operators in the country and abroad (as key participants in the system of foreign trade relations – companies, forwarding, etc.),
- State legislative authorities (Parliament(s) – that create total and so customs legislations and customs policy as well,
- Judicial authorities (domestic and international courts),
- Executive bodies of state (Government, government agencies – except for the Customs Administration – which participate in creating and realization of Customs policy and that in any way mutually influence the customs system),
- Relevant international subjects (such as WTO, WCO, EU, etc.),
- Financial institutions (banks, micro-credit organizations, IMF and others),
- Local community (citizens / public),
- Academic community (universities and other scientific-research subjects).

Management subsystem of total customs system of one country (union) represents, as stated above, Customs Administration of that country (union). This subsystem is a key factor in achieving the overall objectives of the customs system, i.e. the objectives of its system environment. Customs Administration, in accordance with defined criterions (legislation and other rules), manages the transformation processes of the elements of input-output values. However, when it comes to operation and work of Customs Administration as an organizational system, it is regulated, also, by certain criteria, i.e. legislation (most frequently, by law and other regulations on Customs Administration) and other rules and standards (references) that are taken from relevant domestic and international sources. Therefore, in order to perform its functional role, it is necessary that Customs Administration has its own objectives (defined in both mission and vision), defined criterions (based on legislation and other rules), organizational structure (functional units, their dependence and decision-making spots), human resources – people as the key activity performers, necessary material resources (equipment, facilities and other material-technical means) and the integrated information-communication system as the key segment that manages the information and the transfer of communication between Customs Administration and system environment as well as the one within Customs Administration itself.

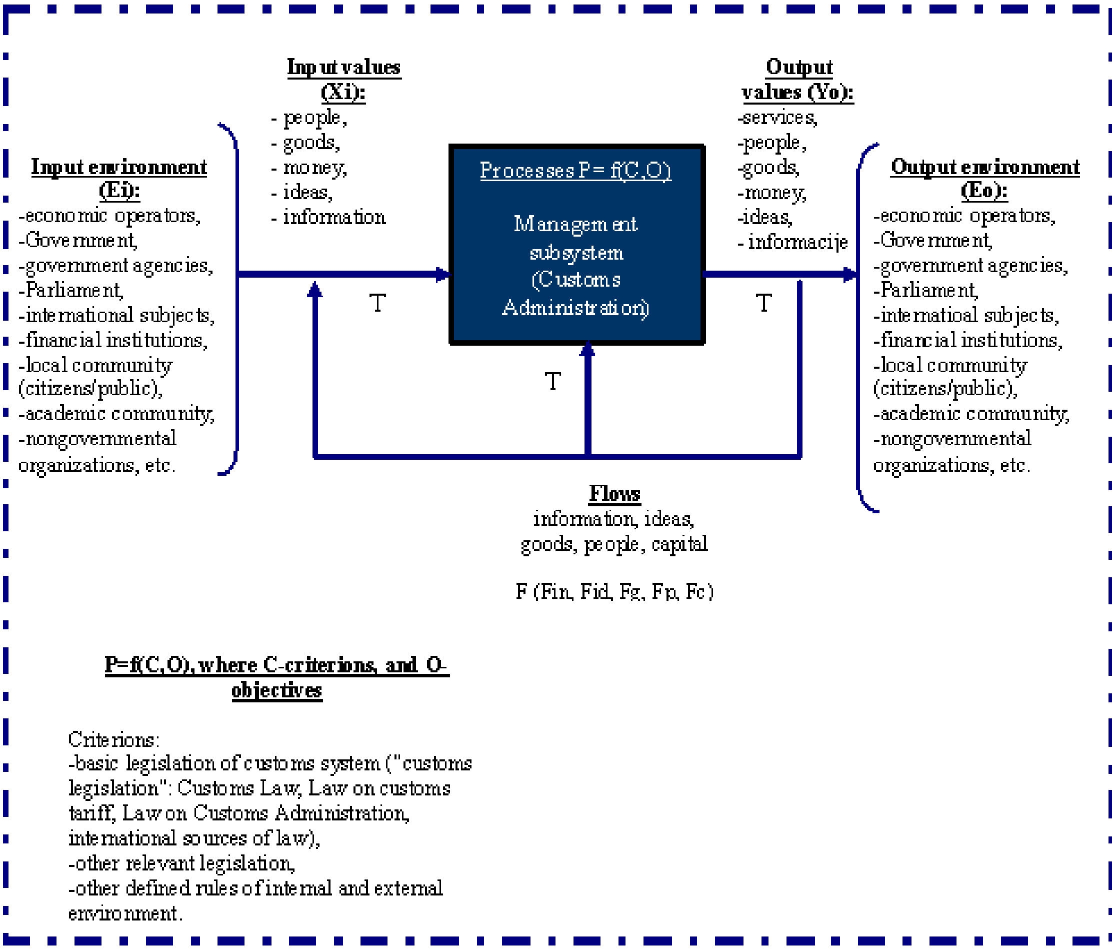

Figure 2 – General process model of customs system
Source: [10]

Therefore, to enable the management element of the customs system (Customs Administration), and all the participants of system environment of the customs system to perform their functions in accordance with their own objectives as well as with those of the total customs system, it is necessary that they have defined criterions which, in this case, refer to the overall legislation and other defined rules (for internal and external environment) that are necessary for the process of transformation of the integral elements of input-output values of the customs system, i.e. the processes of transformation represent a limitation function (of criteria and objectives):

$$P = f(C, O) \qquad (2)$$

In general case, these criterions (C) can be noted as „basic legislation of the customs system“ (so-called „customs legislation“) and, basically, consist of:

- autonomous national law (Customs Law, Law on customs tariff, Law on Customs Administration),
- international sources of (customs) law – multilateral agreements (conventions), bilateral treaties, and
- international trade customs and practices.

3. CONCLUSIONS

Therefore, a conclusion can be made that the customs system, in general sense, represents an integrated system of total system environment of one country (union), that as a relatively isolated unit, it is composed of elements and relations, that it has its defined objectives which have to be compatible with the objectives of the system environment, that it operates according to the rules (regulations and other standards) that are determined from both inside and outside, and that it is managed, in a functional sense, by the Customs Administration of a country. Also, to enable the unimpeded functioning of the customs system, it is necessary to ensure that it functions in accordance with other criterions of its system environment as well. These criterions are also included in the norms of domestic and international legislation and other rules and standards. This means that during the foreign trade process it is necessary to ensure that all the criterions that influence this process are applied in a synchronized way, such as, for example, the foreign trade legislation, customs legislation, legislation on foreign exchange operations, as well as other relevant legislations, standards and references as the integral criterions of these subsystems. What appears as a result from these, noted as general, (law) criterions are various sub-legal regulations that have their defined functional role in the customs system. What can, also, be counted into the criterions of the customs system's functioning are, for example, the recommended standards of so-called "good practice" (mostly of international character).

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NEW LOGISTICS SOLUTION IN WASTE MANAGEMENT

ABSTRACT

Due to the intensive development of technology, techniques and population growth on global level increases the amount of disposed waste and need for systematic management of the same. Waste management is relevant because of possibilities of directing small amounts of waste to landfills, proper waste separation, proper waste disposal and maximizing the useful properties of the waste. Waste management appears as a segment of the concept of green logistics, and system that uses reverse logistics activities.

The development of technology and techniques affects innovation in waste management. Innovations in waste management, such as "smart containers" are aimed to a fair charge of garbage collection service, vehicles routing for maximizing efficiency (minimizing vehicles empty trips) and many other advantages. This paper is comparative analysis of waste management in Croatia and other countries that have implemented certain waste management solutions. Selected new technologies regarding waste management processes optimization will be presented as well.

KEY WORDS

waste management; reverse logistics; municipal waste; innovation;

1. INTRODUCTION

According to Article 3 (1) of Directive 2008/98/EC waste is defined as "any substance or object which the holder discards or intends or must discard" and it can represent a massive loss of resources in the form of materials and energy. Moreover, waste management and its disposal can have serious environmental impacts [1].

Therefore, aim of EU waste management policies is to reduce the impact of waste on the environment and health and to improve efficiency of resource use. The long-term aim of policies is to reduce the amount of generated waste, and when waste generation is inevitable, promote it as a resource and achieve a higher share of waste recycling and safe disposal [1].

Waste management is a part of reverse logistics and segment of green logistics concept. It can be defined as set of activities, techniques and technologies used to minimize amounts of waste disposed on landfills formed to increase amounts of re-used and recycled waste. As technology has progressed in all fields, same is regarding waste management.

Internet of things (IoT) results in information interchange between people, machines and equipment. It is defined as a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with identifiers and the ability to transfer data over a network [2]. IoT is linked with a smart waste management through the sensors and a variety of software solutions which can give new approach to waste management. "Smart containers" equipped with sensors can signal the amount of waste in container (fill level). When designated level is reached and the container needs to be emptied, sensor can signal that information to the municipal utility company. Based on these information, the company performs routing of collecting vehicles. Waste management, by connecting with IoT, gets better solutions in field of recovery and minimizing total amount of waste.

This paper describes the waste management in practice. Some of good examples are mentioned and described, as well as some new solutions and possibilities in waste management.

2. WASTE MANAGEMENT IN PRACTICE

Waste management, as a very important segment of the economy contains a series of procedures, techniques and technologies created with the aim of reducing amount of waste directed to landfills and maximizing utilization of useful properties of the waste. Systematic waste management results in transparent processing and the ability to track the amount of waste recycled or directed to landfills. Except as specified to be carried out upon the generation of waste, it is necessary to prevent the generation of waste and to enable proper recovery when determining the materials for manufacturing of the products (green manufacturing).

Internet of Things appears in the 1990s, resulting in connection between people, machinery and equipment. IoT combines two types of technology: information technology (IT) and operational technology (OT) [3]. With significant progress in technology aspects a series of innovations in waste management were developed (Figure 1). One of them is “smart container”. “Smart container” has a sensor that reports the fill level of the same. If the designated level is reached the containers then needs to be unloaded. Information about fill levels can be checked in real time for each container. Methodology contains a “compactor container” (usually a large volume container) with the press device. After container waste disposal and detecting fill level, the waste within is compressed, reducing the fill level. In this way, volume usability of container is increased, and it also affect the vehicle routing by reducing the need for container to be unloaded. Containers can also be equipped with solar panels connected with press device, so the device does not require extra energy source. In the case of large containers for high rise residential buildings the container can be equipped with locking system with electronic card/token reader for preventing unauthorised use.

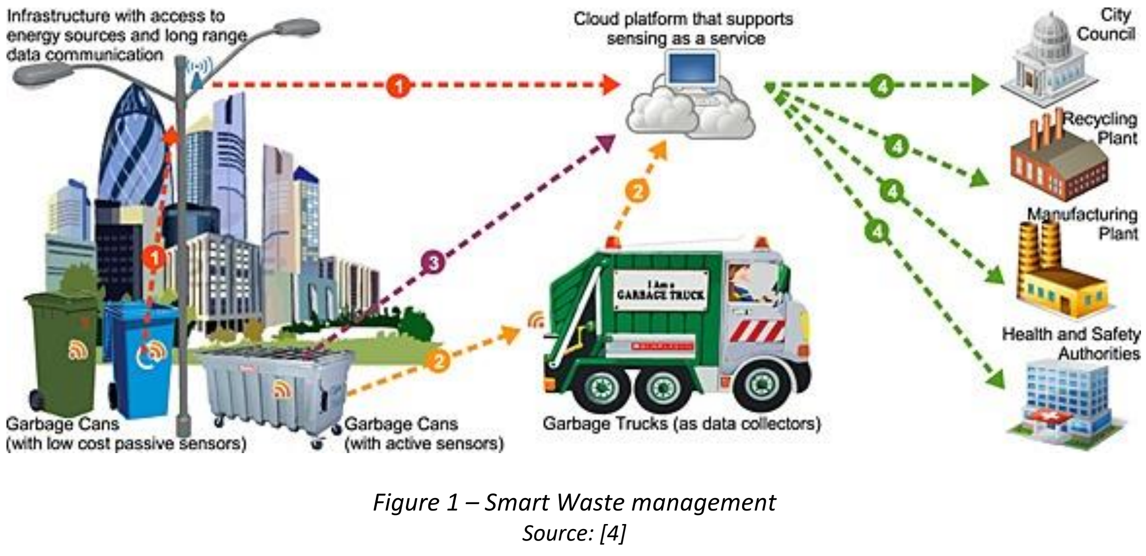

Figure 1 – Smart Waste management
Source: [4]

2.1 Waste management solutions in Croatia

Waste management in Croatia is regulated by the legal and strategic-planning regulations. Each local government must have a waste management plan and they separately determine the rules of waste management pursuant to the Plan of Waste management in Croatia and Law on sustainable waste management. In the area of local governments operates municipal utility company that organizes waste management system or waste collection.

In 2015 was produced 1,653,918 tons of municipal waste, as per capita was 386 kg. Compared to the year before, in 2014 there was an increase in the amount of 1 %. The rate of recovery was 18 % for 2015 the greatest, and the least, amounts of waste sent to a recovery are in next County's: [5]

- Međimurje County: 38.2 %,
- Varaždin County: 24.5 %,
- Koprivnica-Križevci County: 24.5 %,
- Karlovac County: 11.5 %,
- Split-Dalmatia County: 11.3 %.

A great number of local governments (approximately 1/3) have not yet implemented separate collection of useful waste. According to the reports of landfill operators, in 2015 a total of 828,564 tons of biodegradable municipal waste was landfilled and thereby aim of the Act on Sustainable Waste Management (NN no. 94/13) Article 24 is not fulfilled [5].

From that amount, landfill operators can eventually separate even more waste for recovery. In the period from 2010 to 2015 increased the amounts of municipal waste sent directly to recovery. The share of municipal waste sent directly for recovery in 2010 was 4 % and in 2015 was 18 % (Figure 2).

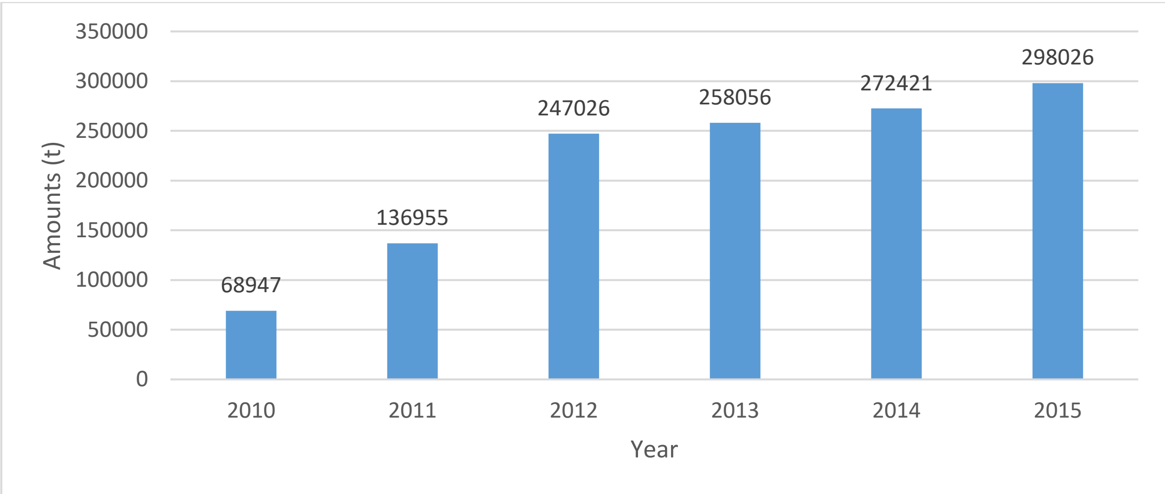

Figure 2 – The amounts of municipal waste sent for recovery
Source: [5]

One of the reasons for increased amounts of municipal waste sent to recovery is the introduction of Internet of Things (IoT) in some of local government areas. In Croatia, there are companies that manufactures IoT components such as sensors for containers, smart bins, authorization cards, etc. With these products companies enable municipal utility companies to monitor container occupancy rate, electronic reading of container code on the vehicle, upgrade for containers with RFID access control, handheld reader for reading RFID tags and barcodes, route optimization and semi-underground containers.

In Koprivnica-Križevci County, in year 2015 GKP Komunalac LLC set innovative containers for the disposal of municipal waste – Bigbelly and Bigbelly Smart in Koprivnica (Figure 3). Except Koprivnica, BigBelly containers are used in other cities such as Dubrovnik, Zadar and Opatija. This system thus provides: [6]

- reduces utilities operating costs to 80 %; a small number of truck driving, fuel savings, reducing C02 emissions,

- eliminates visible waste and prevent waste dispersal by wind,
- prevents access by vermin,
- encourages recycling in public places,
- rises customer satisfaction and results with a smaller number of complaints.

Figure 3 – Bigbelly in Koprivnica
Source: [6]

Municipal utility company KTD IVANJ Ltd from Novi Vinodolski in 2014 began to introduce semi-underground containers equipped with a system for registering disposed waste (Figure 4). It is possible to open the chamber only with RFID card (obtained by each user) and the amount of disposed waste is recorded. Each user pays for actual amounts of disposed waste [7].

Figure 4 – Semi-underground container with RFID chamber system
Source: [7]

The biggest challenge for Croatia, in the field of environment protection, is the improvement of waste management, especially in terms of separately collecting and recycling municipal waste. In 2013 only 15 % of generated municipal waste is directed to recovery while in other European countries that percentage is up to 70 [5].

But, there is a several examples of good practice in Croatia, which could serve as a model, one of them is the Eco Krk island, with a complete model of waste disposal, the first of its kind in the country. Eco Krk island in the 2015 achieved a 50 percent of waste separation and preparation for reuse and recycling, which has already met the target for the period to 2020. Now, they want to increase target to 80 percent for the same period [8].

2.2 Waste management solutions in other Countries

Practical solutions from other countries are mostly based on optimizing collection routes and different payment methods based on actual waste disposed.

An example of an efficient waste collection by dynamic routing is coming from Rotterdam, the second largest city in the Netherlands with population of 620,000 citizens. The city Government are very focused on waste recycling so less than one percent of waste ends up in landfill. To achieve these results, in the city area, was placed 4,800 underground containers for residential waste, 650 for paper and cardboard and similar number for glass waste. About 70 percent of Rotterdam's inhabitants lives in multistory residential complexes which made it practical to develop waste collection points across the city. Source of inefficiency was regarding waste collection from collection points with fixed routes. The pilot project was made including 150 paper and carboard containers equipped with fill level sensors. Sensors could monitor the fill level of each container and they were connected to company's server. By gathering data from sensors, and by predicting fill rates, company have the information on which containers needed to be unloaded and when. So, according to data from sensors, routes for waste collection was made minimizing travelled distances and maximizing resource utilization. During the pilot project, it was discovered that the optimum fill level between unloading of containers was 70 percent. Goal, set up before the start of project, was to increase the efficiency of waste collection by 20 percent, and that goal was achieved in the form of saving time, fuel, service costs and emissions [9].

Another solution is based on actual waste collected by service provider. Waste management based on "Pay As You Throw" approach means paying waste disposal services by the different accounting methods: [10]

- volume or weight based accounting (identification by bin or container),
- volume or weight based accounting (identification by user: electronic user card or token),
- pre-paid bags.

Pay As You Throw system (PAYT) was implemented in the County of Aschaffenburg, Germany. County consist of 32 municipalities with population of 173,000 inhabitants and a population density of 247 inhabitants per km^2. The County implemented a weight based collection of waste from households such as residual waste, bio waste, bulky waste and separate collection of paper and cardboard waste. Collection centers are established for dispose recyclable materials such as glass and metals. The reason for introducing weight based charging system was a fair method for paying waste disposal services for domestic users. Every household is provided with a waste bin with unique code which data are connected to its owner. Waste collection truck is equipped with a bar code reader or RFID identification system, depending of technology used. Also, truck is equipped with weighting device, requiring frequent maintenance and calibration due to truck vibrations. During the process of waste collection each bin collected by the truck is identified and collected waste is weighed and data has been recorded. Gathered data from these devices are transferred to a central server within company. Received data are processed and billing department issue invoices for each customer based on real data of thrown waste. Residents of high rise buildings could have individual bins for each household or large containers for whole building. The choice depends of available space for individual bins. In the case of large containers access to container is restricted, by locking system, only to authorized users. It turned out that buildings with individual bins produce less waste in comparison with buildings with large shared containers. PAYT system resulted in increase of collected recyclable waste and a decrease in residual waste disposal. Today, County of Aschaffenburg has one of the highest rates of recyclable collection which is 86 percent, and one of the lowest rates of residual waste generation: 55 kg per capita per year [11].

In general view, there are three methods for calculating user rates in Pay As You Throw system which are used: [12]

- Model Community Method uses data from successful programs in cities of similar size and characteristics,
- Historical Data Analysis Method examines historical waste generation of community to estimate the PAYT revenue and expenses,
- Full Cost Method as the most rigorous method which attempts to identify and quantify all direct, indirect and future expenses associated with PAYT and calculates user rates accordingly.

3. NEW SOLUTION AND POSSIBILITIES IN WASTE MANAGEMENT

By implementing a different payment methods, total amount of disposed waste can be reduced, as in the case of Aschaffenburg County. The aim is to stimulate the separation and re-use of waste and to minimize the amounts of waste directed to landfills. Also, education of customers is very important in order to minimize amounts of waste at the place of its origin.

There are several models of waste management that can be connected to the IoT, but each of them results with smart waste management. Examples of models are provided:

Collecting waste from households:

every household can be equipped with their own waste containers (capacity up to 240 l) that had built-in RFID tag or barcode and sensor with possibility to monitor container fill level. The vehicle responsible for waste collecting (garbage truck) would read RFID tag or barcode during every unloading of container and it would simultaneously record date about its weight. Data collected for each household would be sent directly to the municipal utility company database. Based on these data, the exact amounts of disposed waste, receipt for waste collection service would be issued for household. With a use of sensors that monitor fill levels collecting route can be optimized by detecting which container needs to be unloaded and thus reduce the costs of service (Figure 5).

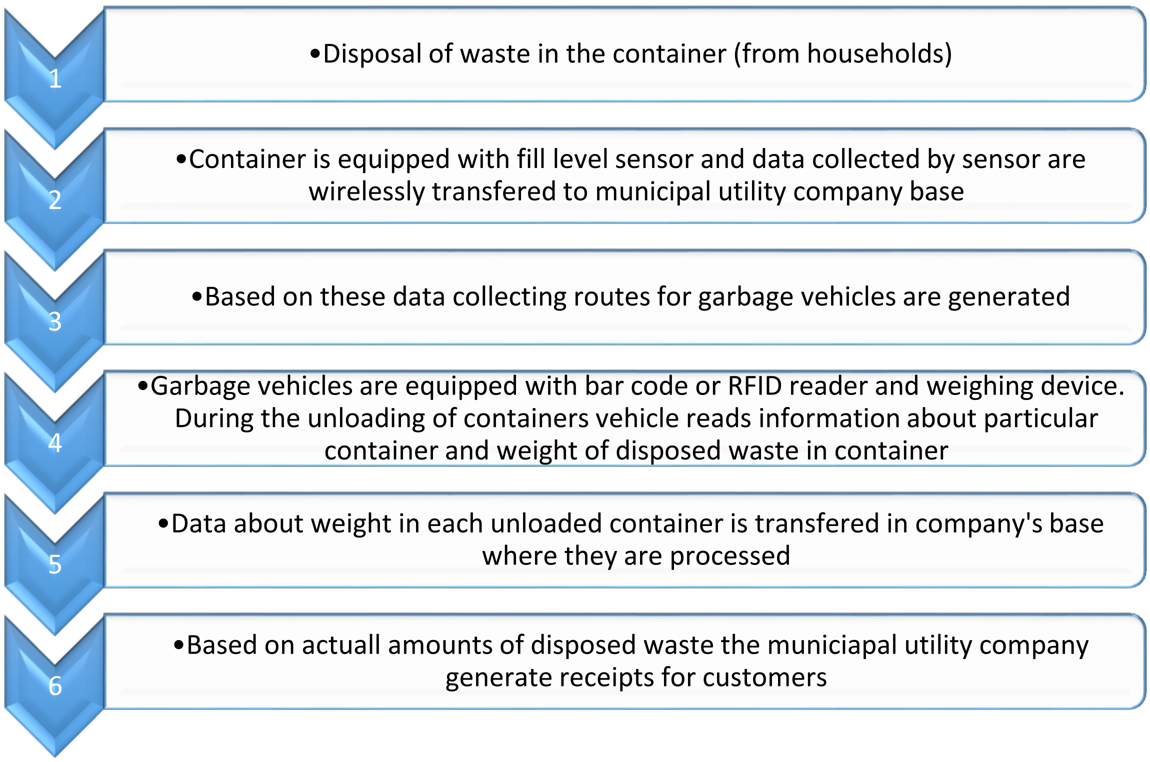

Figure 5 – Model of collecting waste from households

Collecting waste from residents in high-rise buildings:

as for the residents in the high-rise buildings, in the area around the building, if the spatial characteristics permit, a large container system would be installed, such as Bigbelly. That container would be equipped with device for limited access and user identification and chamber for measuring the volume or weight of disposed waste, depending on the type of system. The container could be opened only with an access card that would be provided to each household in the building or building complex. Billing system would be based on data collected from these containers, as every disposed waste is recorded and linked with a household via access card. Every household would pay only for amounts they dispose. In addition, the container may be equipped with the pressing device which can press disposed waste and thus increase the capacity of the container and thereby increase the interval between the unloading container. Also, with sensors for monitoring fill level, collecting route can be optimized (Figure 6).

Graphical example both models are shown in Figure 7. These models can be implemented combined with each other.

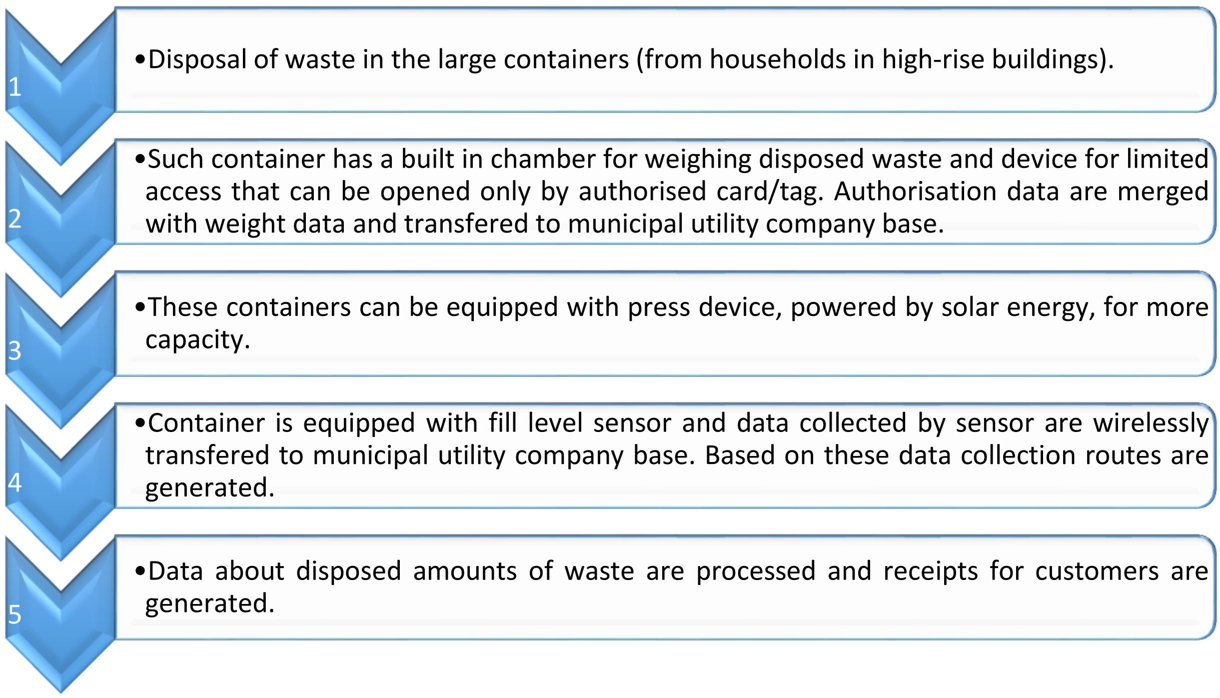

Figure 6 – Model of collecting waste from residents in high-rise buildings

Besides the door-to-door system new model would include a system of separation of useful waste in recycling yards. Where users can dispose useful waste for free or possibly get a fee for disposed useful waste.

Households that produce larger amounts of organic waste, such as food scraps, wet and solid paper and yard trimmings, can request composter bins, special containers for composting organic waste and its re-use as soil improver. In Europe, organic waste represents 30 to 40 percent of total household waste [13].

Figure 7 – Model of waste collecting service

According to similar implemented systems of waste management based on Pay As You Throw scheme expected trends are shown in table 1. Good results are expected in terms of waste collecting efficiency, rate of separately collected waste, composting of organic waste, while there is a risk of illegal waste disposal.

Table 1 – Expected trends after implementation of a Pay As You Throw system

Fraction	Expected trends
Waste collected door to door	Tends to be reduced
Packaging waste collected door to door	Tends to be reduced
Percentage of separately waste collection in door to door collecting	Tends to increase
Commercial organic fraction collected door to door	Tends to increase and contains fewer impurities
Bulky waste collected	Tends to increase
Household composting	Negligible, unless specific tax benefits are provided
Deliveries to the recycling yards	Tends to increase
Illegal waste disposal	Tends to increase but depends on adopted model, service offered and the implementation of sanctions.

Source: [14]

Implementation of Pay As You Throw system in city of Dresden shows good results in terms of reducing generated waste. Since introducing the system in 1994, waste generation dropped over 50 percent from 305 kg to 143 kg of generated waste per capita [15] (Figure 8). The Dresden system is based on volume based charging calculation which contain basic fee and service fee calculated by the container size. Also, price per container unloaded decreases as the size of container raises (80 L container: 0.046 EUR/L, 1.100 L container: 0.02 EUR/L). Level of charges per container has remained constant since 2003 and it is among the lowest in Germany [15].

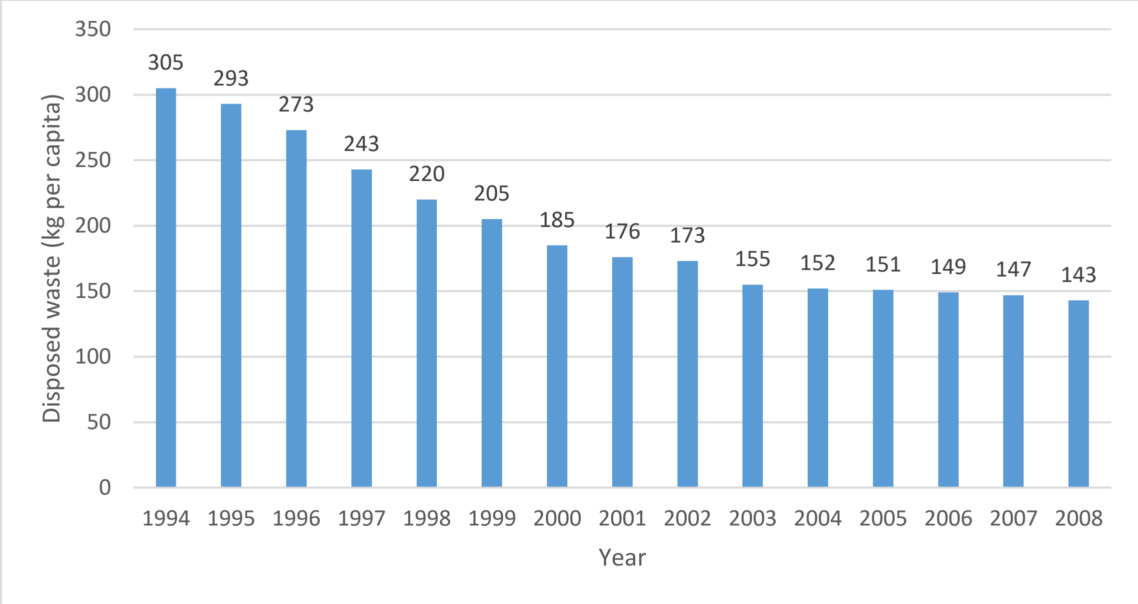

Figure 8 – Waste management trends in Dresden
Source: [15]

4. CONCLUSION

Pay As You Throw system can affect a household behaviour in terms of disposed waste and collected recyclable waste. In the case of County of Aschaffenburg, the amount of generated (disposed) waste decreased and amount of separately collected useful waste increased. With implementation of different methods customers can be stimulated to deliver their recyclable waste to the recycling yard.

The negative side of PAYT and similar systems is possible creation of illegal landfills. In theory, household can throw their waste on illegal sites to reduce waste thrown in garbage container in order to have less to pay for collecting service. This includes illegal waste disposal in bins or places that are not permitted or mixing different types of waste. Creation of illegal dumping sites was not the case in PAYT system in County of Aschaffenburg.

The most important benefit for the customer is paying method for actual amounts of disposed waste. This system encourages household to generate less waste and even to change their behaviour while purchasing products so they produce less waste. In the end this should minimize the cost of waste disposal service for the households.

Numerous examples of waste management solutions in other countries give good results in terms of amounts of generated and recycled waste. The common goal, in the near future, is to increase the amounts of recycled waste and decrease amounts directed to landfill. But, although new technologies bring the required results in terms of recycling and waste generation, these technologies can be very expensive. Therefore, attention should be paid to the profitability of municipal utility companies so that it would not operate with the loss.

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GEVGELIJA AERODROME LOCATION SELECTION

ABSTRACT

The Republic of Macedonia has two airports, the "Alexandar the Great" in Skopje and "St. Paul the Apostle" in Ohrid. For better aerodrome coverage in the southern part of the state, an aerodrome in the vicinity of Gevgelija city is necessary. In the first phase this aerodrome will be intended for sport, pilot school, sightseeing and medical urgency flights. The paper is presenting location selection process. Location must satisfy possibilities of extension runway and aerodrome.

KEY WORDS

Gevgelija aerodrome selection process; aerodrome location criteria's; aerodrome sustainable development;

1. INTRODUCTION

The City of Gevgelija has no aerodrome for general aviation. The main purpose of aerodrome is pilot school. The process of electing and testing several possible locations is based on standards and criteria which leads to election of the best aerodrome location. Using the acquired knowledge for a multidisciplinary analysis and theoretical testing, the most suitable location has been selected.

The process of determining the potential locations complies with given conditions and long term aerodrome development in accordance with the Strategy and the Physical Planning Program of the Republic of Macedonia and Municipality of Gevgelija Regional Planning.

The selection of possible locations is based on meteorological, topographic and navigation parameters, taking into consideration the geological, traffic urban and ecological conditions. The selection of the most potential location would have the most favourable conditions for development, given the determining parameters. In order to avoid the obstacles regarding the surrounding of the city, urban and regional space plans would be taken into account.

The Gevgelija aerodrome would be classified up to 800m length of runway of the finally selected location as non-instrumental, which allows runway extension up to 1,200m length.

2. GEVGELIJA AERODROME LOCATION SELECTION

Having in mind the factors which influence the possible aerodrome location, the location selection will be primary elaborated considering the topographical, meteorological and navigational condition, and also urban space planning, civil engineering and geology, traffic and other conditions.

2.1 Topography

Three potential locations are taken into consideration with regard to settlements, construction condition and free state land for the Gevgelija aerodrome, designated in Fig. 1 as Lokacija 1, Lokacija 2 and Lokacija 3; further in paper as L1, L2 and L3.

Figure 1 – Possible Gevgelija location for aerodrome position

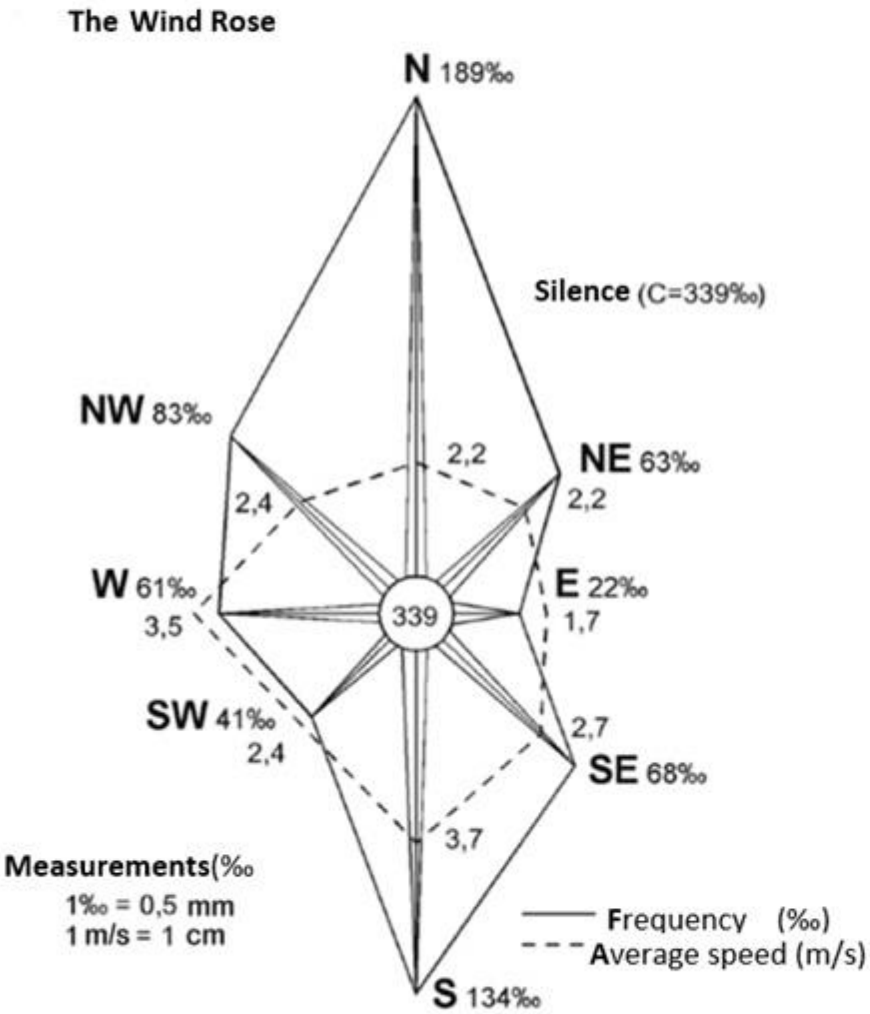
Into consideration for location selection will be taken the state border, the surroundings settlement as well as the Gevgelija area amenities.

Gevgelija is located in the southeaster part of Macedonia 3km away from the Bogorodica checkpoint on the Macedonian-greek border, with the Vardar river on the right side in a valley surrounded by the Kozuf and Pajak mountains. Gevgelija is an intermediate stop on the Skopje-Thessaloniki road, 70km from Thessaloniki and 165km from Skopje. Due to the Aegean Sea proximity, Gevgelija has a Mediterranean climate and Mediterranean characteristics. City coordinates are 41°8’22.2’’N and 22°30’10’’E.

The Municipality of Gevgelija has total area of 483,43 km². Gevgelija is located in Valandovo valley, with Vardar hill on the east side, extending towards the Kozuf mountain. The location is giving Gevgelija a very important economic, administrative and cultural significance. All three locations are flat areas which allows prepare surface with minimal excavation or infill.

2.2 Meteorology

According to the wind rose northern and southern winds dominates. Other winds occur less often and with less intensity. Winds have a generally lower intensity during the summer, while during the winter, the end of autumn and early spring they are of a much greater intensity. The occurrence of storms is very rare. The maximum wind speed from the north is 15,5m/s, from the south 18,9m/s. Calm is approximately 33,9%, wind from north 18,9% and from south 13,4%.



Direction	N	NE	E	SE	S	SW	W	NW	C
Frequency (‰)	189	63	22	68	134	41	61	83	339
Aver.Speed (m/s)	2,2	2,2	1,7	2,7	3,7	2,4	3,5	2,4	/
Max.Speed (m/s)	15,5	15,5	15,5	18,9	18,9	15,5	22,6	18,9	/

Figure 2 – The wind rose for Gevgelija

2.3 Navigation

According to the navigational conditions there is no significant obstacles at the locations. The safety of air navigation in the vicinity of the aerodrome depend on obstacle limitations. Location of surrounding settlements are distanced enough and they are not under the approach and surface. If it should be any obstacles limitation it would be marked and lighted if it would be necessary according to the Annex 14, Volume 1, Chapter 6, 6.2. or 6.3.

The aerodrome boundaries include airspace height up to 4,000ft AMSL (Above Mean Sea Level) defined by the approach and departure routes to the direction of runway. All the activities which would exceed 1,500m MSL (Mean Sea Level) flight must require competent air traffic control approval. The relative height of the school circle must be 300m or 250m according to the eligible amount. The Gevgelija aerodrome traffic pattern for gliders could take place on the east and west side. Aerodrome departure and following arrival procedure border points must be outside the airport zone at 850m MSL.

Compulsory reporting points before entering the airport traffic and maintaining contact to the already established frequency are obligatory for the pilots. To perform the navigation within the airport zone would be realized by using visual navigation. The announcement of the flight approval would be carried out by the Skopje control. The pilots would be required to prepare for starting and finishing the flight operation themselves.

3. LOCATION SELECTION

The selection is according to the international air traffic and common reference system. Geographical coordinates will be expressed in World Geodetic System-84 as Positional Geodetic System. For height reference the MSL system of sea level will be used.

According to the topographical, metrological and navigational conditions, and taking into consideration urban-spatial conditions, civil engineering-geological and traffic conditions location L3 is determined as most suitable.

The selected aerodrome will be intended for ultralight aircraft flights, general aviation's, helicopters, jumping, parachuting and other flight activities. Selected aerodrome location is about 100ha area and positioned 11km from the city of Gevgelija and 3km from the village Prdejci, parallel to the highway and railway on the eastern side. At a distance from 2km north is the Vardar river and on the west L3 side is the Kozuf mountain. The most suitable meteorological, topographical and navigational conditions when taken into consideration imply the most favourable location. The aerodrome location ensures safe operations conduct.

Design and aerodrome operation determined by the Annex 14 to the Convention on International Civil Aviation, volume 1, defines the planned runway threshold, centrelines and reference points coordinates.

Figure 3 – Gevgelija aerodrome location movement area

According to the wind rose runway is situated in direction 350°-170°ensuring that aerodrome will be opened more than 95% of time because of the winds. The conditions for aerodrome reference code A1 and commercial further development fits the selected L3. The most favourable location selection satisfies for extensions and ancillary facilities.

4. RUNWAY PHYSICAL CHARACTERISTICS

Selected location for Gevgelija aerodrome has no obstacles. This aerodrome location selection is justified by the current political and social situation and air transport development.

Location is suitable for aerodrome from the topographical conditions characteristics, meteorological situation, proximity of surrounding aerodromes, facilities and other resources. All elements in the planning process need to be complied with the specifications of ICAO. Selected reference aerodrome field length is 600m and runway land corrected length is 840m. The runway strip with parallel taxiway and its strip would have a rectangular shape of approximately 250x900m. Location, the MSL elevation is 78m.

According to the reference temperature (30°C) longitudinal slope (2%) and elevation (78 metres) correction of the runway length is approximately 840 m.

5. ELEMENTS OF OBSTACLE LIMITATION SURFACES

Corresponding to the aerodrome reference code A1 the reference length of runway is 600m, and the width is 18m. Compulsory runway correction length is made due to temperature, altitude and slope is 840m. Width could be extended to 23m in the second phase of the runway extension, according to the established ICAO regulations. Runway is designed for visual meteorological conditions.

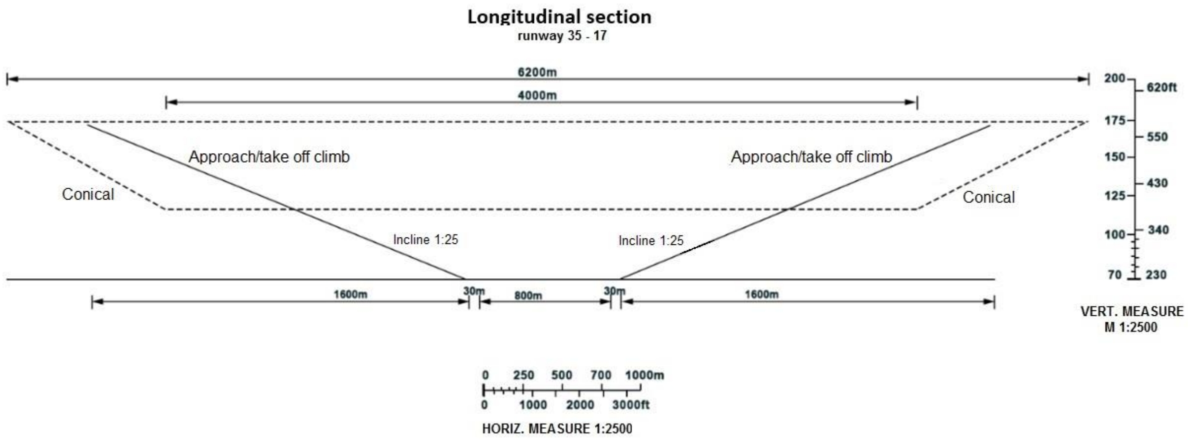


Figure 4 – Obstacles limitation surfaces, longitudinal section L3

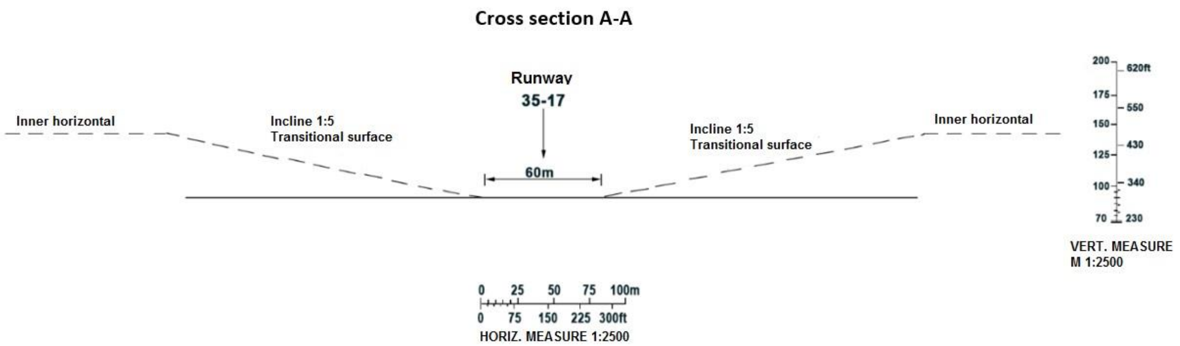


Figure 5 – Obstacles limitation surfaces, cross-section L3

The region as well as the city needs an aerodrome for small aircraft during the whole year. Grassed runway would be operational about 10 month. This situation implies the mostly pilot school aviation needs, while the commercial service could be provided in the future development. The potential location fulfils the conditions for an A1 aerodrome.

Figure 6 – Obstacles limitation surfaces of selected location, L3 floor plan

The location meets the requirements of the necessary conditions for further development.

In order to achieve the conditions for an aerodrome usage throughout the year, the recommendation is to expand and construct the movement area of constructive pavement. The runway and apron are connected with one longitudinal taxiway and to entry exit taxiways. For night flight activities it is necessary to equip aerodrome, and light for visual aids for navigation etc.

6. SUSTAINABLE DEVELOPMENT

The selection of the location for the Gevgelija aerodrome satisfies the present needs and the development possibilities of the future. The selection of the possible location is based on environmental sustainability, economic potential and socio-political needs on both the regional and national level. Ensuring the possible aerodrome development, aerodrome system sustainability and environment, the selected aerodrome location will satisfy the real present demands and anticipated future generation requirements.

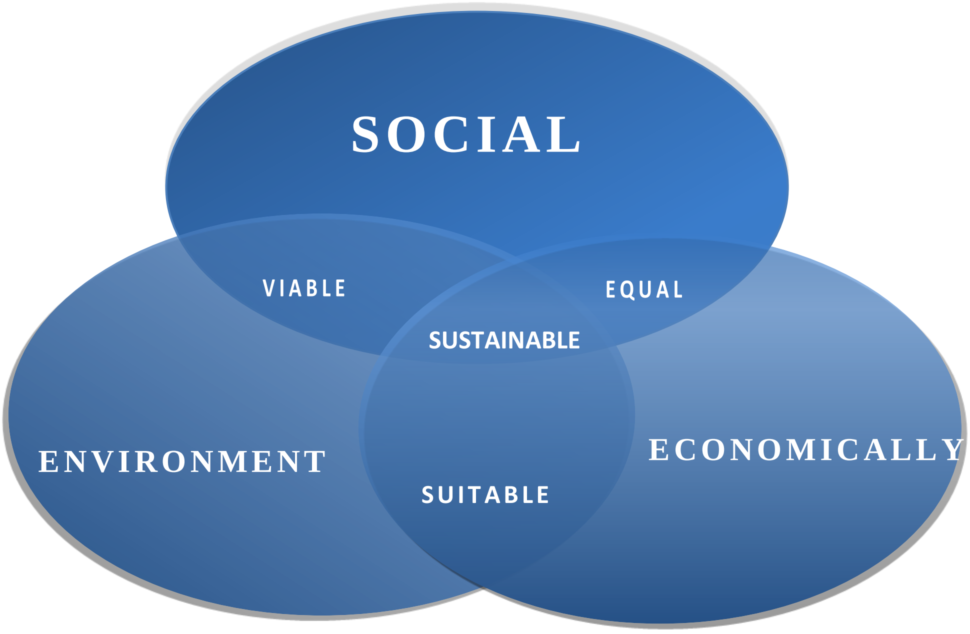


Figure 7 – Sustainable development

Considering structural, institutional and financial consequences the selection of the location is viable, expected and tolerable. The basic requirements for determining the most favourable location are sustainable without the potential of sudden and uncontrolled collapse. The final Gevgelija aerodrome capacity depends on the already basic elements classification and aerodrome categorization. Basically, the aerodrome capacity will be determined by the runway operations (aircraft landing and take-off).

7. CONCLUSION

The development of air traffic and the lack of aerodrome infrastructure in the southeaster part of Macedonia leads to the question of planning an aerodrome for general aviation in the vicinity of Gevgelija city. The selected location is north of the Macedonian-greek border. The selection process is mainly based on the conditions: topography, meteorology and navigation as well as geology, traffic, urban and ecology are also taken into consideration. The most favourable selected location satisfies the further expansion and construction off paved runway.

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THE USE OF THE EXTENT OF MARKETING COMMUNICATIONS IN AFFIRMATION OF ITS SERVICES

ABSTRACT

In the dynamic and intensive market of high technology, there are specific problems and challenges for which the traditional marketing doesn't have adequate answers. This made the upgrade of traditional "technologically-economic" approach necessary in the form of the strong synergy of marketing and innovative technologies. The disciplines to which technological marketing is particularly close are technical disciplines, with a specifically strong focus on disciplines of traffic technologies. To this effect, in the last twenty years, Intelligent Transport Systems have arisen as an innovative concept of solving traffic difficulties, with special advantage in applying this intelligent characteristic to high technologies. The new generation of clients represents a great challenge. In the absence of marketing communication directed to end users, innovative product/service could be left unusable. Because of that, it is necessary to apply and integrated marketing communication tools. With this approach, it is possible to attract attention and influence the behaviour of targeted groups of users.

KEY WORDS

High-tech marketing; Intelligent Transport Systems (ITS); ITS services; integrated marketing communications;

1. INTRODUCTION

The development and introduction of new high-tech products/services caused a notable change in marketing approach. Traditional marketing is no longer able to effectively link the supply and demand of high-tech products and services. Classic marketing tools were transformed and adapted to the modern market. Lately, technological marketing is getting closer to disciplines of transport technology. The innovative and advanced solutions in the field of traffic and transport are being developed under the title Intelligent Transport Systems (ITS). ITS can be defined as a holistic, control and information-communication (cybernetic) upgrade to classic traffic and transport system which adds significantly to the performance, traffic flows, more efficient transport of passengers and goods, improvement of traffic safety as well as comfort and protection of passengers, less pollution, etc. ITS has the meaning of a new critical concept that changes the approach and the trend of development of traffic science and transport technology of people and goods to effectively solve the growing traffic congestion problems, environmental pollution, transportation efficiency, safety and security of people and goods in transportation process [1]. Intelligent Transport Systems have arisen as an innovative concept of solving traffic difficulties, with special advantage in applying this ''intelligent'' characteristic to high technologies. These kinds of solutions need to get closer to costumers properly. The promotional message should be concise and clear for better understanding of the purpose of the product/service and the way of using it. In that sense, an appropriate solution is the application of integrated marketing communications. The Fourth chapter presents the possibility of using integrated marketing communications in ITS. Also, the framework guidelines for practical use are given.

Directive 2010/40/EU is a general document for coordination of ITS development in the European Union. It is the obligation of the Member states to adapt their national legislation to achieve goals set by the directives. The essential part of the document is the list of priority areas and priority actions, as well as plans with set deadlines. The basic objective of the Directive is the setting up of a framework for future activities which will consequently lead to the harmonisation of ITS development in Europe [2].

The adoption of specification for priority areas is the first step toward a harmonised development. Specifications will be developed individually and, depending on the area covered, they can include different types of provisions:

- Functional provisions that describe the roles of various stakeholders and the information flow between them;
- Technical provisions that provide the technical means to fulfil the functional provisions;
- Organisational provisions that describe the procedural obligations of various stakeholders;
- Service provisions that describe various levels of services and their content for ITS applications and services, [2].

ITS architecture can be defined as the basic system organisation consisting of crucial components, their relations, and connections to environment, as well as principles for system design and development during the whole lifecycle. The lack of architecture can result in difficulties because of incompatible components, higher cost for updates, and complications in introducing or adjusting new technologies. ITS architecture provides a general framework for planning, designing and implementing integrated systems in defined period and geographical area.

An ITS Architecture is important for a few reasons:

- it ensures an open market for services and equipment, because there are “standard” interfaces between components;
- an open market permits economies of scale in production and distribution, thus reducing the price of products and services;
- it ensures consistency of information delivered to end-users;
- it encourages investment in ITS since compatibility is ensured;
- it ensures inter-operability between components, even when they are produced by different manufacturers, which is also good for SMEs (Small and Medium-sized Enterprises);
- it permits an appropriate level of technology independence and allows new technologies to be incorporated easily;
- it provides the basis for a common understanding of the purpose and functions of ITS, thus avoiding conflicting assumptions [2].

Based on the content and mandatory use, three main types of ITS Architecture are defined: Framework ITS Architecture, Mandated ITS Architecture and Service ITS Architecture.

2. SPECIFICITY OF ITS SERVICES

With fast expansion of cities and a process of urbanisation there is a vast pool of problems which affect the quality of life of urban areas. Non-efficient traffic system and transport network, non-adequate traffic infrastructure, traffic accidents with casualties, diminished mobility and access, congested traffic and negative effects it had on the environment are major problems which point to the need for a systematic approach to solving them.

In this sense, there is a need for a new approach for accomplishing safe, fiducial and effective transport with minimum impact on the society and the environment. With the implementation of innovative technologies, there is a sustainable, clean and energy efficient traffic in the cities. In this sense, ITS (Intelligent Transport System) presents innovative approaches, models and technologies which solve an array of problems in traffic and transport. Intelligent Transport Systems are here for many of years but urban centres just recently started to implement the new generation of ITS. It is hard to imagine flexibility and quality of public transport without the implementation of ITS.

Services within ITS are grouped and systematised by criteria of sorting which is also called taxonomy of services. Taxonomy of ITS services is conducted by well-defined domains (e. g. traffic management, passenger informing) and by liability (traffic safety, public transport, etc.). This kind of partition is not fixed considering the dynamic rate at which ITS is growing and on the account of possibility of implementing different branches inside of already mentioned division. Initial taxonomy is the result of standardisation of ITS solutions in the frame of International Standardisation Organisation (ISO). The new ITS taxonomy includes 11 functional areas and 32 services. Functional areas are divided as follows [1]:

1. Traveller Information;
2. Traffic Management and Operations;
3. Vehicles;
4. Freight Transport;
5. Public Transport;
6. Emergency;
7. Transport Related Electronic Payment;
8. Road Transport Related Personal Safety;
9. Weather and Environmental Monitoring;
10. Disaster Response Management and Coordination;
11. National Security.

Inside of every functional area, there are related ITS services. The base of 32 services was defined by ISO. Some of the more prominent services in these functional areas are Pre-trip Information, On-trip Driver Information, Trip Planning Support, Route Guidance and Navigation, Incident Management, Public Transport Management, etc. Hereinafter some of the ITS services are described.

2.1 Multimodal passenger informing in urban areas

A lot of significance is given to one of the six priority areas of ITS directive; to the Multimodal Traffic Information in the European Union. One of the more important ITS services is Traveller Information, which provides users with the most efficient travel route and means of travel. Traveller Information (TI), according to ISO taxonomy, is one of eleven functional areas of ITS services [1]. Traveller Information Service (TIS) is a vital part of the strategy of European Commission for the future of travel itself. Today there is several implemented ITS services for advanced traveller information which cover all means of transport in real time. Multimodal travel guidance is becoming increasingly popular. Their integration of pre-travel and travel planning is giving a comprehensive spectrum of relevant information which will help the end-user with planning their “door-to-door” trip [3]. For the even more successful implementation of multimodal traveller information, in the marketing context, the necessity for attractive service for the end-users exists. Access should be enabled through different media and service provider can use social networks to receive feedback.

It is important to note that the benefit of multimodal travel information and services for trip planning can be seen in a broad economy of a country in the sense of providing new business opportunities for service providers and in opening new job positions in a highly dynamic sector. Implementing new systems of informing and travel charging presents a crucial step towards more quality transport system. One of the barriers which alienate the service from an end user is sharing their personal information they collect in this environment.

Lately, a lot of care was given to stop this from happening and to protect this kind of information from leaking. Member countries of EU have committed themselves to take account of fundamental rights and freedoms of individuals when establishing national legislatives. This means that ITS legislative should ensure and protect from abuse all personal data, including unauthorised access, modification and loss of data. For these reasons, it is encouraged to stay anonymous while exchanging information [3].

2.2 Electronic Payment in public transport

ITS services are, among other services, offering electronic payment of public transport. Electronic payment of public transport is a contemporary way of paying for passenger transport. In Zagreb (ZET) there are prepaid cards and validation cards. This type of cards is also called "smart" cards. Smart cards are divided into several groups. They can be produced as memory and microprocessor cards (division based on chip type) and contact, non-contact and combined cards (division based on data transmission and access mechanism). Apart from e-payment via "smart" cards, there is e-payment via mobile phone and an automatic machine for card purchase, [4].

Action plan on urban mobility [5] is encouraging e-paying in public transport through Subject 6 – Optimisation of public transport, action 20 – Intelligent transport systems.

3. MARKET AND POSSIBILITY OF ITS SERVICES IMPLEMENTATION

With increased usage of motor cars in this century, the transport system is globally suffering under enhanced pressure. The outcome is more environment pollution, increased number of traffic accidents and traffic congestion. These issues paved the way for more advanced solutions in the field of traffic and transport, specifically in ITS services. With overcoming the initial difficulty in interoperability and standardisation, ITS market is growing significantly.

In the ITS market supply is divided into two fundamental categories – equipment (hardware) and services which consolidate software with communication services. Demand can be classified by stakeholders: end-users (drivers, travellers), system owners (shareholders), service providers, tourism companies, local community, etc. Global ITS market can be segmented by type, components and implementation [6]:

- Segmentation by Type: Advanced transportation system, advanced public transportation system, advanced transportation pricing system, cooperative vehicle systems and others.
- Segmentation by Component: Sensors, surveillance camera, software, interface board, monitoring & detection system, and others.
- Segmentation by Applications: Telematics, traffic management, parking management, environment protection, traffic signal control, road safety & security, and others.

Demand for digital services is growing exponentially. A big flow of real-time data will contribute significantly to the expansion of ITS services. Communication and information technologies are becoming omnipresent which leads to personalisation of information service. On the ITS market, the most recent services are the ones in the field of informing the end-users. Traveller Information Services are the key part of European Commission strategy for the future of transport. Apart from advanced services of passenger and driver information, the growth of ITS market can be seen in the cooperative services in traffic and transport. Cooperative services in traffic and transport are systems in which vehicle communicates wirelessly with another vehicle, infrastructure and other users. In relation to the existing systems, the technology of cooperative systems allows bidirectional communication: V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure), V2U (vehicle-to-users), I2U (infrastructure-to-users). In other words, C-ITS are systems which provide efficient exchange of data via wireless technology [7]. This provides vehicles with the connection to one another, to road infrastructure and other participants in traffic. Figure 1 shows the future of the Intelligent Transport Systems.

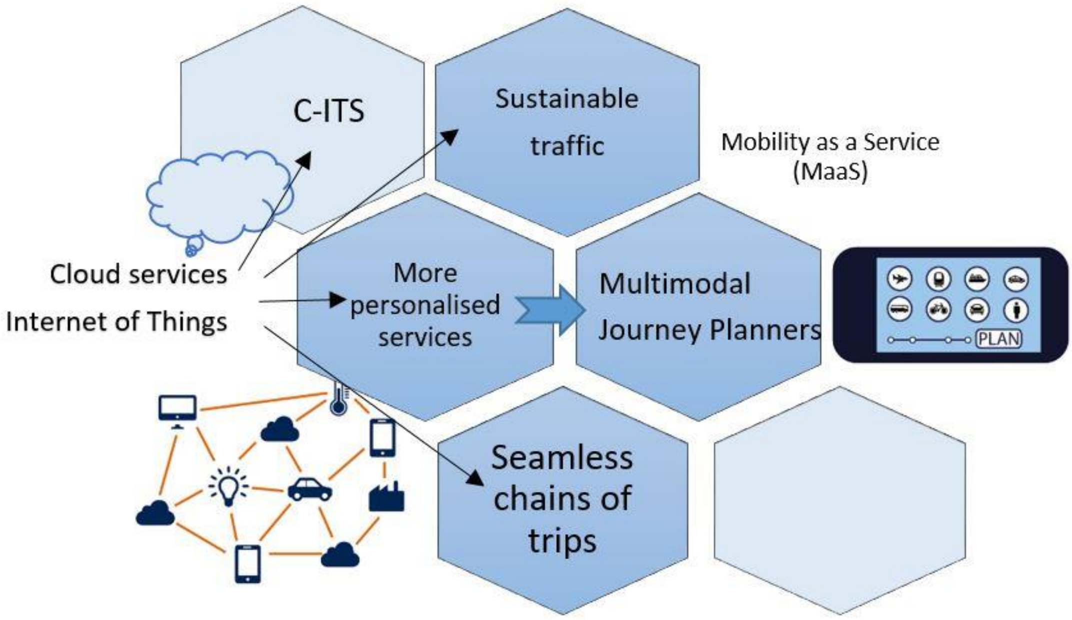

Figure 1 – Future of ITS
Source: Made by the authors

In the coming years, the digitalisation of transport in general and ITS are expected to take a leap forwards. As part of the Digital Single Market Strategy, the European Commission aims to make more use of ITS solutions to achieve a more efficient management of the transport network for passengers and business. ITS will be used to improve journeys and operations on specific and combined modes of transport [8].

4. CHARACTERISTICS OF HIGH-TECH MARKETING

In the dynamic and intensive market of high technology, there are specific problems and challenges for which the traditional marketing doesn't have adequate answers. This made the upgrade of traditional "technologically-economic" approach necessary in the form of the strong synergy of marketing and innovative technologies [9]. The concept of High-Tech Marketing is based on a determinant of general marketing theory; orientation to needs, wants and wishes of a customer, effective connection of supply and demand, organised marketing research, marketing management through analysis, planning, organisation and control, etc. With base determinants, technological marketing involves additional specific concept characteristics, such as, product or service needs to solve the concrete problem of a customer, it needs to aspire to market transparency, as well as technology transparency, meaning that the new product or service is an actual innovation, etc. An interdisciplinary approach is also a specific characteristic of technological marketing and therefore is more prominent than with traditional marketing approach.

The disciplines to which technological marketing is particularly close are technical disciplines, with a specifically strong focus on disciplines of traffic technologies. To this effect, in the last twenty years, Intelligent Transport Systems have arisen as an innovative concept of solving traffic difficulties, with special advantage in applying this intelligent characteristic to high technologies. In the context of ITS, this addresses the ability of data collecting, analysis and delivery of various services to end-users. In this manner, we attain better and adapted behaviour of traffic and transport systems. With the implementation of advanced ITS solutions, it was confirmed that the performances of traffic system and qualities of services for end-users have ascended. Derived from base concept of metamodels of technological marketing, marketing of ITS services will be designed in accordance to the concept of technological marketing of services, while the ITS hardware will be designed in accordance to the models of "industrial" marketing [9]. Technologies are developing, changing and maturing. Technological novelties often make the market uncertain. In the context of marketing, there are two types of uncertainties – technological and market uncertainty. In that dynamic, unpredictable and uncertain environment competition fluctuation arises. Figure 2 shows the placement of technological marketing against technological and market uncertainty as well as rival volatility. It is shown that all three characteristics are active components of high-tech marketing [10].

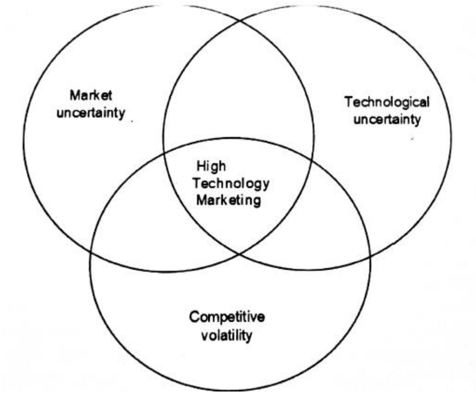

Figure 2 – Features of high-tech marketing environment
Source: [10]

To place the high-tech product/service on the market and make it attractive to end-users, it is necessary to define the needs and demands of the targeted market. This takes into consideration the analysis of existing and future clients. In these terms, Marketing Information System (MIS) is the starting point which precedes marketing development and marketing-mix (P_{MIX}). The traditional marketing mix is based on classic "4P" concept, while because of the complexity of high-tech solutions, the classic concept had to be expanded for three more variable instruments – people, physical evidence and process [9]. Concept "7P" allows high-tech companies with analysis and defining of key problems which could affect the marketing of their products or services. Last several years the "7P" concept has been made the frame for digital marketing mix.

5. VARIETY OF IMPLEMENTING MARKETING COMMUNICATIONS IN ITS

With emersion of innovative technological products/services, a state of uncertainty could develop in the market. This happens, often, in the lack of additional info which would illustrate the product/service better to the users. Since there are new technologies in question, it is of utmost importance that users understand how to use this service, which are its advantages and what is it good for. If this type of information is omitted, it is likely that this advanced technological solution will be unused and out of function. One of ITS services which recently became popular in the EU is advanced multimodal passenger informing in public transport. To be precise, informing the passengers in the right moment and in the right place is of utmost importance for successful public transport, especially for the multimodal transport system. This kind of dynamic system enables a decision of means of travel in due time. This kind of advanced informing service consolidates a set of diverse data collected from the environment. These are data of points of users' interest, habits in route selection and mode of transport [3]. Further development of application goes in the direction of absolute personalisation. Lately, this direction of development raises a variety of ethical questions and one of them is the protection of personal information. Sharing of personal data of this kind made and still makes a barrier towards inexperienced users. Additionally, collecting and analysis of data is a characteristic of other ITS services. Regarding this, it is necessary to inform and educate future users to acquaint them with this kind of advanced service. Marketing can help significantly in this matter.

For successful implementation of the multimodal informing system, it is necessary to apply adequate guidance set by the European Union. One of them is marketing aspect of service of multimodal travel informing. Guideline points out that the service has to be illustrated attractively to all end user groups with an emphasis on user segmentation. Access to information should be possible through various communication channels (smartphones, the internet, newspaper, radio, TV). Additionally, as guidelines cite, to get the insight into the success of the service, user feedback is necessary. This is to be conducted regularly through questionnaires [11]. From all this, it can be concluded that marketing could have a significant role in positive illustration of services for acquiring new users and further developing the service. Development and omnipresence of Internet made an innovative marketing branch, so-called digital or interactive marketing. Rules and tactics of digital marketing are ever-changing in this dynamic digital surrounding. If digital marketing is considered through the theoretical frame of technological marketing and "7P", it can be concluded that Internet had a lot to contribute to development of new products/services. In the context of ITS, it is often referred to as "cloud computing", or transfer of parts of services to the ''cloud''. With "cloud computing" the price of implementation of ITS solutions lowered significantly. In other words, it is no longer necessary to invest big sums of money in computer equipment and software solutions for data storage. You only pay the amount of cloud space necessary. Alongside "cloud computing" the "Internet of things" (IoT) is very popular. IoT supplements "cloud computing" and implies a connection of various physical devices over the Internet. Interactive Internet environment also had an impact on the pricing strategy, so an ITS service/application (in-app purchasing) can be priced differently, in accordance to an additional option based on real-time data or immediate demand. For example, some applications offer service of car-sharing and real-time information about the number of available vehicles and their whereabouts. If the ride is requested during the time of increased demand for the service, the price of the ride will be higher, depending on the demand.

Promotional activities are based on communication with potential service users, while the informatisation and digitalisation made this communication interactive. Coordinating of communication activities in the right moment can result in attracting the attention of targeted user group and make the interest in purchase. Parallel to increase the importance of marketing, integrated marketing communication gains on importance, which results in massive changes in the digital environment. Traditional media loses their significance because of the new media which have developed with contemporary informational technologies. With the development and the ever-growing presence of the Internet globally, new means of communication with users have arisen (social media, forums, chats, blogs).

Integrated marketing communication is a form of market communication which implies the application of various forms of communication with users and potential clients in defined timeframe. The goal is to make maximum communication impact [12]. As such, it can have a significant impact on maintaining existing users, easier acquiring of new ones, user behaviour, and lastly, develop a long-term relationship with them. Appliance in ITS is more than welcome on the account of the complexity of technology/services.

For example, if an ITS service needs to be presented more sophisticatedly to users, it is advisable to use integrated marketing communication. After the market analysis and goal defining, it is necessary to build a strategy which will contain tactics and tools for the best possible result. Selection of tools depends on the targeted user group. If there is a need for support from the appropriate authorities to start a new ITS service, lobbying will be used. Education in this regard portraits significant activity with the goal of making the service closer to the users. Tools of external communication would be used for informational-educational material and web platforms, workshops would be organised, as well as roundtables, etc. Communication towards the media would be conducted over PR publications and organisation of various events [11].

4. CONCLUSION

The traditional marketing tools, in a changing and dynamic high-tech market conditions, are no longer sufficient in the sense of making product/service closer to end-users. Innovation superiority does not guarantee implementation and existence in a rapidly changing competitive environment. There were many cases when a large number of high-tech products/services left unusable because of the absence of adequate communication link to the end-users. Using interactive marketing tools, it is possible to speed up a process that began with the appearance of innovative products/services and ends with the acceptance by the user. Since it is a case of novelty solutions it is necessary to include the extra information about their purpose and application through promotion process. In the paper is given example for ITS service ''Multimodal Journey Planners''. These kind of service is based on the data collection and processing principle which is also the ability of other ITS services. The thing is, system collect and process personal data about the users' daily journeys – interest points and object in urban area, daily habits, etc. Sharing this kind of personal data still makes a barrier towards inexperienced users. In the future, it is planned to connect a large number and type of devices that will have a significant impact on people's lives. For this reason, it is necessary to influence the consciousness of the people and encourage them to accept the new high-tech concepts. A significant role in this sense has an integrated marketing communication, which, depending on the product / service, send a clear message to prospective users. In the context of launching the ITS solutions to the market - it is very important to design a good business model. That business model will, among other things, include a combination of modern and interactive marketing tools, with the main goal - to make product / service closer and attractive to end-users.

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ANALYSIS OF FERRY AND CRUISE TRAFFIC OF PORT OF ŠIBENIK

ABSTRACT

Port of Šibenik is one of the six major ports of special (international) economic interests to Republic of Croatia located along the mainland. In this paper port area intended for maritime passenger transport of port of Šibenik was analysed as well as technological process inside of the port area through Ordinance on the order and conditions for usage of port area managed by Port of Šibenik authority. Data collected from statistical databases (Central Bureau of Statistics of Republic of Croatia, Eurostat and MedCruise) were used in the analysis of the dynamics of ferry and cruise transport. Current development plans within quay Vrulje, which include construction of the terminal building, are described. In further research level of quality of service to the passenger within quay Vrulje should be analysed.

KEYWORDS

passenger; maritime port; Šibenik; ship; ferry; cruise;

1. **INTRODUCTION**

Features of maritime passenger transport in two main European regions, the Mediterranean and Northern Europe, differ significantly. National transport is identified as primarily in Mediterranean European ports, while international in Northern Europe [8]. Of total European maritime passenger transport around 44%, excluding cruise passengers, is national transport. Also in Europe cruise passenger transport is highly represented since Europe is the second cruise destination in the world, after Caribbean. Republic of Croatia has an important role in European maritime passenger transport, Croatian region of Jadranska Hrvatska is the second biggest region of the EU NUTS 2 level by the number of transported maritime passenger transport, after Greek region Atikki [34]

Port of Šibenik is one of the six major ports located along the mainland coast that is declared by Government of the Republic of Croatia as port of exceptional (international) economic interests for the Republic of Croatia and it is classified as comprehensive port on the TEN-T Network [1].

For the purposes of managing and constructing ports of exceptional (international) economic significance for the Republic of Croatia the Government of the Republic of Croatia has established six state port authorities. First port authority was established in 1996 (Port of Rijeka authority). For management, maintenance and construction of the port of Šibenik in 2004 the Port of Šibenik authority was established, hereinafter: PSA. Main activities of each port authority are managing and planning the strategic development of their port, while all commercial functions are taken over by numerous concessionaires and private companies.

At the time of PSA establishment, most passenger traffic towards the islands in the Šibenik archipelago, was carried out via quay Krka, which is in the centre of town of Šibenik, while ro-ro ferry traffic was carried out via quay Vrulje. Existing capacity of the port didn't allowed accommodation of larger ships, such as cruise ships. Therefore, the PSA in 2008 started Infrastructure rehabilitation project of the quay Vrulje. In 2008 preparation of documentation began and in 2011 construction works started. The quay was completed in 2014. Within this project existing quay Vrulje was expanded by 9,800 m^2 which enabled simultaneous accommodation of five ships, of which two berths can accommodate ships up to 200 m, and 260 m. This project, valued at 10 million euros, was financed through a loan of the European Bank for Reconstruction and Development.

Further development of the port, in accordance with *Transport development strategy of the Republic of Croatia 2014 – 2030* [2, p. 94], is focussed on the specialisation of the port to the passenger traffic, for exclusive cruising vessels of smaller capacities (boutique vessels) and for super-yachts. In recent months, there are considerations that official specialization of ports should be removed and port competition should prevail. Commercial investments should be sourced from private funding's and no longer from the national budget, unless clear economic benefits exist. Nevertheless, in accordance with the afore mentioned measure of the *Transport development strategy of the Republic of Croatia* in this paper analysis of passenger traffic in the port area managed by PSA is performed. Analysis is focused on ferry and cruise traffic.

This paper is structured in six chapters. In the following chapter, current situation of the port infrastructure of the quay Vrulje, specialised for accommodation of passenger traffic, will be analysed as well as available services in this area. Port investment plans, primarily plans for new passenger terminal building with all its amenities, will be analysed in the third chapter. In the fourth chapter, *Ordinance on the order and conditions for usage of port area managed by Port of Šibenik authority*[1] [5] will be analysed. Channel of St. Anthony is also described in this chapter as well as its Traffic Monitoring and Management Centre, which oversees channel traffic. In the fifth chapter dynamics of the ferry and cruise traffic is analysed. Conclusions and suggestions for further research will be part of the last sixth chapter.

2. ANALYSIS OF PORT AREA - QUAY VRULJE

Ferry and cruise traffic in port of Šibenik (Figure 1) is carried out via quay Vrulje. Capacity of this port area, after the completion of the infrastructure works in 2014, is 2 million passengers per year. Ships with length (LoA) up to 260 m, and draft of 10 m can be moored without restriction in ship beam and height. But due to the restrictions of channel of St. Anthony usually ships with length up to 230-240 m are moored. Current surface area of quay Vrulje is 24 156 m^2 [3; 4] and it consists of five berths with the following characteristics [cf. 5, Art 7]:

- Berth No. 8 (Vrulje W1) - *intended for mooring of ferry ships.* Berth length is 114 m.
- Berth No. 9 (Vrulje W2) - *intended for mooring of ferry ships.* Berth length is 50 m.
- Berth No. 10 (Vrulje S1) - *intended for mooring of passenger ships in international traffic, cruise ships and yachts.* Berth length is 135 m.
- Berth No. 11 (Vrulje S2) - *intended for mooring of boats and yachts while fulfilling border crossing requirements and for ship tenders.* Berth length is 29 m.
- Berth No. 12 (Vrulje E) - *intended for mooring of passenger ships in international traffic, cruise ships and yachts.* Berth length is 191 m

As per information received from PSA in April 2017, all berths can accommodate ships with draft of 10 m. Security levels of berths No. 10, 11 and 12 are in accordance with the International Ship and Port Facility Security (ISPS) Code, if necessary also berths 8 and 9 can comply with this security measures.

[1] Note: free translation by authors

With slip for ro-ro ferry ships berths No. 8, 9 and 10 are equipped. By exception berths 10 and 12 can be used for mooring of ferries in national traffic and for border crossing control of boats and yachts. Also, other vessels can be moored in accordance with the decision of PSA which has to be approved by Šibenik harbourmaster office. Berths No. 8 and 9 may exceptionally be used for the mooring of cruise ships (ships of smaller length) and for mooring of yachts [5, Art 7].

Figure 1 – Quay Vrulje
Source: [6]

One of the great advantages of the quay Vrulje is its location, namely the quay is located near the city centre and at about 500 meters from the railway and bus station. Ferry ticket-offices are situated at about 50 meters from the berths. For some lines ferry tickets can be bought also via internet.

3. DEVELOPMENT PLAN ANALYSIS

According to the *Regulation on conditions that ports must met* [7] port authority, managing the port open for international passenger traffic, should ensure in the port area building or room adequate for acceptance and stay of passengers and luggage. If port authority is managing the port open for national passenger traffic it must ensure regulated and protected space for passengers and luggage. If the port open for national traffic is of local importance within which smaller scale of traffic is managed, harbourmaster office can exempt the port authority of fulfilment of this requirement.

Purpose of these spaces in the port, which are specially designed for passenger handling, is to increase quality of service in the port. Primarily users of these spaces are departing passengers. Usually these spaces consist of ticket-office, waiting-room and sanitary facilities. When designing this area, it is important to ensure free movement of passengers, and adequate space for acceptance and stay of passengers and luggage, while potentially dangerous spaces for passenger movements must be properly marked [8, pp. 39-40].

Port authority managing the port open for international traffic must provide also a space with the associated facilities and organization for conduction of border control [7, Art. 6], in accordance with the State Border Protection Act [9; 10].

Failure to fulfil above mention requirements, according to the legislation of the Republic of Croatia, may lead to the loss of port status. Therefore, in development plans of PSA construction of maritime passenger terminal building with associated public amenities is anticipated.

Due to the insufficient financial funds, necessary for the realisation of maritime passenger terminal building with associated public amenities PSA has redesigned the initial project. Dimension of the initial building is reduced, many commercial spaces are excluded while spaces designed for the port authority, custom, police, and harbourmaster are minimized. Total cost of this redesigned project is projected at around 2 million euros excluding VAT and cost of equipment necessary for conduction of border control.

The total closed area of the terminal building will be 2,700 m^2. The total unclosed area will be 15,000 m^2, of which 4,000 m^2 is planned as vehicle staging area for road vehicles waiting for embarkation and for road vehicles waiting for border and custom clearance, 2,400 m^2 for green surfaces and 4,000 m^2 for parking. In the next step of the project a multi-storey (underground) commercial parking building is planned.

Maritime passenger terminal is designed as a space for national and international maritime passenger traffic, from ferries and from cruise ships. Space right next to the shore line is planned to be dedicated for operations of ship supply, loading of baggage, passing of vehicles and for other similar operations. Next to this space terminal building is planned. Due to the similar procedures, functional elements of terminal building are designed in accordance with functional elements of airport building. Arrival and departure hall will be situated close to the ship entrance to facilitate embarkation and disembarkation of passengers. Spaces inside of the building are planned to be oriented to the ships and to the sea. Terminal forecourt, designed as a square, will be linked to the public road system.

4. ANALYSIS OF THE ORDINANCE ON THE ORDER AND CONDITIONS FOR USAGE OF PORT AREA MANAGED BY PORT OF ŠIBENIK AUTHORITY

Port areas, i.e. areas of maritime demesne which are under administration of port authority are defined by the *Regulation on establishment of the Port of Šibenik authority* [16]. This regulation also defines port activities as well as infrastructure and superstructure facilities within the port area.

Based on the *Maritime Demesne and Seaports Act* [13; 14] and *Ordinance on the conditions and methods of maintaining order in ports and on other parts of internal waters and territorial sea of the Republic of Croatia* [15] PSA has brought *Ordinance on the order and conditions for usage of port area managed by Port of Šibenik authority* [5, Art 1], hereinafter: Ordinance.

This Ordinance regulate procedures of notification, arrival, berthing, displacement, mooring, and departure of maritime objects, order within the port area, methods of control over the performance of these actions, and other activities related to the implementation of order in the port area. Responsible body for proper organization of arrival, berthing, mooring, displacements and departure operations of maritime objects within port area is PSA [5, Art 8 and 9]. Allocation of each part of the port in the port area is also enacted by this regulation.

Except by this Ordinance, in port area also other regulations are exercised which pertain to security protection of ships and ports, navigation safety, handling of hazardous and pollutants substances, safety at work, border crossing, custom, health, sanitary, veterinary, phytopathological and other regulations. Since operations related to the implementation of order in the port area are primarily prescribed by the Ordinance, this Ordinance is further analysed below.

4.2 Procedures of notification, arrival, berthing, displacement, mooring, and departure of maritime objects

Port of Šibenik is situated in basin which is surrounded by high land, naturally protecting the port from the influence of wind and waves. To its hinterland port is connected by rail and road (state road D8 and motorway A1) [cf. 3; 4].

Approach to port of Šibenik from maritime side leads through Šibenik channel which can be approached from three sides through Logorunska vrata, Šibenska vrata and passage Dvainka. Passage Dvainka is the deepest passage and is used by cargo ships, ferries in international traffic and cruise ships. From Šibenik channel the port basin is approached by channel of St. Anthony, which is analysed in the following section [5, Art 11].

Ship master or agent must announce ship arrival through *Croatian integrated maritime information system* (acronym: CIMIS). Announcement through other channels is not allowed, exception is made only if the reason for usage of other channel is due to technical problems. The ship arrival notice should be delivered at least 24 hours before the arrival of the ship in the port or at latest after leaving the previous port if the navigation takes less than 24 hours. If the destination port is not known at the time of ship departure from the previous port or if destination port has been changed during the navigation, arrival notice should be delivered as soon as information is known. Exceptions are ships in international ferry traffic which do not have to announce their arrival in the port area when operating between Croatian ports [5, Art. 9]. The ship master shall announce the exact time of arrival at anchorage or at the pilot station of embarkation, at least 2 hours before ship arrival. Upon this announcement, PSA is obligated to inform the master of the ship on the place and on the method of mooring or berthing [5, Art. 18].

Pilotage is compulsory for ships with gross tonnage of 500 tons or over and for yachts with over gross tonnage of 1000 tons. Pilot embarkation and disembarkation areas are at outer (before passage Dvainka) or at inner pilot station (within Šibenik channel). Exempt of compulsory pilotage is given to the Croatian warships and public ships, ships engaged in the maintenance of waterways and aids to navigation in these waterways, ferries and ro-ro passenger ships which sail in regular routes. Pilot society suggests to the service of mooring/unmooring service required number of workers [5, Art. 13].

Person operating a ship or a boat within port area is required to announce its operations to the PSA and request the inward clearance.

Priority in mooring and pilotage have warships and public ships, ferries, ro-ro passenger ships, cruise ships and cargo ships. Due to the special reasons (easily perishable cargo, ship failure, availability of port capacity, etc.) different order of priority for ship berthing or temporary change of intend of individual berths can be determined. PSA must notify harbour master's office about these changes and their reasons thus getting its consent for such management. Inward/outward ship on which either directly or indirectly people's life and/or assets are threaten has priority. It will be considered that the ship arrived in the port when he is safety berthed along the shore or when he dropped anchor at anchorage and displayed anchorage mark [5, Art. 14].

Ships, yachts, and boats while operating within port area are not allowed to sail at the speed higher than six knots, but also lower if ship-generated waves could cause damage to other vessels, coast and devices in the port area performing coastal or underwater works. PSA can change the berthing schedule and notify harbour master's office, as well as ship agents [5, Art 14]. Displacement of ship to another berth or to anchorage, for the safety of the ship and the port area, can be ordered by harbour master's office on which he should notify PSA [5, Art. 17].

Anchorage is situated south of Cape Oštrica [5, Art 2]. This anchorage is referred as outer anchorage. Inner anchorage, as referred on official web page of the PSA [4] is positioned west of island of Krapanj between island of Drvenik and Beach resort Solaris on the cost. This area is currently not included under the administration of the PSA [cf. 16]. Currently there are ongoing procedure to include area of the inner anchorage and area of the new proposed outer anchorage as parts of the areas under the administration of the PSA. New proposed outer anchorage would be positioned between town of Zablaće on the cost and island of Zlarin. This anchorage will be primarily used by cruise ships. Transfer of passengers from the anchorage to the town of Zablaće will be performed by ship's tenders.

Figure 2 – P ort area under administration of Port of Šibenik authority
Note: Detached anchorage south of cape Oštrica is not shown on the map
Source: Authors in AutoCAD. Source for coordinates [5, Art. 2]

After completion of embarkation and disembarkation of passengers and of loading and unloading of vehicles and cargo every maritime object should be ready to leave the port, upon expiry of the time needed to prepare the vessel for the sea. Ship master or ship agent, i.e. legal or public person engaged in the carriage of passengers, vehicles, or cargo, is required to deliver port log and copy of bill of lading to the port authority, at least two hours before departure. Upon departure person operating the ship is obliged to announce its leave to the PSA and to request outward clearance immediately before unberthing manoeuvre. Outward vessel has priority in manoeuvring over inward vessel [5, Art. 10].

4.2 Negotiating channel of St. Anthony

Channel of St. Anthony (Figure 3.) is 2,700 m long and 120-300 m wide [4]. From the view of navigation, channel is very difficult to navigate due to the channel not straight form which requires often change of ship course in short periods of time and due to the channels currents and occasional high winds. By-passing of ships over 50 GT within the channel is dangerous, which is why the Control and management system for navigation in the channel of St. Anthony[2] has been introduced. This system consists of Control and management centre,[3] hereinafter: Control centre, and two signal station with signal lights (Figure 4). Control centre and signal station Jadrija are located at cape Jadrija, at left outer entrance in the channel, while signal station Martinska is located at the inner entrance of the channel at the position of cape Burnji. Semaphore lights are placed on supporting pillars of two rows. Daily semaphore lights (red and green) are located above the night lights. A red light indicates that the passage is closed for vessel above 50 GT, while green light that is open for vessels over 50 GT [18].

By *Order on the navigation in entering the port of Šibenik* (…) [17] the manner and conditions of navigation of Croatian and foreign ships, warships, boats, yachts and technical vessels in channel of St. Anthony is arranged. Channel can always and without permission be navigated by ships and yachts to 50 GT, sailing on the right side of the channel, while ships and yachts over 50 GT can navigate the channel only with the permission of the Control centre, which semaphore light indicates that the navigation via channel is open. Ship over 10 000 DWT can be operated with the help of only one tug, while ships over 20 000 DWT should be operated with the help of two tugs. Navigation speed in the channel is limited to 10 knots [17].

[2] Free translation by authors. In Croatian (hrv.): Sustav za nadzor i upravljanje plovidbom kanalom Sv. Ante
[3] hrv. Centra za nadzor i upravljanje

Figure 3 – Channel of St. Anthony
Source: [19]

a) b)

Figure 4 – Semaphore lights of channel of St Anthony
Note: a) Control and management centre, signal lights and lighthouse at cape Jadrija, b) Signal lights at Martinska.
Source: [18]

After giving inward clearance Control centre indicates that the channel is open pointing out green light at the ship entrance in the channel, while on the other side of the channel emphasizing red light indicating that the navigation via channel is prohibited. When ship begins negotiating channel from within the channel, the channel must be closed for navigation of other vessels. Order of ship passing is determined in order in which ships request clearance for navigation. Priority is given to Croatian warships, Croatian public ships, and ships in common carriage, provided they fulfil other conditions for entering the port of Šibenik, i.e. for leaving the port of Šibenik [17, Chapter 2].

4.3 Activities on berths

Berths in the passenger area of the port are assigned based on the weekly and daily schedule of the port authority, with the exact indication of number, place, and time of berth, and are delivered to ships' agents and to the PSA. Ship's agent shall inform the ship master on berth allocation and confirm that the ship accepts the place and time of berth, or notify the PSA if the master of the ship refuses to accept the berth allocated. At the port area mooring and retention of boats on operational berths is prohibited. Boats can use berths only in case of force majeure and with special permission of the PSA [5, Art. 22, Art. 23]

Port of Šibenik authority can [5, Art. 22]:

- order vessels to transfer from one berth to another or to an anchorage, if operation of loading / unloading is not carried out and notify the harbour master's office
- notify the harbour master's office to withhold consent for vessel's mooring or anchoring at berth or at the point of anchoring if this would endanger the safety of navigation, human lives and buildings on the coast or at sea, and if the vessel is in such a condition to pollute sea.

Master of the vessel is responsible for the safety of the vessel at berth in the port area. On the vessel, there must always be enough crew members to be able to operate the vessel. When a group of vessels is berthed alongside each other, the port authority determines the minimum number of crew members. In the event of bad weather that may put the safety at risk, vessels berthed or anchored in the port area shall strengthen their moorings, ie. increase the number of anchors, and, if ordered by harbour master, leave the port area or move, i.e. moor to a safer berth [5, Art. 24, Art. 25].

Vessel can be retained alongside of the cost, after completion of merchant and other necessary operations, free of charge a maximum of two hours and any delay must be reported to the PSA. After expiration of the time needed to prepare the vessel for the voyage, a vessel must leave the port or be displaced to another berth or anchorage assigned by the PSA at the expense of that vessel or operators. Vessel can be retained without charge for longer period if harbour master office, for reasons related to safety of navigation, approves longer retention. By order of PSA, with the consent of the harbour master office, ship master shall permit the mooring of one or more other vessels alongside (abeam) of his ship, to maintain links with the cost. If the vessel is moored or anchored in the port area so that its end portions are protruding beyond the coast, vessel is obligated, at the point where berth is going beyond the vessel, to hoist a red flag during the day, and at night put a red light visible from all sides, and if necessary loosen mooring lines or tighten or untie [5, Art. 27].

If maritime or underwater (sink) object is endangering navigation safety or there is a danger of sea pollution, operator, or owner of maritime object or of the wreck or of a boat shall, at the request of the PSA and harbourmaster office, move this object from the port area. Sunken object must not be left inside of the port area waters. Laid of ship can stay in the port area only with the approval of the PSA for limited time, with the previously obtained consent of the harbourmaster office and the conditions which it requested [5, Art. 28 and 29].

The concessionaire who performs port and economic activities that require exclusive use of the existing and construction of new buildings and other infrastructure and superstructure in the port area, and it is covered by the Security plan of the port area[4] shall [5, Art. 39]:

- after the completion of loading / unloading operation clean the used port area of the coast
- maintain all the other areas where it performs its activities, implement protective measures against fire and organize guard service.

4.4 Waste management and fuel supply

At the port area ships are obliged to comply with the Waste management plan from ships[5]. They are obliged to collect garbage in special storages on board, and submit it to the concessionaires who have a concession for this activity. The ship cannot leave the port area if he didn't handover collected garbage or oily water to the concessionaire, unless the ship storage capacity is sufficient until the next port of destination [5, Art. 23].

Handling of hazardous substances is regulated by the *Ordinance on determining the class and quantity of dangerous substances which can be handled in the port area*[6] and by the *Operating instructions for berthing and stay of the ship in the port area, handling of dangerous goods and manner of calling protective services in the port area*.[7] Handling of dangerous goods and supply of ship with fuel in the port area should be performed according to the *Ordinance on the handling of dangerous materials, conditions under which and manner in which to undertake the carrying, loading and unloading of dangerous materials, bulk and other cargoes in ports and the manner of preventing the diffusion of spilled oil* [20]. Road tanker that supply the ships with fuel can stay in the port area only while supplying fuel to the ship. At berths No. 8, 9, 10 and 12 road tanker must be within security fence. Supply of the fuel to the passenger ships can begin when after all passengers are disembarked and after obtaining the consent of the harbourmaster office and approval of the PSA. While ship is supplied with the fuel it is obligated to hoist flag "B" of The International Code of Signals, and at night the red light visible from all sides. The crew and the extinguishing device must be in pre-alert state [5, Art. 36, 37, 38].

[4] hrv. Plan sigurnosne zaštite lučkog područja
[5] hrv. Plan gospodarenja otpadom s brodovima
[6] hrv. Pravilnik o određivanju klase i količine opasnih tvari kojima se može rukovati na lučkom području
[7] hrv. Operativno uputstvo za pristajanje i boravak broda na lučkom području, rukovanje opasnim tvarima i način pozivanja zaštitnih službi na lučkom području

5. ANALYSIS OF THE DYNAMICS OF PASSENGER TRAFFIC IN THE PORT OF ŠIBENIK

Passenger traffic of port of Šibenik consists primarily of traffic from ferries and cruise ships. Most of passenger traffic in the port of Šibenik is related to coastal traffic, i.e. transport of passengers to the island and from the island to the mainland [21]. In the period from 2011 to 2014 there has been an increase in the total number of ships that arrived in the port. In 2011, 20,087 ship arrived in the port. In 2012, the number of ships that arrived was 21,358, and in 2013 a total number of arrived ship was 21,791. In 2014, a total number of ship arrivals was 23,173, which is an increase of 6.34% in comparison to 2013, and an increase of 15.36% in comparison to 2011 [22, p. 108; 23, p. 105; 24, p. 104; 25, p. 102].

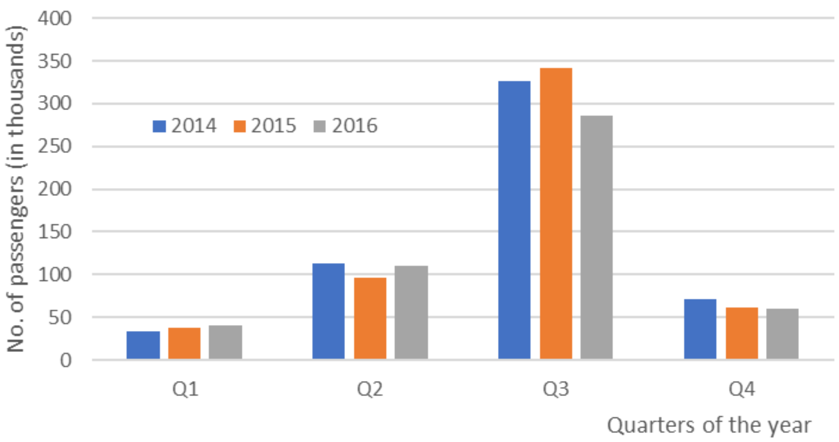
From Eurostat data (Table 1) on passenger traffic, excluding cruise passengers, for the period from 2010 to 2016, it is evident that in 2011 was recorded a significant growth of traffic (+ 74.81%) compared to the year 2010. This growth was not maintained in 2012 and 2013 where there was decrease of traffic in comparison to 2011 of –7,36% in 2012, of – 14,51% in 2013 and of -10,25% in 2014. Growth of traffic regarding to 2011 was recorded in 2015 (+5,34%) and in 2016 (+2,45%).

Table 1 – Passenger traffic in port of Šibenik from 2010 until 2015 (excluding cruise passengers)

Year	Inwards ('000)	Outwards ('000)	Total ('000)	Growth rate according to 2010, (%)
2010	266	270	536	
2011	482	454	937	74.81
2012	431	436	868	61.94
2013	394	406	801	49.44
2014	517	324	841	56.90
2015	530	457	987	84.14
2016	486	474	960	79.10

Source: Compiled by authors from [26]

Passenger traffic in the port of Šibenik is seasonal (Graph 1), i.e. the largest number of passengers use the port during the third quarter of the year, from July to September. During these months 45-65% of total annual passenger traffic in port of Šibenik is performed. Therefore, volume of traffic depends on the success of the tourist season. The lowest number of passenger is recorded during the first quarter of the year, from January to March.



Graph 1 – Total passenger traffic of port of Šibenik, quarters (excluding cruise passengers)
Source: Compiled by authors from [27]

Regular coastal maritime transport service connects the port of Šibenik with the surrounding islands (Zlarin, Obonjan, Kaprije, Žirje and Prvić) by the following ferry state lines [31]:

- Ro-ro ferry line number 532: Šibenik – Zlarin– Obonjan– Kaprije– Žirje
- Passenger (regular) ferry line number 505: Vodice – Prvić – Zlarin – Šibenik
- Fast ferry line number 9502: Žirje – Kaprije – Šibenik.

Technical characteristics of ships, that primarily operate on these lines is shown in Table 2.

Table 2 – Technical data of ferries which operate in port of Šibenik

Ship type	Passenger ship	Ro-Ro passenger ship	High speed passenger craft
Length overall, Loa (m)	37.7	48	29.13
Breadth (m)	7.0	9	9
Draught (m)	2.226	1.71	1.33
Gross register tonnage, BRT	191.02	410.78	209

Source: [29]

Minimum conditions which should be complied by the ships operating on these state lines, according to the *Decision on defining state public transport lines in coastal maritime liner shipping* [28], are shown in table 3. Due to seasonal traffic, this decision regulates higher week frequency of ships calls during the season.

Table 3 – Minimum capacity of ships and its frequency at state ferry lines which operates in port of Šibenik

Type of ferry line	Minimum week frequency			Minimum capacity vehicles/passengers
	Off season	Low season	High season	passengers/vehicles
´Regular´ ferry (line No. 505)	32	33	33	300
Fast ferry (line No. 9502)	9	14	14	100
Ro-ro ferry (line No. 532)	7	14	14	200/25

Source: [28]

The highest passenger traffic on these ferry lines is generated on the passenger (regular) ferry line. In 2013 on these three lines a total of 263,338 passengers was handled, out of which 72.57% was transported on the regular ferry line. During the analysed period from 2010 to 2016 (Table 4), the largest turnover on this ferry line, which connects two mainland ports (Šibenik and Vodice) with islands of Prvić and of Zlarin, was achieved in 2010. From this year, constant decrease of passenger traffic is recorded, in 2013 was the highest decrease regarding 2010 of -14.33%, while in the following years was of -10.26% (2014), -12.06% (2015) and -10,46% (2016).

Passenger (regular) ferry line number 505 was from 2012 to 2014 the second busiest passenger (regular) ferry line by the number of passengers carried in the Republic of Croatia. Ahead of this line was the regular ferry line which connects town of Dubrovnik with the islands Koločep, Lopud and Šipan (port of Suđurađ) on which in 2014 a passengers traffic of 232,092 was recorded. In 2015 ferry line number 505 falls on third place due to the newly established ferry line Zadar-Preko [30].

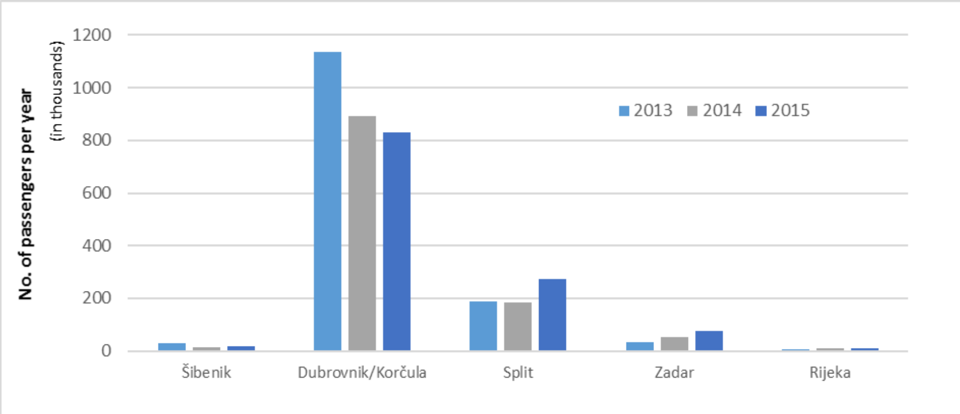
Table 4 – Passenger and vehicle traffic at state ferry lines in port of Šibenik (per year)

No. of passengers and vehicles (no. of ferry line)	**Year**						
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Passengers (line No. 9502)	33,640	30,447	27,723	29,981	28,352	31,295	34,068
Passengers (line No. 505)	223,073	214,461	201,869	191,106	200,185	196,172	199,731
Passengers (line No. 532)	39,350	41,644	39,992	42,301	39,991	41,529	42,259
Vehicles (line No. 532)	5,647	5,447	5,218	5,028	5,144	5,391	5,813

Source: [31]

In the port of Šibenik in 2010 (table 4), the total turnover of vehicles was 5,647 vehicles, of which 2,826 vehicles was embarked and 2,281 was disembarked. In 2011 and 2013 decrease of -3.54% and of -7.59% was recorded regarding to 2010. A further decline continued in 2013. Decline in the number of vehicle was also registered in 2014 and in 2015. In 2016, there was an increase in the number of vehicles handled in the port of 166 vehicles more than in 2010.

Port of Šibenik is a member of MedCruise association [4]. Every year the port of Šibenik is becoming more attractive port for berthing of cruise ships. Comparative display of passenger traffic from cruise ships in the port of Šibenik and in other major Croatian sea ports is shown in the graph below (Graph 2). For the comparison data from 2013 to 2015 were used. In the statistical database of MedCruise, data for port of Dubrovnik and for port of Korčula are consolidated. These two ports together in 2015 recorded the highest amount of traffic of 830,684 passengers. After these ports, most traffic of cruising passengers was recorded in the port of Split, followed by the port of Zadar, Šibenik and Rijeka [32].



Graph 2 – Comparison of passenger traffic from cruise ships in Croatian ports
Source: Compiled by authors from [32]

The largest number of passenger arrivals from cruise ships in the port of Šibenik, in the period 2010-2015 was recorded in 2013 (Table 5). In the following years, there was a decrease in the number of port calls. In 2015, there were 10 ships less than in 2014, but the passenger volume on these ships was bigger which resulted in handling of 4,869 passengers more.

Table 5 – Cruise ship traffic in port of Šibenik

Year	Total Calls	Total Pax	Pax Growth Rate according to 2010 (%)
2010	109	11,624	
2011	113	12,860	10.63
2012	84	15,355	32.09
2013	100	29,784	156.22
2014	93	12,693	9.19
2015	83	17,562	51.08

Source: [32]

As per information received from PSA in April 2017, in 2017 port of Šibenik is expecting mooring of 113 cruise ships with a total of 30,000 passengers. For the first time, it is expected arrival of the cruise ships that cannot pass through the channel of St Anthony. These ships will be anchored outside of the port basin and passengers will be transferred by ship tenders.

From the analysis of the dynamics of passenger traffic in the port of Šibenik it can be concluded that there are synergies in the port of pure passenger ferry traffic, ro-ro ferry traffic and cruise traffic. These synergies were also identified in analysis from the economic point-of-view of Spanish port system in which likelihood of a port to have cruise traffic and explanatory variables that have impact on the overall number of achieved cruise traffic were examined [35]. Synergies of cruise traffic with ferries and ro-ro traffic, which is expected since infrastructure usually isn't profitable when constructed for cruise traffic alone [36].

6. CONCLUSION

Although passenger traffic is stagnating during the last years, port of Šibenik should provide to its passengers more adequate waiting area. Port of Šibenik is classified as a port of exceptional (international) economic significance for the Republic of Croatia and is responsible for ensuring certain facilities for handling of passengers. As with other transport facilities, type of additional services available in this area reflects the traffic that the terminal serves. The size of the area should be dimensioned according to the traffic imposed on it (frequency of calls, ferry capacity, type of traffic – national or international, etc.) Passenger waiting area can be open or closed, preferably air-conditioned. Open area is mostly equipped with various embodiments of the backrest and / or benches and with various embodiments of covered waiting area (shelters and / or sheds), while most of indoor space are dimensioned as a waiting area within the passenger building.

In maritime passenger transport, as well as in other branches of traffic, increasing role has the quality of the service provided to the passenger, which in the maritime transport is affected also with the quality of service provided in the port. Extending the quay Vrulje, capacity of passenger terminal of port of Šibenik, is increased in national and international traffic. This extension did not include the construction of adequate space for passenger handling. Given the increasing role of the cruise ships in total passenger traffic of the port, it is necessary to further investigate the overall traffic demand, to define the area and diversity of additional services that port should offer. In addition, it is necessary to consider the requirements of persons with reduced mobility and safety requirements.

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A SURVEY ON TRAFFIC GROOMING ALGORITHMS IN ELASTIC OPTICAL NETWORKS

ABSTRACT

The growth of users' traffic demands requires a rational usage of optical fibers. Introducing of elasticity in the optical domain is a promising solution for design of the next generation optical networks. Although the elasticity provides a solution to adapt the capacity of lightpaths to the user demands, a more efficient use of resources could be obtained if that property is combined with grooming at the optical level. Optical traffic grooming involves setting up an optical tunnel that carries several connections in a contiguous block of spectrum without inserting guard bands in order to minimize the number of guard bands and optical transmitters. In this paper, we considered and classified a range of traffic grooming algorithms in elastic optical networks, including static and dynamic traffic scenario as well as spectrum engineering techniques such as multipath routing, modulation adaptive, fragmentation aware and survivable traffic grooming.

KEY WORDS

Elastic optical networks; frequency slot; optical traffic grooming; grooming algorithms;

1. INTRODUCTION

To provide higher spectrum efficiency and flexibility in the future elastic optical networks, the Orthogonal Frequency Division Multiplexing (OFDM) technology is adopted [1]. The elastic optical network (EON, Elastic Optical Network) is network architecture towards beyond the 100-Gb/s era. Because of the spectrum resource slicing and elastic allocation according to bandwidth on demand, this architecture was first named the spectrum sliced elastic optical path network architecture (SLICE) and is currently called the EON for simplicity [2]. Its main features are spectral efficiency, cost and energy efficient traffic grooming in the optical domain.

1.1 Background

The concept of elasticity allows that some parameters such as modulation format, channel spacing, optical bit rate which have been fixed in conventional WDM (Wavelength Division Multiplexing) networks become adaptable in elastic optical networks. In 2012, in order to support the adaptive spectrum allocation concept of EON, the ITU-T updated its G. 694.1 recommendation to include the flexible grid option based on a newly introduced frequency slot concept [3]. The nominal central frequency granularity of 6.25 GHz, the channel width (12.5 GHz) and the concept of frequency slots (FS, Frequency Slots) are defined. 12.5 GHz frequency slot is nothing else than the frequency range of an optical signal could take. The total spectrum is than divided on FSs and every connection is assigned a different number of slots, so EONs are also called flex-grid optical networks and their key features are: bandwidth segmentation, bandwidth aggregation, efficient accommodation of multiple data rates, elastic variation of allocated resources and reach-adaptable line rate. The architecture of EON requires the application of specific hardware components such as: BV-OXC (Bandwidth Variable Optical Cross-Connect), ROADM (Reconfigurable Optical Add/Drop Multiplexers) which contain several BV-WSS (Wavelength Selective Switches) and BVT (Bandwidth Variable Transponder) that need to be designed to support multi-services and sometimes guard band in between, which is also referred to as sliceable transponder. For the telecommunication operators it is a matter of time when the existing (fix-grid) equipment should be replaced with flex-grid equipment. Additional spectrum savings could be obtained if elasticity is combined with traffic grooming. Traditional electrical traffic grooming approach adds additional OEO (Optical-Electrical-Optical) conversions and electrical subcarrier switching requirements to intermediate OXC nodes what results in higher cost and energy consumption. These issues may become even more significant when higher speed transmission systems are deployed. In order of improving flexibility and eliminating the OEO conversions, optical traffic grooming is considered where traffic demands are grouped directly on the optical level [1], [4-6].

1.2 Methods used - eligibility criteria

The analysis includes all the titles and abstracts of the papers which were subject to the electronic search of the scientific papers databases, according to the pre-defined keywords. The studies have been analyzed, grouped and arranged on the basis of the most significant differences found in the analyzed studies and related to: traffic scenario where grooming without additional spectrum engineering is considered and optical grooming with a number of spectrum and energy efficiency issues such as multipath routing, green grooming, spectrum defragmentation and survivability.

1.3 The objective and the structure of the paper

The problem of traffic grooming in elastic optical networks is a nascent research field and so far we did not find literature where the grooming methods are integrated. So, the main goal of this paper is to make an overview and classification of numerous traffic grooming algorithms in elastic optical networks according to their main features and objective functions.

The rest of this survey paper is structured as follows. Second section gives a brief introduction to the optical grooming approach. Third and fourth section review grooming algorithms considering traffic scenario, so the static and dynamic grooming algorithms. Optical grooming algorithms in combination with some spectrum and energy efficiency techniques are classified and discussed in fifth section while the sixth section concludes the paper.

2. OPTICAL GROOMING APPROACH

There are three basic problems in communication networks: 1) Traffic engineering, which is about putting the traffic where the bandwidth is; 2) Network engineering, which is about putting the bandwidth where the traffic is; and 3) Network planning, which is about putting the bandwidth where the traffic is forecasted to be [7]. Traffic grooming can be involved in any of the three problems, depending on the phases of network operations and plays a similar role in flexible-grid networks as in the traditional fixed-grid networks under the current grooming paradigm. Since the term elastic in optical networks refers optical spectrum dividing in accordance with traffic volume and elastic optical paths establishing or paths with variable bit rates the basic idea of optical grooming is to group multiple sub wavelength optical paths into one BV transmitter. This group of optical paths is called an optical tunnel [4]. By employing optical grooming, the total number of transmitters can be reduced, and spectrum resources can be saved by eliminating guard bands between the groomed sub wavelength optical paths. It should be noted that the optical grooming approach saves only transmitters, not receivers, because traffic from different source nodes needs to be received separately.

2.1 Optical grooming principle

Let us first to clear what is the role of traffic grooming if we have optical layer with flexible grid and elastic rates. It may be argued that traffic grooming can be eliminated in future flexible-grid networks, as they can provide fine-granular optical channels [8]. But the problem is that optical channels must be distinguished one from another and therefore spectral guard bands must be placed between them to avoid interference. Provisioning each low speed connection with a separate optical channel may lead to high spectrum wastage by guard bands. Also, low speed optical channels usually have lower spectrum efficiency than high capacity ones. So, from the spectrum utilization point of view, provisioning connections without traffic grooming is inefficient.

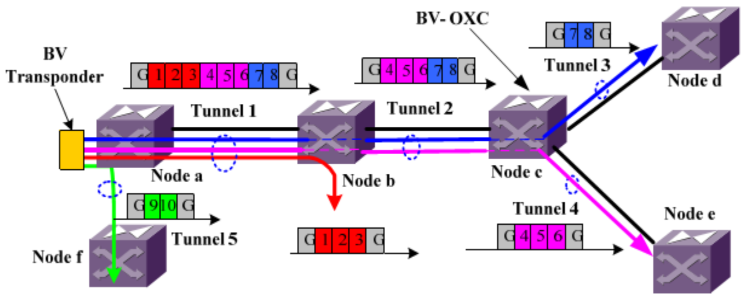

Figure 1 – Optical grooming principle
Source: [4]

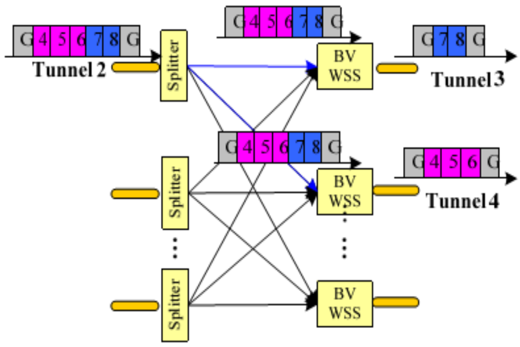

Figure 2 – Broadcast-and-select node (OXC) architecture
Source: [4]

Using the OFDM technique, traffic originating from the same source (BV transmitter) can be groomed together without any guard band in between. Guard bands are only needed between different optical tunnels for switching purposes. For services with the same source and same destination, they are switched as a single optical tunnel and no filtering impairments will affect the optical paths within the tunnel. For services with the same source and different destinations, BV-OXC are required to adopt a broadcast-and-select structure [1], [9] where a subset of subcarriers in the optical tunnel can be dropped or switched optically at any intermediate node along the route. Optical grooming principle is shown by *Figure 1*. Broadcast-and-select node architecture is presented by *Figure 2*, where the same slots could be treated as signal slots as well as guard band slots.

2.2 Optical grooming algorithms

For planning elastic optical networks, RSA (Routing and Spectrum Allocation) algorithms are essential. Optical grooming adds complexity to RSA since the usage of a single transmitter for multiple service aggregation is constrained. Therefore, besides the main constraints configuring in the RSA statement, namely the spectrum contiguity and continuity constraint [10], aggregated sub wavelength services should use a consecutive set of spectrum slots within the transmitter's spectral range and the number of groomed services is limited by the maximum subcarrier capacity of the BV-transmitter. So, more constraints are added to RSA algorithms and the problem is often called traffic grooming with RSA (TG-RSA) [11]. Optical tunnels containing multiple optical paths should be separated by guard bands, while optical paths within each tunnel do not have guard bands in between. The objective of the optical grooming is to either minimize the number of transmitters or minimize the total spectrum usage. The problem could be solved using ILP formulations for the small size networks and using heuristic algorithms for the large networks. Optical grooming algorithms are classified in the following sections.

3. STATIC TRAFFIC GROOMING ALGORITHMS

Offline optical traffic grooming arises whenever the traffic patterns in the network are well-known in advance and any traffic variations take place over long time scales. According to [11] static traffic grooming is an effective technique for provisioning a set of semi permanent connections. Since these connections are assumed to remain in place for relatively long periods of time, it is worthwhile to attempt to optimize the way in which network resources (spectrum or transmitters) are assigned to each connection, even though optimization may require a considerable computational effort.

Aggregating demands for transport on a single lightpath presents two opportunities for spectrum savings. The first one is related on achieving efficiency if transporting a single high-rate (e.g., 400 Gb/s) connection than transporting a number of low-rate connections with the same total data rate (e.g., 4 x 100 Gb/s). The second is related to that a smaller number of independent lightpaths results in a smaller number of guard bands around these lightpaths, hence reducing the spectrum required to support a given set of demands. The most important fact is that grooming is done at the optical layer thereby eliminating expensive OEO operations.

The offline optical grooming problem could be defined as following: for the given inputs that include physical topology $G = (N, L)$, where *N* is the number of nodes and *L* is the set of links; the spectral resources on each link which are classified into spectrum slots, where each slot corresponds to an OFDM subcarrier; the maximum capacity of BV-transmitters which corresponds to the maximum capacity of an optical tunnel; guard band size between optical tunnels which is often *2g* slots (*1g* on each side of the tunnel); traffic matrix with the required capacity in number of subcarriers between each source and destination node pair, the objective is to assign a physical path and contiguous spectrum to each demand so as to minimize the total amount of allocated spectrum or the number of optical transmitters.

Mixed integer programming (MILP) formulations of offline optical grooming have been presented in [1], [4], [5]. The objective in [1] and [4] was to minimize the maximum utilized spectrum slot indexes of all links in the network and the total number of transmitters used to carry all traffic requirements while in [5] fiber lengths in the network topology to be the weight of the fiber link were considered and the objective function was to minimize an average spectrum utilization rate weighted by fiber length. Since ILP does not scale well for the large networks, two heuristics were presented in [1] and [4] to solve the problem of optical grooming with RSA. The topology of NSFnet network was used as a realistic network. The heuristics are called the Least Spectrum Grooming (LSG) and the Minimum Transmitter Grooming (MTG) algorithm. The LSG algorithm minimizes the total spectrum usage by grooming the optical paths that share the longest common route from the source node. This algorithm aims to maximize spectrum gain by the reduced guard bands. The MTG algorithm aims to minimize the number of transmitters. It is mostly similar to LSG in terms of algorithmic steps. The difference is that when searching for possible placement of a tunnel, the MTG algorithm uses maximum spectrum capacity of a tunnel instead of the real capacity of a service (reserves the spectrum for grooming). Comparative study of optical networks with grid flexibility and traffic grooming has been presented in [12] where static traffic scenario was also used. The authors compared different network architectures in mixed-client-rate and mixed-line-rate environments from the cost and spectrum efficiency perspective. The networks are classified into four architectures based on the existence or nonexistence of grid flexibility and sub wavelength traffic grooming capability. The total costs are assumed to be the cost of transponder and electrical cross connects. Simulation showed that the elastic models are more effective than fixed-grid models in terms of spectrum efficiency, but the trade-off between grooming gain and its additional cost should be considered especially in elastic models, larger network topologies and more realistic traffic patterns.

4. DYNAMIC TRAFFIC GROOMING ALGORITHMS

Traffic patterns induced by emerging services such as cloud computing, big-data applications and content delivery in data centre networks require a transport network to support dynamic connection setup and release. The flexibility enabled by the EON makes it more suitable for dynamic traffic than WDM networks [13]. Dynamic traffic or online traffic scenario arises when traffic conditions are changed in time so the algorithms must be executed every time when the connection arrives. If there is a lack of resources when connection arrives, it is blocked. The random nature of connection arrivals and departures in such a scenario adds more difficulty to source aggregation. Generally, in dynamic grooming approach, incoming traffic demands are aggregated (groomed) with already existing connections in the network.

The inputs for online grooming scenario differ from the static one in the following: the traffic demands between each source and destination node pair are not known in advance. Instead, connection requests arrive one a time, hold for certain duration, and then depart. A source and destination nodes as well as the requested bandwidth in term of FSs are known when connection arrives. A new lightpath can be established by two operations: by using an existing transmitter or receiver (optical traffic grooming) to setup a new lightpath or by using a new transmitter or receiver to setup a new lightpath [13]. The objective may be according to the intention of the network operator: minimize the number of used transmitters, minimize blocking ratio, minimize energy consumption etc. Note that offline optical grooming problem can be solved through Integer Linear Program (ILP) formulations and it is mostly used in resource planning as a part of spectrum engineering. For online grooming problem the heuristic methods are mostly used. Some of them will be discussed in the following text.

Dynamic source aggregation of sub wavelength connections in EON was proposed in [9]. The objective was to simultaneously minimize the spectrum and transmitter usage in the network. The authors developed the First-Possible Aggregating (FPA) algorithm with the aim of maximizing the transmitter capacity utilization of network by aggregating same source sub wavelength connections over their common route. Also, it improves the spectrum utilization of network by reducing the number of required guard bands between connections. The number of guard bands was also minimized in [14] where the aggregation of multiple low speed traffic demands into a multi-hop elastic light-trail was done. So, the authors introduced a novel concept called elastic light-trail to utilize full potential of an elastic optical network. An elastic light-trail is a generalized version of an elastic lightpath, where multiple nodes (in the light-trail) could optically expand allocated spectrum for active length only of the elastic light-trail to communicate each other [14]. The authors proposed the algorithm “Multi-hop Elastic Light-Trail– MELT” that performs an elastic light-trail expansion instead of creating a new elastic light-trail because new light-trail is always equipped by a guard band. The objective was to maximize elastic spectrum utilization of an optical beer link.

The next algorithms solve the dynamic traffic grooming problem building an auxiliary graph each time that a connection request is received. The performance of flexible grid EONs and fixed grid WDM networks under dynamic traffic with and without grooming were compared in [15]. The results were compared in terms of blocking probability and network resource occupation, thus showing quantitatively the advantage of EON compared to grooming based WDM networks. The multi-layer graph (MLG) model was proposed where each layer corresponds to one FS. To catch the property of spectrum contiguity required in the RSA process, an improved MLG can be obtained by associating one layer to every possible set of *t* adjacent FSs, where *t* is the total number of FSs required by a specific connection including guard bands. The advantages of the EON concept over WDM are provided by utilizing lower amount of spectrum as guard bands, especially when provisioning super channels connections. A layered graph model was also used in [16, 17], where authors proposed a three-layered Auxiliary Graph (AG) model to address mixed-electrical-optical grooming under dynamic traffic scenario. By adjusting the edge weights of AG, various traffic-grooming policies for different purposes have been achieved. Traffic grooming policies were compared under two spectrum reservation schemes: the first is called spectrum reservation for each lightpath (SRLP) where a sub-transponder's working channel for each new lightpath was reserved. The second scheme is called spectrum reservation for each node-pair (SRNP). The policies proposed to set the weights are the following:

- Maximal Optical Grooming (MOG) and Maximal Electrical Grooming (MEG)- minimize the number of newly established lightpaths.
- Minimal number of Virtual Hops (MVH)- minimize the number of virtual hops the new connection goes through to reduce the number of OEO conversions.
- Minimal number of Physical Hops (MPH)- minimize the number of physical hops.
- Load-Balancing (LB)- this policy aims at balancing the load carried by the fibers.

The above grooming polices are compared in terms of bandwidth blocking ratio (which is defined as the ratio of total blocked bandwidth over the total requested bandwidth), number of used transponders, number of virtual hops, and number of physical hops. Simulation results showed that there is a trade-off among policies and they should be implemented depending on the objectives of the network operator.

Since a layered graph models used in [16, 17] assumed QPSK (Quadrature Phase-Shift Keying) modulation and an ideal physical medium, the study in [18] extends it by analyzing the network performance when other modulation formats (16QAM (Quadrature Amplitude Modulation) and 64QAM) are employed and when physical issues are taken into account. Also, the paper analysed how the policies proposed in [16, 17] can be used in the operation of a heterogeneous networks, where QPSK, 16QAM and 64QAM modulation formats coexist. The results showed that the use of transponders supporting subcarriers with different modulation formats reduces blocking ratio. Although these transponders are expensive, the reduction of blocking ratio makes possible the use of cost effective policies like MVH even for high traffic loads, so a better trade-off between cost and performance could be obtained than when using transponders employing a single type of modulation format.

The next section discusses some issues added to the grooming approach such as multipath routing, adaptive modulation, defragmentation aware and survivability issue. The algorithms are classified in groups and discussed according to their main features and objective functions.

5. OPTICAL GROOMING ALGORITHMS WITH SPECTRUM AND ENERGY EFFICIENCY TECHNIQUES

5.1 Multipath routing traffic grooming algorithms

Traffic grooming and multipath routing are two techniques recently applied in elastic optical networks to increase spectral efficiency [19, 20]. By splitting a traffic request into multiple small size subconnections and individually transmitting them through several optical paths, multipath routing algorithms can more flexibly utilize spectrum resources than single path routing algorithms in dynamic traffic scenario. Here, it has been shown that traffic grooming and multipath routing, applied together increase spectral efficiency and reduce resource consumption. Dynamic multipath routing algorithm with traffic grooming (MPTG) under heavy traffic was proposed in [19]. The basic idea is to split traffic connections and route them across multiple path where small size connections originated from the same source node and sharing common fiber links are aggregated. Because of the splitting additional guard bands and BVT are needed. Applying traffic grooming the BVT bandwidth can be better utilized and guard bands reduced, which therefore alleviates the impact induced by multipath routing. Three traffic grooming policies are used in [19]: shortest path first, maximum usable bandwidth and largest spectrum savings. The simulation results showed that the proposed MPTG algorithm effectively reduces blocking ratio and enhances network throughput compared with the previously reported multipath routing or single path routing algorithms.

The authors in [20] presented TMG heuristic which combines traffic grooming (**T**R), multipath routing (**M**PR) and physical impairment model (PLI) which was estimated using the Gaussian noise model (**G**N). For a small size networks an ILP formulation and a heuristic for large networks are presented. The primary objective of the study was to increase the spectral efficiency (higher spectral efficiency implies a reduced maximum subcarrier index). Besides that, the performance of the proposed algorithm was evaluated in terms of resource consumption (router ports and transponders) and network size. The proposed TMG heuristic resulted in an increased spectral efficiency because of accommodating traffic connections that cannot be routed due to excessive PLI or due to the absence of spectrum along a single path using TG and MPR. The proposed algorithm also achieves considerable router port savings over the existing algorithms, although consuming slightly more transponders.

5.2 Energy efficient traffic grooming algorithms

The continuous traffic growth except high capacity system requires minimizing power consumption or a power efficient system. Since BVTs consume more power, it is necessary to develop energy efficient or so called green algorithms. Such algorithms including modulation format changing are proposed in [21-23] where authors developed a green grooming heuristics based on auxiliary graph. Green heuristic (GGA, Green Grooming Algorithm) proposed in [21] is based on weighted double-layered graph. Each weighted double-layered graph corresponds to a certain modulation level. This graph includes one virtual topology layer (VTL) and one physical layer (PL), and two layers are connected with each other via logical links. Each virtual node on the VTL corresponds to the physical node on the PL, and the virtual link between two virtual nodes denotes the existing lightpath that has available sub-carriers. If the client data traverse along the existing lightpath, it will be groomed into this lightpath. For the new client data, the algorithm first configure the weights of established lightpaths on the VTL and fiber links on the PL according to the spectral usage, and finally determine the connection with the minimum costs. The main features of this algorithm are the utilization of a single-carrier modulation (e.g., QPSK) to set guard bands and subcarriers. So distance adaptive resource allocation was applied. The objective was to improve spectrum and power efficiencies. It has been shown that single-carrier modulation results in lower spectral efficiency and worsened receiver sensitivity.

In order to improve the study investigated in [21] the authors extended their research in [22] and included adaptive multilevel modulation which integrates GGA with DASRA (Distance-Adaptive Spectrum Resource Allocation) what means that, according to the client data rate and transmission performance/distance, the BVT adaptively adjusts the modulation format by using the minimum necessary spectral resources. A novel auxiliary graph is constructed by copying the weighted double-layered graph according to the number of available modulation formats and allocated/released spectral resources with the dynamics of client data through the operations of adding and deleting graph edges [22]. The performance metric were: average power and average spectrum as well as total power and total spectrum consumption. The simulation results demonstrated that the adaptive multilevel modulation plays an important role in saving spectrum and power consumptions for the green grooming in EONs but results in large amount of spectrum fragments. This auxiliary graph with different modulation formats has been also used in [23] but for the static traffic scenario.

The impact of adaptive modulation on cost efficient traffic grooming in EON was also discussed in [24] where authors tried to identify the best network conditions for adaptive modulation by changing the traffic volume and topology of the evaluation networks. Simulation results showed that network designs employing both adaptive modulation and traffic grooming achieved up to 25% optical line reduction compared to single-modulation traffic grooming designs. Also, it was found that such cost reduction effect grows with the increase of network size and traffic volume.

Energy efficient traffic grooming in IP-over-elastic optical networks with a sliceable optical transponder was studied in [25]. Three BVT based on their slice ability, namely, no sliceable BVTs, fully sliceable BVTs, and partially sliceable BVTs were investigated. For each transponder an ILP model and a heuristic algorithm with the aim of energy minimizing were developed. Five grooming operations including both electrical and optical layer grooming are proposed. All of them serve the traffic from the highest bandwidth requirement to the lowest in the traffic demand matrix, and they compute total energy consumption after the last traffic is served [25]. After the comparisons, the results showed that significant power savings can be achieved by using a sliceable optical transponder. Second, power savings do not keep improving linearly while transponder slice ability is increasing, and traditional electrical layer grooming is still required to work together with optical layer grooming to reduce power consumption.

5.3 Traffic grooming algorithms with spectrum defragmentation

The research in [22] is extended in [26] with spectrum reservation to solve the problem of spectrum fragments. The main power contributors: BVT, optical amplifier and BV-OXC are first considered. A comprehensive power consumption model and an ILP formulation were proposed. For a large scale networks a green grooming heuristics was also proposed. The grooming policies implemented are: Minimize Spectrum (MS) consumption grooming policy and Minimize Power (MP) consumption grooming policy. In the first one, the link cost in the auxiliary graph reflects the number of consumed subcarriers while in terms of MP the link cost reflects power consumptions. In order to support a heuristic a threshold-based spectrum reservation which efficiently utilizes the bandwidth variability of BVT is included. In this mechanism, each subcarrier has three states: used, reserved and vacant. Reserved means that the lightpath is reserved for the future bandwidth extension. The optimization objective of this algorithm was to minimize the total number of occupied spectrum slots, and to minimize the total power consumed by transceivers, OXCs and optical amplifiers. The simulation results demonstrated the effectiveness of this approach.

The problem of spectrum fragmentation was also solved in [27] where a novel concept of spectrum engineering was introduced. Spectrum engineering was incorporated into the traffic grooming polices and implemented by spectrum defragmentation. Different from [26] the authors considered spectrum defragmentation operation instead of spectrum reservation scheme, and allocate the exact necessary spectrum resources for each new coming request. The auxiliary graph differs from the first one in the model layers that are: virtual layer, transmitter layer, and receiver layer. Between the nodes, there are four kinds of directed edges in the auxiliary graph: transmitter edge, receiver edge, existing lightpath edge, and potential lightpath edge [27]. The edge weights are varied implementing different grooming policies which determine how to provision connection requests. In this study bandwidth blocking ratio was used as a metric to reflect spectrum efficiency and the average number of used transponders, as an OPEX metric. The results showed that there is a trade-off among different traffic grooming policies, and they should be adopted according to the network operator’s objectives and network state. The proposed traffic grooming algorithm with spectrum engineering can reduce OPEX as well as increase spectrum efficiency by efficiently utilizing the bandwidth variability and capability of sliceable optical transponders.

5.4 Survivable traffic grooming algorithms

This class of algorithms addresses both grooming provisioning and survivability which is defined as the ability of an optical network to survive after the occurrence of failures.

The survivable traffic grooming problem for elastic optical networks was investigated in [28]. These protection algorithms are all based on the path-shared protection mechanism, in which each traffic demand will be first assigned a working path, and then the working path will be assigned a link-disjoint backup path. The study in [28] proposed a novel shared protection specific to elastic networks, namely, Elastic Separate-Protection-At-Connection (ESPAC). The basic idea was to groom a connection request with shared protection against single fiber failures. The algorithm offers a new opportunity of spectrum sharing enabled by the elasticity of the transponders: first, if the working paths of two connections are link disjoint physically, and second, if their backup paths traverse two lightpaths which are adjacent on a fiber link, then the two backup lightpaths can share spectrum. When a single failure occurs in the network, because of the elasticity feature of the transponder, lightpaths carrying backup flows can be tuned to appropriate rates in such a way that the overlapped spectrum is used by only one of the adjacent lightpaths. In order to support a heuristic approach an auxiliary graph is used to solve the routing and spectrum assignment problem in ESPAC. After the simulation in dynamic traffic environment the results showed that this backup sharing in elastic network context achieves significant gain on spectrum saving.

Path-shared protection may lead to long restoration time and complicated protection switching procedure. Therefore, some previous works [29] proposed pre-configured protection cycles (p- cycles). This method offers ring like fast restoration because p- cycles are pre- cross- connected and offer a mesh- based high efficiency. Cost efficient grooming based on p- cycle protection in elastic optical networks was also studied in [30] where a heuristic algorithm called Shared p-Cycle Grooming Protection (SCGP) to get enough protection and less resources consumption was proposed. The performances (in terms of the number of transponders and power consumption) are tested with and without grooming.

The overview and classification of various traffic grooming algorithms are given in *Table 1*.

Table 1 – The classification of various optical grooming algorithms

	Algorithm	**Traffic type**	**Features/Objectives**
No spectrum engineering	Least Spectrum Grooming (LSG) algorithm [1], [4]	static	minimizes the total spectrum usage
	Minimum Transmitter Grooming (MTG) algorithm [1], [4]	static	minimize the total number of transmitters
	Traffic grooming scheme based on Spectrum-Elastic Optical Path Networks [5]	static	minimize an average spectrum utilization rate weighted by fiber length
	First-Possible Aggregating (FPA) algorithm [9]	dynamic	maximizing the transmitter capacity utilization
	Multi-hop Elastic Light-Trail (MELT) algorithm [14]	dynamic	maximize elastic spectrum utilization of an optical fiber link
	Multi-layer graph model [15]	dynamic	minimizing blocking probability and network resource occupation
	Three-layered Auxiliary Graph (AG) model [16], [17]	dynamic	address mixed-electrical-optical grooming/minimizing bandwidth blocking ratio/number of used transponders/number of virtual hops, and number of physical hops depending on the grooming policy
	Three-layered Auxiliary Graph (AG) model [18]	dynamic	different modulation formats used instead of one/ the reduction of blocking ratio

Spectrum engineering- multipath routing issue	Dynamic multipath routing algorithm with traffic grooming (MPTG) [19]	dynamic	minimizing blocking ratio
	TMG heuristic which combines traffic grooming (**T**R), multipath routing (**M**PR) and physical impairment model (PLI) which was estimated using the Gaussian noise model (**G**N) [20]	dynamic	increasing the spectral efficiency
Spectrum engineering- energy efficient issue	Green Grooming algorithm (GGA) based on weighted double-layered graph [21]	dynamic	single-carrier modulation/ improving spectrum and power efficiencies
	Green Grooming algorithm with adaptive multilevel modulation [22]	dynamic	saving spectrum and power consumptions
	Grooming algorithm with multiple modulation formats [23]	static	saving optical paths
	Energy-minimized traffic grooming heuristic with a sliceable optical transponder [25]	static	reducing power consumption
Spectrum engineering- spectrum defragmentation issue	Green Grooming Algorithm with adaptive multilevel modulation and threshold-based spectrum reservation scheme [26]	dynamic	minimize the total number of occupied spectrum slots, and minimize the total power consumed by transceivers
	Optical traffic grooming algorithm with spectrum defragmentation [27]	dynamic	Minimizing bandwidth blocking ratio and the average number of used transponders
Spectrum engineering- survivability issue-	Shared protection algorithm (Elastic Separate-Protection-At-Connection (ESPAC)) [28]	dynamic	Auxiliary graph is used/achieving significant gain on spectrum savings
	Shared p-Cycle Grooming Protection (SCGP) [30]	dynamic	ring like fast restoration/less resource consumption

The algorithms are classified into the groups according to various spectrum engineering techniques with related traffic scenarios and objective functions. The static problems are usually related to resource planning while bandwidth assignment aims at dynamic problems. The static problem could be solved with ILP formulations while dynamic problem is solved mostly with heuristic algorithms. Hence, we did not find any metaheuristics dealing with this optical grooming problem, as swarm intelligence approach, what is of our interest and will be our next research step.

6. CONCLUSION

Traffic grooming directly at the optical level is one of the main features of the elastic optical networks. Combining the elasticity with the grooming approach turned out to be an excellent solution in spectrum savings. The routing and spectrum allocation problem is therefore a more complex if grooming constraints are added. Since the ILP solutions of such problem do not scale well for large networks because of their complexity and a running time, heuristic methods are developed in achieving a solution near to optimal in a reasonable computing time.

In the process of literature survey we considered a range of papers where the optical grooming algorithms were described and tested individually, but there were not references where these algorithms are surveyed and classified. So, the objective of this paper was to gather these algorithms and to classify them according to some criterion, discuss their procedures and objective functions as well as their pros and cons. The criteria used for classification were: traffic scenario, multipath routing issue, green grooming, spectrum defragmentation and survivable grooming issue.

After having the state of the art in this field, we are able to develop our own metaheuristic algorithms for optical grooming problem. Further research will include swarm intelligence metaheuristic approach, namely bee colony optimization to solve RSA with traffic grooming as one complex combinatorial optimization problem.

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APPLICATION OF ARTIFICIAL IMMUNE SYSTEMS FOR PLANNING OF BEVERAGE'S DELIVERY TO NETWORK OF RETAIL SHOPS

ABSTRACT

The article presents the problem of deliveries to customers with the use of delivery vans fleet. This problem relates to a Capacitated Vehicle Routing Problem with Multiple Trips (CVRPMT). Three methods of this problem solution are presented on the example of deliveries from a wholesale. In every method, the length of whole routes of all used delivery vans was minimized with restrictions based on delivery vans capacity. The branch and bound method was firstly used. Next two methods of artificial immune system (AIS) were used. In the first of this methods, the routes for each delivery van were determined while simultaneously allocating customers to service. In the second method of AIS, at first, the reception points were divided into groups of customers due to the distance criterion, due to the minimal fuel consumption and with limited weight of goods due to the permissible capacity of the vehicle. Subsequently, the shortest routes were determined for designated groups of customers and cars. All the results were compared. Better results were obtained using artificial immune system. The best results were received with first method of AIS. The second method was not much worse and it can be applicable for solving large problems.

KEY WORDS

Capacitated Vehicle Routing Problem with Multiple Trips; artificial immune system; clonal selection; branch and bound method; clustering

1. INTRODUCTION

A transportation is an indispensable component of a business activity. It serves as an important service both the producer and the customer. On the other hand, the transport market is highly competitive, resulting in lower prices and operating costs. The routes planning is one of the methods to minimize costs. As it is known, the fuel consumption and exhaust emissions, cushioning, driver's time and comfort depend on the length of routes and their travel time. As it is seen, minimization of length of routes has an impact on reducing the harmful effects of transport on the environment.

The research entity, in this article is a company providing retail stores with both alcoholic and non-alcoholic beverages. At present, the company has more than 100 clients and works with the largest beverage producers in the area. In this company, drivers do not receive any guidance on the route operating. They only get a list of reception points. The issue of route selection is individual and intuitive. The presented considerations focused on the company's activity in the northern part of the Silesian Voivodship in Poland, where the supply includes 30 retail stores.

It was proposed to solve the problem of planning the allocation of customers to specific cars and planning routes for them in an optimal way. Minimizing the sum of route lengths was used as the optimization criterion. This is equivalent to the criterion of cost minimization assuming that the costs are proportional to the length of the road traveled. The branch and bound method (BBM) and two methods of the artificial immune systems (AIS) were applied. In the BBM at the initial stage of the calculation, the customers were divided into groups due to the minimum distance, with the restriction on the volume of goods delivered to the given customer group. A similar solution has been used in the second AIS method, but the selection of vans due to minimum fuel consumption has also been included.

The purpose of this article is to demonstrate that using AIS for optimization does not produce worse results than BBM, often used in such cases. In addition, data clustering method was proposed, which can streamline the method of solution, and even allow large tasks solving.

2. METH(1)ODOLOGY AND SOLUTIONS

The issue of supply to many consumers can be classified mathematically as a travelling salesman problem [1]. The salesman starts from the home warehouse, visits all customers and at the end he returns to the warehouse. Because of the cost minimization, the road should be as short as possible. Solving the task of a salesman is a problem where complexity grows exponentially.

For a small number of visited points, the solution can be obtained by strict methods. They can include, among others, integer programming methods and branch and cut methods [2].Many heuristic methods and artificial intelligence methods are often used to solve larger tasks [3-6]. These methods do not get exact solutions, but even if the results are approximate, the received results are certainly better than the intuitive ones.

In the article results, which were received using three methods: branch and bound method [7] and in two ways using the artificial immune system [8, 9] were presented and compared. The calculations were carried out for 30 picking points (Fig.1) for which coordinates and size of goods supplied are shown in Table 1. The wholesale is at a point with E19 ° 00 'N50 ° 21'6'' coordinates.

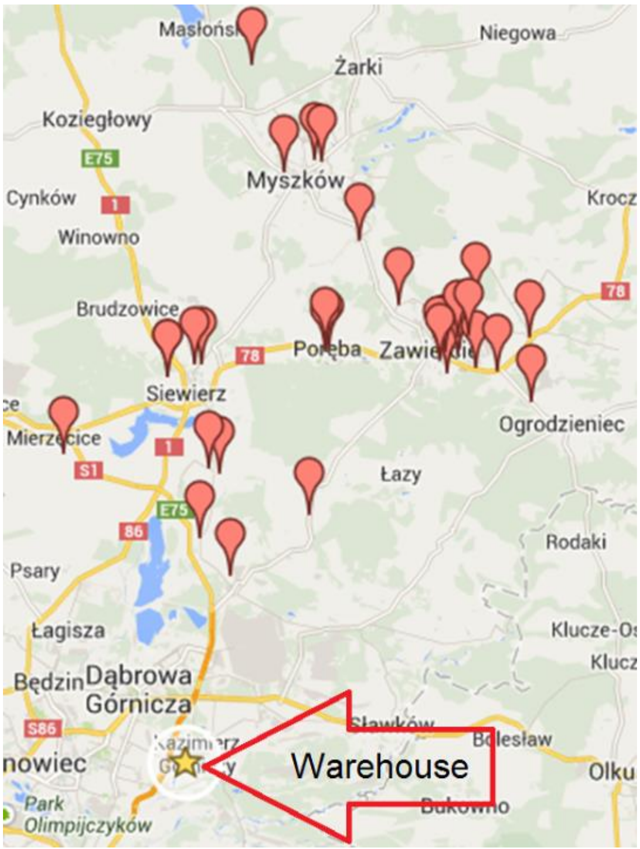

Figure 1 – The warehouse and picking points
Source: [10]

Table 1 – Picking points with size of goods delivered

	Picking points		Mass of goods		Picking points		Mass of goods		Picking points		Mass of goods
	X	Y	[kg]		X	Y	[kg]		X	Y	[kg]
1	15.84	0.62	1560	11	26.32	7.61	515	21	14.5	1.73	622.75
2	18.31	12.43	811.5	12	28.17	6.6	142.5	22	26.79	7.63	1084
3	20.25	7.19	316.25	13	19.75	12.78	182	23	20.51	12.62	1356
4	27.14	6.7	406	14	19.53	2.4	416	24	20.2	7.4	557.75
5	14.54	6.8	225	15	25.47	7.14	37	25	12.95	6.45	1048
6	29.71	5.71	74	16	27.17	8.71	88	26	25.5	6.91	589
7	20.39	7.29	587	17	21.81	10.43	163.75	27	14.9	3.75	335
8	23.66	8.56	1589	18	14.23	6.84	231.25	28	26.36	7.07	304
9	15.34	3.62	839.25	19	16.89	15.57	483	29	8.24	4.21	954
10	25.8	6.55	3928.25	20	29.64	7.59	217	30	25.77	7.17	499.5

Source: Made by the author

The tab.2 presents the technical specifications of delivery vehicles that supplied goods to selected customers.

Table 2 – Technical specifications of delivery vans

	Brand	Model	Load capacity [t]	Model year	Engine capacity [cm³]	Power [kW]	Fuel consumption [l/100km]
1	Volvo	FL 614	7.4	1994	5480	132	24
2	Mercedes	Atego	5.9	2005	4249	130	22
3	Iveco	R 380	5.68	2004	3920	125	17
4	Iveco	Eurocargo ML 100	5.68	2004	3920	125	17
5	DAF	FA 45	3.50	2001	5886	118	14

Source: Made by the author

The data to be computed and the results obtained by the branch and bound method are derived from [11].

2.1 Solution with branch and bound method

Calculations were done in two stages. In the first stage, the data were clustered and in the second the route were minimized for individual cars [12, 13]. The division of customers into clusters was made using the Forge algorithm. The main characteristic of the cluster membership was the distance from each other. In addition, the cargo volume per cluster could not exceed the payload of the delivery van. At each step of the Forge algorithm, the centers of gravity of the individual clusters were determined using the formulas (2) and (3), then the distances of all points from the centroid determined using the formula (4).

$$c_x = \frac{\sum_{i=1}^{n} x_1 \cdot W_1 + \cdots + x_k \cdot W_k}{W} \tag{2}$$

$$c_y = \frac{\sum_{i=1}^{n} y_1 \cdot W_1 + \cdots + y_k \cdot W_k}{W} \tag{3}$$

$$d = \sqrt{(c_x - x_i)^2 + (c_y - y_i)^2} \tag{4}$$

where:

(x_i, y_i) - coordinates of i-th point in cluster,

W_i - mass of charge to be delivered to i-th point,

W - mass of the entire charge in the cluster,

k - number of points in the cluster,

(c_x, c_y) - centroids coordinates.

The points were divided into 4 main clusters (Fig.2).

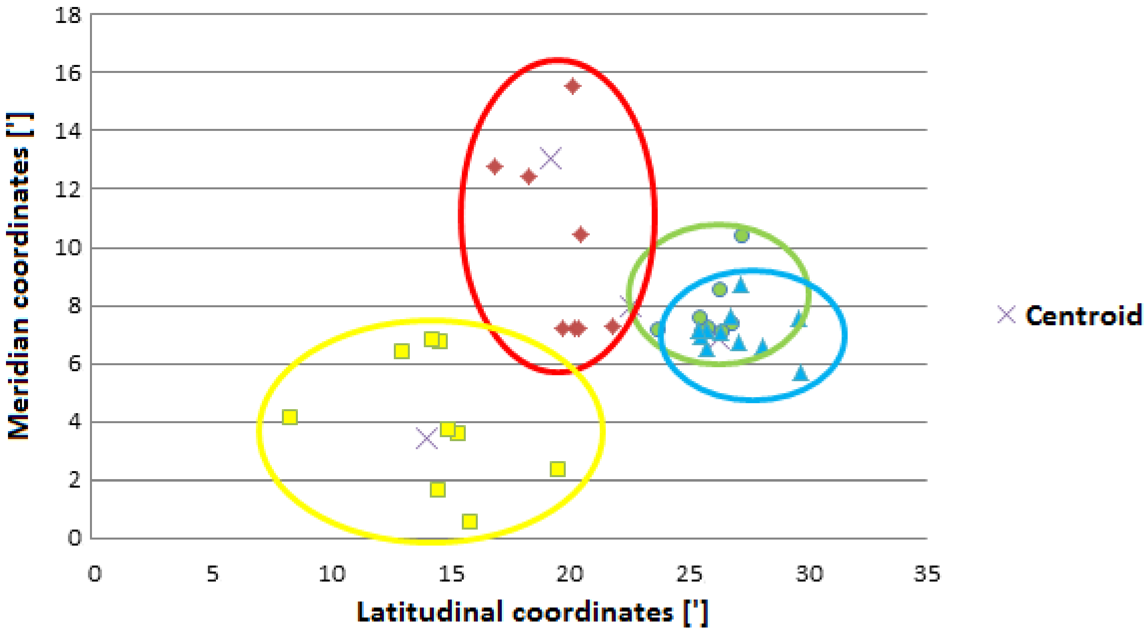

Figure 2 – Results of the clustering with the Forge algorithm
Source: [10]

After the division in each cluster, all shortest routes were routed through all points. Algorithm of Little was used, which is one of the branch and bound method variant. This algorithm is described in detail in [14] and available on the website [15]. Results of calculations are shown in Table 3.

2.2 Solution with clonal selection algorithm

Artificial immune systems belong to artificial intelligence methods. They are inspired by the natural defence system of the human body. The clonal selection used in the calculations imitates a process that is triggered by a human organism after it enters antigens. The antigens are recognized by some type B lymphocytes. The best cells are cloned and then mutated for refinement. In the end, the antibodies, that is, the cells that recognize the enemy, start to be rapidly multiplied. Organism begins to defend itself. After countering the threat, the number of antibodies is stabilizing. Some become memory cells to store useful patterns for the next attack, some wander in the bloodstream and are ready for action.

In the clonal selection of the artificial immune system, the solutions proposals are antibodies. They are initially generated randomly and evaluated. Then the best antibodies are cloned, mutated and evaluated. The best pass to the next cycle. The procedure is repeated for a specified number of cycles.

On issues that can be reduced to the salesman's task, the author assumes that the antibody is a finite sequence of points through which the salesman's route goes, in the order corresponding to the order in which the points are visited, and that the points in the sequence do not repeat. In turn, mutations are operators that map the sequence of points to a new sequence of points. The antibody thus defined is evaluated according to the criterion. In the calculations described here for each antibody, the length of the route is determined by the points in order of their sequence in sequence. The distance of the first and last one from the base (warehouse) is also taken into account. Since the road minimization is carried out, the assessment is equal to the inverse of the length of the entire road.

In the case of the first of the algorithms, the vans serve the points of the route according to the established list. The load is summed up and when it exceeds the allowable payload of the vehicle, the vehicle returns to the warehouse without operating this last point. From this point, another vehicle from the list begin the route.

2.3 Clonal selection algorithm supported by clustering

In the clustering algorithm, the antibody is a sequence of numbers of those nodes that represent the centroid of the clusters being built. The node closest to its centroid is added to the cluster. The sum of all distances should be minimal, so the fitting function is the inverse of this sum. In order to take into account the fuel cost per kilometer of the road to each distance the cost of fuel must be added. In this model, vehicle loading capacity operating the cluster was also taken into consideration. This condition is also included in the objective function as a function of punishment (5).

$$f = \sum_{i=1}^{n} d_i + w_0 \sum_{i=1}^{n} d_i \cdot c_{ik} + w_1 \sum_{j=1}^{m} (\hat{V}_j - V_j) \tag{5}$$

where

d_i – length of i-th road segment,

c_{ik} – cost of running the i-th section of the road with k-th vehicle,

$\hat{V}_j$ – a permissible j-th vehicle capacity,

V_j – j-th vehicle load,

w_0, w_1 - weight coefficients, $w_0 \geq 0$,

$$\hat{V}_j > V_j \Rightarrow w_1 > 0 \tag{6}$$

$$\hat{V}_j < V_j \Rightarrow w_1 = 0 \tag{7}$$

Calculation using clonal selection algorithms was performed several times. The best of results are shown in Table 3.

2.4 Results of calculations

As a result of clustering with artificial immune system, clusters with the smallest road lengths, minimal fuel costs and distribution of goods not exceeding the payload of a vehicles designated for a given cluster were obtained. In the Forge method only the first criterion was taken into account and requirement on the payload of vehicles. The fuel consumption criterion was taken into account in the optimization with the clonal selection method. In the Forge method the values of fuel consumption were calculated from the data in Table 2 and the obtained lengths of the roads traveled by vehicle. The results of Forge clustering and the artificial immune system clustering were used in subsequent calculations.

The results of the optimization of the routes for delivery vans by all three methods are summarized in Table 3. The best results were obtained for the optimization performed by the clonal selection algorithm directly, without the clustering step. But the results obtained by the clonal selection algorithm with clustering are not much worse. The worst results were obtained by the Little algorithm with Forge clustering.

The results met the expectations of the author. Further work will be on the use of developed clonal selection algorithms to solve problems with more distribution points. All calculations using artificial immune systems were carried out with their own implementation of algorithms written in C ++.

Table 3 – The results of optimizations

Methods	Criteria for optimization	Vehicle (from tab.2)	Mass of good [kg]	Length of road [km]	Fuel consumptions [l]	Suggested routes
Branch and bound method	Minimizing the length of road while taking into account vehicle capacity	5	2833	100	14	0-2-13-19-23-0
		4	4265	122	21	0-17-3-7-8-15-30-24-11-0
		1	6231	114	27	0-21-29-25-5-18-14-9-1-27-0
		1	6833	87	21	0-6-12-20-16-22-28-4-10-26-0
				422	**83**	
Clonal selection supported by clustering	Minimizing the length of road and fuel consumption while taking into account vehicle capacity	3	3980	71	16	0-2-13-19-1-18-23-17-0
		1	7196	90	21	0-10-15-4-12-20-6-0
		4	4699	84	14	0-3-7-8-16-22-11-24-30-28-26-0
		2	4287	94	16	0-5-9-21-29-27-14-25-0
				338	**67**	
Clonal selection	Minimizing the length of road while taking into account vehicle capacity	1	7363	103	25	0-27-3-17-7-8-16-20-6-12-4-26-30-28-22-11-14-0
		2	5849	124	27	0-29-24-18-13-19-23-2-5-25-0
		3	5390	74	13	0-21-10-9-0
		5	1560	28	4	0-1-0
				330	**69**	

Source: Made by the author

3. CONCLUSIONS AND FUTURE PURPOSES

The aim of the article was to compare three methods of planning the optimal routes of delivery vehicles, which supply goods from the wholesale to customers. The methods, which were used:

- a branch and bound (algorithm of Little) with the clustering (method of Forge),
- an artificial immune system (clonal selection algorithm), which optimizing without division delivery points into groups
- the clonal selection algorithm with an initial division delivery points into groups and with determining the optimal routes within each group

The results received show that the clonal selection algorithm of artificial immune system is an effective tool in all problems presented here. As a grouping tool, the artificial immune system has divided all delivery points into four groups that meet the criteria: the shortest path, the lowest fuel consumption, with the limitation that in a given cluster the mass of delivered goods does not exceed the allowable payload of the delivery van.

The artificial immune system also proved to be more effective in solving the optimization of the vans route by the designated pick up points. The best results were obtained with the second method, but for the third method with data clustering, the results were not much worse. Such a result gives hope for an effective application of the route optimization method with the initial separation of pick up points by the clustering method shown here for a large number of distribution points and a large delivery vehicles fleet.

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AN OBJECT-ORIENTED MODEL FOR EXPANSION OF THE MINIMUM SET OF DATA TRANSMITTED DURING eCALL SESSIONS

ABSTRACT

The focus of this paper goes beyond the horizon of the current status of the implementation of Europe's unique emergency distress platform for road traffic accidents called eCall (Emergency Call). In the near future, the eCall system will provide end-to-end communication service that will be used for transmission of an accident related information between the vehicles in distress and nearest Public Safety Answering Point (PSAP). Currently, different pilot projects strive to test the transmissions of the Minimum Set of Data (MSD) upon the accident occurrence, containing the information such as the location of the accident and a vehicle type. The received MSD is used by the PSAP operators for incident management purposes. In this study, we propose an Object-Oriented Model (OOM) for expansion of the MSD to include more information needed for efficient coordination of the emergency services at the scene of the accident as well as for more accurate investigation and analysis of the accidents.

KEY WORDS

eCall; communication system; architecture; model; minimum set of data; UML

1. INTRODUCTION

In recent years, significant effort has been invested worldwide into reducing the number of injuries and fatalities caused by road accidents (see, for instance, [1-2]). Vehicle manufacturers, infrastructure operators, scientific, research and educational institutions, civil organizations, national/international regulatory bodies and other stakeholders are continuously (co)working on the improvement of road safety by developing and implementing a wide range of Intelligent Transport System (ITS) solutions. Hence, nowadays we are witnessing the implementation and operationalization of various systems, for instance, active and passive in-vehicle safety systems, adaptive navigation systems capable of dynamic vehicle routing, new and improved information systems, intelligent lighting systems, and (semi-) autonomous vehicles. One of the most promising systems, with the ability to notably reduce the negative impacts of traffic accidents, is the Emergency Call or eCall system, currently developed and tested as a part of HERO (Harmonized eCall European Pilot) project [3].

The eCall system is a communication platform capable of collecting and distributing vital traffic accident related information to all parties involved in the process of accident management and clearance (i.e. incident management). In the core of the system sits the communication network; both fixed and wireless telecommunication networks are interconnected. The network connects drivers and vehicles with the infrastructure, i.e. Public Safety Answering Point (PSAP) responsible for handling the accidents [4]. This includes also the connection with emergency services as well as other organizations.

The communication system, therefore, connects mobile users (vehicles, i.e. drivers) with the PSAP responsible for the certain area of the road network (usually one or more regions).

Upon the accident occurrence, the vehicle automatically sends the information about the event to the PSAP or, in another use case, the driver of the vehicle initiates the eCall session manually [5]. Next, the onboard vehicle system transmits the Minimum Set of Data (MSD) to the PSAP, indicating e.g. vehicle type and geographical location of the vehicle [6-7]. A voice channel between the vehicle and the operator in PSAP is established as well; thus, the operator can acquire additional information from the driver and/or the passenger(s) if they are conscious. The received information helps PSAP operators to efficiently dispatch required emergency services to the location of the accident and to dynamically route the emergency vehicles to/from the location. Hence, the system directly increases the probability of transporting the victims of the accident to the medical facilities within the "golden" hour, ergo, reducing the fatality rates of the accidents.

Note that the eCall system is based on the 112 SOS platform, i.e. it upgrades the functionalities of the Europe's joined emergency response system. Furthermore, the eCall system requires appropriate communication capabilities of the vehicles. It is planned that all new-produced vehicles will be equipped with the eCall technology from April 2018 onwards (as indicated in [8]), while different solutions are currently being developed for older vehicles (e.g. see the work presented in [9-10]).

In this paper, we argue for the expansion of the MSD transmitted during the eCall sessions to the PSAP and propose an Object-Oriented Model (OOM) of the upgraded system that would be capable of accommodating the proposed functionalities. The main motivation for this work stems from the fact that modern vehicles are collecting a wide range of data from the on-board sensors, while Next Generation Mobile Networks (NGMN), namely Long Term Evolution (LTE) and future 5G networks, are capable of fast and reliable data transfers. By expanding the MSD, the PSAP operators would have a complete traffic accident related information at their disposal which can improve the process of incident management as well as the accuracy of traffic accident investigations. Note that some possibilities for the expansion of the MSD are previously discussed in [11-12].

The remainder of the paper is structured as follows. Section 2 provides a brief overview of the current architecture of the eCall system, setting up a baseline for our proposed expansion of the system. In section 3 we present the OOM of the new and upgraded system, while in Section 4 we draw conclusions.

2. SYSTEM ARCHITECTURE

Based on the results of the HERO project [3], in this section, a brief overview of the eCall system architecture will be presented. The system consists of three integral subsystems as depicted in *Figure 1*. Namely, the eCall platform connects the mobile users (i.e. In-Vehicle System or IVS) with PSAP operators via a telecommunication network, enabling the MSD transmissions and voice communication.

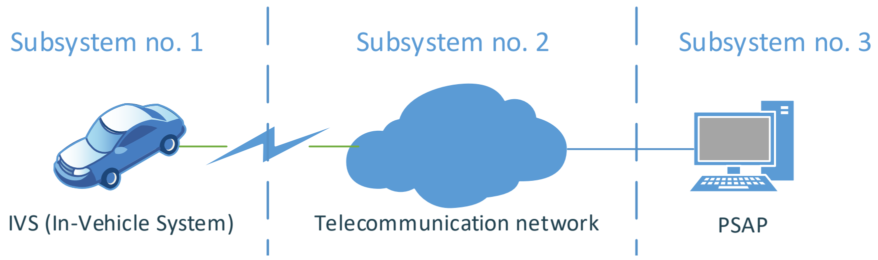

Figure 1 – Three subsystems of the eCall system
Source [3]

2.1 In-Vehicle System (IVS)

To become fully operational, the eCall system requires that the vehicles can participate in the network communication and data exchange [13]. The equipment used to collect and transmit the data is depicted in *Figure 2*. The key component is the MSD generator that collects the on-board data (e.g. geographical location of the vehicle and airbag status) and transmits them to the PSAP via network access device and the antenna. Note that the size of the MSD is 140 Bytes and it contains six different types of information, tabulated in *Table 1*.

The IVS consisted of these components (*Figure 2*) has to meet the following functional demands: (a) network access device, such as GSM or 3G module, has to be installed onboard and IVS has to detect when the eCall has been initiated; (b) in case of an accident, IVS has to be able to autonomously decide whether to initiate the call or not, but it has to enable manual initiation of the eCall session as well; (c) upon the initiation of the eCall, IVS has to transmit MSD to any local mobile network service provider; (d) voice communication has to be enabled between the vehicle and PSAP (therefore, the integral part of the IVS is a microphone and a speaker, as indicated in *Figure 2*); and (e) the IVS communication equipment has to be robust and durable so that it is immune to the damage caused by the accidents as well as the elements.

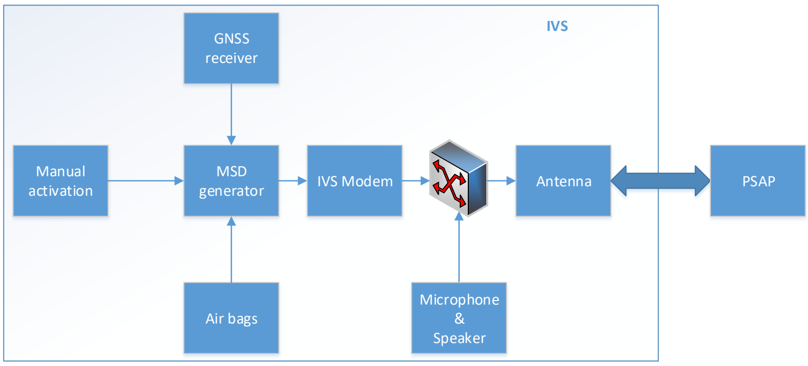

Figure 2 – IVS components
Source [3]

Table 1 – The Minimum Set of Data transmitted during eCall session

Control	Size in Bytes = 1
• Type: Integer • Validation: No • Description: Bit 7: Automatic activation | Bit 6: Manual activation | Bit 5: Test call | Bit 4: No confidence in position | Bit 3 - Bit 0: Reserved	
Vehicle identification	Size in Bytes = 20
• Type: String • Validation: 17 characters, excluding the letters I, O or Q • Description: Vehicle Identification Number according to ISO 3779	
Time stamp	Size in Bytes = 4
• Type: Integer • Validation: ≥ 0 • Description: UTC seconds	
Location	Size in Bytes = 9
• Type: Integer (latitude and longitude) and Byte (direction in degrees) • Validation: [-324.000.000, 324.000.000] for latitude; [-618.000.000, 618.000.000] for longitude; [0, 255] for direction in degrees	
Service provider	Size in Bytes = 4
• Type: Byte • Validation: IPv4 format or blank field • Description: Service provider IP address or blank field	
Optional data	Size in Bytes: 102
• Type: String • Validation: No • Description: Additional data or blank field	

Source [14]

As seen from *Table 1*, there are 102 free Bytes for transmission of additional (optional) data from IVS to PSAP. In this study, we propose to use that free space to transmit other onboard data that is frequently collected by the vehicle systems (e.g. the accelerator/brake pedal status, vehicle speed etc.). This will be further discussed in section 3.

2.2 Telecommunication network

One of the key eCall stakeholders are the mobile service providers. Similarly to IVS, the telecommunication network (i.e. the providers) also needs to meet different case specific demands. Namely, the eCall service must be available across Europe regardless of the state borders, without any charges. The vehicles, representing the User Equipment (UE), must gain access to the network through BTS (Base Transceiver Station) and BSC (Base Station Controller). eCall UE must be recognized by the MSC (Mobile Switching Centre) and the initiated eCalls must be prioritized within the network. Each eCall must be treated by the network as an emergency call, meaning, the network must flag the call with *eCall flag* and acquire the location and ID of the UE. The eCall is routed to the nearest PSAP over Transcoder and Rate Adaptation Unit (TRAU), Media GateWays (MGW) and Wireline Switching Centres (WSC) when the MSC receives the call with the abovementioned eCall flag (*Figure 3*).

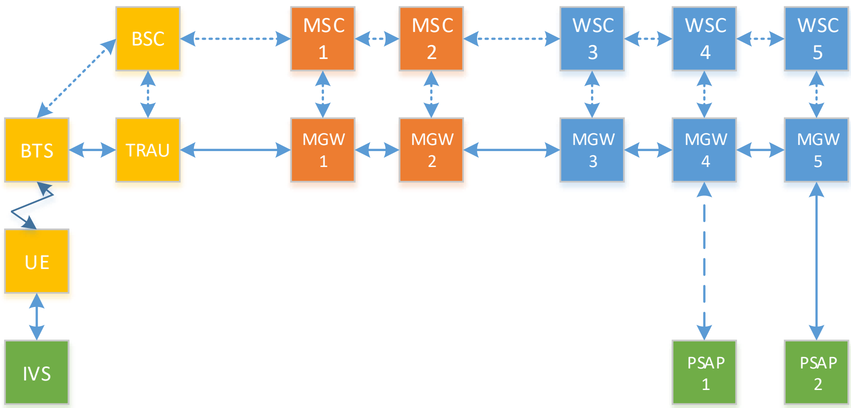

Figure 3 – Network components of the eCall system
Source [15]

The network also must be able to differentiate between the eCall and the standard 112 emergency calls. The eCall must be routed only to those PSAP complying with the eCall requirements (e.g. PSAP must be capable of receiving the MSD), while the standard emergency calls can be routed to any PSAP in the area. If a PSAP can receive both the eCall and the standard calls, then the network must route the eCall to appropriate interface of that PSAP. Based on the location of the UE, the service providers must provide a mobile cell ID, i.e. the cell location from where the eCall is routed.

2.3 PSAP

One of the proposed solutions for the PSAP architecture is presented in *Figure 4*. To this day, the eCall system is not fully operational [16], thus the PSAP architecture is still evolving; however, it is clear that some key functionalities have to be enabled by the architecture. Naturally, the PSAP must be connected to the mobile and fixed telecommunication networks, i.e. the PLMN (Public Land Mobile Network) and PSTN (Public Switched Telephone Network), respectively. The ingress components of the PSAP are the Eones (eCall identification equipment) and the eCall modem responsible for extracting the MSD from the eCall.

Based on the type of information that receives (voice or data), the Multiprotocol Switched Services (MSS) device conducts the routing within the PSAP. The voice communication is forwarded to the PBX (Private Branch Exchange), Voice over Internet Protocol (VoIP) server, as well as to the Data Base/Application server. The MSD is forwarded to the MSD decoder that decodes the received data set and joins them with the additional data sources such as VIN DB (Vehicle Identification Number DataBase), TPS (Third Party Service provider) or EUCARIS (European CAR and driving license Information System). In addition, local emergency station(s) are also provided with the eCall information via IP connection.

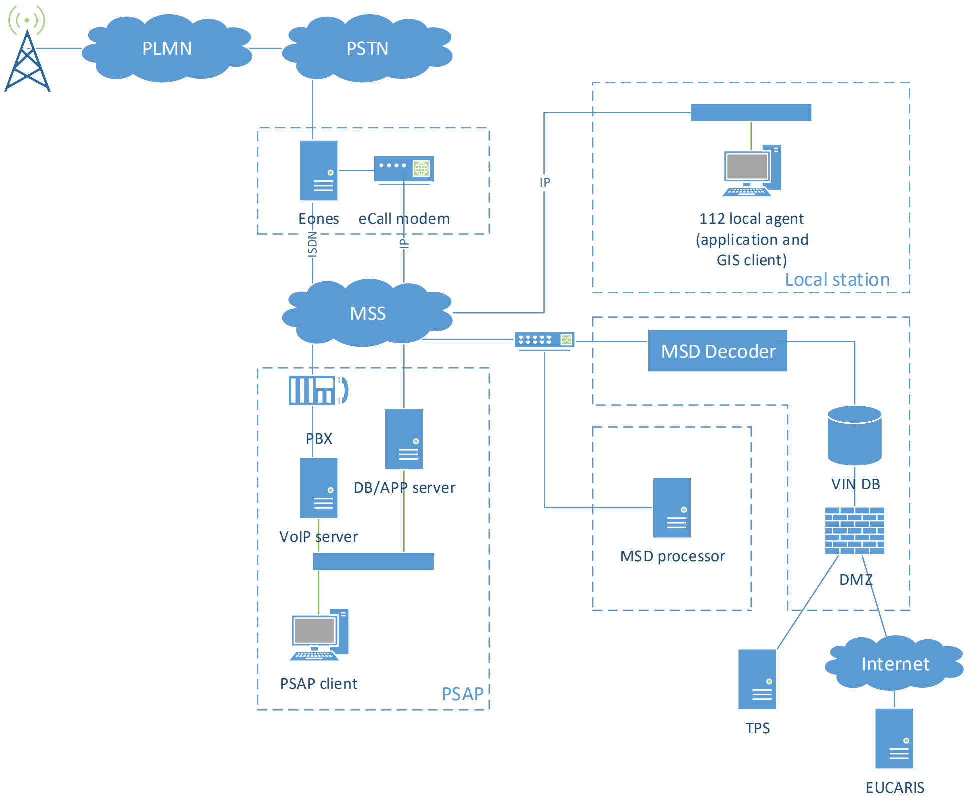

Figure 4 – The PSAP architecture
Source [3]

3. OOM OF THE PROPOSED EXPANDED SYSTEM

3.1. Upgraded IVS

The primary incentive for development and implementation of the eCall system is to decrease the time needed for emergency response to the scene of the accident; thus, reducing the negative impacts of the accidents. The current blueprints of the system, i.e. the system architecture discussed in the previous section, will enable that since the call is initiated immediately upon the accident (automatically or manually) and the location of the accident is sent to the PSAP. Hence, some sources, for instance [8], state that the time needed for an emergency response can be decreased with the eCall system by 50 and 60% in urban and rural areas, respectively. However, the potential of the system goes beyond the transfer of MSD, given the fact that modern vehicles are mobile sensors capable of collecting a wide range of traffic and vehicle status data. Apart from the incident management, these data could also be used for accident scene investigation.

In this study we propose to use in-vehicle EDR (Event Data Recorder) device as another data source and to collect and transmit the data, such as, vehicle speed (ranging from 0 to 250 km/h) and position of the accelerator pedal (0-100% of the pressure), number of Revolutions Per Minute of the engine (0-12.800 RPM), status of the brake pedals (pressed or not), position of the gear shifter (R/N/P/D/5/4/3/2/LO/B/Seq), position of the steering wheel (in degrees ±375°) and status of the cruise control (on or off). Furthermore, onboard Inertial Measurement Unit (IMU) can also be used as another data collector. The proposed new components of the IVS are depicted in *Figure 5*.

This new data would take up to 20 additional Bytes of those 102 Bytes reserved for additional (optional) data (*Table 1*). The Extended MSD (EMSD) would provide information not only about the location of the accident, vehicle type etc.; the EMSD provides the insight into driver behavior as well.

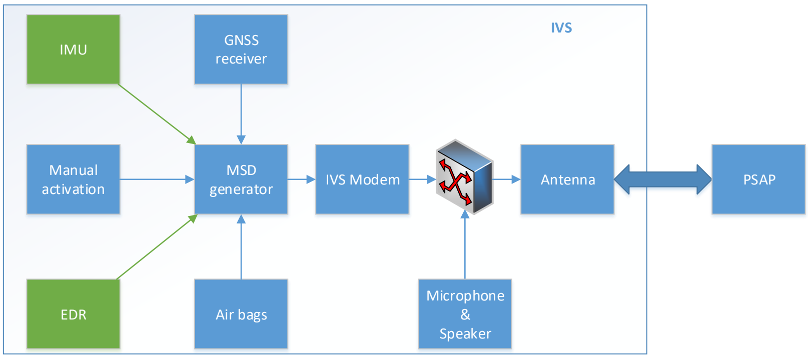

Figure 5 – Additional IVS components

Note, that the data send with EMSD can contain different timestamps so, for instance, vehicle speed can have two timestamps: one indicating the speed at the exact time of the accident (i.e. before the impact), and another record indicating the speed, e.g., 10 seconds before the accident. This would consume only 1 additional Byte of transmitted information but could produce a profound impact on the accuracy of the accident scene investigation.

3.2. Proposed PSAP architecture

Apart from the expansion of IVS functionalities, the proposed model includes the introduction of the connection between the PSAP and local/regional/national Traffic Management Centre (TMC) via Internet network, as indicated in *Figure 6*. This new system would be able to integrate different sets of data that are now dispersed over various data providers. For instance, Road Weather Information System (RWIS) can provide important information to the PSAP operator when he or she tries to dispatch the emergency services at the scene of the accident and prevent secondary incidents from happening. In fact, the proposed connection is beneficial also for the TMC, since the PSAP operator can inform the center about the occurrence of the accident; thus, the center detects and confirms the event with more accuracy. This, in turn, improves the efficiency of the incident and traffic management around the scene of the event [17] and as well as the accuracy of travel information.

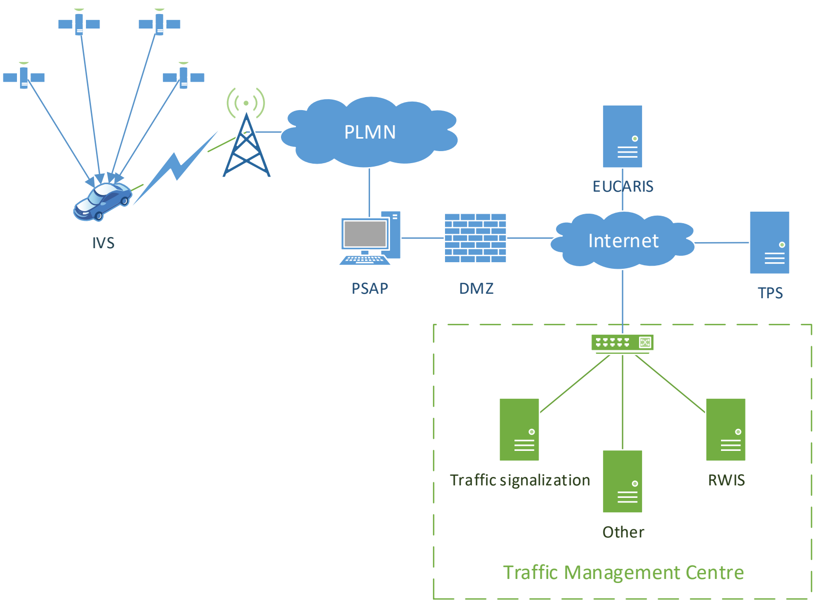

Figure 6 – Interaction of the PSAP and other systems

Another important benefit of this extension is the data collected from the Traffic signalization component of the TMS. Consider the following case presented on the sequence diagram depicted in *Figure 7*. The accident occurs at a signalized intersection. The exact time of the accident is recorded by the IVS and transmitted to the PSAP through the eCall system. After receiving and decoding the MSD, PSAP operator acquires the signaling plan for that intersection from local TMC and determines the exact signaling phase at the time of the accident. Thus, the accuracy of the accident investigation improves.

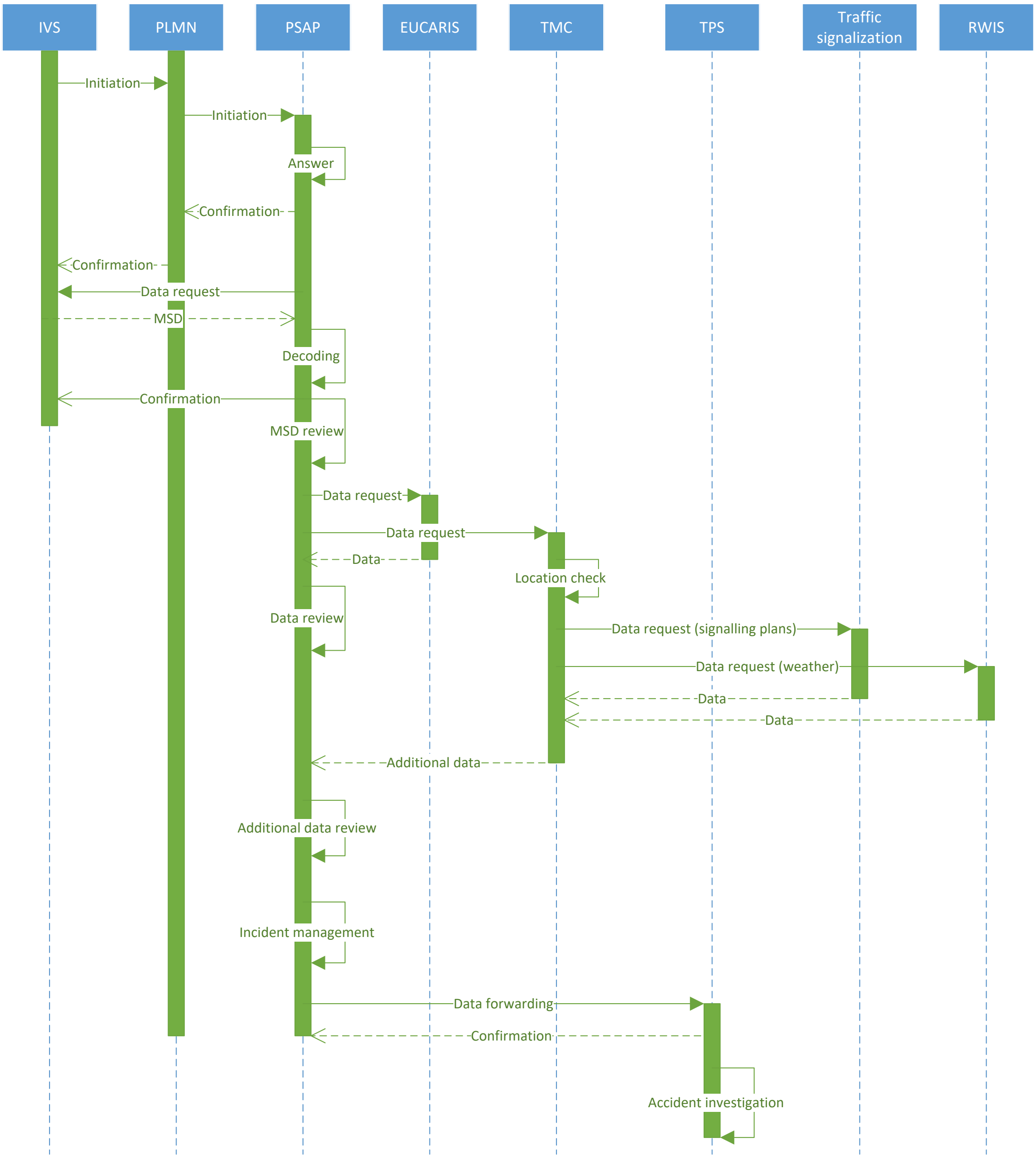

Figure 7 – Sequence diagram for one case of eCall session

5. CONCLUSION

As seen from the available results of field tests referenced in this paper, the eCall system can significantly reduce the time needed for emergency response to the location of an accident and provide essential information to the incident management personnel enabling more efficient and safe accident clearance. Most time savings originate from the reduction of time needed for accident detection and verification since the eCall system provides automatic and manual initiation of the eCall session, immediately upon the accident occurrence. Additional savings in time are achieved by MSD transmissions that provide the PSAP operators exact location of the accident; thus, enabling fast dynamic routing of emergency vehicles to/from the accident scene.

Currently, the MSD contains only basic information about the vehicles involved in the accident and their location, even though modern vehicles are collecting a much wider set of data from their onboard sensors. Thus, with this paper, we argued for introducing EMSD to include another type of data that can give an insight also on the driver behavior at the time of the accident. We believe that this new information can significantly improve the incident management and accident investigation processes.

Apart from IVS upgrades, our OOM of the new eCall system includes expansion of the PSAP functionalities as well. Namely, the connection between the PSAP and local/regional/national TMC is introduced. The communication between these two objects would enable different synergies, resulting also in improved safety (prevention of secondary incidents due to the fast and reliable trip and pre-trip travel information dissemination) and accuracy of accident investigation since traffic signaling plans could be joined with other accident related information.

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SUSTAINABILITY EVALUATION FOR THE DISTRIBUTION OF GOODS

ABSTRACT

Goods distribution in supply chains is carried out by very different logistics companies, mainly in the field of transportation and storage, whereby they cause a great burden to the environment and other fields of sustainability. Measuring of sustainable operation is made very difficult due to a wide variety of concepts of reporting and a lack of unified criteria. The model 3PL GIF, which we developed with the intention to objectively report on the success of their sustainable operation and enable a comparison between widely varying providers of various logistical services. To demonstrate the functioning of the 3PL GIF model, we carried out a research among important Slovenian logistical companies and shown the differences in their operation in sustainability fields within ecology, society and economy. Research results show that the model 3PL GIF enables the acquisition of information on sustainable operation among logistics companies in a relevant way and objective comparison between companies, enables insight into the operation of companies in sustainability fields within ecology, society and economy and provides useful information for the logistical services clients, logistical companies, organisers of supply chains, and the entire interested public.

KEY WORDS

goods distribution; measuring of sustainable success; logistics service providers; index 3PL GIF; supply chains

1. INTRODUCTION

Distribution of goods takes place through supply chains - business networks, connecting different companies from manufacturers, distributors, logistics companies, to recipients, with connections for the reception and delivery of goods, services and information. These business networks constantly change, adapt to the demands of distribution of goods, and include logistics companies with widely varying structures. As stated in (1) the supply chains are, with the intention to best meet the demands of the clients, based on efficient management of the flow of goods and services, a logistical infrastructure with material and organisational assets, information, controlling the operation, and personnel, which is required for the provision of logistical services.

Along with an economically efficient management, the sustainable aspects of performance are becoming more and more important for successful supply chains as well, as we wish to have better transportation, efficient storage, and the carrying out of all other activities in a way, which does not burden the environment and is also friendly towards other sustainable fields. Awareness of responsibility towards the environment and the reduction of resource use, as well as responsibility towards the society as a whole causes, that the provision of logistical services, too, is ever more dedicated to sustainable development, as described in the Executive Order #13423 (2): "Sustainable development creates and maintains conditions, in which people and nature coexist in an efficient harmony, so that they enable the fulfilment of social, economical and other requirements of the current and future generations." Logistics companies in business networks of goods distribution cooperate mainly with storage and transportation. These activities are a large burden in the field of ecology and other sustainable fields. Due to a stricter legislation in the environmental field, awareness of the importance of successful sustainable operation, acquisition of important competitive advantages, and ever larger sensitivity in the social area, logistics companies, too, strive towards a more transparent and sustainable operation (3). Thus, many companies now report on their means of operation, but each does it in its own way, with a selection of a wide variety of criteria and data.

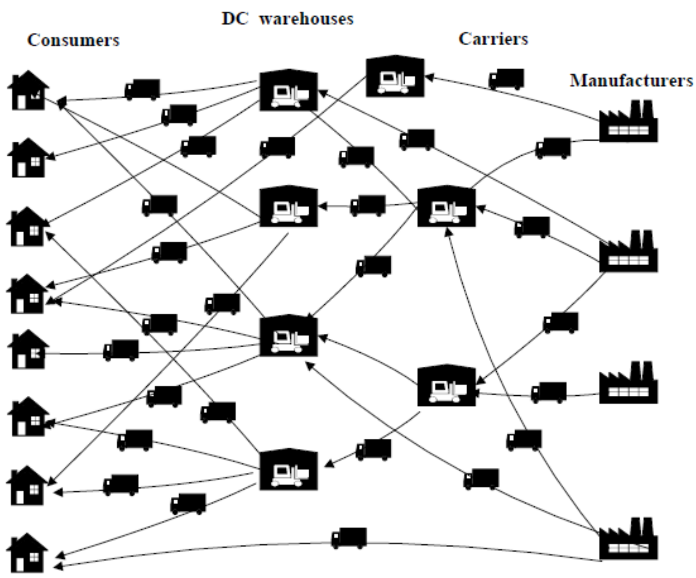


Figure 1 – Business network on goods distribution;
Source: Made by the authors

In logistics activities of transportation and storage, many different service providers may take part, differing in size, equipment, and capacity for an appropriate demonstration of their operation. At the same time, supply chains change very fast, various companies are included along with their subcontractors, whereby we often have no information regarding the sustainable operation of the latter.

In a business network of goods distribution, where the changes of participants with a wide variety of structures is constant, information on sustainable efforts of participating companies are very important, as well as the quality of performance of logistical processes. We wish to know, how companies, in their operation, burdened the environment and caused other sustainable consequences. Along with that, the interested public also wishes to know, how safe the work in transportation and storage is, how the employees are treated, are they suitably educated and paid, as we wish to choose better transportation, more efficient storage, and compare operative processes of various companies between themselves.

Even now, service providers report on the means of provision of their services, due to the awareness of the importance of sustainable operation, but every one in their own way, with unclear methodology of data acquisition from fields, chosen at will, and with a limited amount of data itself. Thus, it is very difficult or nearly impossible to acquire suitable and comparable data, based on which to figure out, how all these various companies operate in terms of sustainability.

2. THE IMPORTANCE OF MEASUREMENT OF SUSTAINABLE OPERATION

In most of the supply chains, very different logistics service providers cooperate in the field of transport and storage. If we wish to measure sustainable success of provision, we must capture all service providers, and in such a way, where they can be compared between each other. Measuring of success of a supply chain at the levels of strategy, tactics, and implementation was described by Gunasekaran (4). A suggestion for a new SCM framework based on the theory on resource dependence, costs, transactions, population ecology and resources, available to a company, has been present since 2008 by Craig (5). Sharma at al (6) states, that constant improvements in the field of supply chain management are essential due to ever larger demands for success. Sustainable management of supply chains (GSCM) requires a different approach in strategy and decisions based on knowledge and competences in the field of sustainability. GSCM is a strategy, which integrates environmental thinking in the entire SCM as argued by Srivastava (7). As an example of a measurement model, GSCM with five groups in various areas was described by Zhu (8).

As stated by Vachon & Klassen (9) due to the importance of sustainable operation, logistics, that operate according to the principles of sustainable development are ever more important, whereby the attention is directed mainly towards sustainable and green supply chain management. In Europe, there is a tendency for all companies, which cooperate as logistical service providers, to connect with clients, who are ever more sustainably oriented. The current practice is that contracts with major clients include sizeable questionnaires on sustainability demands, and the monitoring of these requirements is unresolved and as such, problematic as argued by Böhringer & Jochem (10). In the analysis of 72 different scientific articles on the environmental sustainable logistics, it was found, that the articles are not focused on the initiatives of sustainable operation between external companies, and that there is a considerable lack of research and publishing in this area (11). In the research of 3PL companies in Italy, factors were analysed, which encourage or inhibit the introduction of sustainable requirements for logistical companies (12).

3. PRESENTATION OF THE MEASURING OF SUCCESS IN SUSTAINABLE OPERATION WITH THE 3PL GIF MODEL

The green innovative framework 3PL GIF represents a logical structure, which describes and detects the complete environmental activity of logistical companies. It is based on the generally recognised *Triple Bottom Line* for economical success, improvements, and measuring of environmental success, as well as care for the social environment, on the example of the company Shell UK (13) The model 3PL GIF consists of indicators, which show success in all three areas and are united into the 3PL GIF index. We have named the model with the name of the most spread and thus demanding example, when logistical services are provided by external service providers, who only have a contractual relationship with the client. Thus 3PL GIF means Third Party Logistics Green Innovative Framework.

When selecting the indicators for the 3PL GIF, we used various existing means of sustainability measurement and selected those, who relate the most to logistical operation in supply chains.

To form the system of success measurement with constant improvements in the PDCA (Plan-Do-Check-Act) four phase, repeating, cyclic system of constant improvements according to the guidelines of Environmental management standard ISO 14031, three types of success indicators are assumed according to the system PSR (*pressure-state-reaction)* ECI, OPI ad MPI. Based on the measurements of ECI (*Environmental Condition Indicator*), we acquire data on the state of environment due to our activities, such as harmful concentrations of solid particles per m^3 in the air, or the drop of ground water levels in meters. OPI (*Operational Performance Indicator*) provide information at the operative level of the company, such as energy, used per unit of the product, average fuel consumption of the entire fleet per 100 km, use of water per unit of product. MPI (*Management Performance Indicator*) measure success of management performance, such as an increase of budget, planned for environmental management, percent of achieved environmental goals in regards to planned ones, number of environmental incidents per year. Those being indicators of management success, operative indicators and environmental condition indicators.

World Bank (14) added, along with economical and ecological, also social criteria in 1995 in the scope of PSR, "*Sustainable is to leave the future generations at least as much opportunity as we had ourselves, if not more*" and based on the environmental economy and society, added a triangular frame of the ESD (*Environmentally Sustainable Development*).

Walmart (15) created an evaluation of the sustainability of its suppliers based on a questionnaire in the fields of energy and climate, with the intention to reduce costs for energy and emissions, efficient material handling with the intention to reduce waste, and an increase in quality of natural resources with the intention to responsibly acquire raw materials, as well as a high quality in the field of people and community with the intention of a responsible and ethical production.

Alexander Nehm (16) suggested a concept of sustainabilty measurement of logistics companies with two dimensions, Concepts and Measures. In the dimension Concept, the CO emissions are measured, as well as the strategy of sustainable policy, use, certificates for environmental operation of subcontractors, and cooperation with science. In the dimension Measures, he deals with the field of car park, real estate, resource protection, carrying out of measures in social areas, transport, parking and intralogistics.

3.1 Indicators of the model 3PL GIF

The indicators help us understand what our current state is, which direction we are moving in, and how far we are from the set goal. The selection of indicators is based on rules that they have to be relevant, causally connected, they must be evaluated in an understandable and simple way. The data acquisition means for indicators must be regular, reliable, with low costs (17) , (18).

An indicator simplifies information, which may help reveal complex phenomena and are based on data of various variables, which are observed in a particular time period. Indicators must be set based on a fundamental scientific demand of fulfilment of three key steps, normalisation, weighing, and unification (10). To compare individual variables, different technologies are available, enabling unification into indicators (19). Normalisation is based on measuring the distance from the goal (20), and these indicators which we defined in our work, too, are based on this principle.

Based on an analysis of the listed resources and our own experience, we chose indicators that are the most relevant in the fields of ecology, society and economy, tied to the use of standards and measuring of implementation, and which contain PDCA principles. For every field - environment, society and economy - we thus have a select group of indicators, which, in the most general and simple way, demonstrates success of sustainable operation of the logistics company.

An indicator is a monitored value, which representatively introduces the studied phenomenon (21). In general, indicators evaluate information by uniting different data. We chose indicators which, in our opinion, best reflect the implementation of sustainable policy of a company. Mostly, the data for indicators in companies is already prepared, as it is based on acquired data which is requested in the implementation of standards. Indicators are generally measured per unit, e.g. SKU, to enable a comparison of data in regards to different scopes of operation.

The concept of 3PL GIF is designed in away where companies are, by means of indicators, warned about standards, according to which logistical activities should be carried out, measured, and cyclically constantly improved. Considering the fact that the company itself evaluates success, we connected individual indicators everywhere with the use of international standards, which are verified with external certified evaluators, and thus expect appropriate relevance of data. As stated by Hervani, Helms & Sarkis (22) the division of responsibility of companies is extremely important for the achievement of environmental success, which is, in turn, achieved in a way where all participants adopt the standard ISO 14000. If a company does not use standard quality measuring systems, this is a very important information, showing that a company does not have a suitable sustainable policy.

For normalised and comparable values, we first define the area, where we measure results. With this, we get a bottom and top limit for values, wherein we can place the current, acquired result. With a desire for constant improvement, we attempt to at least minimally improve the best previous achieved result. The target value is a value, which we set as a planned result in our operation. The current value is a value, achieved in the measurement of operation. The trend shows, how much we progressed from the previous state.

The area if the widest span between the highest and lowest value among all results, including the current value. The indicator value is calculated by formula (1).

$$\text{Indicator value} = \frac{\text{Area} - (|\text{Target value} - \text{Current value}|)}{\text{Area}} \times 100 \tag{1}$$

After such normalisation of results, the value of an indicator for an individual area is always between 0 and 100 and the result shows progress or regression in regards to the set goal. Since we always expect a certain progress in sustainable development, we do not expect that anyone would want to set the target value lower than the previous state. The area must not have a value of 0. In such a case, when a company does not plan and progress and measures none as well, the value of the indicator of progress is set to zero. Such situations are prevented during entry into the application for data entry.

Example:

The target value is the value we wish to achieve: we wish to reduce emissions by 4%.
The current value is the value we achieved: we reduced emissions by 3%.
The distance is the absolute value between target and current value and is 1%.
The area is the difference between the highest value between target or current value and distance and is 3%.
The indicator value is thus (3-1)/3*100=67

3.2 Weighting of Individual Indicators

Weighting of individual indicators represent the importance of an indicator in regards to others and, in our case, all are weighted equally, with the weight for all indicators being equal to 1. At the level of an individual area of the environment, society and economy, we can have a different number of indicators. Since every area is equally important, every indicator for such an area is also worth so much, that a maximum sum of all indicators achieves 100 points. Example - if there are 8 indicators in an area, each is worth 12.5 points; if there are 7 indicators in an area, each is worth 14.29 points. In the case of the indicator above, the indicator is, for the entire value of ecology, worth 67 * 14.29 / 100 = 9.57 points.

3.3 Index 3PL GIF

The data pyramid, showing how we arrive from data to identification of progress in the achievement of sustainable development, was presented by Zegras (23). The pyramid shows the complete information structure from data to indicators, united into an index, which shows the distance from the goal. The index is a quantitative unification of numerous indicators, which can ensure a simplified, consistent and multi-dimensional view of the system (24). Indicators from the fields of ecology, society and economy are united into the index 3PL GIF, which describes sustainable orientation of an individual company as a stakeholder in the supply chain. Indicators in an individual area are thus subject to norm and can be simply added up to get the value of the index. Index 3PL GIF is shown separately in individual chapters for the fields of ecology, society and economy.

4. INDICATOR DESCRIPTION 3PL GIF

Below, we present the description of indicators in the 3PL GIF structure for all three sustainable areas.

4.1 Ecological Success Indicators

These show what sustainable effort a company demonstrates in the field of ecology.

Indicator of environmental standard use.

The indicators of environmental standard show, whether a company uses standards, which ensure that the set environment policy is being carried out. Success of environmental standard use in logistical activities, such as ISO 14000 and similar, shows how dedicated a company is to planning, implementation and measuring in the environmental area. At the same time it uses an already built in system, the PDCA, which enables constant progress and reporting on environmental operation in logistical services.

Indicators of pollution measurements

Reduction of emissions during logistical activities;

Reduction of pollution and use of water;

Reduction of energy use;

Reduction of solid waste in logistics.

These indicators show the care of a company in measuring environment pollution of its activities. We measure pollution with solid waste, air pollution and water pollution which, in many places, is also prescribed by law. We also record efficiency in energy use reduction.

The recycling indicators

Shows the care of a company for waste substances, where we measure, what the increase of recycling scope in logistical activities is.

Ecological incident indicator

Shows that a company is aware of the problematic of ecological incidents, that it records the state of ecological incidents, and that it wishes to reduce them through measures.

4.2 Social Success Indicators

These indicators are directed towards personnel that carries out logistical services. Especially in storage and transportation, people are the key factor for successful carrying out of logistical processes.

Indicators of social security

Warn about the improvement of social security of employees, sustainability of employment, pay increase, employee benefits, achievement or exceeding of ILO standards.

Work safety indicators

Show the improvement of security in logistics with the carrying out of security politics of a company, measurements and constant improvements. Work safety begins with prevention.

The preventive measure increase indicator

Shows the carrying out of various preventive measures in the field of safety in logistics and evaluates the efficiency of such measures.

Reduction of accidents in the use of work assets

Is an indicator we use to measure success in the reduction of accidents in logistical activities.

Education indicator

Warns about the increase of education per employee, as, especially due to quickly changing technology and introduction of information technology, education of employees is a condition for successful work.

Improvement of quality of the environment in which employees work

Is an indicator, showing how a company carries out the policy of work environment improvement, so that the employees are not exposed to harmful influences, have appropriate ergonomics in the work place, care for the establishment of successful work teams and similar.

Indicators of work condition improvements

Shows the care of company for its employees with appropriate work schedules, ensuring that the employees do not have excessive workload, have time for food and rest, and similar.

4.3 Economical Success Indicators

We chose two groups of indicators, which are tied to operation in the logistics field. In the first group are indicators of general economical success. Indicators showing general economical success of a company ensure, that a company operates successfully and provides necessary assets for operation in the field of logistics.

Indicator of market share increase in the logistics segment

Shows how a company is successful in conquering the logistics market, or increase in the scope of its operation.

Indicator of net income increase in the logistics segment

Shows economical success in the logistics field.

Indicator of business activity policies

This indicator shows the credibility of a company and commitment to fair business. We adopt it from a very influential Dow Jones sustainability index, also marking it as an important economic risk, as stated by I. Knoepfel (25). We thus measure incidents, which could e.g. mean bribery or other improper or even criminal forms of business and thus represent a serious economic risk. Indicator shows the existence of a code of conduct at the company and measures the implementation of this code in operation.

Indicator, which shows the increase of assets for ensuring green production in the logistics field

Shows how many assets are intended for investments into sustainable improvement. Only through investments can we achieve desired goals in sustainable development, e.g. reduction of energy use can be achieved with investments into more economical users, change of fuels, investments into alternative sources.

In the second group are indicators of economical success in provision of logistical services

Indicator of cost reduction due to use of lean logistics

Lean logistics has the same goals as lean production - improvement of quality, productivity and efficiency of logistical process execution with active cooperation of all employees. We thus set an indicator, which shows, whether a company uses lean logistics principles and if they record a reduction of costs due to its implementation.

Reduction of costs per an SKU unit

Generally recognised indicator for economically efficient logistics processes measures costs per individual transport unit SKU (Stock Keeping Unit).

Indicator for the improvement of economical efficiency of transportation

Shows what kind of economical effects have been achieved in the improvements of internal or external transport per kilometre driven.

Reduction of waste water, energy, waste costs

With successful development, effects must also be visible in cost reduction for energy, waste water, waste, which is recorded with the appropriate indicator.

5. RESEARCH RESULTS AND DISCUSSION

We conducted a research in logistical companies, using interview and questionnaire methods. The research took place in the first half of 2016 and relates to data from 2015. We chose companies which designate their primary activity as transportation, distribution centre 3PL, and distribution trade centre. With a questionnaire, we evaluated the indicators 3PL GIF in individual companies. These are major Slovenian companies, dealing with logistics of goods distribution and covering land, air and sea transport. We studied 6 companies which, for business confidentiality, we renamed to companies A, B, C, D, E, F.

In the first part of the questionnaire, we acquired data on the company and person, responsible for filling out the questionnaire, their position in the company and the relationship to company management, field of work, number of employees and similar. For every indicator, it is first necessary to find out whether they measure it and have data, so that we have an explicit answer and not simply an empty field. In such a way, we checked that the data was credible and that we can trust it. Since the majority of indicators relates to the use of various standards or their significant elements, the evaluations which we got could be verified through reviews of various standard implementation.

All results of indicators are first set to norm within the scope of areas, as shown in the equation for the acquisition of the indicator value. Later, their value is adjusted in regards to the number of indicators in each individual company - the larger the number of indicators, the smaller, proportionally, is the value of an individual indicators. When we unite indicators into the index, their sum is always between 0 and 100.

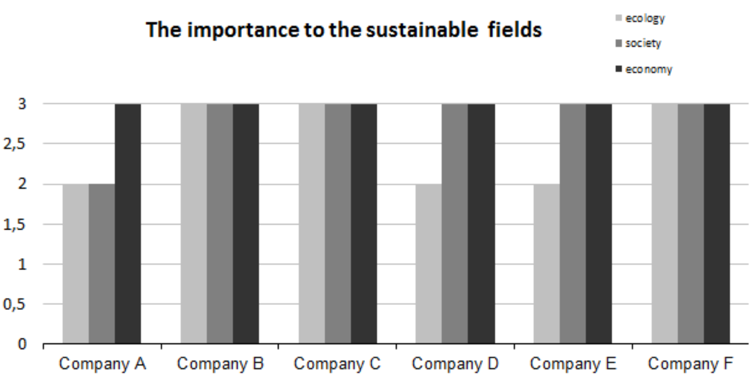
5.1 Importance of Achieving Economic Results at the Company

Through the Questionnaire, we test how companies themselves evaluate importance of sustainable areas. For a high grade of importance, we expect that the company also demonstrates success in sustainable operation. The importance of an individual pillar was assigned values: 1 = less important, 2 = important, 3 = very important; if there are no answers, the value is 0. In all studied companies, they are aware of the importance of all three pillars - economy, society and ecology. The importance of ecological pillar is the smallest, but does not deviate much from the other two pillars.

Table 1 – Ranks of importance for fields of ecology, economy and society, measured in individual companies.

Designation	Company in supply chain	Company outside logistical services	Importance of sustainable fields (0 to 3; 0 = no answer; 1=least; 3 = most)		
			economy	society	ecology
A	X		3	2	2
B	X		3	3	3
C		X	3	3	3
D	X		3	3	2
E		X	3	3	2
F		X	3	3	3

All companies are aware that it is necessary to measure and follow operation in all three fields of sustainability, so the average value of economy is the highest possible, 3, society is a bit lower at 2.8, and ecology at 2.5. The importance of sustainable operation is extremely high



for all companies considering their way of operation.

Figure 2 – Evaluation of importance for fields of ecology, economy and society as seen by individual company. Source: Made by the authors

All companies assign the highest importance to the economical field, only one company for a grade less in the social field, and two companies for a grade less in the ecological field. Thus, all companies are strongly aware of the importance of sustainable operation, which is above the expectations we had before the research.

5.2 Indicators 3PL GIF in the Field of Ecology

Figure 3 and Table 2 show indicators in the environmental field and their values by individual companies. Most companies use environmental standards and measure emission reduction. We see that the conditions are the worst in the ecological incident indicator and solid waste reduction, where improvements are needed.

The success of all companies is very high in the use of environmental standards ISO14000, which is very encouraging, whereby two companies do not measure and report on environmental operations. Most companies strive to reduce emissions, pollution and use of water, reduce energy use and extend the scope of recycling. Reduction of solid waste is worse, but the surprise is the attitude towards environmental incidents, which is not considered in most companies.

Table 2 – Values of indicators in the environmental area by individual company

Environmental indicator / Company	Company A	Company B	Company C	Company D	Company E	Company F
Success of environmental standard use	12,50	8,33	11,25	12,50	12,50	12,50
Measuring and reporting on environmental operations	12,50	NA	11,25	NA	12,50	12,50
Reduction of emissions	12,50	8,33	9,38	12,50	6,25	12,50
Reduction of water pollution and use	0,00	NA	9,38	12,50	12,5	12,50
Reduction of energy use	6,25	8,33	10,00	12,50	NA	6,25
Reduction of solid waste	2,50	NA	9,38	NA	12,5	2,50
Reduction of the scope of recycling	8,33	NA	11,25	12,50	12,5	8,33
Reduction of ecological incident	0,00	NA	12,38	NA	NA	NA

Source: Made by the authors

The companies A, B and D are transport companies. The company A is successful in the ecological area with most indicators, but does not follow pollution and use of water, nor ecological incidents. The company B assigns importance to only three environmental indicators, those being emission reduction, success of environmental standard use in logistical activities, and reduction of energy use. The company D achieves better results especially in terms of recycling and water use.

The companies, which provide external logistical services are C, E and F. The company C is an expressed external service provider and has very high results in the environmental area, with the exception of solid waste reduction and not processing ecological incidents. The company E also has high results in environmental indicators, a slightly lower result is detected in emission reduction, and they do not pay attention to the reduction of energy use and ecological incidents. The company F shows the highest success in the achieving of environmental goals in comparison with other companies, but still pays no attention to the ecological incidents. The diagram (Figure 3) shows indicators by company - where indicator value is not shown, they do not measure it.

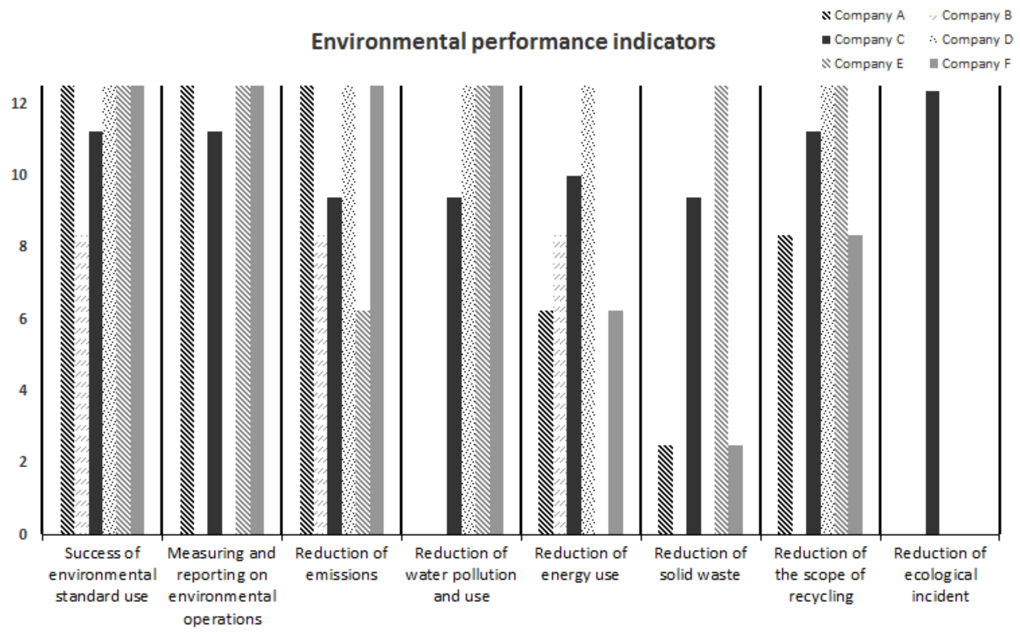


Figure 3 – Environmental indicators by individual company
Source: Made by the authors

5.3 Indicators 3PL GIF in the Field of Society

Results show, that most companies do not measure all indicator. Where they do measure indicators, they are successful enough and show dedication of companies to improve the field of society. Results of indicator values in the field of society are shown in Table 3 and on Figure 4. These are indicators of social security, work safety, education and work conditions. It is surprising that some companies do not pay attention to the improvement of work conditions and environment in which the employees work.

Table 3 – Values of indicators in the social area by individual company

Social Indicator / Company	Company A	Company B	Company C	Company D	Company E	Company F
Improvement of employee social security	NA	11,43	7,14	14,29	NA	14,29
Improvement of logistical production safety	7,14	NA	11,43	14,29	7,14	14,29
Increase of preventive measures	NA	NA	10,00	11,69	7,14	14,29
Reduction of accidents in work asset use	14,29	NA	14,29	11,43	7,14	14,29
Increase of education per employee	4,76	10,71	10,71	NA	NA	14,29
Improvement of work conditions	NA	NA	10,71	14,29	NA	NA
Improvement of work environment quality	8,57	14,29	11,43	NA	NA	NA

Source: Made by the authors

Company A is not the most successful in social indicators, as it does not pay sufficient attention to the increase of preventive measures, improvement of social security and improvement of work conditions or does not follow these indicators. Company B only measures social security, education and environment quality areas. Company C measures all indicators. Company D has very high indicators, but does not measure progress in education and improvement of work environment quality. Company E measures only indicators of work safety, while company F shows very high indicator values, but does not measure work conditions and work environment quality. In the following diagram (Figure 4), we show indicators by individual companies; where no values are shown, the indicator is not measured.

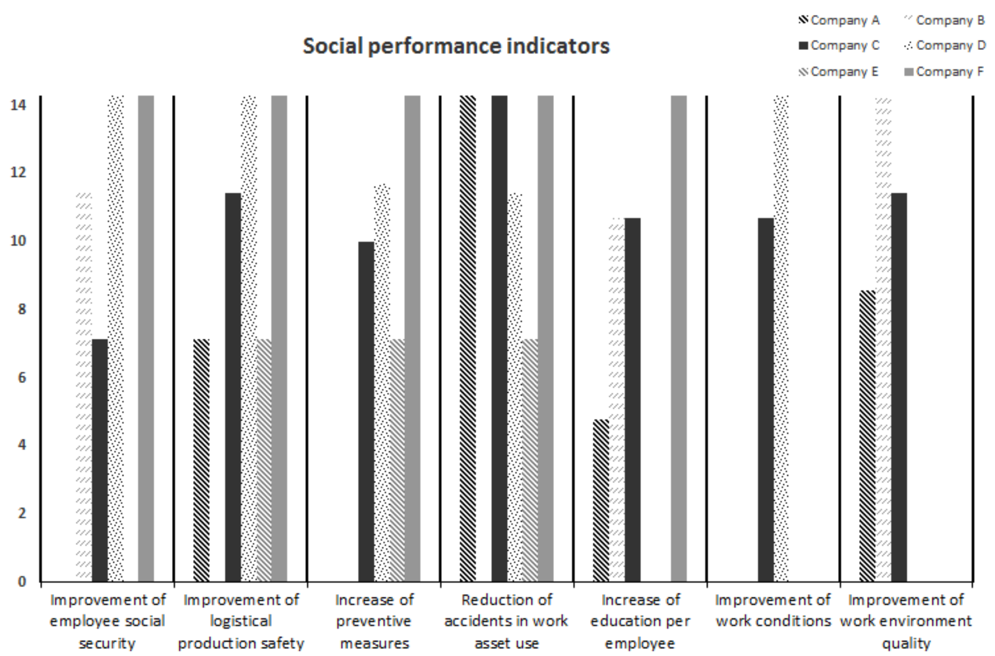


Figure 4 – Social indicators by individual company
Source: Made by the authors

5.4 Indicators 3PL GIF in the Field of Economy

In the field of economy, the selected companies are successful in terms of indicators, but there are many areas, where indicators are not measured. No company measures the business behaviour according to code or ethical business which is, among others, recommended by Dow Jones (25).

General economic success contains market share increase, net income, and assets for green operation, as well as success of logistics operations: reduction of costs due to lean logistics, reduction of costs per SKU unit and reduction of costs for energy, waste, and following of actions according to code of conduct (Table 4 and Figure 5).

Table 4 – Values of indicators in the economic area by individual company

Economic indicator / Company	Company A	Company B	Company C	Company D	Company E	Company F
Market share increase	NA	9,38	11,43	12,50	0,00	NA
Income increase	NA	8,33	14,29	12,50	14,29	11,46
Cost decrease due to lean logistics	6,25	NA	14,29	NA	NA	12,50
Cost reduction per SKU unit	6,25	NA	NA	NA	NA	12,50
Improvement of transportation economic efficiency	1,25	6,25	10,00	12,50	NA	12,50
Operation by code of conduct	NA	NA	NA	NA	NA	NA
Reduction of energy, waste water, waste expenses	NA	NA	7,14	NA	NA	12,50
Economic effort to ensure green production	NA	9,38	10,71	8,33	NA	12,50

Source: Made by the authors

In these indicators, along with general economic success of the company, we also emphasized economical success of sustainable and lean operations and measured increase of investment into green logistics, as well as behaviour in business. Data shows that some companies, at least in the logistical area, do not measure direct economical success, mainly from the group of those connected in constant supply chains, in spite of it being very important for them. They also do not measure the market share or increase of income in this segment. Companies measure economical efficiency per logistical unit and savings due to lean operations poorly as well. Most measure and improve economical efficiency in transportation.

No company measures incidents due to disputable or incorrect actions, which are against the code of conduct, nor do they measure or plan means for their reduction. Most companies have no set goals to reduce energy, waste water, and waste costs. We did notice, however, that investments into sustainable operation are increasing and planned goals are being reached. On the next diagram (Figure 5) we show indicators by individual companies. Where no value is shown, the indicator is not measured.

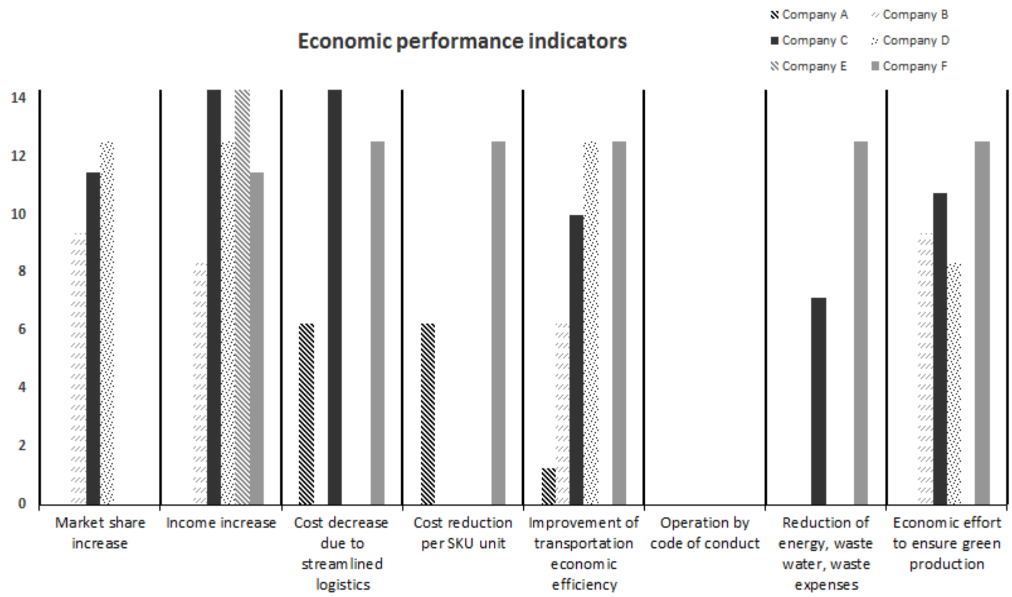


Figure 5 – Economic indicators by individual company
Source: Made by the authors

5.5 3PL GIF Index

The 3PL GIF index unites indicators at the level of the company for each of the fields of ecology, society and economy individually. The common index represents an efficient presentation of the operation of companies and enables an easier comparison between them. The 3PL GIF Index is designed based on three values - one for each individual sustainable area. The Index is determined by simply adding up all indicator values on a particular field. For the company A, the value gained for the field of economy is thus 0 + 0 + 6,25 + 6,25 + 1,25 + 0 + 0 + 0= 13,75

The common comparison diagram (Figure 6) shows a comparison between companies and their success in the ecological, social and economic fields. The index clearly shows differences between researched companies and warns of areas, where changes are required.

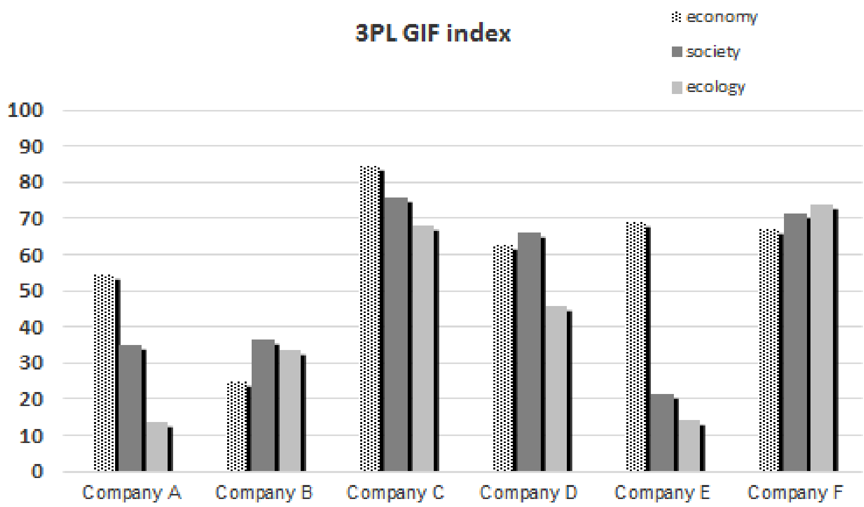


Figure 6 – 3PL GIF Index, showing diversity of companies in economic, social and ecologic areas.
Source: Made by the authors

The companies reported on the declarative importance of sustainable areas (Figure 2). However, a large difference is noticeable between declarative and actual operation, which we show in the index 3PL GIF at the studied companies. The companies are declaratively clear about the importance of environmental activities, with as many as 14 out of 18 grades being maximal. When this is compared to the results of 3PL GIF index, quite a few companies show significant deviations, which warn, that these companies should direct additional efforts into sustainable development.

6. PRACTICAL USE OF THE MODEL

The model 3PL GIF allows every company and the entire supply chain to acquire information on the success of carrying out logistical services and their progress in the most important sustainable elements. The complete structure of the model is used to improve all logistical activities according to the principles of cyclical improvements, lean logistics and constant progress in the field of sustainability. The model 3PL GIF shows success of operation of very different logistical companies, from global giants to small local family companies, which have the same goal - to be successful in their operation. The model represents a tool with which companies can improve success of operation and their reporting in the operative area. The model takes the growing trend of transparency and visibility in the operation of logistical companies into consideration and is an appropriate tool for quick comparison between companies. In the competitive environment of today, the possibility of demonstration of data in 3PL GIF can also represent a significant advantage for logistical companies and entire supply chains.

Data, published in the 3PL GIF structure, is interesting for various groups of stakeholders, who participate in supply chains and thus managers of individual 3PL logistical companies, who wish to achieve a more successful operation, clients, who seek logistic services from external providers, managers of supply chains, who can choose better service providers in the field of sustainability, and end consumers of the goods, who can check, what companies a particular product travelled with through the supply chain and how the suppliers burdened the environment with logistical services.

7. CONCLUSION

The research has shown that the studied companies demonstrate considerable care in the area of environmental, social and economical policies, but some show more on the declarative level than in the implementation itself. With this model, we gained a tool that can be used to compare providers of logistical services in a fairly simple way in regards to success in the field of sustainability. The model can be used by all companies, connected into supply chains of goods distribution so, that the complete result of all companies shows common effort of the whole supply chain. In this way, different supply chains can compare themselves to each other. Even though companies alone evaluate themselves, the selection of indicators allows verification of many evaluations, as they are tied to international standards of the quality of operation.

The model allows companies to improve their operation and constantly measure and compare their operation with the competition. The model also helps in managing supply chains for the identification of the weakest links in fields, which aren't at an appropriate level. 3PL GIF allows the informing of the whole public, from manufacturers, clients, service providers, to consumers, about what way and how sustainably the logistical services were carried out in. We predict that this model will aid in easier selection of logistics service providers, transparent notifications on the logistical operations and more sustainable provision of logistical services.

The model, through research of companies, has shown immediate use for comparable evaluation of sustainable operations with data, which already exists, which was not possible until now. In the study, we, among other things, identified for each individual area, that there are companies without records and goals on the reduction of ecological incidents, some don't improve work conditions and work environment of the employees, and do not comply with a code of conduct in their business. On the other side, we are surprised by the high level of commitment to more sustainable operation and also their success in individual fields.

With the 3PL GIF index, we can reach quick conclusions about the way of current logistical service provision in a particular supply chain and see their shortcomings. There is a considerable possibility, that unsuccessful companies will not wish to provide data, but even such information tells, that the service provider does not care for sustainable development. Service providers, who are part of supply chains, will, in the future, vary more and more also by the quality of sustainable operations, as it will influence how desired they are for cooperation with other shareholders. 3PL GIF is an appropriate and interesting solution in the long-term for measuring of environmental success in transportation, storage, and the whole distribution of goods and services, as the service providers are well aware of the importance of sustainable operation.

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AN EVALUATION OF BOSPHORUS STRAIT MARITIME TRAFFIC, MARITIME ACCIDENTS AND EXPECTED EFFECTS OF CANAL ISTANBUL

ABSTRACT

Maintaining safe transport of vessels through canals is quite challenging with its extreme structure. Bosphorus is a naturally formed strait which divides European and Asian sides of İstanbul. Being a unique strait with every aspect from scenery to transportation of maritime vehicles, Bosphorus hosts 42,553 vessels in a year. In this article, maritime accidents present within the Bosphorus Strait for 2016 are given along with the information of example Canals throughout the World. Additionally, planned Canal İstanbul project explained briefly. Analyses regarding the feedbacks are made, in the presence of a newly introduced route alternative from Black Sea to Marmara or vice a versa. With the newly built canal, maritime accidents in Bosphorus Strait are expected to be decreased. On the other hand there will inevitably be interference to environment. In general current standards for Bosphorus Strait along with Montreux Convention are explained to have a perspective from law point of view. Intention of this study is to specify current situation of Bosphorus Strait maritime transport related accidents and state expected effects of Canal İstanbul. For this purpose, statistical data of Bosphorus Strait maritime traffic, maritime accidents are analyzed and a literature review for Canal İstanbul project is conducted.

KEY WORDS

Bosphorus Strait; Maritime Accidents; Canal İstanbul

1. INTRODUCTION

Bosphorus Strait is a unique waterway providing not only bridge between Europe and Asia continents but also hosting sea transport on international basis. As an active waterway Bosphorus is under threat of some major accidents. Although current maritime traffic management system within Bosphorus Strait is sufficient for safely travel of vessels. Unexpected accidents can cause severe damages. Turkey's new project Canal İstanbul can be an alternative route for safe travel of vessels. On the other hand Montreux Convention signed in 1936 is expected to be a restriction. In this article, Bosphorus Strait traffic, maritime accidents and Canal İstanbul is analyzed and relevant offers are made accordingly.

2. REGULATIONS AND AGREEMENTS FOR BOSPHORUS STRAIT

Bosphorus Strait is located between Marmara and Black Sea. Black Sea is connected to Aegean Sea and Mediterranean Sea by Bosphorus Strait and Dardanelles Strait respectively. Marmara Sea is an inland sea having two different water masses. This is as a result of water from Black Sea with low salinity concentration and low flow density on surface of Marmara Sea. Additionally, water has a high salinity concentration and density from Mediterranean Sea passing through Dardanelles Strait constitutes the bottom layer. For this particular reason, Marmara Sea has a sensitive and unique ecosystem which is as a result of thousands years of loop. [18]

When adopting a new system for regulation of traffic or constructing a new infrastructure project, policy makers, engineers and politicians should make no concessions from ecological values while developing socio-economic aspects. This case is also valid for İstanbul. İstanbul is not only an economic center and have strategic location with its geopolitical characteristic, but also it is unique with ecological balance; flora and fauna. Located between European and Anatolian Side of İstanbul, Bosphorus Strait connects continents and provides a passage way for vessels from countries all over the world as well as neighboring countries.

For transport of vessels from Bosphorus and Turkish Straits a Convention is law in force. Free transit passages of trade and military vessels from Turkish Straits are regulated under the frame of conditions within Montreux Convention since the year 1936. The agreement provides free transit passage for trade vessels day and night. The only fee taken from vessels is light house charges, lifeboat services and health control document fee. This freedom of passage through Turkish Straits is turn into harmless pass, paying extra attention to environment, health and life safety aspects in today's agreement. Turkish Straits are the system consisting of Bosphorus, Dardanelles and Marmara Sea.

In Montreux Convention, the section related with war ships state that, both trade and war ships have three class of passing time. Those are; during peace time, war time and when there is a nearby war threat. There are important limitations present for foreign flagged ships passing Turkish Straits and appearing in Black Sea. War ships have to inform Turkey before passing and there is also tonnage limitation. Additionally, antiaircraft ships are not allowed to pass through Turkish Straits. There is an obligation for submarines to pass at day time and on water. Only Black Sea coastal state countries have the majority right for transportation of submarines. War ships of Black Sea non-coastal state countries, have limitation to stay on Black Sea and total tonnage that cannot exceed 45,000 ton.

Ships of all Black Sea coastal state countries have right to benefit harmless transit in their territorial waters. Government has the right to prevent non-harmful transit. At the end of each five-year period from the date on which the Montreux Convention is signed, each of the High Contracting Parties may attempt to propose amendments to revise clauses of the Convention but Turkish Straits cannot be closed to international navigation. The Montreux Convention is crucial to the security of the Black Sea and the peaceful settlement of the region.

In addition to all this, the Straits Regulation was prepared in 1994 to regulate the maritime traffic. The Regulation covering all ships to be cruised to the Turkish Straits was enacted on 01.07.1994 and some changes were made in 1998. Then it is reintroduced as the Turkish Straits Maritime Traffic Regulation. [1]

2.1 Control System

Maritime traffic is controlled by Department of Vessel Traffic Services for Turkish Straits (TSVTS) that established in the year 2003. Inside this department there are Vessel Traffic Centers in İstinye-İstanbul and Akbaş-Çanakkale. There are also 16 unmanned traffic observation stations which includes radar system, Closed Circuit TV (CCTV) and infrared cameras. TSVTS is equipped with latest technological requirements. Services given in TSVTS are; Information, Navigational Aid and Traffic Organization Services.

Under Information Services; Maritime traffic information, location information of vessels according to other vessels, location, route and speed information of vessels to vessel which is informed, possible movement of other vessels, warning to sailors, Hydro-Meteorological information upon request and reported information about navigation aid conditions upon request are given.

Navigation Aid Service is given in cases when there is severe navigation and meteorological conditions, in case of malfunction or deficiency, upon request of master mariner or when Maritime Traffic Services (MTS) operator finds it necessary. MTS operator provides position information transfer to vessels for safely navigation, information about vessels around and warnings about dangerous conditions.

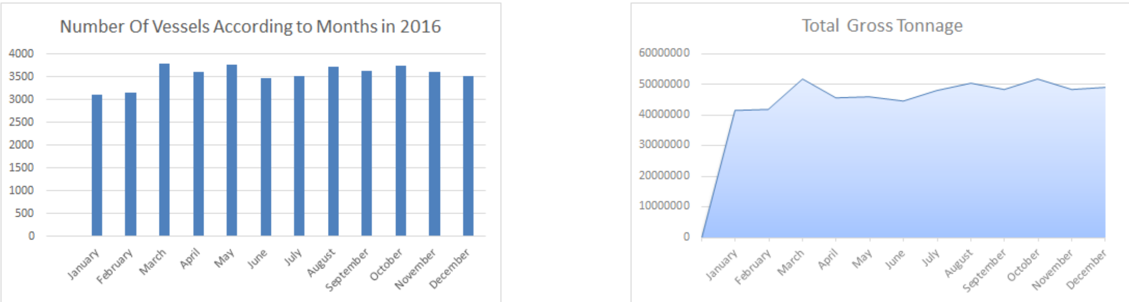
Traffic Organization Services includes; vessel navigation plan, Enterance Clerance for İstanbul and Dardanelles Straits with date and time, possible varitions on navigational plans of vessels, providing required operational information to vessels about Traffic Management Plan before entering Straits, operational information about Maritime Traffic Regulation Act for all vessels on Straits, timing information for docking, mooring, guidance of vessels in constituted MTS area, reports prepared by MTS.

Guidance services is given to provide safe operational services. Maintaining vessels to navigate according to national and international regulations, aiming to protect life, goods and surroundings during entering and exiting harbor, dock in and unberth action, buoy mooring, mooring and leaving or displacement for any reason. [5]

2.2 Vessel Traffic on Bosphorus Strait

Bosphorus is an actively used waterway stemming from its geographical location. Everyday approximately 117 vessels pass. [2] Additionally small maritime vehicles such as; boats, yacht and sailing boats also travel along and through the Bosphorus Strait.

In this section traffic data on Bosphorus Strait is presented for 2016. Total number of vessels passing Bosphorus Strait is; 42,553 and total gross tonnage is; 565,282,287 for 2016. (*Figure 1 a,b*)



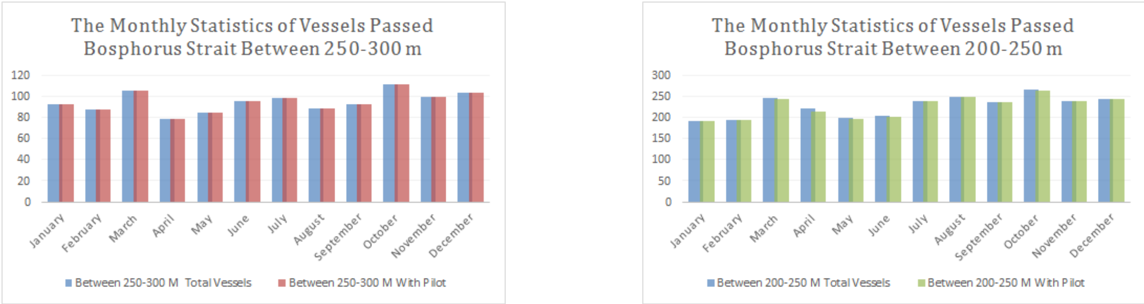
(a) *(b)*

Figure 1 a, b. – Number of vessels passing according to month (a) and total gross tonnage (b)
Source: Made by the author according to data obtained from [2]

53% of the vessels took maritime pilot service with a number of 22,356. There are 14% of Other Tankers; TTA, 2% of Liquefied Petroleum Gas/Natural Gas Tanker; LPG/LNG and 4% of Chemical Tanker; TCH transporting through Bosphorus Strait in 2016.

According to data obtained from General Directorate of Maritime GDMT. There are also statistical data for vessels categorized according to their length. There are no vessels present longer than 300 m in the Bosphorus Strait in 2016.

Total number of vessels between lengths 250-300 m is 1,143 and 100% of them taking maritime pilot service. For Vessels between 200 – 250 m length total numbers is 2,730 and 99% of them taking maritime pilot service. (*Figure 2 a,b*)

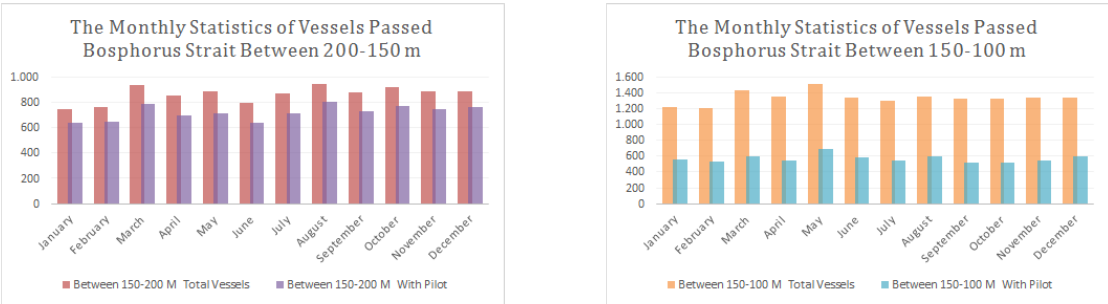


(a) *(b)*

Figure 2 a, b. – Number of vessels passing according to their length; 250-300 meters (a) and 200-250 meters (b) respectively

Source: Made by the author according to data obtained from [2]

Total number of vessels between length 200-150 m is 10,363 and 8,659 of them taking maritime pilot service. Where total number of vessels between length 150-100 m is 16,077 and 42% of them taking maritime pilot service. And finally total number of vessels shorter than 100 m is 12,240 and 25% of them taking maritime pilot service. (*Figure 3 a,b*)



(a) *(b)*

Figure 3 a, b. – Number of vessels passing according to their length; 200-150 meters (a) and 150-100 meters (b) respectively

Source: Made by the author according to data obtained from [2]

Statistics of Vessels Passed Bosphorus Strait according to their ship type for 2016 are presented with a graph below. (*Figure 4*)

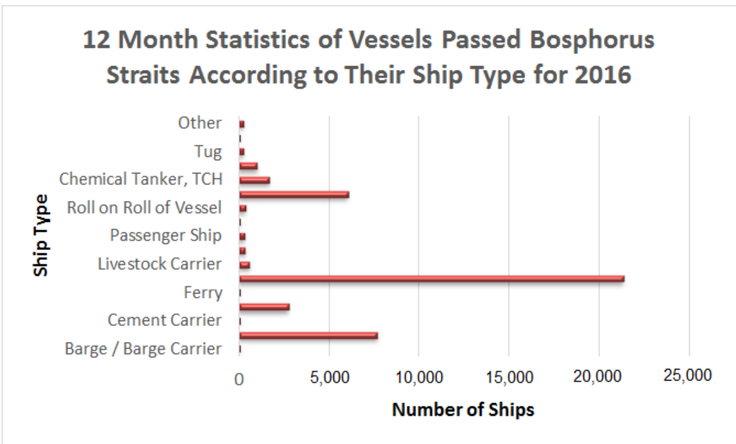


Figure 4 – Vessels passed from Bosphorus Strait according to ship type

Source: Made by the author according to data obtained from [2]

According to statistics, out of total 42,553 vessels, highest number of vessels passing belongs to General Cargo Ships (21,344), secondly; Bulk Carrier (7,664) and thirdly; Other Tankers TTA (6,033). [2]

2.3 Accidents on Bosphorus Strait

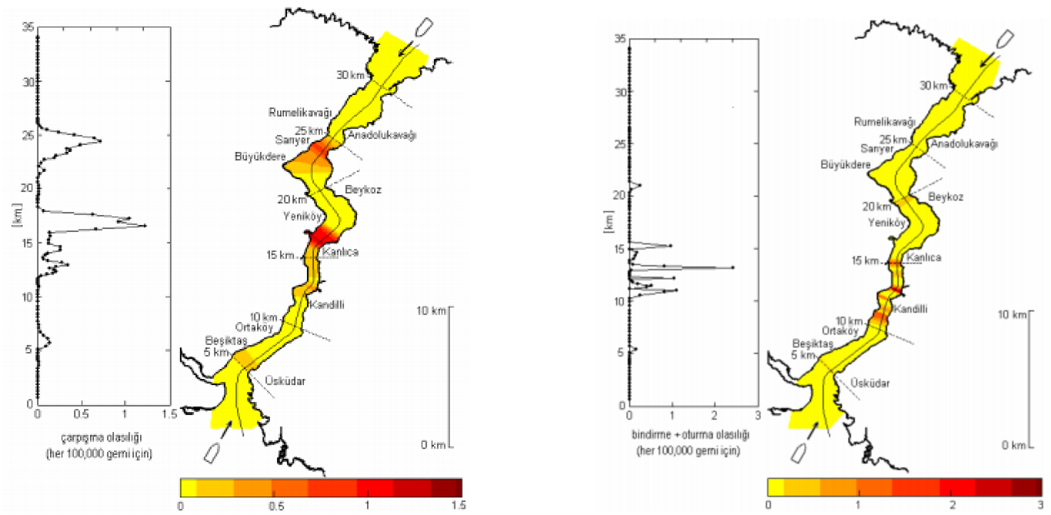
On Bosphorus Strait there are more than 200 maritime accidents present in 2016 according to records. These accidents happened as; collision, grounding and fire. According to Oğuzülgen (1995) the cause of these accidents are explained as:

- Lack of maritime pilotage
- Natural structure of the Bosphorus Strait
- Surface flows
- Limited visibility distance
- Local conditions
- Mechanical breakdown and technical incompetence [11]

In different locations and conditions narrow waterways are affected with a different degree. In other words, exact location and time of the accident cannot be determined by a deterministic approach.

Beside this, studies show that smaller sized vessels more frequently make accidents. Another point is, vessels travelling southern direction cause more accidents compared to vessels travelling to northern direction. This is as a result of flows disabling steering wheel control. [12]

In Otay and Özkan study [12], collision risk maps for Bosphorus Strait are formed. It is reflected in these collision maps the probabilities for each 100,000 transit passing vessel. When the results are compared according to accident type, frequency of collision accidents is higher than grounding and wrecking accidents. (Figure 5 a,b)



(a) Risk map for collision (b) Risk map for grounding and wrecking

Figure 5a, b. – Bosphorus strait risk map for collision and grounding & wrecking respectively.
Source: [12]

Additionally, highest risk-bearing regions for collision are: Sarıyer, Emirgan-Kanlıca, R.Hisarı-Kandilli. Whereas highest risk-bearing regions for grounding and wrecking are: Emirgan, K.Bebek, and Kuruçeşme. [12]

Narrow canals are also listed as one of the factors increasing the possibility of a maritime accident. Through Bosphorus Strait the narrowest location is between Aşiyan and Kandilli which has a width of 698 meters. At this location maximum maritime accidents took place. [1]

Back to recent history there are two massive maritime accidents took place in Bosphorus Strait. An oil tanker and a cargo ship collided killing 29 sailors in 1994. The Bosphorus Strait is closed for days. Second maritime accident is a split of a Russian-built tanker into two, spilling 235,000 gallons of fuel. The tanker split into two at the mouth of the Bosphorus Strait and blacken miles of shoreline. [16]

From the statistical information regarding maritime accidents. Bosphorus Strait Marmara Sea accident statistics are classified as "Marmara Sea and Straits" comprising Bosphorus Strait, Dardanelles Strait and Marmara Sea. For this particular reason, Figure 6 represents accident statistics data of Marmara Sea, Dardanelles and Bosphorus Strait.

According to data in 2016 (*Figure 6*), accidents present in this region is 123. Out of 123 accidents, 14 of them resulted in life loss and 836 people were rescued. Accidents resulting in material damage include grounding, collision, capsizing, sinking and fire. As well as non-damaged; man overboard and machine failure, steering wheel failure and burnout accidents.

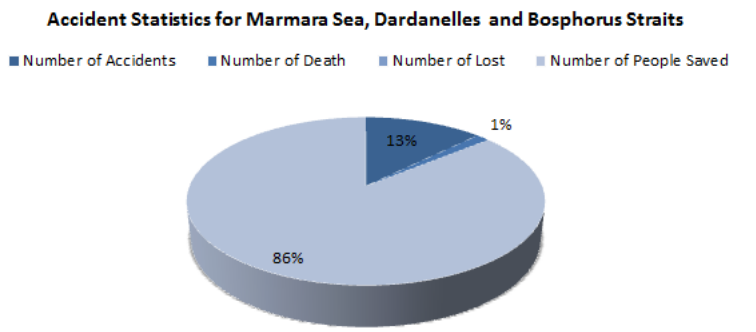


Figure 6 – Accident Statistics for Marmara Sea, Dardanelles and Bosphorus Strait (2016)
Source: Made by the author according to [3]

In addition to all of this, unless the accidents reported to Ministry of Transport, Maritime and Communications, presence of material damage, damage ratio and amount of damage cannot be recorded and remain as unknown. As a result, we can state that this statistical data only covers major and reported accidents. Unreported, minor accidents are neglected and not reflected to the maritime accident statistics.

3. CANALS & STRAITS

3.1 Canals & Straits Located Within Marmara Region & World

Bosphorus Strait and Dardanelles Strait are currently providing passage from Black Sea to Marmara and Marmara to Aegean and Mediterranean Sea in Marmara Region. Both of them are naturally formed Straits

These Straits have strategically important place. Primary reason is vessels transporting trade materials from countries within the region (Bulgaria, Romania, Georgia, Ukraine and Southern Russia). Table 2 gives brief information about Bosphorus Strait, Dardanelles Strait and Canal İstanbul (which is currently under project phase.)

Each Strait or Canal aim to minimize distance, fuel and time spent on transporting while maximizing safety and comfort.

Canal İstanbul which will be an artificial canal is a new alternative to provide accessibility from Black Sea to Marmara Sea and finally Aegean to Mediterranean Sea.

Panama Canal; Kiel Canal are as well artificial canals which are shortcut waterways preventing vessels to travel around Denmark and Suez Canal is an artificial canal that is a shortcut waterway vessels to travel around Africa continent. Alternatively, it connects Mediterranean and the Red Sea. Fuel transportation is made from the North of the Canal to Mediterranean and from South of the Canal to the Red Sea.

In this section, brief information about Bosphorus, Dardanelles Strait, planned Canal İstanbul project from Turkey, Panama, Suez and Kiel Canal throughout the world is given. (*Table 2*)

Table 2 – Straits and Canal in Marmara Region

STRAITS & CANALS	**Bosphorus Strait**	**Dardanelles Strait**	**Canal İstanbul**	**Panama Canal**	**Suez Canal**	**Kiel Canal**
Country	Turkey	Turkey	Turkey	Panama	Egypt	Germany
Junction	Black Sea and Marmara Sea	Marmara Sea and Aegean Sea	Black Sea and through Marmara Sea to Aegean and Mediterranean Seas	Atlantic Ocean and Pacific Ocean	Mediterranean Sea and Red Sea	North Sea and Baltic Sea
Length	31 Kilometers	61 Kilometers	45-50 Kilometers	77 Kilometers	193.30 Kilometers	98.7 Kilometers
Depth	13-110 Meters	103 Meters	25 Meters	26 Meters	23-24 Meters	11 Meters
Width	700 - 3420 Meters	1.2 - 7 Kilometers	125 – 200 Meters	33.5 Meters	205-225 Meters	90 - 162 Meters
Number of Vessels passing (in a year)	42,553	44,035	57,600 (Expected Value)	14,114	16,833	29,284
Alternative Route	No alternative	No alternative	Bosphorus Strait	Strait Magellan or Cape Horn (South of the South America)	Navigation of Africa continent through Cape of Good Hope	Journey around the Jutland Peninsula
Total Gross Tonnage	565.282.287	772.922.682	Under Project Planning Phase	330.433.362	974.184	128.481.009
With Pilot	22,356	19,007	Under Project Planning Phase	Unknown	Unknown	Unknown
Average cost to pass	Only taxes	Only taxes	Under Project Planning Phase	Depends upon type, size and type of cargo.	Depends upon type, size and type of cargo.	Depends upon type, size and type of cargo.
Lock System	No	No	Under Project Planning Phase	Yes	No	Yes

Source: Made by the author according to [7], [13], [15], and [6]

The possible accident risks for all canals & straits above is; Conflict, Shipwrecking, Machine Check, Oil Pollution as a result of Accidents, Low Level Piracy and Terrorism.

Prevention to avoid from these accidents can be listed as; Improvement of navigational aid, Lock systems and Building new lock, Vessel Traffic System (VTS), Enlarging canal, Deepening entrance and exit, Oil pollution immediate action plans.

In the traffic system of Suez Canal, vessels are allowed to pass at a certain speed and distance between vessels in a convoy. For tankers and large vessels speed limit is 13-14 km / hour, for other vessels 16 km/hour. Distance between vessels in convoy are 2-3 km; 10 – 16 minute. In the canal there are 14 guidance stations. For vessels transit passing the canal, guidance is mandatory. Additionally, for every transit passing vessel Suez Canal Administration gave maritime pilot in four different points. For Kiel Canal allowable is 15 km/ hour likewise in Suez Canal.

4. CANAL İSTANBUL

4.1 Route alternatives

Canal Istanbul project is located at the European Side of İstanbul. So called crazy project will divide İstanbul into three parts, aiming to minimize the vessel traffic in Bosphorus Strait. Once completed, Canal Istanbul project should provide; scientific, technical, environmental, financial and legal eligibilities. [1]

Estimated project cost for Canal İstanbul is 100 Billion Dollar. And number of vessel expected to pass is 160 per day. For Bosphorus Strait this number is 117 vessels per day.

Though the final project has not been announced yet, there are three assumed alternatives for Canal İstanbul. [18]

I) Silivri Route
II) Büyükçekmece-Terkos Route
III) Küçükçekmece-Sazlıdere-Terkos Route

Silivri Route, starts near Silivri in South, continuing west of Terkos Lake and reaching Black Sea. This route is 47,8 km in length going through an irregular topography. Terrain altitude is 50 to 270 meters. As the depth of the canal is 25 meters, underwater excavation required in Marmara Sea is; 500 m and 2,5 kilometer for Black Sea.

Out of three options, with its length and elevations, this route has the requirement of the highest value for excavation. In addition to this, in northward direction, half of the route passes through cultivated terrain, rural settlements and subsequent section passes through forest land and at the end from Terkos Lake.

Figure 7 – Canal İstanbul project map.
Source: [14]

Second alternative; Büyükçekmece Terkos Route starts from shores of Marmara, Büyükçekmece Lake, crossing middle of Terkos Lake in North and connecting to Black Sea. Totally it is 47,6 kilometer long. Within this route, Büyükçekmece Dam and Terkos Lake are found that provides 7% and 10% of

Istanbul's water requirements respectively. Also on this route, 12,5 kilometer of the canal will be inside water basins. [1]

Third possible route is Küçükçekmece – Terkos Route. Its length is 45,2 kilometers. This route also passes from Terkos Lake and Sazlıdere Dam. Sazlıdere region of the canal is along Trans European Motorway (TEM). In this section a worldwide known, Yarımburgaz Cave left from the Palaeolithic Era is located.

Apart from the sea excavation, total excavations for each route is: Silivri Route: 869 million m^3, Büyükçekmece – Terkos route; 365 million m^3 and for Küçükçekmece – Terkos Route; 237 million m^3. With respect to this, Küçükçekmece – Terkos route is the most suitable one but this means abandoning Sazlıdere Dam and decreasing Istanbul's water usage by 6.7%.

In all three routes, minimum 3 new bridges needed to be built. Additionally, there are big structures which are needed to be displaced with the construction of Canal İstanbul. These railway, roads and structures are; İstanbul – Thracian Railway, TEM Motorway, E5 Motorway, several highways, Terkos – Alibey historical water tunnel and drinking water conveyance lines and Ataköy waste water collector.

4.2 Project explanations

Canal İstanbul Project after completion will have following units; Marina, Luxury Dwellings inside Northern Forests, Bridges, Educational Complexes, Harbor, Airport City, Financial Center. With it's closeness to 3rd airport which is currently under construction, new cities integration is expected to be faster.

During construction of Canal Istanbul project, there is expected to be a necessity for employment. Important point is to maintain this demand after the completion of the construction. Targeting the establishment of a financial center can be an important step for the region and İstanbul by means of economic income. Additionally, shaping this region as an attraction zone by organizing touristic tours that will provide income gain can also be listed in positive effects list.

Besides, we should not forget that the project will bring upon major negative effects as well, as a result of interference to natural habitat. The facts are not limited with wildlife. As analyzed in World Wide Fund for Nature Turkey, WWF there are also possible risks for Marmara transforming into a Dead Sea and İstanbul Sewer System Project which is dependent upon Straits flow system. Responsibilities under the Montreux Convention are also an important point for directing vessels to pass from Canal İstanbul rather than Bosphorus Strait.

As mentioned in regulations and agreements for Bosphorus Strait section, a similar regulation for Canal İstanbul should be formed as; "Canal İstanbul Maritime Traffic Regulation". In addition to this VTS should also be implemented to Canal İstanbul. [1]

A more important topic is, with the increasing population current potable water reserve loss will be present by transforming İstanbul into an island and disconnecting rivers that are a connection to Istıranca Mountains. Also it will divide Thracian from end to end which will result in some limitations for protection of İstanbul by military forces, evacuation of millions of people in the presence of a natural disaster.

For this mega investment, economic sources and over valuable ecosystem services are important facts for Turkish Citizens as every investment in parallel causes tax increase. During Project phase and completion fragile issues that are deem important are; ethical principles, participatory approach and transparent period. Decision makers, politicians and engineers should take immediate action for optimum solutions. [1]

5. ANALYSIS OF THE EXPECTED EFFECTS

Bosphorus Strait hosting large numbers of vessels with changing travel purposes from trade to leisure. Passage through route from Black Sea to Marmara or vice a versa is difficult to manage. Providing a safe passage without the presence of accidents is quite challenging. Though the present system is adequate to eliminate the risks with a newly introduced alternative passage, vessels categorized as hazardous can be diverted to the new canal.

As vessels outside of Turkey have free entrance rights according to Montreux Convention. Government will not have a possible option for restraining vessels to enter Bosphorus Strait. However, Government can provide advantages to make traveling from Canal İstanbul attractive compared to Bosphorus Strait. That can provide advantages such as; free fee entrance for vessels, low price from fuel or fuel without special consumption tax (SCT) and tourist attraction zone can be created utilizing from its closeness to 3rd airport. Currently, fuel without special consumption tax is implemented for Turkish Straits. [10]

With the completion of the project, there is expected to be a vessel traffic shift from Bosphorus Strait to Canal Istanbul. As a result there will be a reduction in maritime accidents.

6. CONCLUSION

Maritime accidents; collision, grounding and machine failure possibly can happen in Canal İstanbul. Risk is higher compared to Bosphorus Strait as it is narrower. (*Table 2*)

In case the presence of a tanker accident, there is a possibility of pollution in Black Sea; Dniester, Dnieper, Volga and Danube Rivers, petrol pollution can lead to more problematic cases.

In parallel with the increase in maritime trade in the world, channel enlargement and deepening investments are being made due to the size and width of the ships growing. It may be necessary to further expand the possible Channel Istanbul in the future and increase its depth.

Apart from this, a similar or parallel arrangement to the Montreux Convention can be made to contribute to the peace of our country and Black Sea region.

Tankers waiting time on Bosphorus Strait result in cost overruns. But in 2016 only 47% of the vessels passing through Bosphorus Strait took maritime pilot service. Meaning those vessels will continue to pass from the Bosphorus Strait. Additionally, 53% of vessels taking maritime pilot services will continue passing as a result of secure VTS systems within Bosphorus Strait.

For this particular reason, by not taking light house charges, health control document fee from vessels and decreasing waiting time can increase the preferability of Canal İstanbul.

Completely closing the strait and subjecting it to the regime of inland water is not possible if international law rules and treaties are taken into consideration.

Canal İstanbul expected to have an overall effect on economy, transport, and environment. It is likely to attract quite large number of vessel traffic which in terms expected to affect Bosphorus maritime traffic in a positive way.

With the introduction of the new system, there is expected to be a decrease in the vessel traffic on Bosphorus which will lead to possible maritime accident reduction. On the other hand, there is expected to be a non-ignorable adverse effect to the environment, eco system.

Turkish Government is planning to direct vessels from the Bosphorus Strait to Canal İstanbul. Plan to allow only touristic and sportive intended facilities to take place. Actions and approaches regarding this will be revealed with the completion of Canal İstanbul project.

Canal İstanbul project which is introduced as a dream can easily return into a nightmare in case of imprecise management. With the implementation of the project, affected flora and fauna by removal of forestry area, population growth and oil spill possibilities from maritime accidents are the expected negative outcomes. Professionals and decision makers should list positive and negative outcomes of the system and go towards the alternative where positive aspects overweight.

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NETWORK REVENUE MANAGEMENT COMMONLY USED APPROACHES

ABSTRACT

Network revenue management in the airline case is managing the capacities of a set of connecting flights across the network. This principle of network management does not require an explicit network structure as such, yet it is mix of approaches that base their principle, in one way or another, in single-leg control and on implementation on one of heuristic models. Due to the need to work in the existing reservation systems airlines adopted approaches such as virtual nesting. As the need for frequently updating indexing increased many airlines work to make these indexations more dynamic which lead to the dynamic virtual nesting approach.

KEY WORDS

Network revenue management; origin-destination control; bid price; virtual nesting; heuristic models

1. INTRODUCTION

Revenue management (RM) is the collection of strategies and tactics airline companies use to scientifically manage demand for their products and services. Since American Airlines' successful implementation in the post-deregulation era, development of revenue management systems has progressed from simple single leg control, through segment control, and finally to origin-destination control. Each of these advances has required investment in more sophisticated information systems, but the return on these investments has been excellent. Improvements in information technology could soon allow airlines to generate customized fare offers for individual passengers. [1] The problem of capacity control and its approaches on a network of resources will be revised in the paper.

2. NETWORK REVENUE MANAGEMENT CAPACITY CONTROL APPROACHES

In the airline industry, network revenue management is also called "O&D (origin-destination) control".

Revenue management is concerned with the methodology and systems required to make demand-management decisions, which can be categorized into:

- Structural decisions: Which selling format to use (such as posted prices, negotiations or auctions); which segmentation or differentiation mechanisms to use (if any); which terms of trade to offer (including volume discounts and cancelation or refund options); how to bundle products; and so on.

- Price decisions: How to set posted prices, individual-offer prices, and reserve prices (in auctions); how to price across product categories; how to price over time; how to markdown (discount) over the product lifetime; and so on.
- Quantity decisions: Whether to accept or reject an offer to buy; how to allocate output or capacity to different segments, products or channels; when to withhold a product from the market and sale at later points in time; and so on. [2]

Practical complexity of revenue management could be illustrated by its elements [3]:

- customer behavior and demand forecasting (demand volatility; seasonality, day-of-week variation; special events; sensitivity to pricing actions; demand dependencies between booking classes; return itineraries; batch bookings; cancellations; censorship of historical demand data; defections from delayed flights; diversions; go-shows; group bookings; interspersed arrivals; no-shows; recapture; upgrades)
- control system (booking lead time; number of controllable booking classes; leg-based, segment-based, or full ODF control; distinct buckets, parallel nesting, or full nesting; reservations systems connectivity; frequency of control updates; overbooking)
- revenue factors (fare values; uncertainty of fare value; frequent flyer redemptions; company or travel agent special vouchers; cancellation penalties or restrictions)
- variable cost factors (marginal costs per passenger; denied boarding penalties; goodwill costs;
- fare products (number of products; restrictions)
- problem scale (large airline or airline alliance)
- problem interfaces (market strategy; code-sharing alliances, routing; gate acquisition and schedule planning; fleet assignment).

The practical complexities of revenue management are daunting. Modelling, theoretical analyses, and implementation rely on assuming away many of these complicating factors and approximating others. It is important to remember that such approximations have yielded enormous revenue benefits for airlines and other enterprises. [2]

Simulation studies of airline hub-and-spoke networks have shown that there can be significant revenue benefits from using network methods over single-resource methods. However, network revenue management poses major implementation and methodological challenges.

Network RM vastly increases the complexity and volume of data that one must collect, store and manage. Optimization is more complex as well. Therefore optimization methods necessarily require approximations of various types. Achieving a good balance between the quality of the approximation and the efficiency of the resulting algorithms becomes the primary challenge. [3]

In the next sections various solution approaches to the network management problem will be given, such as bid pricing, virtual nesting and the composition of the first two: DAVN method.

2.1 Bid pricing

Request for a seat on the ODF will be accepted if potential obtained income is greater than the sum of the lowest acceptable price (bid price) in certain segments. Network bid price control requires only two controls per leg – a bid price and a total booking limit. This seemingly simple approach is not so simple in reality considering the fact that bid prices demand to be updated (at least in theory) each time a booking is accepted or a cancellation occurs.

In a network setting, a bid-price control sets a threshold price - or *bid-price* - for each resource in the network. Roughly, this bid-price is an estimate of the marginal cost to the network of consuming the next incremental unit of the resource's capacity. When a request for a product comes in, the revenue of the request is compared to the *sum* of the bid prices of the resources required by the product. If the revenue exceeds the sum of the bid prices, the request is accepted; if not, it is rejected. [3]

Booking requests arrive an online processor known as the availability processor shown in figure 1. It calculates the fare associated with each request and compares it to the current bid price for the requested product. [4]

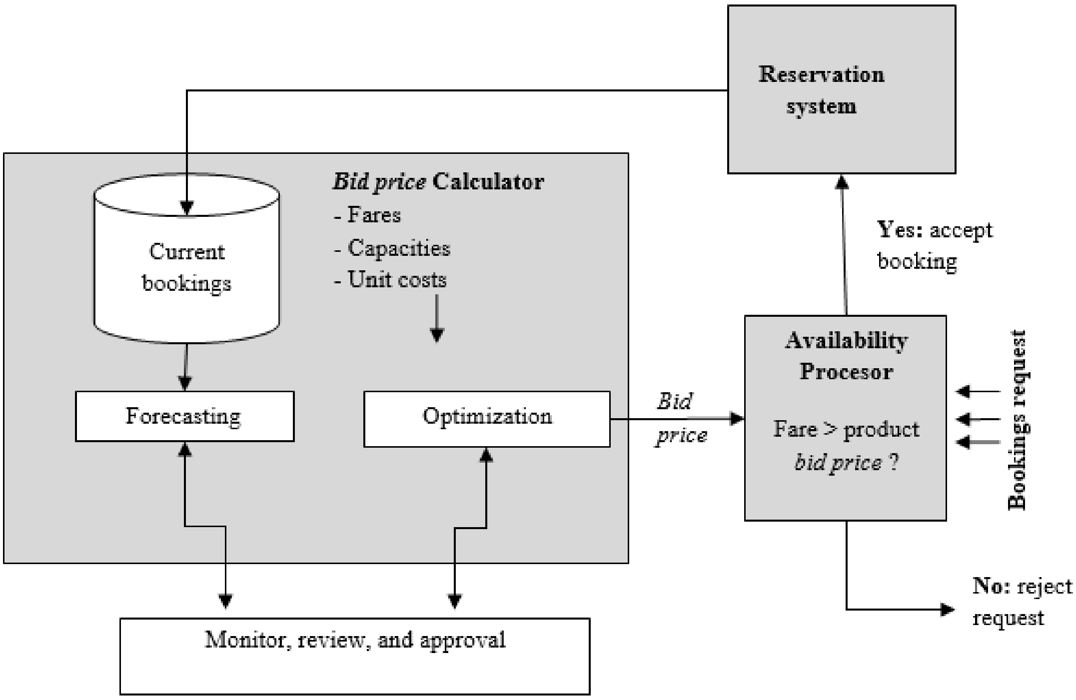

Figure 1 – Schematic view of an availability processor architecture for network management
Source: Phillips, R.: Pricing and Revenue Optimization, Stanford University Press, Stanford, CA, USA, 2005

There are two commonly used approaches to calculate bid prices, and both are quite complex – so much so that developing faster and more accurate bid-pricing algorithms is a very active area of research. One way to calculate the bid price is to solve the network linear problem twice: the first time with the actual capacities ant the second time with the capacity reduced for one seat. The difference will be the displacement cost on the leg, which will be the estimate of bid price on the leg. [4] As mentioned, this way requires solving the linear program twice, which is computationally intensive and ungainly.

The second approach is to calculate bid prices by sequential estimation [5] which is based on the observation that the bid price on a leg should be equal to its boundary between the lowest open bucket and the highest closed bucket on the leg in a virtual nest which will be explained further in the paper. Even though this principle is rather simple in its core it does not provide information in determining minimum price for the service, but can provide very useful input into capacity decisions. For example if there is a flight leg that has a high opportunity cost (increased revenue from an additional seat on a leg) at departure would be an excellent candidate to be considered for assignment to a larger aircraft.

2.2 Virtual nesting

Virtual nesting was the earliest approach to network management. [2] First applied by American Airlines its approach, although with certain variations, has been used at many airlines today. This approach allows airline to apply the preexisting, leg-based control structures in their reservation systems in order to solve the network management problem with minimizing the change. First step is to define a set of buckets on each flight leg. Each bucket represents a range of fare values. Second step is indexing the ODFs into buckets on legs. Each bucket has a booking limit and a protection level that is updated every time a booking is accepted or a cancellation occurs.

Figure 2 shows the architecture of a virtual nesting system. Each booking request is first mapped to bucket on its constituent resources according to some indexing scheme. Availability is then checked in each of these buckets. I there is sufficient availability in each bucket, the request is accepted; otherwise it is rejected. The function of the revenue management system is both to maintain and communicate the latest indexing and to calculate and update booking limits for each bucket on each leg. [4]

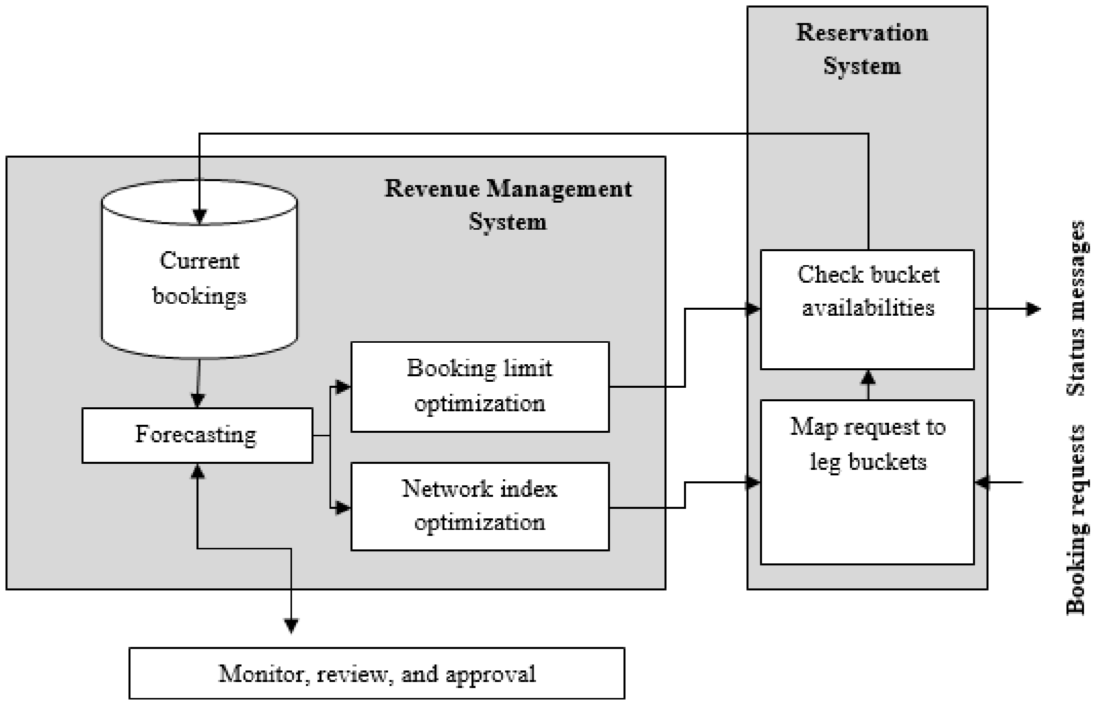

Figure 2 – Schematic view of a virtual nesting architecture for network management
Source: Phillips, R.: Pricing and Revenue Optimization, Stanford University Press, Stanford, CA, USA, 2005

According to Phillips [4], the best way to value an ODF is to subtract from the total fare the opportunity cost, that lead us to the formulation: Net leg fare for ODF *i* on leg *k* = Total fare for ODF *i* minus sum of opportunity costs on all resources other than *k* in ODF *i.*

Let us presume that on a certain simple hub-and-spoke network with three airports (A, B and C) the opportunity cost on flight A-B is 150€, and on flight leg B-C is 300€, and each bucket if defined as it follows:

- Bucket 1: Net leg fare ≥ 650€
- Bucket 2: 400€ ≤ NLF < 650€
- Bucket 3: NLF < 400€

In the table 1 six different ODFs are mapped into buckets. From the table below can be seen that on the flight 1, ODF leg A-C of low class passengers were assigned the lower bucket than on the flight 2. That means that on the flight 1 the seats will be protected for the passengers who travel on ODF leg A-B, low class, while the situation will be reverse on the second flight.

Table 1 – Net leg fare and indexing for six ODFs in the simple hub-and-spoke network

ODF		Total fare €	Flight 1		Flight 2	
			NLF	Bucket	NLF	Bucket
A-B	Low class	350	350	3	-	-
A-B	High class	580	580	2	-	-
B-C	Low class	390	-	-	390	3
B-C	High class	700	-	-	700	1
A-C	Low class	650	350	3	650	2
A-C	High class	1000	700	1	850	1

Source: Made by the authors according to [4]

For this two-flight example there can come a situation where an unanticipated ruffle in bookings results in flight 1's closing to all future bookings, while flight 2 remains open in bucket 1 yet closed in bucket 2 and 3. Based on this principle the system will close to all bookings even though there are seats available on flight 2. If the opportunity cost could be updated often enough based on booking and cancellations as they occur as well as on changing expectations of total demand for a flight, it could serve as control for network revenue management, which is the idea behind bid pricing.

3. DISPLACEMENT-ADJUSTED VIRTUAL NESTING

Displacement-adjusted virtual nesting (DAVN) is the marriage of bid pricing and virtual nesting. DAVN starts with a set of static bid prices. These estimates may be obtained from one of the various network heuristic models such as deterministic linear programming model (DLP), randomized linear programming model (RLP) or probabilistic nonlinear programming model (PNLP).

Based on current bookings and forecasts of future demands new bid prices are frequently recalculated for all legs in the network. Each time new resource bid price is calculated new NLF us calculated for each leg in the network which are then used to define a new indexing for virtual nesting. This indexing will last until the new recalculation is triggered. A request for product is converted into a request for the corresponding virtual class on each resource required by product using the indexing scheme. [4]

If the virtual class on each resource is available, the request is accepted. If the virtual class on one or more resources is closed, the request is rejected. Once the indexing is performed, the control logic is an independent, nested allocation class-level control on each resource in the network. Due to this characteristics this method is quite appealing in the airline industry because it produces the sort of booking-class-level controls that are widely used by GDSs. [5]

DAVNs strength is comprised in updates of bid prices so that they can reflect the current situation on each leg while utilizing virtual nesting. Predisposition of effectiveness of DAVN approach is in the frequency of the recalculation. If bid prices are continually updated, DAVN will approximate network bid price control for single-seat bookings. This approach, due to the demand of high frequency recalculation of bid price, is in close correlation to "high class" fast information systems and remains the state-of-the-art approach to network revenue management industry.

4. CONCLUSION

Network revenue management is on the front line of pricing and revenue optimization practice. Current approaches are a compromise between theoretically correct method and practical implementation in the preexisting reservation systems. The combination of bid pricing with virtual nesting combined with one of numerous heuristic models gives an approach that decomposes the complex network problem into a collection of computationally tractable leg-level problems. Research into better than "good enough" approaches into network revenue management continues. The transition from leg-based management to network management requires business process changes as well as software system changes.

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HIGHLY RETROREFLECTIVE HORIZONTAL ROAD MARKINGS: DRIVERS' PERCEPTION

ABSTRACT

Horizontal road markings are common safety features that can be found on all roads. Scientific analyses demonstrated that road safety was improved on roads where the markings had higher retroreflectivity. The standard retroreflectivity reaches only about 350 mcd/m²/lx initially and is permitted to drop to 100 mcd/m²/lx. On a 2 km stretch of a curved rural road, we have applied markings with improved retroreflectivity, approaching 700 mcd/m²/lx initially. Whereas durability of the system is still under evaluation, opinion of drivers about the increased retroreflectivity was assessed using a questionnaire.

Amongst 156 valid filled questionnaires, 58-75% of respondents reported noticing markings with retroreflectivity higher than the standard with those who use the road every day most likely to observe this added safety feature. Over 80% of respondents felt that road safety during nighttime driving would increase if horizontal markings had higher retroreflectivity. Amongst the responders, there was an overrepresentation of young drivers and underrepresentation of older ones, which might have skewed the results.

KEY WORDS

Road marking; glass beads; retroreflectivity; waterborne paint; drivers' perception; young drivers

1. INTRODUCTION

Increasing road safety is an important aim of European Union countries. An ambitious programme started in 2010 with a goal to reduce the number of fatalities by 50% before the end of the decade. Statistical data demonstrate that the programme is so far on track, even though on European Union roads in 2014 occurred over 1 million vehicular accidents, resulting in about 1,4 million people injured and over 26 thousand dead [1].

One of the main causes of traffic accidents is failure to scan the road [2]. Since driving belongs to visual input-depended cognitive processes, clearly visible travel path should lead to lesser number of drivers' errors and thus improved safety. For that purpose, horizontal road markings, which guide the drivers and help them in maintaining their vehicles within a set travel path are commonly used feature. Improved positioning of vehicles on roads with clearly marked lanes was reported and the effect was particularly prominent during nighttime driving [3][4]. Analysis has shown horizontal road markings to be one of the most effective and inexpensive safety features and can bring up to 60:1 in benefit:cost ratio, which is a sufficient warrant to install them on almost all roads [5]. By maintaining traffic flow, horizontal road markings became critical support elements of road transport.

1.1 Horizontal road markings to improve road safety

The number of accidents that occur after dark is disproportionately high when adjusted for the driven distances. Moreover, severity of those accidents is higher and fatality rates are higher [6]. One of the ways to lower this risk is providing focus points for the drivers to help them in keeping the appropriate travel path. Horizontal road markings serve that purpose: Up to 20% reduction of accidents was reported on roads with appropriate horizontal markings [7]. In particular, during adverse weather conditions and at night the markings are very important for the drivers [5]. To be effective at night, the markings must be reflectorised, which is commonly done with glass beads since the 1950s[8].

Research has demonstrated that drivers of all ages navigating the roads at night are more likely to observe retroreflectivity (R_L) of road markings than luminosity [9][10]. Therefore, high R_L is considered by road users as one of the key factors for increasing their personal safety and confidence during driving [11]. A subjective perception of safety by people who drive on clearly marked roads with high aesthetic quality was reported two decades ago [12]. Statistical analysis correlating increased R_L with a decrease of number of vehicular collisions demonstrated that increase in R_L of 100 mcd/m²/lx could be linked to a decrease in accidents by as much as 23% [13]. Evaluation of safety effects of horizontal road markings with retroreflectivity significantly exceeding the standard value of about 350 mcd/m²/lx has never been done, because such highly retroreflective markings are still not widespread.

1.2 Horizontal road marking materials

Horizontal road markings have to be considered as **systems** consisting of the coloured layer and retroreflective layer [8]. In Europe, most frequently white markings are used with yellow or orange in reserved for temporary markings, but in some countries yellow lines may separate the directions of traffic or indicate dangerous stretches. Other colours are utilised relatively seldom and only for special purposes. The coloured layer – most frequently paints (either solventborne or waterborne), coldplastics, or thermoplastics – is reflectorised with glass beads. Other reflective materials are rare due to their high cost. Materials commonly used for road markings were recently summarised [14].

Waterborne road marking paints, which are commonly utilised in many countries remain almost unknown in most of Central and Eastern European countries. Lack of awareness combined with low marketing efforts, slightly higher unit price, and the previous absence of quickly drying stable materials can be pointed as the reasons for the lack of usage of this modern technology. All waterborne road marking paints have one disadvantage that must be mentioned: They develop washout resistance (resistance to a sudden rainfall) some time after dry-through is achieved. Hence, there is a risk of damaging freshly marked lines in case of unexpected poor weather. However, under normal application conditions, waterborne paints dry quicker than solventborne materials [14]. Durability of high quality modern waterborne road marking paints is generally higher than can be achieved with comparable solventborne materials; our research repeatedly demonstrated that advantage [15][16]. We can attribute the superior durability to engineered drying and curing mechanism and the associated good affinity for glass beads. Another amongst advantages of waterborne paints is their lesser environmental impact: We have calculated that volatile organic compounds (VOC) that evaporate from solventborne road marking paints can significantly contribute to production of tropospheric ozone, a very significant constituent of non-particulate smog. The savings for our environment could be enormous: Up to 82% lower VOC emissions and as much as 95% lower potentially formed tropospheric ozone could be realised in case of a switch from solventborne toluene-containing paints to waterborne materials [15][17][18].

Glass beads are the most commonly used reflective elements that at present cannot be matched in terms of the effectiveness and cost by any other material. Appropriate selection of glass beads and their correct embedment in the colour layer are critical for application and durability of road marking systems [8]. Glass beads must be appropriately coated to match chemistry of the colour layer to prevent their removal by passing vehicles. Typical glass beads used for road markings have low refractive index of 1.5 and can furnish retroreflectivity reaching in the field about 350 mcd/m^2/lx. Much higher R_L, even exceeding 2000 mcd/m^2/lx, can be readily obtained with glass beads of higher refractive index, but such beads tend to be prone to scratching and, due to production process and required raw materials, are prohibitively expensive. These issues were overcome at SWARCO by the development of SOLIDPLUS glass beads, which due to exceptional finish quality, specially selected raw materials, and a proprietary production process can furnish retroreflectivity reaching even 1000 mcd/m^2/lx despite low refractive index.

2. APPLICATION OF ROAD MARKING SYSTEMS

The selected 2 km test stretch on National Road 28 in Poland carries annually averaged daily traffic of 5885 vehicles (including about 7% of lorries), it is a two-lane road, each lane 270 cm wide, with narrow shoulders secured with safety barriers. The road is quite curved, so good visibility and retroreflectivity of markings at any weather conditions and at night is of profound importance.

For the test, waterborne road marking paint LIMBOROUTE AQUA W15 (SWARCO Limburger Lackfabrik GmbH; Diez, Germany) was applied at ±550 g/m^2 and reflectorised with appropriately coated drop-on 200-800 µm glass beads SOLIDPLUS (M. Swarovski GmbH; Amstetten, Austria) applied at ±300 g/m^2. The glass beads contained 20% of anti-skid material to assure safety under wet conditions and to meet skid resistance requirements. The application (double centre and edge lines, each 12 cm wide) was done by a professional road marking crew (DUBR sp.z o.o.; Kielce, Poland) using a self-propelled application machine ORLIK (PHU Cemar; Bielawa, Poland). There were no problems whatsoever with the application, even though it was the first time the crew had to mark with waterborne materials. The weather conditions were perfect and the paint dried expectably within a few minutes [14]. Application was supervised by road authority personnel. The control consisted of standard materials used in Poland: A solventborne toluene-containing paint and a typical appropriately coated 125-600 µm glass beads (without anti-skid material). Marking with control was done a couple days earlier by the same crew using the same equipment; no issues were reported.

All of the measurements taken initially and after three months were meeting our expectations: Results are provided in

Table 1 (standard deviations from 13 measurements taken at both lines are given in parentheses).

	EXPERIMENTAL SYSTEM: Waterborne paint W15 + SOLIDPLUS glass beads		CONTROL SOLVENTBORNE SYSTEM: Solventborne paint + standard beads	
	Edge lines	Centre lines	Edge lines	Centre lines
R_L [mcd/m^2/lx]	553 (34)	690 (70)	374 (57)	378 (20)
RW [mcd/m^2/lx]	150 (32)	120 (28)	18 (15)	42 (8)
Qd [mcd/m^2/lx]	174 (6)	210 (8)	204 (11)	180 (6)
Skid resistance (SRT)	58 (3)	50 (0)	54 (2)	n/a

After three months, mild degradation of R_L was measured, but deemed insignificant and is therefore not reported. Very high retroreflectivity under both dry (R_L) and wet (RW) conditions were measured for the test system. The difference between centre and edge lines may be attributed to road geometry, asphalt quality, and application parameters. Daytime luminance (Qd) measured with waterborne paint was similar to the control, even though one could visually observe its slightly different shade. Skid resistance was high. Evaluation of the markings for durability and resistance to winter maintenance is ongoing.

Table 1 – Results of application (initial).

	EXPERIMENTAL SYSTEM: Waterborne paint W15 + SOLIDPLUS glass beads		CONTROL SOLVENTBORNE SYSTEM: Solventborne paint + standard beads	
	Edge lines	Centre lines	Edge lines	Centre lines
R_L [mcd/m²/lx]	553 (34)	690 (70)	374 (57)	378 (20)
RW [mcd/m²/lx]	150 (32)	120 (28)	18 (15)	42 (8)
Qd [mcd/m²/lx]	174 (6)	210 (8)	204 (11)	180 (6)
Skid resistance (SRT)	58 (3)	50 (0)	54 (2)	n/a

Source: Authors.

3. METHODOLOGY

To understand drivers' attitudes toward retroreflectivity of horizontal road markings, a survey was designed and administered. Surveys dealing with personal opinions, thoughts, and feelings are widely acceptable research tools and are often used to make studies of road users' and traffic behaviour [19][20]. We report here only demographic information like age or sex and responses to questions related to retroreflectivity. Other modules of the survey, pertaining to driving experience and attitudes toward road safety in general were omitted for this paper. Assessment was done based on a five-point Likert Scale, where 1 meant no influence, 2 – slight influence, 3 – minor influence, 4 – significant influence, and 5 – great influence, with appropriate modifications.

The survey was carried out in the area near the location of test application and took place 4-5 months after the experimental road making application. Support from the local authorities permitted for administering the survey at a local high school and at municipial offices. In addition, the survey was filled-in by local inhabitants, professional drivers from a local transportation company routinely using the road stretch with experimental markings, and tourists visiting a roadside bar.

Even though 302 questionnaires were filled, for the purpose of this paper we selected 156 responses from 74 (47%) females and 82 (53%) males. Disregarded were responses from people who held no valid driving licence (80 filled questionnaires) or who admitted to not travelling through the test area at night since installation of the experimental markings (66 filled questionnaires). Age distribution of the respondents is shown in Figure 1. Over-representation of young drivers was caused by including the high school students. On the other hand, there was a meaningful underrepresentation of older drivers, for whom markings with high retroreflectivity could provide significant benefits [9].

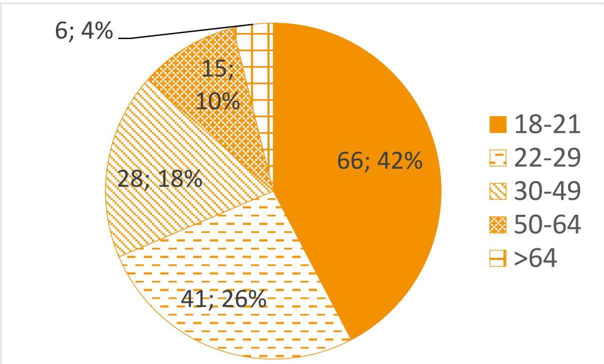

Figure 1 – Survey respondents' age structure.
Source: Authors.

4. RESULTS AND DISCUSSION

Firstly, to assess the attitudes of the respondents towards features of horizontal road making and their personal comfort during nighttime driving, we asked questions: "*How important for road safety do you consider visibility and quality of horizontal road marking?*" and "*Is driving during hours of* *darkness associated with more risk than driving during daytime?"*. As shown in Figure 2, for over 80% of respondents, high quality (i.e. lack of ambiguity of markings and their visibility) were of significant and great influence: Weighted average response was very high at 4.4. This result confirms that maintaining high quality of horizontal markings is perceived as safety feature, indeed, which agrees with literature reports [12][21].

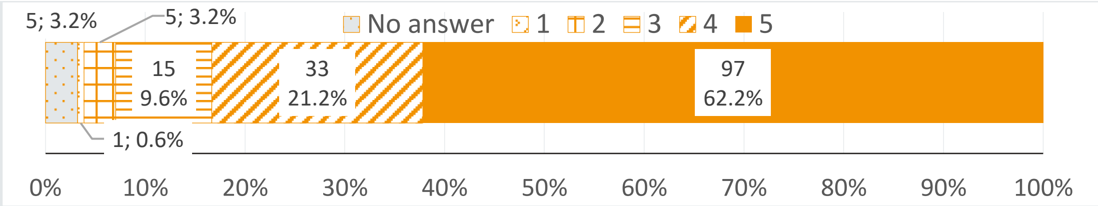

Figure 2 – How important for road safety do you consider visibility and quality of horizontal road marking?
Source: Authors.

Assessment of perceived risk during nighttime driving as compared to daytime was done to estimate the personal feeling and compare it with the literature reports clearly linking driving at night with increased chance of accidents. For only for 21% of the interviewed drivers nighttime driving was perceived as having significant and great negative impact of personal safety and comfort (Figure 3). Comparison of the responses based on drivers' ages demonstrated that young people, most likely due to their lack of experience, did not associate nighttime with very high risk (Figure 4). However, overall, the response was similar for all ages and had weighted average of only 2.6. Such low score, in the light of the literature reports and statistical data correlating nighttime driving with increased risk of accidents, might be the result of insufficient education and awareness of drivers.

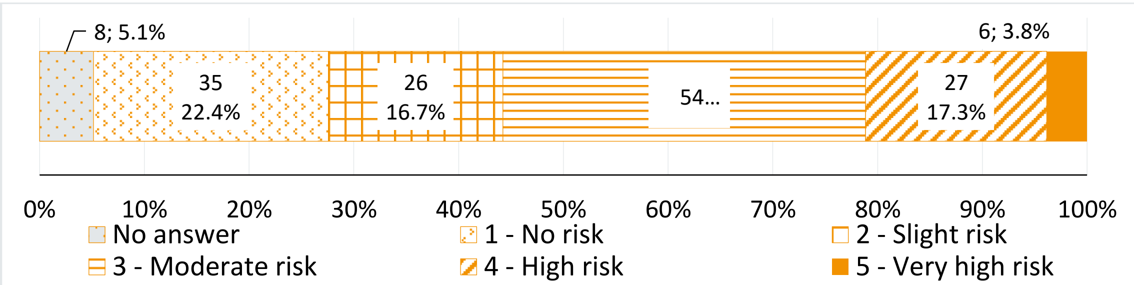

Figure 3 – Is driving during hours of darkness associated with more risk than driving during daytime?
Source: Authors.

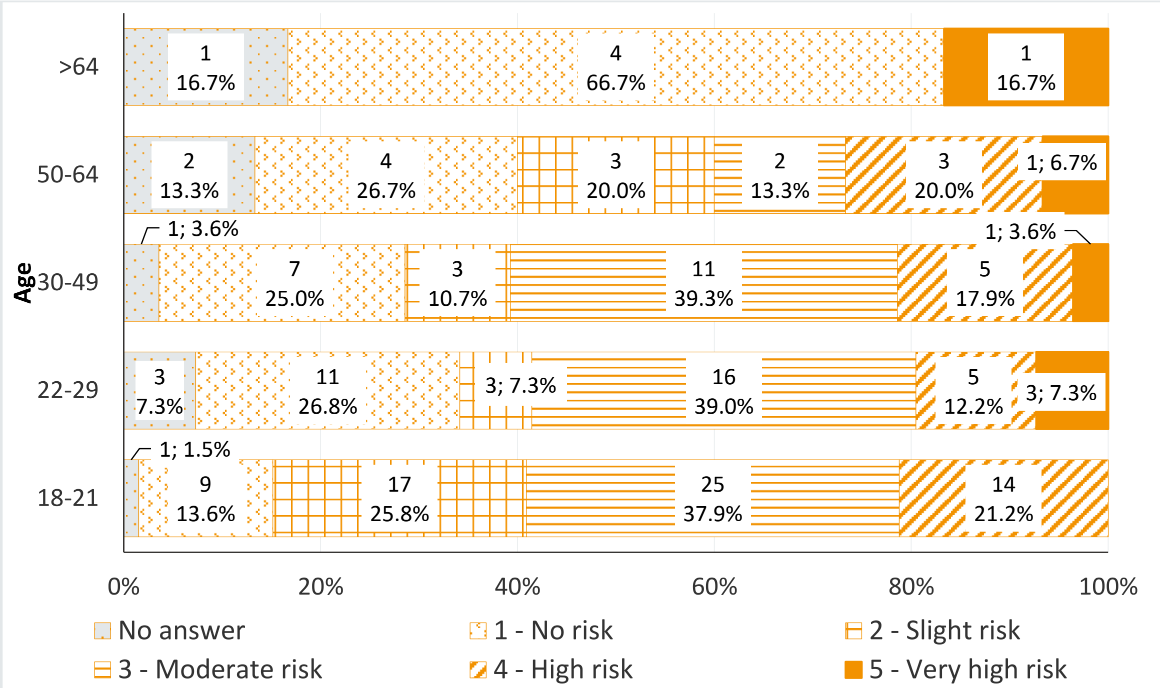

Figure 4 – Is driving during hours of darkness associated with more risk than driving during daytime? Drivers' age.
Source: Authors.

Quite good correlation was found between sex and perception of the risk associated with nighttime driving, as shown in Figure 5. For females, the weighted average response was 2.8, while for males 2.4. Whereas 25% female and 20% male drivers perceived driving at night as risky or very risky activity, quite interestingly more males than females considered it to be very risky. The overall results agree with literature reports pointing out that male unexperienced drivers tend to take more risks while driving [22]. While this analysis does not clearly point to any risky driving behaviour implications, correlation with results from driving behaviour questionnaire may be possible [23].

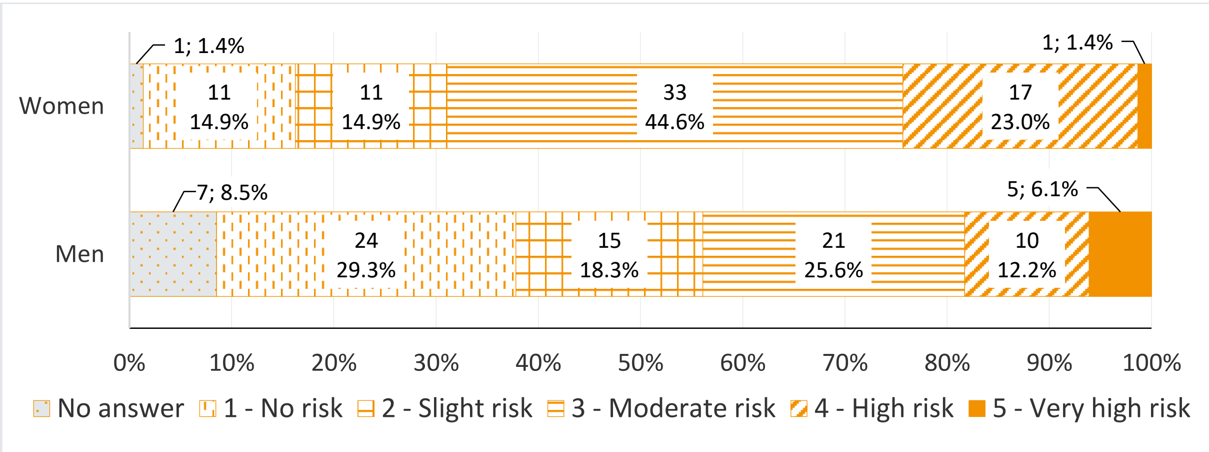

Figure 5 – Is driving during hours of darkness associated with more risk than driving during daytime? Drivers' sex.
Source: Authors.

The frequency of nighttime driving through the test area within the last three months, presented in Figure 6, was a direct indication of the exposure of the responding drivers to the horizontal markings with high retroreflectivity. Amongst the respondents, 38% drive at night very seldom – we cannot assess whether this was caused simply by the lack of necessity or by self-restriction, as is frequent amongst drivers who are older or with less-than-perfect vision [24]. We found relatively flat distribution amongst other responders.

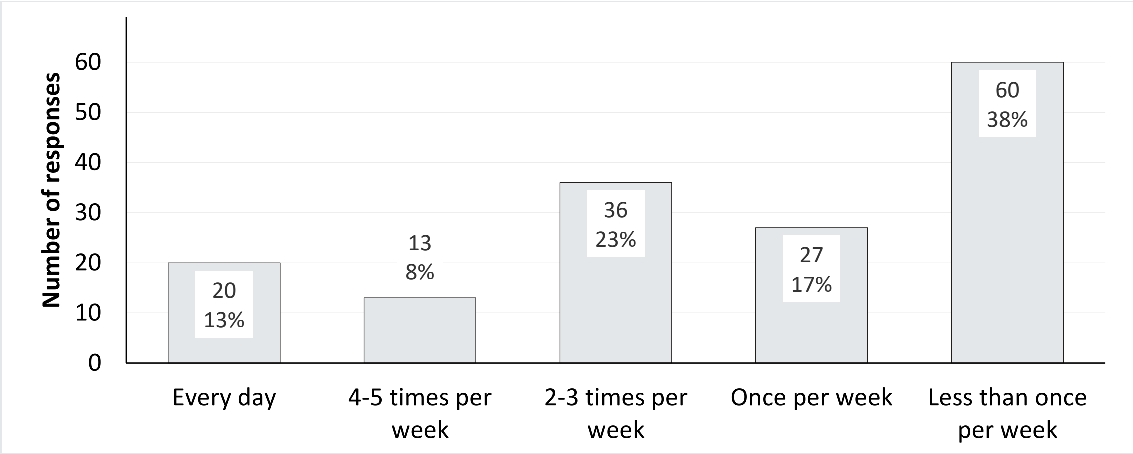

Figure 6 – Frequency of nighttime driving on through Gruszowiec pass in the past 3 months.
Source: Authors.

Assessment of drivers' attitudes toward markings with high retroreflectivity was done based on the following questions:

- Have you noticed horizontal road marking with increased retroreflectivity during your nighttime driving?
- Does the road marking with high retroreflectivity appear to you more visible during nighttime driving in difficult weather conditions (rain, rain, fog)?
- Do you think that highly retroreflective horizontal road markings could improve road safety?
- Do you think that people of poorer eyesight would benefit from horizontal markings with high retroreflectivity?

The responses to the question "*Have you noticed horizontal road marking with increased retroreflectivity during your nighttime driving?*" are illustrated in Figure 7, with breaking into groups based on the frequency of driving through the test area. Between 58% and 75% of drivers did notice the increased retroreflection of road markings in comparison with the standard markings, indeed. Drivers who travel that road stretch every day were most likely to observe the change, which finding can serve as confirmation of a simulator research demonstrating that even though habituation does play a significant role, habituated drivers are very likely to observe any changes related to road safety and environment despite being more likely to drive without awareness [25].

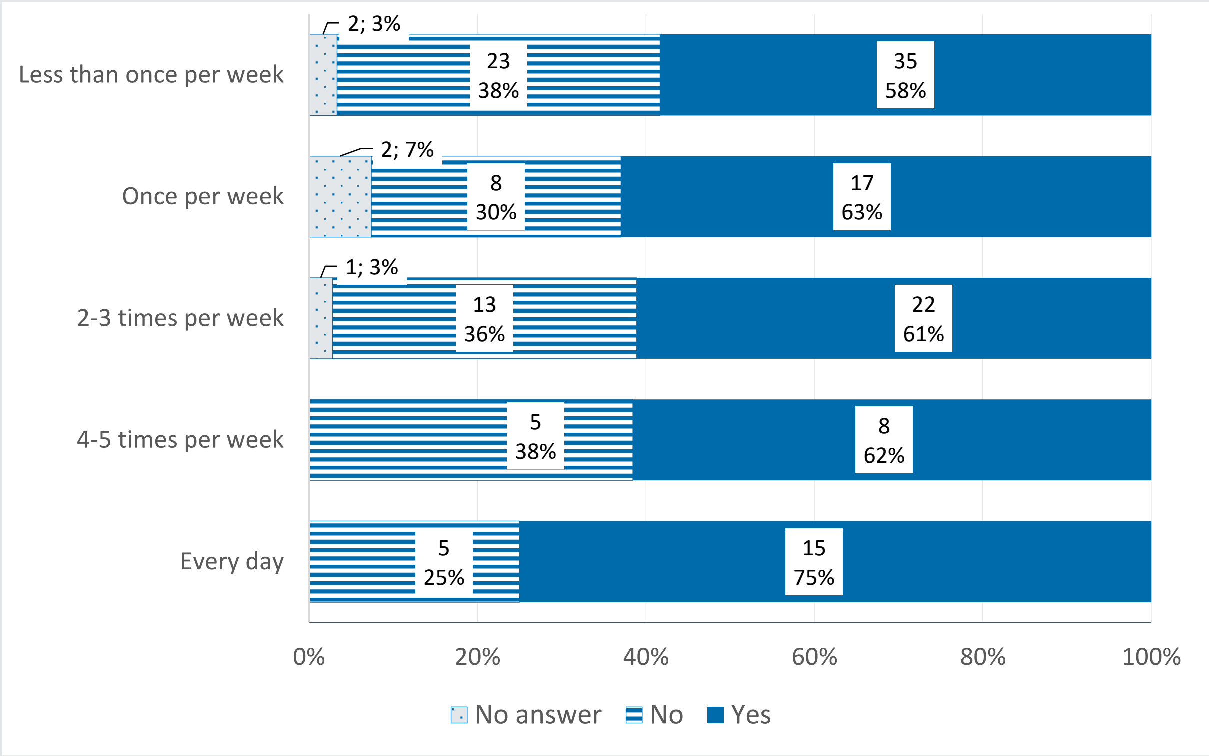

Figure 7 – Have you noticed horizontal road marking with increased retroreflectivity during your nighttime driving?
Source: Authors.

Figure 8 presents opinions of drivers in reply to the question *"Does the road marking with high retroreflectivity appear to you more visible during nighttime driving in difficult weather conditions (rain, rain, fog)?"*. Whereas for 56% to 77% of respondents the response was positive, over 20% of drivers could not answer this question. It might be suspected that they did not drive through the test area at night during the inclement weather, but there is no confirmation. The distribution of responses indicated that increased retroreflectivity of markings would be mostly helpful to people who are either only vaguely familiar with the road or drive there frequently. These responses do confirm the aforementioned reports related to guiding role of horizontal markings and automaticity while driving on familiar roads [4][25].

Vast majority of the respondents agreed that markings of high retroreflectivity would be beneficial for their safety. The results are provided in Figure 9. Obviously, drivers expect clarity and maximised safety features, even if they may perceive driving as a task of low risk. Finally, as shown in Figure 10, equally overwhelming majority of respondents, despite their low age, perceived horizontal markings with high retroreflectivity as beneficial to drivers who have less-than-perfect vision.

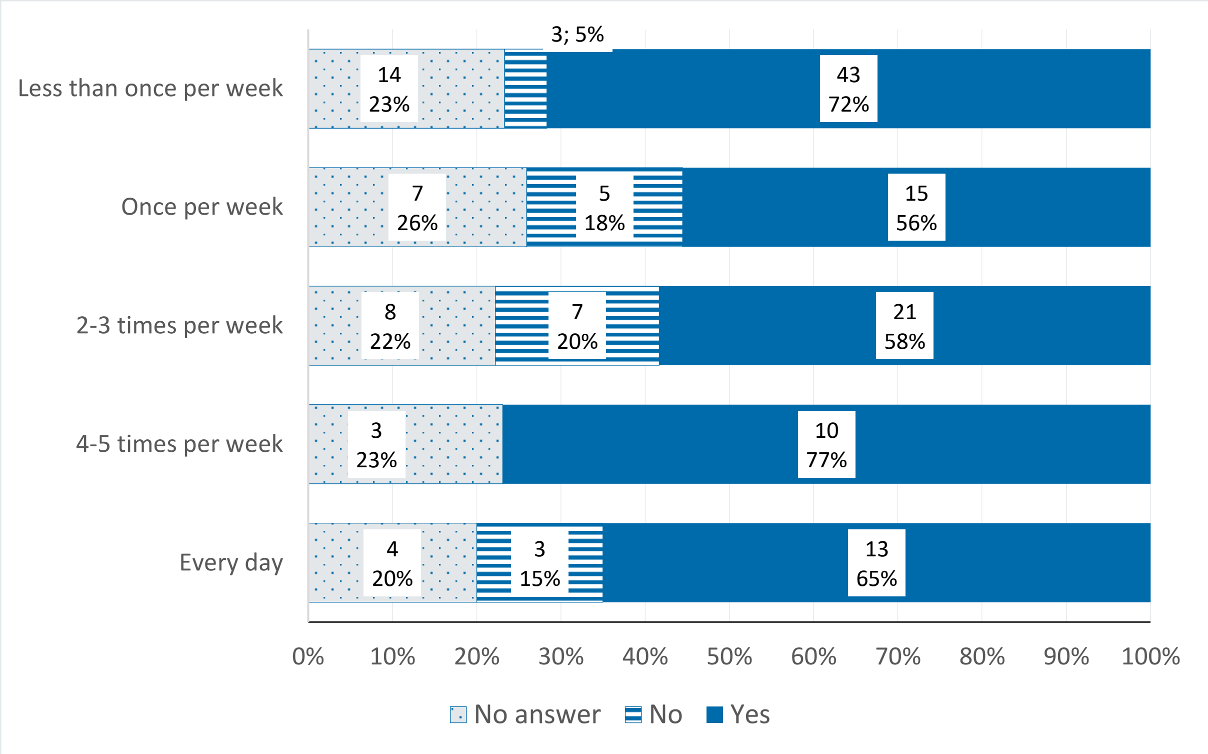

Figure 8 – Does the road marking with high retroreflectivity appear to you more visibly in difficult weather conditions (rain, rain, fog)?
Source: Authors.

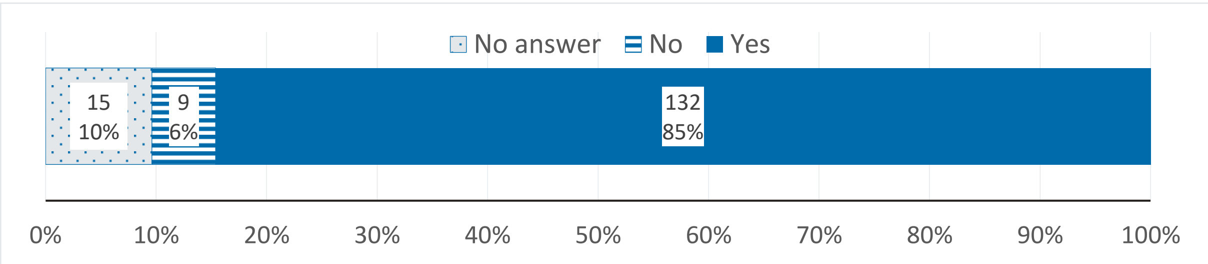

Figure 9 – Do you think that highly retroreflective horizontal road markings could improve road safety?
Source: Authors.

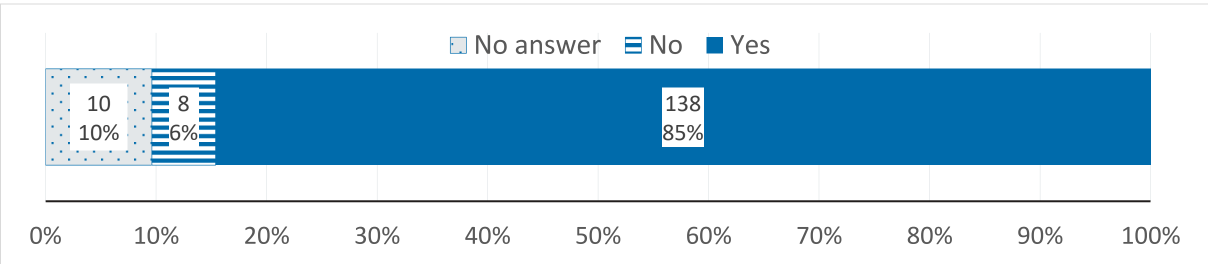

Figure 10 – Do you think that people of poorer eyesight would benefit from horizontal markings with high retroreflectivity?
Source: Authors.

The results point uniequivocally that drivers do notice increased retroreflectivity of horizontal road marking while driving under difficult conditions. Whereas road familiarity may breed inattention and automaticity while driving, the results are real life confirmation that road safety features are noticed and appreciated [25]. We are aware that the perception of increased safety might lead to compensation by higher speeds and more reckless driving, which could then nullify the actual safety effects. Such compensation was reported in cases of installation of artificial lighting [26]. However, we did not find in the literature any information that improved retroreflectivity would lead to more reckless driving and analysis of accidents frequency would deny it [3][13]. Even though somewhat higher speeds were measured on well-marked roads, the safety effect – keeping the lane – was more prominent and drivers' comfort increased [3][27][28].

We are aware that the underrepresentation of experienced and older drivers could skew the results of this analysis. Additional related work is in progress.

6. CONCLUSIONS

We have applied an environmentally-friendly road marking system with enhanced retroreflectivity and through interviews analysed response of drivers to such markings. The measured retroreflectivity for the first four months after application was about 700 mcd/m²/lx, as compared with the control system furnishing only approximately 350 mcd/m²/lx.

Majority of respondents considered quality of horizontal road markings as an important safety feature. High retroreflectivity of the test stretch was noticed by 58-75% of interviewed road users with those who reported driving there every day observing it most frequently.

We have demonstrated that there is an increased perception of road safety caused by significantly increasing retroreflectivity of road markings. There is no sufficient data to statistically validate the actual effect of such markings on accidents: The test area is too small.

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PLANNING OF DELIVERY ROUTES FOR A SMALL VEHICLE FLEET: A CASE STUDY IN KRAKOW

ABSTRACT

The reduction of empty vehicle-kilometers is a challenge for road freight transport. Especially, this problem concerns transport companies working within the urban area. One of approaches to solve such problem is by implement algorithms of the Vehicle Routing Problems (VRP), which allow to improve the routing planning process and, thereby, to increase the quality of vehicle fleet management. Unfortunately, most of case studies in this field are oriented on the large companies and firms with small vehicle fleet are not considered. Herein, we present a case study based on real data from a small company operating in Kraków, Poland. The main aim was to calculate delivery routes for selected dates using Clarke-Wright savings algorithm and then to compare the calculation results with real routes that were realized during the same dates. Such analysis woke up the discussion, whether it makes sense to implement optimization algorithms for small-size problems.

KEY WORDS

Vehicle routing problem; Clarke-Wright savings algorithm; small vehicle fleet

1. INTRODUCTION

Transport of goods is a very important element of economic life on all levels: local, city, region, country, and international. These activities incur large expenses. Efficient management of distribution network and vehicle fleet done by transport companies could reduce these costs not only on the local level of firms, but also on the level of the whole country. According to Eurostat, in 2015 approximately 24.3 % of national and only 12.6 % of international transport were empty runs [1]. Efficient fleet management is therefore critical.

It is difficult to realize good management of distribution network without efficient usage of the vehicle fleet in the company. Vehicle equipment with modern control and assistance systems helps drivers to calculate optimal routes and, thereby, minimises the empty runs. Simultaneously, there are computer software packages, which allow to optimize distribution management as well as vehicle fleet management based on routing models. The introduction of such optimization approaches in the logistics processes was reported to brings average savings reaching even 20% [2].

1.1 Freight transport in cities

Problems of freight transport are especially important and difficult in large cities and agglomerations. That is why they are pointed out as a specific research area in the transport field. On the one hand, as the economic and administrative centers, they concentrate the demand for goods in a limited area and, therefore, cumulate all the inconveniences of transport activities there, which provide to such challenges as congestions and air pollution [3]. On the other hand, however, the concentration of loads, customers, carriers and infrastructure elements gives an opportunity to influence efficiently on these components of the transport system by using rationally selected means.

Transport of goods in cities has a great impact on economy, quality of life, accessibility and attractiveness of the local community. Much more attention was being paid to these issues during the last decades. Also it must be mentioned that transport of goods is one of the main factors contributing to the development of the most economic and social activities taking place in urban areas [4]. This is related to the supply of shops and working and leisure places as well as to the waste management.

In Poland, vast majority of cargo is transported by roads: in 2015, total cargo transported reached 1 803 818 thousand tonnes, out of which 1 505 719 thousand tonnes (83.5%) were transported by roads, 224 320 thousand tonnes (12.4%) by rail, 54 850 thousand tonnes (3.0%) by pipelines, 38 (0.002%) by air, and 18 891 (1.0%) by water. The overall percentage of freight transport by road has remained essentially unchanged since 2006 (see Figure 1) [5].

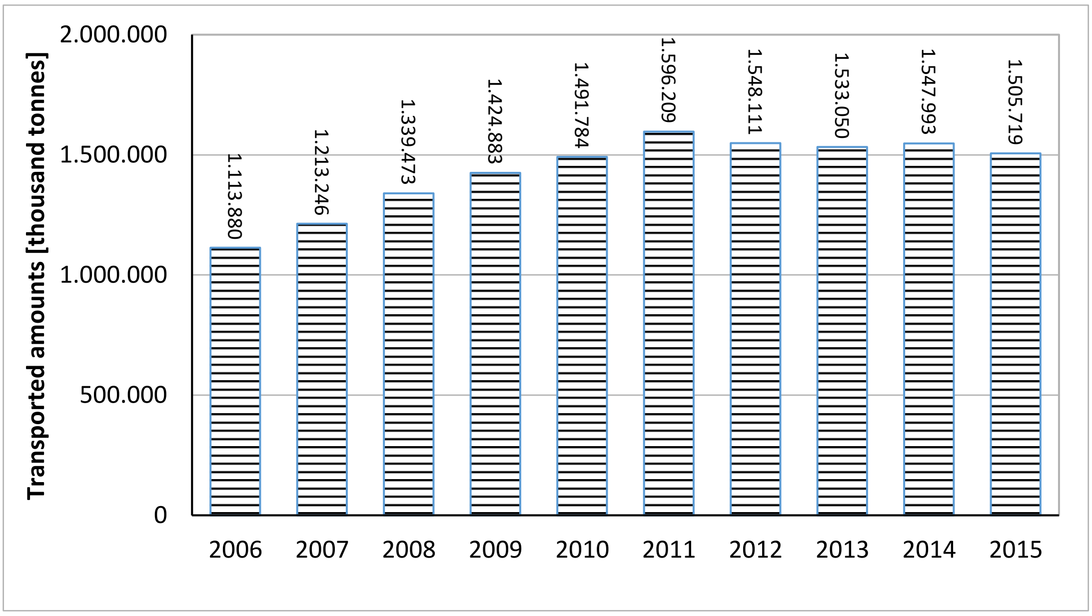

Figure 1 – Cargo road transport in Poland, 2006-2015.
Source: own work based on data from the Central Statistical Office.

1.2 City logistics

City logistics includes all activities, which optimize the flows of goods, people, and information within a city and its suburbs. Transport companies are under the pressure to increase service levels while simultaneously reduce costs. Transport demand is increasing together with the growth of urban population, which leads to steady increase of the traffic. Carriers, suppliers, and regular users of the infrastructure are looking for opportunities to save time and money. In such situation, new technologies start to play key role in the process of transport organization. Modern equipment used in vehicles, such as the navigation system, can allow a driver to be constantly updated about traffic situation and thus optimise the routes. In addition, integrated technologies of telecommunication can solve many problems of the freight transport. Also, it must be mentioned that the supply chain management starts to be an important component to introduce the concept of city logistics [6].

City logistics can be divided into three main functional areas: an organizational area with the task of determination of the course of logistical processes, a technical area related to the usage of vehicle fleet and technical equipment in urban subsystems, and economic area aiming at reduction of expenses connected with the implementation of the logistics processes.

2. PROBLEM DESCRIPTION

For the case study was selected a small company, which deals mainly with sale and delivery of different office goods for enterprises situated in the city of Kraków, Poland. The company operates from Monday till Friday during normal business hours, but late deliveries are occasionally occurring. The office goods are all items required for an office work, starting from paper and pens, through computer accessories and consumables, to small cafeteria food items, hygiene articles and cleaning products. Share of different items delivered by the company is provided in Table 1, with the division into the delivered masses and volumes.

Table 1 – Amount and share of different group of goods.

Group	[kg]	%	[m^3]	%
Office supplies	602,4	62,2	1,9	47,1
Chemical articles	63,3	6,5	0,7	17,6
Food products	253,7	26,2	1,1	28,6
Other	49,5	5,1	0,3	6,7
Sum	968,9	100	4,0	100

Source: Authors.

Logistics process of a client service starts with an acceptance of the order. Company serves daily around 40 orders, which are all gathered until 17:00 of previous day. The main tasks on this step for company manager is to understand all needs of clients and to check the availability of all positions in the warehouse. If any items are out of local stock, the manager sends requests to the main suppliers by 17:00, which guarantee early morning delivery to a local warehouse. The second step takes place directly in the warehouse, where goods for each order are completed and packed up as one unit. This element of the logistics process is finished around 10:00. At the same time, fleet manager organises the third step: determination of delivery routes. When this phase is ready, goods are loaded in vehicles and each driver starts the deliveries on previously established routes. The fourth step – delivery process itself – starts between 10.30 and 11:00 and takes 3-4 hours, depending on route. When delivery is finished, drivers return vehicles to company headquarters.

For the operations process, route planning is a component, which could be optimized. Presently, this process is done half-manually. Since the company operates mainly in Kraków and its suburbs, the area was semi-arbitrarily divided into three main zones: a green zone comprising southern part of Kraków, a yellow zone comprising north-western part of the city, and a blue zone that covers north-eastern part of Kraków. The division of the city into three parts was partially dictated by the number of available vehicles, which are only three. They are homogenous – each has load capacity 930-1000 kg and body volume 4 m^3. Therefore, the first phase of route planning is to assign all clients to one of above mentioned cluster. On the second and final step, fleet manager, based on his personal experience, determines a sequence of the visited clients in each zone. Typically, the vehicles travel approximately 30 000 km annually.

For the purposes of this case study, three typical working days were chosen for calculation and analysis: Tuesday (18.11.2016), Wednesday (19.11.2016), and Thursday (20.11.2016). For each day, the following information were gathered: names, locations (addresses) and demands of all clients served (masses and volumes of deliveries), as well as data concerning real routes created by fleet manager.

3. METHODOLOGY

The Vehicle Routing Problem (VRP) is one of the oldest and most difficult problems and widely discussed in the optimization theory [7]. Its aim is to determine optimal routes, which start and end in a certain depot, for a certain number of vehicles, which task is to serve an amount of customers with known demands located at different points, taking into account most often such constraints as vehicle capacity and route length. It is also called the Classical Vehicle Routing Problem [8]. The optimization criterion for such problems is normally the total cost of transport (expressed in terms of distance, price, or time).

As it was mentioned above, the Classic VRP is often defined under such restrictions as vehicle load capacity and route length. If only first restriction is presented, the problem is named CVRP. Future development and adaptation of the VRP depend on concrete aims of model application and are based on adding necessary restrictions, for example, time window constrains (VRPTW) or constrains concerning amount of depots (MDVRP) [9][10]. For the presented case study the Classic VRP was used with small changes in its typical constraints: (1) load capacity was considered together with body volume; (2) amount of served clients per route or amount of possible routes were taken into account instead of route length.

There are two general approaches to solving the VRP: exact and heuristic algorithms. The first type of algorithms generates an optimal solution for initial data. The main disadvantage here is so that the VRP is non-deterministic polynomial-time hard (NP-hard), which could result a large amount of iterations and, consequently, quite long calculation time. Heuristics have normally a reasonable amount of iterations and, therefore, much shorter time to get the final outcomes in comparison with exact algorithms. The main minus of these two algorithms is that they do not return the optimum solutions, but solutions that are better than initial one. For the reason of iteration amount, the second approach was chosen to make the case study calculation.

Regarding the vehicle fleets, the Classic VRP has no lower or upper limits for the number of vehicles, which can be involved in the calculation process. Heuristics can be even applied to plan a route for one vehicle, because the classic initial solution assumes that each client is served by separate individual route. As mentioned previously, most of the reported case studies are based on large vehicle fleets, reaching even 26,000 vehicles [11][12]. Such approach is used because it is much easier to describe and to present results and effects of the proposed model implementation. On the other hand, there is no case studies, which aim was to confirm advantages or disadvantages to apply the VRP for companies with small vehicle fleet.

For the case study, the most famous heuristic for route constructions was used – the savings algorithm proposed by Clarke and Wright in 1964 [13]. Its concept is based on saving, which estimates how cost is reduced if two clients are served one-by-one in the same route (Figure 2, scheme 2) instead of in two separate routes (Figure 2, scheme 1) [14]. It must be mentioned that above-assumed constraints for the considered case study do not make any barriers to use Clarke-Wright savings algoritm in its original form.

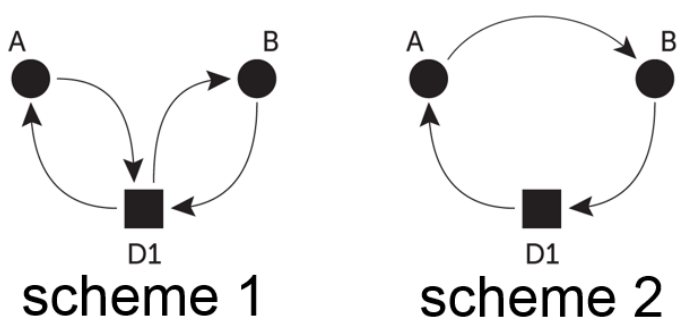

Figure 2 –The savings concept.
Source: Authors.

To make the necessary analysis for the case study, two types of savings algorithm were calculated:

1. sequential savings algorithm;

2. parallel savings algorithm.

The first type of savings algorithm requires building of a route until it satisfies the required conditions and any imposed restrictions are not exceeded. Only when further construction of the considered route is impossible, the new one is stared to build. In such situation, the restriction concerning a maximal amount of served clients per route must be fulfilled. The parallel savings algorithm, in its turn, allows to build few routes in the same time. That is why, within the scope of the case study calculation, it is important to take into account the number of possible routes, which is restricted to three because of company's vehicle fleet. Real routes planned by fleet manager is assumed as an initial solution.

The initial data required for savings algorithm is information concerning clients, which need to be served, and vehicle fleet, which is owned by the company and is available to realize orders. The data about customers includes their number, locations, and demand for office goods expressed in both mass and volume units. The information concerning vehicle fleet consists of load capacities and body volumes for each available vehicle, which in the studied case are the same.

Based on client locations as well as depot location, time and distance matrices were created by using the Google Distance Matrix API [15]. This service allows to collected information about the shortest travel times between given points while considering the actual traffic situation in the road network. To make the calculation closer to real conditions, information was gathered between 12:00 and 13:00 for the days taken for the case study. The time to serve one client was assumed to be 3 minutes.

4. RESULTS

The main aim of the case study was to calculate delivery routes for the selected orders using the chosen heuristic methodology with established restrictions and then to compare the calculation results with real routes realized by the company vehicles.

Table 2 – Masses of transported office goods for calculated routes (expressed in kilograms).

Sequential savings algorithm					Parallel savings algorithm				
Routes	18.11.2016	19.11.2016	20.11.2016	Sum	Routes	18.11.2016	19.11.2016	20.11.2016	Sum
R1	250.6	266.1	248.6	765.3	R1	253.5	148	162.1	563.6
R2	718	261.9	330.1	1310	R2	576	311.1	347.6	1234.7
R3	367.6	328.8	135.2	831.6	R3	506.7	397.7	204.2	1108.6
Sum	1336.2	856.8	713.9	2906.9	Sum	1336.2	856.8	713.9	2906.9

Source: Authors.

Table 3 – Masses of transported office goods for real routes (expressed in kilograms).

Routes	18.11.2016	19.11.2016	20.11.2016	Sum
R1	454.1	255	162.1	871.2
R2	440	337.1	341.6	1118.7
R3	442.1	264.6	210.3	917
Sum	1336.2	856.7	714	2906.9

Source: Authors.

In the beginning, it is necessary to pay attention on the restrictions of model and their satisfaction during the calculation process. Here there are two aspects, which must be pointed out. In the first place, it must be mentioned that constrains of load capacity and body volume did not play any role, because there is no route, which reached even one of the two set limits during calculation - maximal transported mass was only 75% of the load capacity (see Table 2). At the same time it must be pointed out that the difference in the load capacity usages for the same day could achieve more than 45%. It is quite a lot in contrast to the real routes, where such values are not higher than 18% (see Table 3). This fact says that delivery zones of the company create together a scheme, which distributes load equally.

The second focus concerning the restrictions is the number of served customers per route. Assignment of clients to pre-defined delivery zones described above is the reason for unequal number of customers served by each lorry (see Table 4). The same situation can be seen for routes calculated by using parallel savings algorithm (see Table 5). However, application of sequential savings algorithm, the delivery zones restriction was removed and the number of clients served was more similar for every delivery vehicle.

Table 4 – Number of served clients for real routes.

Routes	18.11.2016	19.11.2016	20.11.2016	Sum
R1	12	13	13	38
R2	16	15	12	43
R3	13	10	14	37
Sum	41	38	39	118

Source: Authors.

Table 5 – Number of served clients for calculated routes.

Sequential savings algorithm					Parallel savings algorithm				
Routes	18.11.2016	19.11.2016	20.11.2016	Sum	Routes	18.11.2016	19.11.2016	20.11.2016	Sum
R1	13	12	13	38	R1	13	9	13	35
R2	14	13	13	40	R2	12	16	13	41
R3	14	13	13	40	R3	16	13	13	42
Sum	41	38	39	118	Sum	41	38	39	118

Source: Authors.

Two optimization criteria of obtained solutions, which were considered within the scope of the case study, are route times and lengths. These characteristics are compared with the initial solution to calculate whether there implementation of the heuristic approach would be beneficial. For the described case study, real routes constructed by fleet manager were assumed the initial solution. To calculate the criteria for real routes, sequences of customers on these routes were taken from the company and time to serve one client as well as time and distance matrices were used obtained from the savings algorithms.

Tables 6 and 7 show route times both for initial and obtained solutions. As the first outcome, it must be pointed out that the total time of all routes for considered days is smaller and thus better for the applied models than for initial solution. However, when compared each day separately, it becomes evident that the selected approaches did not always return better solution: total time for 18.11.2016 was shortest for the real routes. The second outcome from the analysis shows very low improvement rate of only 2.5% between the proposed and initial solutions.

Table 6 – Time of calculated routes (expressed in minutes).

Sequential savings algorithm					Parallel savings algorithm				
Route	18.11.2016	19.11.2016	20.11.2016	Sum	Route	18.11.2016	19.11.2016	20.11.2016	Sum
R1	153	151	185	489	R1	141	124	164	429
R2	130	147	128	405	R2	109	168	134	411
R3	184	148	136	468	R3	221	135	140	496
Sum	467	446	449	1362	Sum	471	427	438	1336

Source: Authors.

Table 7 – Time of real routes (expressed in minutes).

Route	18.11.2016	19.11.2016	20.11.2016	Sum
R1	133	161	173	467
R2	180	160	127	467
R3	143	127	164	434
Sum	456	449	464	1368

Source: Authors.

Upon optimising the routes by the criterion of driving distance, the savings of using the results from the simulations were 6.2% and 9.7% for the sequential and parallel algorithms, respectively. The real data and simulation results are shown in Tables 8 and 9.

Table 8 – Length of calculated routes (expressed in kilometres).

Sequential savings algorithm					Parallel savings algorithm				
Route	18.11.2016	19.11.2016	20.11.2016	Sum	Route	18.11.2016	19.11.2016	20.11.2016	Sum
R1	56.3	56.7	75.1	188.1	R1	49.3	42.2	70.5	162
R2	36.1	70	37.2	143.3	R2	34.5	74.2	37	145.7
R3	80.7	46.8	45.5	173	R3	86.4	45.8	45.7	177.9
Sum	173.1	173.5	157.8	504.4	Sum	170.2	162.2	153.2	485.6

Source: Authors.

Table 9 – Length of real routes (expressed in kilometres).

Route	18.11.2016	19.11.2016	20.11.2016	Sum
R1	47.7	73.4	89.4	210.5
R2	72.3	60.5	35.7	168.5
R3	55.6	46.6	56.4	158.6
Sum	175.6	180.5	181.5	537.6

Source: Authors.

5. DISCUSSION

The main benefit from the implementation of selected approaches could be directly calculated using the information about changes in optimization criteria – route time and length. These criteria produce savings, which arise from their reduction. In addition to this aspect, there is also transportation work of vehicle fleet, which could be expressed in tonnes and tonnes-kilometres. So far as the amount of transported goods in tonnes for selected days was not changed, only the second type of transportation work must be considered. The Table 10 presents a summary of optimization criteria and transportation work together with their relations to the initial solution. On the one hand, as it was discussed above, there is the reduction of route time and length for considered days, which cuts the costs. On the other hand, transportation work was increased for both heuristic solutions and, therefore, it provided to the growth of expenses. This is due to the fact that trucks on real routes visited clients with largest demand first. Savings algorithms did not pay any attention on this factor.

Table 10 – Summary of route optimization criteria and transportation work.

Method of route planning	[km]		[min]		[tkm]	
	Sum	%	Sum	%	Sum	%
Real	537.7		1368		62.1	
Sequential savings algorithms	504.3	6.21	1362	0.44	76.5	-23.19
Parallel savings algorithms	485.6	9.69	1336	2.34	81.7	-31.56

Source: Authors.

According to the company's information, the cost to drive 100 km and the cost of 1 driver's working hour are 38 PLN[1] and 10 PLN, respectively. To understand profits from the reduction of route length and time, savings were calculated for each approach and presents in Tables 11 and 12.

Table 11 – Profits extracted from the reduction of route length.

Savings algorithms	[km]	Difference with initial solution	PLN / 100 km	Profit
Sequential	504.3	33.4	38	12.69
Parallel	485.6	52.1	38	19.80

Source: Authors.

Table 12 – Profits extracted from the reduction of route time.

Savings algorithms	[min]	Difference with initial solution	PLN / 60 min	Profit
Sequential	1362	6	10	1.00
Parallel	1336	32	10	5.33

Source: Authors.

To assess the loss arising from the increase of transportation work, it was assumed that the maximal fuel consumption is up by 1 litre per 1 tonne, which is transported for 100 km. 4.7 PLN per 1 litre was taken as the maximum possible price of gasoline. The Table 13 shows the results of loss calculation for both savings algorithms.

Table 13 – Losses arising from the growth of transportation work.

Savings algorithms	[tkm]	Difference with initial solution	PLN / 100 tkm	Loss
Sequential	76.5	-14.4	4.7	0.68
Parallel	81.7	-19.6	4.7	0.92

Source: Authors.

The final step of benefit assessment is put all profits and losses together.

Table 14 – Final balance of profits and losses.

Savings algorithms	Profit				Loss		Balance
	[km]	[PLN]	[hours]	[PLN]	[100 tkm]	[PLN]	[PLN]
Sequential	33.4	12.69	0.10	1.00	0.14	0.68	13.02
Parallel	52.1	19.80	0.53	5.33	0.20	0.92	24.21

Source: Authors.

The Table 14 shows the results of balance between profits and losses for the considered case study. Both approaches present a positive benefit of their implementation. However, the parallel savings algorithm seems to be more profitable for such kind of goods transport.

6. CONCLUSIONS

This paper pointed out the problem of vehicle fleet management for small-size companies. The main aim was to analyse and to estimate an opportunity, whether the implementation of optimization approaches for route planning could return any benefits for such kind of firms. The case study based on real data from a small Polish company was calculated and showed quite positive outcomes. On the one hand, the improvement rate of route times was only 2.5% between the best proposed and initial solutions. On the other hand, the simulations showed much better results for the criterion of driving distance: there were 6.2% and 9.7% for the sequential and parallel savings algorithms, respectively.

[1] PLN – Polish zloty, Poland's national currency; 1 euro is equal around 4,23 PLN.

In the end of the article, an attempt to make financial assessment of calculated scenarios within the scope of the case study was done. The best profit was achieved by the parallel savings algorithm and was about 8 PLN for one working day of vehicle fleet.

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LEAN AND GREEN LOGISTICS: CONCEPT AND ITS IMPLEMENTATION IN SLOVENIAN COMPANIES

ABSTRACT

The adoption of lean and green logistics management practices represents an opportunity for Slovenian companies to competently respond to the escalating expectation of a global logistics market and achieving environmental performance profitably. In this paper, we present some results from a wider survey analysis based on the implementation of lean and green logistics inside Slovenian companies. Although similar analysis on lean and green do exist, only a few of them focus on the field of logistics as such and due to our knowledge, none of them have been performed in Slovenia. Key findings indicate that the surveyed Slovenian companies obtain more certificates/recognitions concerning lean than green, most of them prove their leanness or greenness namely by ISO standards and finally that the surveyed companies highly implement lean and green concepts within their companies.

KEY WORDS

logistics; lean; green; sustainable; case study

1. INTRODUCTION

Well-functioning logistics system to support all operational units is one of most important parts of today's businesses, particularly their effectiveness and competitiveness. Logistics activities are often identified with a high degree of manual control and human resource management of, which in turn greatly affects the execution of operations. The importance of maintaining low costs in a bid to maintain the competitiveness is of substantial significance; consequently, companies are forced to examine every part of their organization for potential improvements. It is therefore not surprising that in logistics there are many initiatives for possible improvements. We also have to acknowledge that global logistics costs were estimated at USD 9,177 billion in 2015 [1], so every failure, inconsistency or any kind of waste represents great costs.

One of modern companies' challenges besides eliminating non-value added activities in logistics processes is also assuring processes to be sustainable. The environmental aspect and ecological consciousness have increased drastically over the last two to three decades, especially in the developed economies. This has been shown by BearingPoint research [2], where 35% of global companies state that they have incorporated a green supply chain policy in the company's vision. The impact of logistics management within supply chains on environment is vast due to occupying land for transportation and storage, such as transportation access, consuming fuel, transport and storage equipment, generating wastes, producing loss and waste due to distribution processing, consuming material and the like. According to statistics of the "Internationale Energieagentur" almost one third of Carbone Dioxide (CO2) emissions are caused by transport activities which are also are closely related to logistics activities [3].

Given the facts, we have decided to present some survey results, which are part of a wider research concerning lean and green logistics concepts (see [4,5]) mainly to analyze the Slovenian companies respondent's familiarity with the terms lean logistics and green logistics and their opinion on the implementation of both concepts within their own companies. Furthermore, the attempt has been made to highlight which certificates or recognitions from both areas Slovenia's companies hold.

2. LEAN AND GREEN LOGISTICS

Not long ago industrials also started to put their focus on logistics non-value-added activities. From here on the new concept – lean logistics – appeared. Ref. [6] defines lean logistics as logistical dimension of lean manufacturing. Its primary objective is to deliver the right materials to the right locations, in the right quantities, and in the right presentation; its second to do all this efficiently. The same author continues that lean logistics could be and has been the concept applied to services, but they have focused on the manufacturing as a domain whereas it is rich in logistics concepts, approaches and techniques which can be addressed as lean because either they are part of the Toyota Production System or they were adapted from it for application in different contexts. According to Jones, Hines & Rich [7] lean logistics also takes its fundamental philosophy from the Toyota production system (TPS) and is based around extended TPS right along supply chains from customers right back to raw material extraction.

Since lean logistics systems brought logistics to a new level of efficiency, the latter enables faster delivery of goods to costumers which in contrast surely affects our environment. It is therefore an inevitable global trend to develop and adopt green logistics management in every sphere of national industry, especially in the production and transport sectors [8, 9]. During 1990s, environmentalism as the practice of responding to environmental issues in a socially responsible manner has become increasingly important. It has been characterized as one of the most significant force shaping the economy [10].

The fundamentals of greening as a competitive initiative have also been discussed by [11]. Their basic reasoning was that investments in greening can be resource saving, waste eliminating and productivity improving. They state that green initiatives could lower not only the environmental impact of a business but also raise efficiency, possibly creating major competitive advantages in innovation and operations. Skjoett-Larsen [12] wrote a foresight work upon European companies facing new challenges in the next millennium one of which is also green logistics. The author stipulates that within the next five to ten years green supply chains will increasingly dominate the theory and practice in the logistics area. Similar was also indicated by [13] who compared US and non US (Canadian and West European) firms with respect to selected propositions regarding environmental issues, practices and strategies. They've indicated that both firms tend to share similar perspectives and practices regarding the management of environmental logistics and that green concerns will broaden the scope of logistics as well as influence the way that logisticians do their jobs. Moreover, with green logistics a completely new sub-sector of logistics appeared, using new models and tools as green logistics management. The trend is therefore to switch from traditional logistics to green logistics [14].

As concern for the environment is at this time crucial we also have to take into account lean logistics which aim is to satisfy customers' needs at the right time and at the right place with at least waste as possible. Modern lean logistics therefore uses sophisticated transport and manipulation equipment, modern technologies on logistics terminals and warehouses to secure lean supply chains. Combining all those elements and developing environmentally – friendly logistics is an issue which has been very topical in recent years.

Additionally, researchers state that lean companies, which include green practices, achieve better lean results than companies which do not. Their findings indicate that only when both concepts are implemented simultaneously, they can disclose their full potential and make a greater contribution than if they were implemented separately. As such Ref. [15], emphasize that while lean practices can lead to positive environmental contributions, conversely environmental practices often lead to improved lean practices.

3. METHODOLOGY

Our sample size constitutes out of 104 completed questionnaires and required special attention to formulate appropriate conclusions. The analysis was conducted through 4 phases: (1) theoretical overview where conceptual and descriptive methods were used, (2) the empirical phase features an empirical methodology which employs quantitative approaches to collecting primary data for our database and a statistical analysis. Our survey was divided into two parts, where the first set consisted of 7 questions related to demographic issues. Second part consisted of 7 questions which were divided by individual areas of intralogistics, for which it was necessary to evaluate two aspects: lean logistics and green logistics aspect. This means that individual company evaluated the importance of every part of intralogistics area. For the purpose of this paper we only focused on the first part, which also contained two questions regarding the familiarity with both of terms, their implementation in companies and also certificate or recognition connected to lean or green which companies could hold. (3) Theory matching between theory findings and statistical analysis findings; and at last (4) theoretical conclusions and applications.

4. ANALYSIS AND RESULTS

The following sub-sections present and discuss results.

4.1 Analysis of the demographic results

Table 1 presents demographic data connected with respondents and companies in which respondents are employed.

Table 1 – Demographic data related to companies, in which respondents are employed

Variables	**Replies**	**Percent (%)**
Company activity		
Service	81	38.21
Manufacturing	**97**	**45.75**
Trade	34	16.04
Company size		
a) Up to 10 employees (micro enterprise)	**76**	**35.85**
b) Small (11-50 employees)	63	29.72
c) Medium (51-250 employees)	37	17.45
d) Large (more than 251 employees)	36	16.98
Company as part of an international corporation		
a) Yes	41	19.43
b) No	**170**	**80.57**

A detailed examination shows that on the question »what is the main activity of the company according to the standard classification of activities« answered 212 respondents. The results indicate that most respondents come from manufacturing activities (45.75%), services (38.21%) and least from trade (16.04%). Concerning question about company size reveals that most of the respondents come from micro enterprises (35.85%) and least from the category of large companies (16.98%). 80.57% of companies, participating in our survey state they are not part of an international corporation.

Table 2 refers to data concerning survey respondents.

Table 2 – Demographic data related to respondents

Variables	**Replies**	**Percent (%)**
Working position		
a) Senior management	70	**35.90**
b) Head of Logistics	40	20.51
c) Head of Purchasing	8	4.10
d) Head of Production	5	2.56
e) Head of Warehouse	5	2.56
f) Technical Assistant in logistics	13	6.67
g) Head of processes/projects, which also deals with logistics	13	6.67
h) None of these	41	21.03
Gender		
a) Male	**113**	**58.85**
b) Female	79	41.15
Highest level of education completed		
a) High School or less	39	20.21
b) College	50	25.91
c) High Technical School	46	23.83
d) University degree or more	**58**	30.05

We have included senior managers (35.90%), heads of logistics (20, 51%), heads of purchasing (4.10%), heads of production (2.56%), heads of warehouse (2.56%), technical assistants in logistics (6.67%) and heads of processes/projects, which also deal with logistics (6,67%). 21.03% of respondents carry out other work.

Respondents' average age is 35 years. In survey participated 113 men (58.85%) and 79 (41.15%) women. For the question concerning "completed education" largely participated in the survey those with a university degree or more (30.05%), followed by those with completed high school (25.91%), higher professional education (23.83%) and the last, the ones with high school or less (20.21%).

The next question was connected to certificates or recognition concerning lean and green management which companies could hold. There were more than one answer possible (see *Figure 1*).

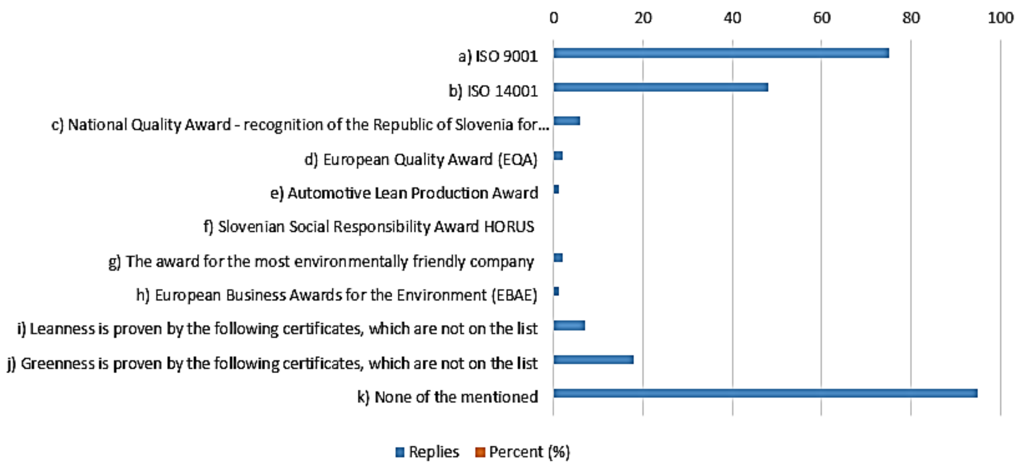

Figure 1 – Data related to certificate or recognition obtained by surveyed companies

Table shows that 255 respondents answered this question out of which most of the companies holds ISO 9001 (29.41%) and ISO 14001 (18.82%). 7.06% of respondents claim that they prove greenness by the following certificates/recognitions, which are not on the list and 2.75% claim that they prove leanness by the following certificates/recognitions, which are not on the list. 2.35% held the National award for quality - the recognition of the Republic of Slovenia for business excellence, 0.78% held the European Quality Award (EQA), and the prize for the most environmentally friendly company. 0, 39% of the companies held the Automotive Lean Production Award and European Business Award for the Environment (EBAE) and no one holds the Slovenian award for social responsibility HORUS.

Figure 2 presents data related to the respondent's opinion with regard to the implementation of lean and green concepts within their companies.

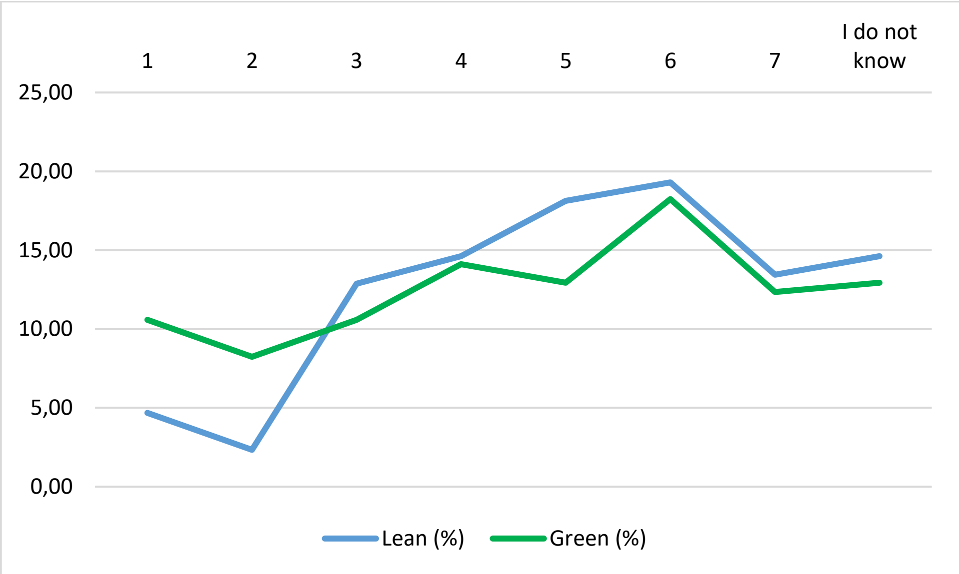

Figure 2 – Data related to the respondent's opinion with regard to the implementation of a lean or green concept within their own company

In connection to *Figure 2*, *Table 3* present additional measures related to the respondent's opinion with regard to the implementation of a lean or green concept within their own company.

Table 3 – Measures related to the respondent's opinion with regard to the implementation of a lean or green concept within their own company

Measures	**Lean**	**Green**
Mean	5.24	4.79
Standard Dev.	1.91	2.20
Variance	3.63	4.83

The results show that for the opinion on the implementation of lean concept in their own company, the respondents on the 7 point Likert scale usually rated very highly, with level 6 (19.30%) and 5 (18.13%), but at least with grade 2 (2.34 %) and 1 (4.68%). The answer "I do not know" was given by 14.62% of the respondents. The arithmetic mean of the responses is 5.24.

The results show that for the opinion on the implementation of green concept in their own company, the respondents rate on 7 point Likert scale usually as very high, with a rate of 6 (18.24%) and 4 (14.12%), but at least with grade 2 (8.24%), 1 and 3 (10.59%) . The answer "I do not know" has given 12.94% of the respondents. The arithmetic mean of the responses is 4.79.

5. CONCLUSIONS

Survey findings indicate that most respondents come from manufacturing activities (45.75%) and most of the respondents from micro enterprises (35.85%). The first results are logical since the area of manufacturing is one of most developed and also largely represented Slovenia's sectors, also the majority of Slovenia's companies are micro companies.

Approximately 80% of the surveyed companies are not part of an international corporation which provides an insight on a national level. Most of our survey participants work in top management (senior managers and heads of logistics), are highly educated and are on average 35 years old. There were also almost equal parts of female and male participants participating in the survey.

In the analysis we were interested in any certificates or recognition regarding lean and green paradigms, which Slovenian companies could hold. The results indicate that most of the companies hold ISO 9001 (29.41%) and ISO 14001 (18.82%) standards. Approximately 7% and 3% of respondents claim that they prove greenness/leanness by the following certificates/recognitions, which are not on the list. Approximately 2% hold the National award for quality - the recognition of the Republic of Slovenia for business excellence, less than 1% hold EQA, and the prize for the most environmentally friendly company. Only a few hold the Automotive Lean Production Award and EBAE and no one holds the Slovenian award for social responsibility HORUS.

From this on we conclude that the surveyed Slovenian companies obtain more certificates/recognitions concerning lean than green, also most of them prove their leanness/greenness by the mentioned ISO standards. The future research question remains which are the other certificates or recognitions with which they prove leanness/greenness within their own companies. We were also curious about the respondents' opinion in regard to the implementation of lean and green concepts within their companies. The results show that on the opinion on the implementation of lean concept in their own company, the respondents on the 7 point Likert scale rated very highly (mean 5.24). On the implementation of green concept in their own company, the respondents also rated very highly (mean 4.79). From this we conclude that surveyed Slovenian companies state that they mainly implement lean and green concepts within their companies. Our findings may be useful to suggest some missing areas or unresolved issues in our knowledge of lean logistics and green logistics. Also, in any business area, a new thought process will be embraced by many new practitioners who will put their own way of thinking on our survey results.

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AN INTERNATIONAL REVIEW OF ROUNDABOUT GEOMETRY, TRAFFIC EFFICIENCY, SAFETY, MULTI-CRITERIA AND MULTI-OBJECTIVE OPTIMIZATION MODELLING

ABSTRACT

Studying and implementing state-of-the-art roundabouts requires optimizing traffic (operational) efficiency (TE) and traffic safety (TS) while considering geometric factors, traffic characteristics and local constraints. Most existing simulation-based optimization models do not simultaneously optimize all these factors. Here we describe and analyse a recent overview of state-of-the-art roundabout geometry, TE, TS, multi-criteria (MCDM) and multi-objective (MOO) optimization models. It also gives a brief literature overview on roundabout design, TE and TS in Croatia. This review findings suggest that it is necessary to develop a MOO model that can simultaneously optimize a set of various design and traffic parameters according to given constraints. Also needed is an MCDM model that can quantify how much certain geometric elements of roundabouts affect TE and TS parameters, and that allows optimization of those elements during design and modeling. Such a next-generation model should take better account of local conditions and traffic dynamics than existing simulation models do. Development and validation of such methods would be useful to better understand the TE and TS parameters for Croatian conditions or other. These models with its criteria weighting structure may help policy makers, civil and traffic road engineers to select appropriate roundabout design for implementation.

KEY WORDS

roundabout geometry design; traffic (operational) efficiency; traffic safety; multi-criteria optimization; multi-objective optimization

1. INTRODUCTION

The popularity of roundabouts around the world has driven substantial efforts to optimize their geometry planning and modelling design. Studies of how geometric elements, traffic flow movements, driver behaviour and other factors influence roundabout traffic (operational) efficiency (TE) and traffic safety (TS) have led to the development of numerous simulation-based computational models. This models use empirical and gap-acceptance models to determine TE (mainly focused on capacity and delay) and “before-after” statistical models to determine TS. Recent studies explore advances in traffic accident prediction (i.e. determining the level of TS) and in multicriteria decision making (MCDM), which can accurately optimize several parameters and identify the most influential factors in a given design context. Other studies began to implement the power of multi-objective optimization (MOO) models that can simultaneously optimize a set of various design and traffic parameters per given constraints. What would be useful is a MOO model that can simultaneously optimize a set of various design and traffic parameters according to given constraints. Also needed is an MCDM model that can quantify how much certain geometric elements of roundabouts affect TE and TS parameters, and that allows optimization of those elements during design and modeling. Such a next-generation model should take better account of local conditions and traffic dynamics than existing simulation models do. Although some of these models are validated and well established in design engineering processes, they often provide inadequate solutions because they are not well suited to environments with certain traffic regulations or driver behaviour, or they are based on limited or poorly representative traffic and driver data.

As a step in this direction, the present study aimed to describe and analyse the state-of-the-art roundabout geometry, TE, TS, MCDM and MOO design optimization. It also gives a brief literature overview on roundabout design, TE and TS in Croatia.

The first section summarizes previous studies on roundabout geometry, TE, and TS worldwide and in Croatia. The second section extracts from the literature overview the MCDM and MOO procedures and their application to transport-related and roundabout problems. In the last section, the discussion and conclusion are drawn.

2. ROUNDABOUTS

2.1 Geometry

Numerous models for determining roundabout capacity under mixed-traffic conditions suggest that it is strongly affected by geometric elements. One such example is a microsimulation model for determining approach capacity [1], while another model suggests that approach width and entry approach width significantly affect approach capacity [2]. Several authors have developed models demonstrating the importance of, and correlations among, geometric elements, circulating traffic flow, proportion of heavy vehicles, follow-up time, and critical headway for determining roundabout capacity and delay [3,4]. Geometric elements of roundabouts also strongly influence pedestrian flows and behaviour [5].

Generally countries with updated roundabout design guidelines apply Highway Capacity Manual (HCM) models for analysing roundabout capacity [6,7]. These models consider empirical and/or gap-acceptance models, but they do not address the level of service (LOS) or TS, nor do they simultaneously optimize capacity and geometry parameters.

Studies of roundabouts in various countries, particularly of single-lane roundabouts (signalled and unsignalled) in urban areas, have shown that proper design and modelling can significantly improve operational efficiency [8–11], as well as traffic safety [12–17]. On the other hand, these and other studies [18–20] have highlighted that existing design and modelling standards are not always adequate for cases when there is a need for simultaneous optimization of geometry, TE and TS.

Geometry considerations have also proven useful for analysing driver behaviour in roundabout situations and implications for traffic safety [21,22]. These studies have adopted a variety of approaches, including video analysis to examine traffic flow movement and dispersal in and around roundabouts [23], as well as vehicle type, speed and trajectory [24]. Methods for predicting traffic accidents have been described based on geometric elements [25], sight distance [26,27], as well as traffic dynamics and driver behaviour when passing through the „potential conflict" zone of the intersection [28].

2.2 Traffic (operational) efficiency

Studies of roundabout TE, conducted primarily in Western Europe and Australia, have led to several computational mathematical models that have been integrated into various roundabout software engineering simulation tools, including ARCADY, RODEL, SIDRA, TORUS, and PTV VISSIM. These mathematical models can be classified as (1) empirical, (2) gap acceptance, and (3) microsimulation; each category has its disadvantages [20]. Empirical models use multivariate regression to examine and predict how geometric elements, circulating flows and other variables affect entry capacity. They are limited primarily by statistical and sampling constraints. Gap acceptance models are based on parameters reflecting headway between vehicles, so their power is limited by the relatively weak relationship between roundabout geometry and driver behaviour. Microsimulation models examine vehicle kinematics and interactions under real-world conditions. They allow analysis of queue length, and they can provide more accurate predictions of fuel consumption, exhaust and traffic noise. They are more flexible than the other two types of model, but they depend heavily on how accurately the model depicts vehicle–vehicle interactions. These interactions are notoriously difficult to model, even when field observations are used.

Differences among these models in how data are collected and analysed, as well as deviations between predicted and actual driver behaviour, make it difficult to identify the most suitable ones for given conditions [18,19,29]. Planners and designers should be aware of the specific limitations of these models when designing their approach [20], and the selected model(s) must be calibrated against field data or other validated models to ensure accuracy. Unfortunately this calibration step is often neglected [30]. In situations where the model is not even developed and the ideal model is in doubt, it may be advisable to analyse roundabout TE using various approaches and then compare the results in order to synthesize them into reliable conclusions. HCM models may be the most appropriate for such work [18].

2.3 Traffic safety

Traffic safety in roundabouts can be improved primarily by reducing conflict surfaces and conflict points, the number and rates of traffic accidents and speed around and inside roundabouts [18]. In practice, TS is most often measured in terms of the number of traffic accidents observed during a given period or mathematically modelled during a given simulation time frame. Several models have been developed to predict the number and types of accidents based on main roundabout geometry design elements [25,26,31].

More recent models have been developed that focus on geometric aspects of rural multi-lane roundabouts. Qin et al. [32], uses basic geometry variables in the project planning stage to develop intersection-level crash prediction models for Wisconsin highway and rural unsignallized single and multi-lane roundabouts. Those authors found that geometry and traffic demand parameters, and their interaction, strongly influence TS. A similar conclusion was reported by Kamla et al. [33], who developed an accident prediction model for highway and rural unsignallized and signallized multi-lane roundabouts using a random-parameter negative binomial approach.

2.4 Croatian experience

Croatia has more than 200 roundabouts, of which more than 60% lie within urban areas, and many of them deviate substantially from international standards for roundabout planning, design and modeling, which compromises their TE and TS. The country has no tradition of systematically monitoring capacity and other key performance indicators of roundabouts, though the government has called for the building and reconstruction of roundabouts as part of its National Traffic Safety Plan 2011-2020 [34].

Several studies have examined how geometric elements influence the capacity and safety of roundabouts in Croatia. The *in situ* work by Legac et al. [35] on 30 roundabouts in Zagreb examined relationships between main geometric elements and the numbers and types of traffic accidents, traffic flow demand and its structure, and numerous other determinants of capacity and safety. That study confirmed that unsignallized roundabouts in Croatia are safer than classical intersections, as observed in many other parts of the world [12,14,16,36]; and it showed that geometric elements strongly influence safety. That work also created a qualitative and quantitative roundabout database and a method for classifying roundabouts based on geometric elements and traffic flows. It is one of the few studies in the global literature to apply field data from roundabouts to the analysis of TE and TS.

Other authors have focused on applying roundabout models from outside Croatia to the Croatian situation. Their results suggest that imported models can work well, as long as they are calibrated for local conditions [10,37,38]. For example, Ištoka et al. [39] used neural networks to calibrate a traffic microsimulation model for two urban single-lane roundabouts in Osijek. That work analysed TE parameters as a function of traffic flow demand, predicted and measured travel time and queue length. Also working with urban single-lane roundabouts, Šurdonja et al. [40] optimized geometric elements such as inscribed circle radii, entry/exit radii, entry/exit approach width, and vehicle path trajectory, while Pilko et al. [41] examined the relationship between vehicle trajectory design speeds through the roundabout and observed vehicle speeds.

Recent studies have focused on geometry, sight-distance and vehicle speed on rural single-lane roundabouts [42,43], and various geometry design principles when designing turbo roundabouts [44]. These studies suggest the feasibility of modelling and predicting how roundabout geometry affects TE and TS in detail. The most recent national guidelines stipulate where urban and suburban single-lane roundabouts should be built, what geometry they should have, and how capacity should be calculated [45]. However, the guidelines do not indicate what models or simulation software should be used for analyzing common TE parameters. These characteristics make the country attractive for studies on developing and applying MOO and MCDM roundabout models adaptable to different local conditions.

3. MULTI-CRITERIA AND MULTI-OBJECTIVE OPTIMIZATION

3.1 Multi-criteria

MCDM involves optimizing one or several objective functions, where the objective refers to the system condition under consideration, over a defined set of solutions corresponding to the various alternatives available. The alternatives can differ in one or more attributes, known as criteria. MCDM methods are the approaches most frequently used to guide decision making in transport sciences; three examples include the preference ranking organization method for enrichment evaluation (PROMETHEE), AHP, *"višekriterijumsko kompromisno rangiranje"* (VIKOR), and the technique for order preference by similarity to ideal solution (TOPSIS) [46]. These methods are often used in combination.

The AHP method is often implemented in conjunction with fuzzy AHP (FAHP), analytic network process (ANP), and strength-weakness-opportunities-threats (SWOT) analysis. AHP has been used most often in railway transport for planning railway routes [47], and in logistics for process optimization [48]. In road transport, the AHP method has been applied most often to decisions related to planning and investing in transport infrastructure [49,50], as well as to the assessment of road safety [51]. A recent review of the AHP literature [34] indicates that although the method has been applied to nearly all types of transport problems, few studies have used it to evaluate traffic parameters or the geometry, TE and TS of roundabouts.

3.2 Multi-objective

MOO approaches are already well established and widely used in engineering [52], particularly in heuristic solution approaches [53] such as genetic algorithms and ant colony optimization algorithms, which are now widespread in civil and traffic engineering. Mathakari et al. [54] used a geometry-based multi-objective genetic algorithm to perform Pareto ranking of electrical transmission towers. Hejazi et al. [55] used MOO to develop and optimize structural passive central systems based on genetic algorithms.

MOO and genetic algorithms have also been applied to analysis of traffic flows. Vlahogianni et al. [56] described a multilayered structural optimization strategy that can help capture the spatiotemporal characteristics of traffic flow as well as identify the most appropriate neural network structure for doing so. Teklu et al. [57] devised a genetic algorithm-based approach for optimizing the duration of green signals and cycling time in an urban traffic network while taking routing into account.

Putha et al. [58] developed and compared approaches based on ant colony optimization or genetic algorithms to coordinate traffic signals under oversaturated conditions.

Several studies have also applied MOO to roundabouts. Al-Masaeid [59] developed a logit model to optimize geometric design and traffic flow dynamics, while other authors have focused on maximizing speed consistency, safety and operational efficiency [60,61].

4. DISCUSSION AND CONCLUSION

The main purpose of the study was to describe and analyse the state-of-the-art roundabout geometry, TE, TS, MCDM and MOO design optimization models. Also, here we show the recent advances in MCDM and MOO procedures that can be applied to transport-related and roundabout problems.

Studies have shown that the MCDM AHP method can be used to solve complex traffic infrastructure problems, such as the construction and analysis of roads and intersections, while taking TS into account. At the same time, the method has rarely been used to evaluate roundabout geometry and traffic parameters. MOO has been successfully applied to the optimization of roundabout geometry design, traffic flow dynamics, safety and operational efficiency. However, MOO studies have not aimed to simultaneously optimize geometry, TE and TS.

The best TE and TS models to apply to roundabouts in Croatia are unclear because relatively little work has been done on roundabout design in the country. In addition, the country has no tradition of systematically monitoring capacity and other key performance indicators of roundabouts. The most recent national guidelines stipulate where urban and suburban single-lane roundabouts should be built, what geometry they should have, and how capacity should be calculated [45]. However, the guidelines do not indicate what models or simulation software should be used for analysing TE.

Future work should compare geometric alternatives in terms of parameters related to traffic, construction, economics, and environment. In addition, future work should address the implementation of MOO models that can simultaneously optimize a set of various roundabout design and traffic parameters according to given constraints. Future work should also study the need for an MCDM model that can quantify how much certain geometric elements of roundabouts affect TE and TS parameters, and that allows optimization of those elements during design and modeling. Such a next-generation model should take better account of local conditions and traffic dynamics than existing simulation models do. These models with its criteria weighting structure may help policy makers, civil and traffic road engineers to select appropriate roundabout design for implementation.

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OPTIMISATION OF AIRPORT GROUND HANDLING LOGISTICS

ABSTRACT

This contribution describes the development of a heuristic ground handling logistics optimisation method at a regional airport. The goal was to develop a solution that would generate schedules for the ground crew services that require dynamic scheduling, e.g. with frequent rescheduling and flexible shifts. Ground crew scheduling is a complex problem as in addition to common constraints of personnel scheduling, the required equipment and skills of the crewmembers have to be considered. Additionally there are conflicting demands in assigning personnel and equipment to aircraft handling services, while there is little flexibility in the provision of these services. Staff scheduling algorithms described in literature proved to be unsuitable due to specific requirements of the airport, which required the development of a heuristic algorithm that performs task schedule optimization, personnel and equipment requirements optimization for airport ground crews. The resulting algorithm is applicable to other airports with a similar organization of ground handling services.

KEY WORDS

airport logistics; ground handling; ground crew; staff scheduling; optimisation

1. INTRODUCTION

Ground handling addresses the many service requirements of an airliner between the time it arrives at a terminal gate and the time it departs on its next flight. Speed, efficiency, and accuracy are important in ground handling services in order to minimize the turnaround time, i.e. the time during which the aircraft must remain parked at the gate [1]. Airlines are challenged by a diverse range of characteristically complex scheduling problems, such as fleet or aircraft scheduling [2–5], aircraft landing sequence scheduling [6, 7], ground crew scheduling [8], disruption management [9], and scheduling of staff training [10].

Like other service oriented companies, airports operate in a very competitive market. Passengers expect comfort, efficiency and safety, while airlines seek to reduce costs and require efficient and adaptable ground services. Airports need to generate profits while providing high quality, efficient services and optimizing their labour and equipment other costs. Airports thus face challenging optimization problems. An airport is a complex logistics system, making the analysis and optimization of processes a difficult and laborious task. Many processes are interwoven, can't be analysed or optimized independently and are typically too complex or dynamic to be optimized with an exact mathematical method.

An important part of optimization of airport operations are delays and their costs. Approximately 20% of delays are caused by airport operations [11]. According to analysis of tactical delay costs [12], the costs of delays for passenger flights is approximately 100 USD per minute, and can be transferred to the airport, depending on the contract with the airline. Delays can furthermore have a cascading effect at busy airports, influencing other flights and their take-off or landing time slots. Most of airport optimization research has been dedicated on optimisation of airport surface operations [13], and ground crew optimization has only recently gained attention. Optimization of ground crew operations is an important aspect of airport operation optimization, and its proper implementation is vital for quality, safety and security of airport services.

1.2 Problem description

The project goal was the optimisation of ground handling logistics at a regional airport with approximately 30,000 flights and 1,500,000 passengers per year. There are 25 independent parking positions, the terminal capacity is 500 passengers per hour, and there are 13 check-in counters and 2 baggage claim conveyors. Ground handling at the airport is executed by three airport service departments:

- Aircraft supply service,
- Passenger service and
- Technical service (including the Fire department).

Service departments employ staff with skills matched to one or several types of tasks. During shifts, staff with similar skills are grouped into work groups, and a work group composition does not change for the duration of the shift.

Every arrival or departure of an aircraft requires ground handling services, which are performed as a predefined series of tasks. Tasks can be performed by work groups that have appropriate skills. To simplify staff scheduling, individual skills are grouped into skills groups. Depending on their competences, every employee is assigned one or more skill groups. Employees with a skill group can therefore perform all tasks listed in this skill group.

In staff schedule development, the staff and equipment requirements for a type of task and their scheduling depends on the flight schedules and parameters of each flight, e.g. destination, air-craft type, and carrier. The tasks that required scheduling optimization are:

- Aircraft supply service: Load balancer, Supply controller, Group leader, Sorter, Baggage handling worker A and B, Tractor driver, Cleaner/Driver and Cleaner,
- Passenger service: Check-in, Gate, Transfer, Guidance, Lost and found desk,
- Technical service: Follow me driver, Bus driver, Power unit operator, Water tank driver, Aircraft towing, Flatbed operator, De-icing, Disabled people van driver, Air-start system operator and Aircraft cabin and engine blades heating operator.

Staff and equipment scheduling is performed by the heads of individual service departments, with the help of human resources (HR), which provides personnel skills and availability data and IT services, which provides the flight schedules. Schedules are prepared biweekly, and changes have to be approved at least 24h in advance, barring exceptions such as flight schedule disruptions. The scheduling process depends heavily on the experience and individual knowledge of the planners. In order to prepare schedules, planners needed to be aware of the staff requirements for every task of the day. Manually generated schedules are not optimized or adapted to the high fluctuation of service requirements between peak and off-peak times. Due to the manual nature of scheduling process, schedule development takes several days, and is not fast enough to allow quick schedule adaptation to changes in flight schedules, which occur daily.

Staff schedules are prepared according to flight plan and the service requirements which depend on aircraft type, flight type, arrival/departure carrier and destination. These parameters influence which services are required, the sequence of tasks and the manpower and equipment required for each task. The following flight attributes have been identified as the scheduling criteria types:

- Type of stopover (arrival or departure),
- Flight type (charter, scheduled or transfer),
- Aircraft type (320, CRJ, SH3 etc.),

- Carrier (9 carriers are currently using the airport),
- Destination.

For each criteria type, e.g. "Aircraft type", multiple sub criteria can be defined, i.e. the aircraft type of a particular flight can influence the requirement and parameters of different tasks, e.g. number of cargo handlers, sorters, passenger guidance attendants etc.

The main scheduling problem in the this project was the high fluctuation of staff requirements during the day, which was the cause for mismatch between manually produced schedules and actual staff requirements for certain skill groups at peak and off-peak times. The manually produced schedule did not take the peak demands into account, as the peaks are too short to warrant additional shifts, but still scheduled more staff than what the off-peak time requirements were. The schedules were thus inefficient at off-peak times and understaffed at peak times. To alleviate the peak-time problems, students were also hired part-time, but this practice was stopped by work legislation changes. The difference between the number of scheduled workers and the number of required staff is shown in Figure 1. Figure shows that while there are surplus staff working outside of peak time, there is a shortage of staff at peak times, which causes staff overload and potential errors and flight delays.

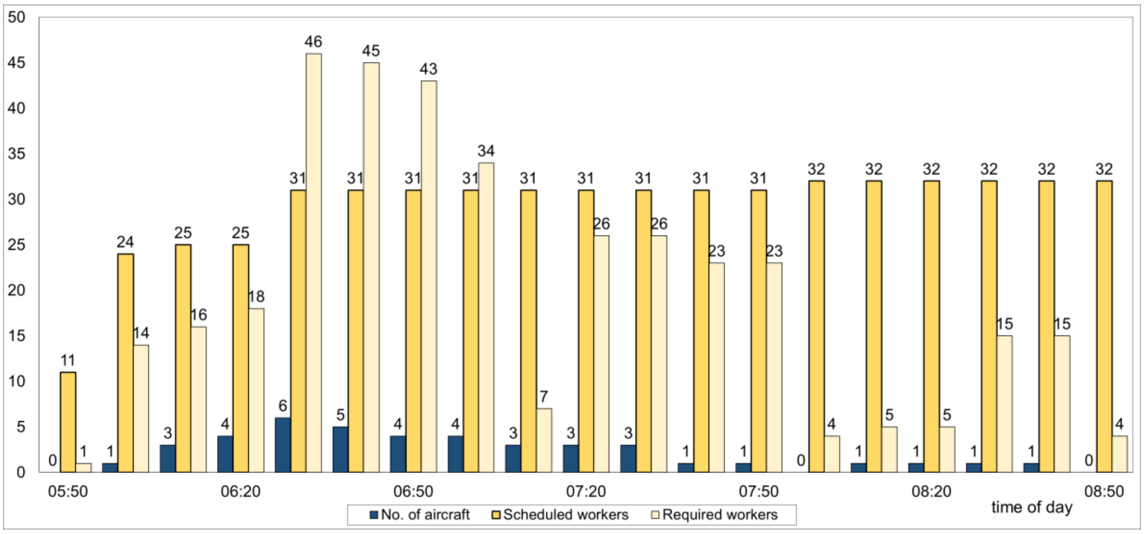

Figure 1 – Difference between the scheduled workers and the required workers according to heuristic rules
Source: authors

Furthermore, due to frequent changes in the flight schedule as a consequence of adverse weather and technical problems, the timing of flights and type of aircraft change often and with little warning, requiring rescheduling of ground handling tasks and required staff. The airport response to the flight changes needs to be timely and efficient, and should not create flight delays or inconvenience the passengers or air crews. With manual scheduling methods, airport planners depend solely on their skills and inventiveness to adapt their staff schedule to unforeseen flight changes.

Although there is previous research on optimization of ground handling schedule optimization, such as [14], it is limited to fixed shifts and predictable staff requirements. The final goal is however to develop an automatic staff scheduling and shift planning system, that would produce moving shifts that can be quickly adjusted to changes in staff requirements due to flight changes, and would thus enable dynamic rescheduling in case of disruptions. In order to optimize the staff and equipment scheduling aspect of ground handling logistics, staff costs have to be minimized while also keeping the aircraft delay costs low.

2. LITERATURE REVIEW

Arriving and departing aircraft require services, performed by the ground crew. The services are executed as a series of tasks, which depends on several factors (e.g. type of aircraft) which are used to schedule the individual groups of workers, and their equipment. The ground handling tasks include passenger service tasks, e.g. check-in, guidance and aircraft service tasks: maintenance, cargo handling, baggage handling, loading, cleaning, catering, towing and operations [6].

Most of the research on ground crew scheduling offers partial solutions for individual work groups e.g. check-in [14, 15, 16], baggage handling [15, 17], security [18], or runway [13, 19, 20]. Although mathematical (linear programming) models can be used to resolve rostering problems of a specific work group type, it cannot be applied to a complex system, therefore other techniques need to be employed [21]. Staff scheduling is usually carried out in several stages, where the demands are calculated first, followed by the generation of work shift plans [22].

In most airlines, several departments are involved in the scheduling process [11]. On the other hand, ground crew schedules are usually handled by a division of the airport management [6]. For a single work group of employees with different skills, staff demands can be calculated and a memetic algorithm can be used to evaluate the schedule [18]. The study of aircraft maintenance staff with the time constraint and different skill requirements is presented in [10], where the first step of schedule generation is the definition of optimal skill mix, and the second step is the optimization of training costs. In the case of check-in and baggage handlers scheduling [15], each day is divided into time blocks with different constraints defined and a required number of employees given, and finally, employees are scheduled for work in three different shifts, 8 hours each. Goal programming also proved to be efficient for generating shift duties for baggage services section staff [17].

A simulation study focused on aircraft maintenance, uses a classification of aircrafts according to the time of stay at the airport [15]. Depending on the length of stay, maintenance programs are scheduled for technicians and total technician requirements are calculated for each sub-shift of the day. Using the stochastic methods, delay costs in air traffic can be calculated [23]. Attempts were even made to influence the schedule of aircraft landings in order to balance the work-load of ground staff [24]. In addition to optimization methods and heuristics, discrete event simulation (DES) can be used to improve aircraft ground handling performance [25]. Agent based modelling (ABM) was used to simulate and optimize the complex socio-technical air transportation system [26], while [27] used ABM simulation to predict the airport capacity.

3. GROUND HANDLING OPTIMISATION

3.1 Ground crew scheduling

The heads of service departments that prepared the manual schedules depend on their expert knowledge (i.e. heuristics) to generate manual schedules. The data on expert heuristics was collected to define the constraints and scheduling requirements used in the heuristic approach. A two-step approach was used to generate a feasible scheduling solution for ground crew scheduling, with the first step defining the work force requirements and the second step constructing shifts based on the work force requirements, business rules and legal limitations. In the first part of the solution, the requirements and constraints for all tasks on flights within a selected time frame are identified to generate a feasible skill group and equipment schedule. This schedule defines the number of personnel for each skill group and the required equipment for every minute within the time frame, and does not include shifts or employee names. Due to length constraints, his contribution focuses on the first step of the solution and does not describe shift generation. The algorithm for generation of floating shifts and assignment of individuals to shifts is described in [28].

As the availability of the equipment was determined not to be a constraint of the scheduling problem, the equipment requirements are modelled, but not subject to optimization in the presented solution. The focus is therefore on personnel scheduling optimization.

The scheduling criteria types, presented in Table 1, stated by the airports experts were included in the heuristics algorithm: type of stopover, traffic (flight) type, aircraft type, carrier and destination.

Table 1 – Description of the scheduling criteria types

Criteria type	Priority	Value domain	Short description
Type of stopover (base criterion type)	1 (highest/first)	[A, D] (arrival, departure)	This criteria is used to set the initial values for the required skill groups. Lower priority criteria may subsequently change the values. Whether a flight is arriving or departing is the main factor for the time frame of tasks and required skill groups.
Traffic (flight) type	2	[all valid traffic type codes] (E.g. for Passenger flight, Charter flight, Technical flight)	E.g. technical flights do not require baggage handlers, cleaners, ground attendants.
Aircraft type	3	[Aircraft type codes] (Over 30 different aircraft types use the airport.)	Passenger and cargo capacity depend on aircraft type; therefore, the staff and equipment demands differ. In addition, certain aircraft types require specific equipment, e.g. auxiliary power unit. Only some aircraft types dictate specific task requirements. Aircraft type codes without a match in the database are ignored (they don't change tasks).
Carrier	4	[Codes of carriers using the airport]	Certain carriers have different requirements, esp. regarding the equipment and check-in counter operation. Only some carriers have specific task requirements. Carrier codes without a match in the database are ignored.
Destination	5	[Codes of destination airports]	E.g., flights to certain destinations require additional transfer staff as most of passengers will be transferred from another flight. Only some destination airports dictate specific task requirements. Airport codes without a match in the database are ignored.

These criteria are used to determine the tasks that need to be performed per flight and their parameters. There are four basic scheduling parameters per each task:

- Skill required,
- Start of task,
- Duration of task, and
- Number of workers per task.

Advanced task parameters, tied to skill groups, include the possibility of time shifting and skill groups allowed to perform the task.

The criteria have different priorities, i.e. they must be used in a prescribed sequence to arrive at the solution. The first criterion to be used is type of stopover with priority value 1. This is the base criterion, which sets the initial requirement values, which can later be altered by the subsequent criteria (with priority value 2 or more). The allowed time frame of task execution depends on the type of stopover. In addition, two types of criteria exist: relative and absolute. Relative criteria will reduce or increase a scheduling parameter (e.g. required number of workers or task duration) while absolute criteria, if defined for the given flight parameters, will set the scheduling parameter to a predefined value. For example, certain carriers have a fixed demand for the number of ground attendants at check-in. Therefore, all previously calculated staff demand at check-in are overridden with a fixed number.

Figures 2 and 3 describe the process of aircraft supply service (fixed tasks are not included) for the arrival and departure of an aircraft of type C (e.g. Airbus 321). The aircraft supply service department included nine different operational tasks which were mapped to skill groups with the same name, listed in Figure 2. Most of the skill groups required one person to be assigned to the skill group. The two exceptions are the skill groups Cleaner, where according to the requirements, two workers should be assigned to the task, and Baggage sorter type A, where only half of person (i.e. a half of worker's full time utilization) is assigned to the task. The assignment of "half persons" per task in combination with time shifting of tasks allows a degree of staff requirements optimization of certain types of tasks. The required number of individual workers in specific task group is not shown in the graphical presentation. As it can be seen from Figure 2 and 3, most of the tasks overlap and can be performed simultaneously. The only task which requires a strict sequence is the task of baggage sorting (A and B) in Figure 3, which has to be finished before the tractor driver drives the baggage to the air-craft.

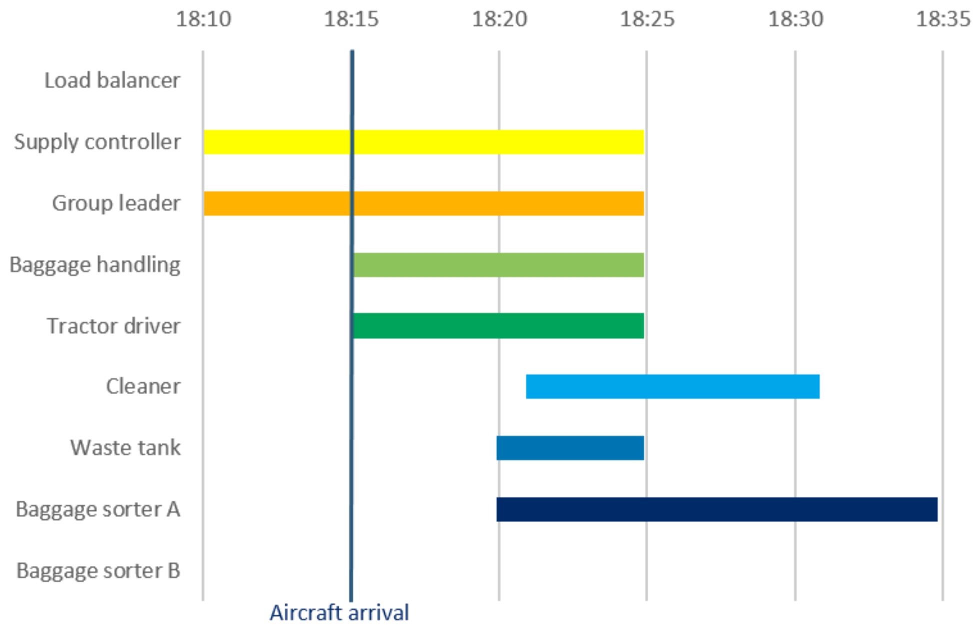

Figure 2 – The process of aircraft supply service for the arrival of type C aircraft
Source: authors

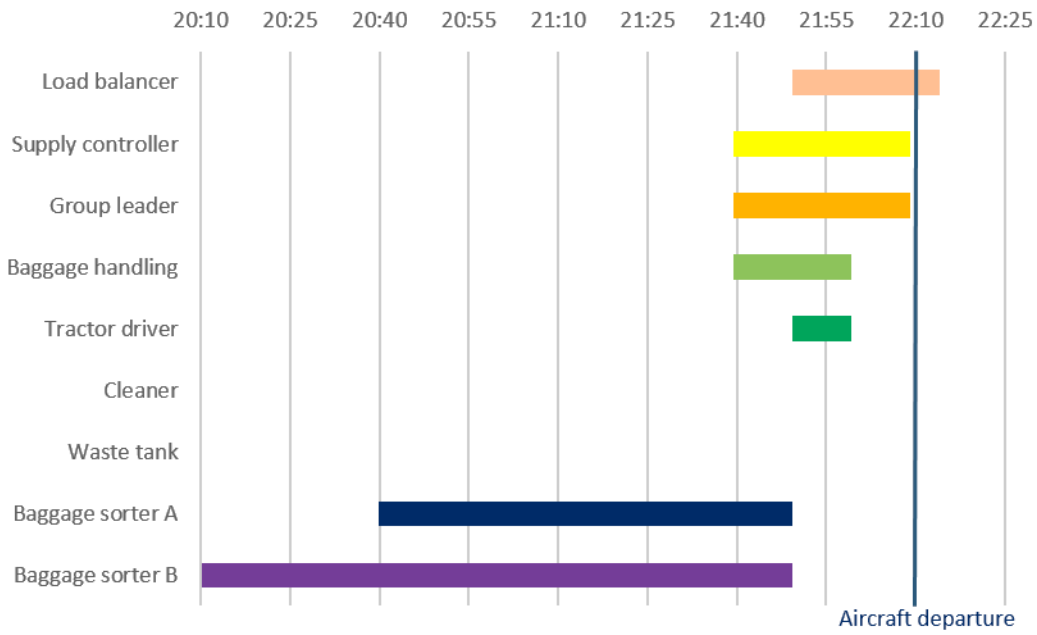

Figure 3 – The process of aircraft supply service for the departure of type C aircraft
Source: authors

3.2 Heuristic scheduling algorithm

Based on the recorded heuristics, the algorithm was coded in a software program to generate a timeline of staff requirements for all tasks. The algorithm uses flight information and documented criteria to calculate staff requirements for every flight, per task. The required number of workers for every type of task is then calculated for each minute within a given time frame (the end and start date of the schedule), producing a timeline of heuristic (ideal) staff requirements. Basic heuristic scheduling rules were provided by the airport personnel planners, but observation of actual ground crew operations revealed that workers and shift managers performed dynamic optimisation of tasks: were found to temporarily change task assignments to help overloaded colleagues, and several types of tasks were per-formed either sooner or later than defined in the basic heuristics in order to avoid peak worker overload. Furthermore, the most overloaded skill groups were found to be temporary overloaded during peak times, and performing two tasks in the same time period.

Therefore, additional heuristic rules were implemented to reproduce the in-field optimization behaviour of the examined system. In this way is possible to “smooth” the requirement peaks, implemented by shifting the execution of a task to a time, where more workers are available. A task can be shifted to an earlier or a later time, according to limitations defined by airport planners and implemented in the algorithm. Further optimization is done by the temporary reassignment of workers, which is implemented by the option of a worker being assigned to several tasks simultaneously inside a short time frame (e.g. a tractor driver usually helps as a baggage sorter when he stops the tractor, although he is formally still busy waiting to drive the tractor back). The maximum duration of an overlapping activity is limited by the duration of peak time requirements (typically less than 30 minutes) and the end of a shift. The algorithm improves on the manual schedules by reducing staff requirements in the off-peak times, and replicates the temporary overloading of personnel during peak times. Diagram of the heuristic scheduling algorithm is presented in Figure 4.

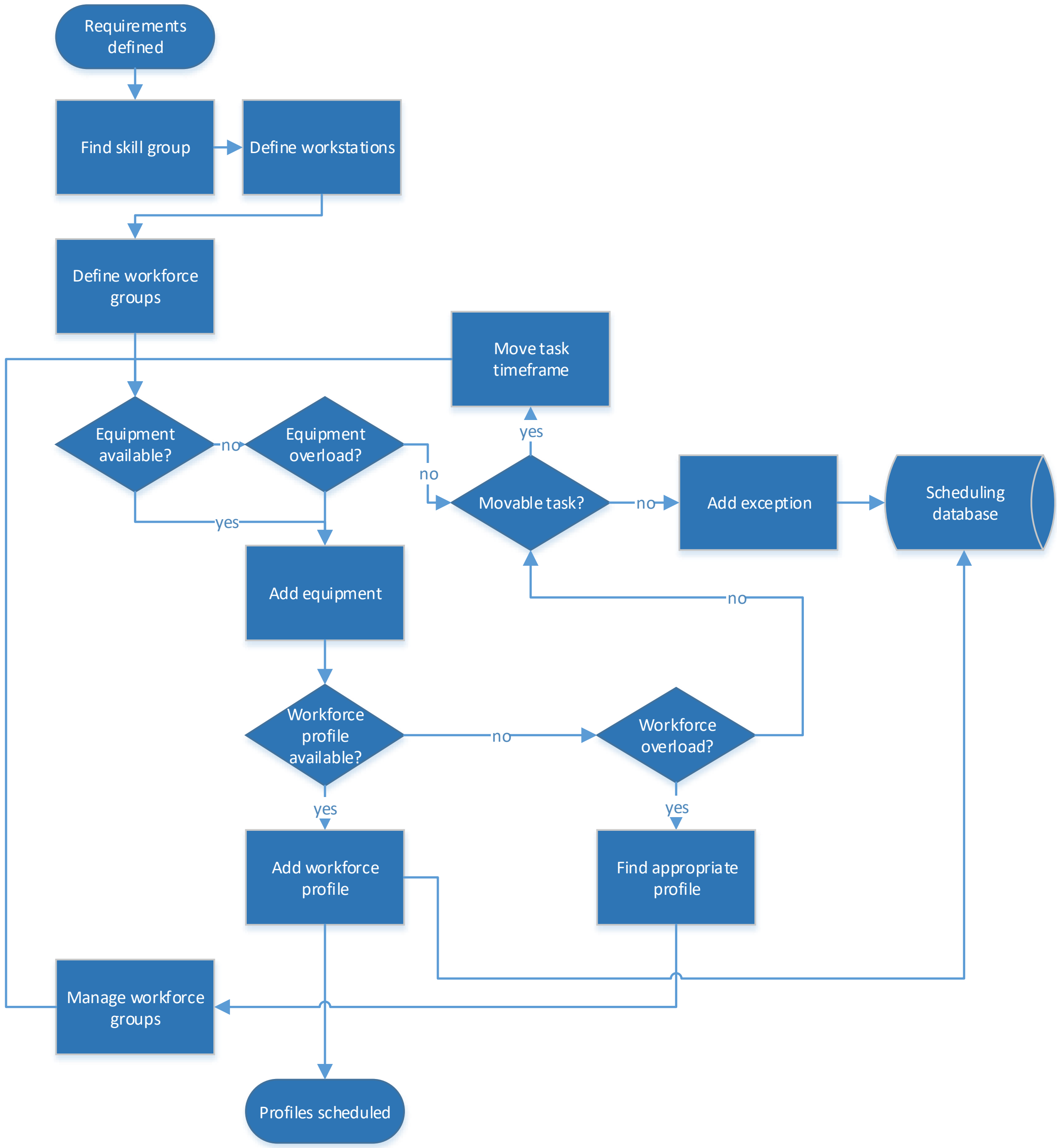

Figure 4 – Heuristic scheduling algorithm
Source: authors

The optimized staff requirements scheduling algorithm was implemented as a standalone application in Java, using an Oracle database to store the data on flights and heuristic rules. 24 relational tables were used to describe the criteria and the demands of the airport ground crew scheduling problem. Before the start of scheduling procedure, flight and personnel data is transferred from the FIS and HRS. Table 2 shows an example of parameters stored in the database, assembled from the FIS into a single table using an SQL query. DD1 defines the date of the flight, FLTNO_A and FLTNO_D describe the aircraft's arrival and departure code. The type of traffic (e.g. C – charter passenger only, F – scheduled cargo/mail, S – scheduled passenger) is defined in column TRFTYP, ST_A and ST_D show the time of arrival or departure, with ROUTE_A and ROUTE_D as arrival or departure airport. ACTYP defines the type of aircraft.

Table 2 – Flight schedule stored in database

DD1	FLTNO_A	FLTNO_D	TRFTYP	ST_A	ST_D	ROUTE_A	ROUTE_D	ACTYP
01.05.2016		JP648	S		00:20:00		IST	735
01.05.2016	JP395		S	01:30:00		BRU		CRJ
01.05.2016	JP299		S	02:40:00		CPH-BCN		320
01.05.2016	FAH6972	6972	F	06:25:00		VIE		F27
01.05.2016		OK827	S		06:40:00		PRG	AT4
01.05.2016		JP376	S		06:45:00		BRU	CRJ
01.05.2016	JP649		S	06:50:00		IST		735
01.05.2016		JP102	S		06:50:00		MUC	CRJ
01.05.2016		JP938	S		07:00:00		WAW	CRJ
01.05.2016	JP687		S	07:05:00		IST		735

According to the criteria types and detail information on considered flight schedule, heuristic rules stored in the database can be used to generate a schedule. Table 3 shows an example of heuristic rules stored in the database. The column ID_CT stands for identification number of criterion type, DM for demand (number of workers to be set, added or subtracted according to criterion value), ST for task start time, DR for duration of task, ABS for the distinction between absolute and relative criteria, and CV for criteria value, i.e. the condition where this particular rule/line is used, ID_S for identification number of skill, i.e. which skill group this rule applies to, MVB for indication of movable tasks, i.e. tasks with flexible start or end time, LEBD for latest allowed time for task completion before departure and A_D for the arrival/departure label. Absolute criteria require setting the work demand/start/duration to their value, thus replacing the current value, while the relative criteria require adding their value to the current values for work demand/start/duration.

Table 3 – Heuristic rules stored in database

ID	ID_CT	PARAMETER	SKILL	DM	ST	DR	ABS	CV	ID_S	MVB	LEBD	A_D
401	24	EVENT TIME	CHECKIN	1	30	-30	R	360	1			D
1	7	TRFTYP	CHECKIN	2	120	100	A	S	1			D
253	10	CARRIER	CLEANER ORD	-2			R	EZY	19		20	A
250	6	TRFTYP	CLEANER ORD	2	6	10	A	C	19		20	A
278	10	CARRIER	CLEANER DRV	-1			R	EZY	20		20	A
279	10	CARRIER	CLEANER DRV	-1			R	W	20		20	A

The heuristic rules stored in database define the flow of the scheduling procedure in detail. The base criteria for scheduling the tasks is the stopover type: arrivals and departures require different skills and require a different time frame calculation method, i.e. in case of a departure, the task start times are to be subtracted from the departure time, while for arrivals the task start times are added to the arrival time.

For example, the criterion in Table 3, row 2 applies if the flight type (A_D) is D (Departure), TRFTYPE value is S (scheduled passenger flight), and CV (carrier) is S. In that case, the CHECKIN skill demand (DM) is 2 (two workers). Therefore, two ground attendants with skill ID number 1 (ID_S) should start their work 120 minutes (ST) prior to the flight departure (A_D), and should perform their task for 100 minutes (DR). Since the value for ABS is A, the DM (demand/number of workers) value of 2 is absolute, thus it overrides any previously set value for DM for this skill type. Since the task is not movable (MVB is empty), the start time of the task cannot be changed and therefore no value for the latest start before departure is given. CV criterion defines specific rules for certain carriers, which may for example require a check-in to complete earlier.

For example, if the flight carrier has the CV value “360” an additional criterion with a lower priority also applies (Table 3, row 1). This criterion type is R (relative), which means that the start time is 30 minutes (prior to the departure of the air-craft), 1 ground attendant is added to the check-in counter, and the relative event duration is -30 minutes, which means the duration of this task is reduced by 30 minutes (i.e. check-in ends 30 minutes sooner, but there is an additional ground attendant present).

Figure 5 shows the staff requirements for load balancers estimated by the first heuristics algorithm (solid line), and the requirements “smoothed” by the optimized heuristic algorithm (dashed line). Short periods of peak times are clearly visible.

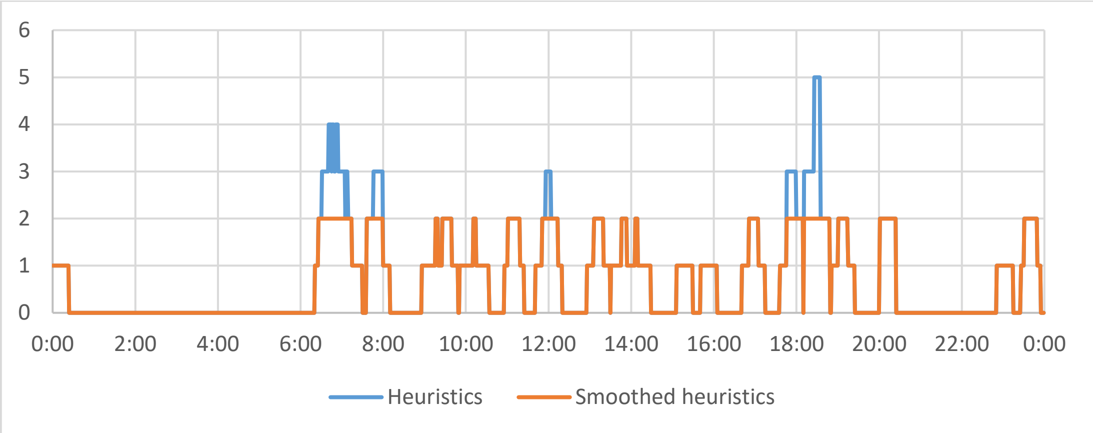

Figure 5 – Optimised algorithm results: staff requirements for the load balancer group
Source: authors

4. CONCLUSIONS

International airports are complex systems that require efficient operation and coordination of all their departments. Therefore, suitable personnel and equipment scheduling solutions are vital for efficient operation of an airport as a system. The current results include a heuristic work-force requirements scheduling algorithms and a shift construction algorithm. The algorithm for generation of floating shifts and assignment of individuals to shifts is described in [28]. The shifts are generated according to the generated staff requirements and demands about shift length.

Based on the experiences from the presented ground handling logistics optimization project, the conclusion is that the problems of airport ground crew scheduling are more demanding than general machine or order scheduling problems found in literature and encountered in previous projects, even at smaller international airports. Mathematical scheduling models were not applicable in described projects, therefore customized heuristic algorithms were to be developed.

While the end user is satisfied with the current solution, as it produces schedules in a fraction of the time required for manual schedule development (minutes vs. hours), and the schedules are better than manually produced schedules at least during off-peak times, there is still potential for optimization during peak-time. In order to achieve optimal staff deployment, the criteria of personnel costs and aircraft delay costs have to be minimized. Next step is the development of a simulation model based optimization solution, which would find the optimum between the ideal numbers of workers and the smoothed staff requirements. The simulation model under development combines DES and ABM simulation methods. Whereas competitiveness is definitely the main reason for the optimization of airport operations, sustainability issues also need to be considered. Efficient airport ground operations are one of the key aspects towards sustainable air transportation [29].

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ENVIRONMENTAL IMPACTS OF INDIVIDUAL CAR TRANSPORT AND RAILWAY PASSENGER TRANSPORT

ABSTRACT

Nowadays, the environmental aspects of transport are very actual issues, mainly the energy consumption and GHG production. This paper analyses and evaluates final energy intensity and GHG production of two passenger transport modes - individual road and railway. Comparison is made for electric and diesel railway vehicles, as well as for cars with different fuel types (gasoline, CNG, diesel, electric and hybrid). The European standard EN 16 258:2012 was used for calculation. The results show the final environmental aspects counted absolutely and also per capita.

KEY WORDS

passenger car; energy consumption; fossil fuels; greenhouse gas production; simulation; railway vehicle

1. INTRODUCTION

Mobility is one of the most important human needs in this century. Average number of trips and the average travelled distance per inhabitant is constantly rising. Transport is becoming a very important element of human existence which has very negative impact on the environment. The most intensive of them are energy consumption, emissions production, noise, vibration, accidents, area needs, congestions – which should be transformed in to the external costs of the community [1, 2, 3].

Entering energy is transformed in to the movement of vehicles during the transportation process which provides the required transfer of goods and passengers in the area. Therefore, the transport depends on the supply of energy. Today transportation is largely dependent on oil, as the vast majority of vehicles are driven by engines combusting petroleum products - hydrocarbon fuels [4, 5].

Railway transport is representative mode of transport where most railway vehicles are now powered by electric traction motors, so the rate of dependence on oil is lower than previous modes. Nowadays the electricity is produced through petroleum products or coal in most countries. All of these are non-renewable natural resources and their stocks have steadily declined. Primary sources used in the electricity production influence the environmental impact of this electricity using in the transport process.

2. STANDARD EN 16 258:2012

This European standard specifies a general methodology for calculation and declaration of energy consumption and GHG emissions in connection with any services (cargo, passengers or both). It specifies general principles, definitions, system boundaries, methods of calculation, allocation rules (allocation, assignment) and recommendations on information to support standardized, accurate, reliable and verifiable declarations regarding energy consumption and greenhouse gas emissions associated with any freight service. It also contains examples of the use of these principles.

The calculation for one given transport service must be performed using the following three main steps:

- Step 1: Identification of the various sections of the service,
- Step 2: Calculation of energy consumption and greenhouse gas emissions for each section,
- Step 3: Sum of the results for each section [6].

The standard does not consider only the secondary emissions produced and energy consumed during combustion of the fuel (energy conversion from fuel to mechanical energy), but also primary emissions incurred in the extraction, production and distribution:

- ew – well-to-wheels energy factor for the defined fuel,
- gw – well-to-wheels emission factor for the defined fuel,
- et – tank-to-wheels energy factor for the defined fuel,
- gt – tank-to-wheels emission factor for the defined fuel.

Well-to-wheels factor covers also primary and secondary emissions and consumption. Somewhere, this factor is also called life-cycle analysis/assessment (LCA). Tank-to-Wheels factor considers only secondary emissions and consumption.

This standard specifies a general methodology for calculation and the declared value for the energetic factor and factor in greenhouse gas emissions must be selected in accordance with Annex A [6].

Emission gases are composed of several individual components (gases). Each of them has different chemical and physical properties and thus participates in environmental degradation differently. In order to compare emissions from different activities, fuels, vehicles when emissions have different tracks, it is necessary to designate one representative unit usable for the comparison. This is the CO_2 equivalent, which is a measure of impact of specific emissions and likens it to the impact of CO_2. The label is CO_2e (equivalent) [7, 8, 9].

Table 1 shows the energy and emission EN standard factors for different fuels.

Table 1 – EN standard factors

Fuel	Energy factor				Emission factor					
	Tank-to-wheels (e_t)		Well-to-wheels (e_w)		Tank-to-wheels (g_t)			Well-to-wheels (g_w)		
	MJ/kg	MJ/l	MJ/kg	MJ/l	gCO_{2e}/MJ	$kgCO_{2e}$/kg	$kgCO_{2e}$/l	gCO_{2e}/MJ	$kgCO_{2e}$/kg	$kgCO_{2e}$/l
Gasoline	43.2	32.2	50.5	37.7	75.2	3.25	2.42	89.4	3.86	2.88
Diesel	43.1	35.9	51.3	42.7	74.5	3.21	2.67	90.4	3.90	3.24
Liquid petroleum gas (LPG)	46.0	25.3	51.5	28.3	67.3	3.10	1,70	75.3	3.46	1.90
Compressed natural gas (CNG)	45.1	-	50.5	-	59.4	2.68	-	68.1	3.07	-

Source: Made by the authors according to [6]

3. CALCULATION METHODOLOGY

3.1 Calculation of Energy Consumption and Emission Production

Software Railway Dynamics [10] has been used to calculate the energy consumption of the train. The power consumption of the train has been calculated on the basis of predefined and selected values on the defined route. The software works with imported maps and elevation profile of railway routes. Based on these defaults and selected parameters (locomotive type, train weight, train length, axle load, number and location of stops) power consumption was calculated in kWh. This software can be used to calculate energy consumption and operational or driving time of some arbitrary train on some arbitrary railway track. It is needed to import data of train and track for calculation [11, 12].

It is necessary to use the principle well-to-wheels for relevant comparison of the results for different types of consumed energy.

3.2 Electric Energy Consumption

Calculated energy is the mechanical work needed to move the train. If is it transformed into units of MJ, it can be subsequently converted to total consumed energy by an overall energy efficiency of equation (1). It means that the well-to-wheels principle is used - factors e_w , g_w [6] or f_{LCA} , or total energy efficiency η_{TE} [13].

$$E_{TE} = (E_{ME} \times 3.6) \times \eta_{TE} \quad \text{(MJ)} \tag{1}$$

where E_{TE} total energy consumed by electric traction (wtw) (MJ)

E_{ME} mechanical energy consumed by the movement of the train (train dynamics software result) (kWh)

Energy and emission factors ($e_{W,}$ g_W) or overall energy efficiency (η_{TE}) reflect a partial losses of production and distribution of power energy in the chain:

- energy mixture used in electric energy production,
- the efficiency various energy sources (depending on the source),
- transfer efficiency (distribution) el. supply to the final consumer (circa 0.93) [14].

These facts imply that the effectiveness (efficacy) of the el. energy is directly related to power production technology, the composition and proportions of individual resources and the effectiveness of its distribution [14].

$$\eta_{TE} = \eta_P \times \eta_T \times \eta_V \tag{2}$$

where η_{TE} overall energy efficiency (-)

η_P efficiency of energy production (sources mixture) (-)

η_T power transfer efficiency (-)

η_V efficiency of vehicle system (-)

The value of overall energy efficiency is 0.34 in Slovak republic. This value is calculated on the basis of statistical data (efficiency and ratio of each primary energy source). For comparison this value is the same in Germany and the average value of EU countries is 0.35 [6].

This calculation of energy consumption is applicable only for the electric train. The procedure is another for the diesel train. We do not consider the energy source mixture. It is appropriate to use the factors and procedure form of the EN 16 258:2012 for diesel train. The amount of consumed fuel should be multiplied by energy factor for that fuel from Appendix A of the standard to calculate the total energy consumption.

3.3 Energy of Combustion Engine Vehicle

Calculation of total energy combustion by diesel vehicles is by equation (3).

$$E_{TF} = FC_V \times e_W = \left[(E_{ME} \times m_{Pe}) \times \frac{1}{\rho_F}\right] \times e_W \qquad \text{(MJ)} \qquad (3)$$

where E_{TF} total energy consumed by diesel vehicles (MJ)

FC_V fuel consumption of vehicle (l, dm^3)

E_{ME} mechanical energy consumed by the movement of the train (train dynamics software result) (kWh)

m_{Pe} vehicle engine specific fuel consumption (g/kWh)

ρ_F fuel (diesel) specific weight (density) (g/dm^3)

e_W energetic factor „wtw" for defined fuel (MJ/dm^3)

3.4 GHG Production

The emission factor LCA was used to calculate the amount of produced emissions of the electric train. The consumed energy (MJ) is computed by mechanical work and efficiency of the vehicle. This value is multiplied by LCA factor which takes the energy source mixture into account, too [15].

$$G_{TE} = \left[\left(\frac{E_{ME}}{\eta_V}\right) \times 1{,}000\right] \times f_{LCA} \qquad (tCO_2e) \qquad (4)$$

$$G_{TE} = \left[\left(\frac{E_{ME}}{\eta_V}\right) \times 3.6\right] \times f_{LCA^g} \qquad (gCO_2e)$$

where G_{TE} the total amount of emissions produced by electric traction (tCO_2e)

f_{LCA} emission factor for electric energy in Slovakia (tCO_2e/MWh)

f_{LCA}^g emission factor for electric energy in Slovakia (gCO_2e/MJ)

For the GHG production calculation, the consumed amount of diesel fuel should be multiplied by an emission factor for that fuel from Appendix A of the EN standard.

$$G_{TF} = FC_V \times g_W = \left[(E_{ME} \times m_{Pe}) \times \frac{1}{\rho_F}\right] \times g_W \qquad (gCO_2e) \qquad (5)$$

where G_{TF} the total amount of emissions produced by diesel vehicles (gCO_2e)

g_W emission factor for defined fuel (tCO_2e/MWh)

The basic units of MJ and gCO_2 were chosen for the calculation because they are declared units in the standard. However, for better comparison and expression, it is possible to expressed individual amounts in other units, for example GJ, KJ, tCO_2, $kgCO_2e$ or a combination of them, in the case of proportional expressing of quantities (see the evaluation) [14, 16].

4. RAILWAY TRANSPORT

In this case study we consider the transport along one chosen valley in Slovakia. This track connects Zilina (administrative capital city of northern territorial unit of Slovakia) and a small town Rajec situated in the southern part of valley with amenities for people lived in valley villages. Routing of track is North – South with distance of 21.3 km.

The calculation for this model study was done on the track in bidirectional ways, so one way down the hill and the other way up the hill. This elevation is seen in the energy consumption which is higher for uphill track, from Zilina to Rajec. Only the numbers as the results from transport in both directions are in the evaluation table and graphs.

4.1 Railway Track Parameters

Difference of the altitudes between Zilina (340) and Rajec (450) causes the track slope which reaches the highest value 13 ‰, except a small hill before the railway station in Zilina where is the slope 17 ‰ but only on a short distance. Average slope between end stations is 5 ‰.

There are 12 stops (stations) on the track. The highest track speed limit is 60 km/h but on some sections there are the speed limits only 50 or 40 km/h. Travelling time between the end stations is 37 minutes. The average number of transported passengers for the year 2014 was 32 passengers on one train.

4.2 Vehicle Technical Parameters

Simulation of the energy consumption was done for two railway vehicles used in Slovak republic in a regional passenger transport. The choice of the railway vehicles was done due to similar capacity and construction size of these railway vehicles. They are:

- electric three units railway vehicle with the series number 425.95,
- diesel two units railway vehicle with the series number 813-913.

The electric vehicle was made by consortium EMU-GTW High Tatras (Adtranz, nowadays Bombardier Transportation; Stadler Fahrzeuge, nowadays Stadler; ZOS Vrutky). This railway vehicle was made in the years 2000, 2001 and 2002.

The diesel vehicle was made by ZOS Zvolen as a reconstruction of an old diesel one unit railway vehicle with series number 810. ZOS Zvolen has been making this diesel railway vehicle since 2007.

Table 2 – Basic technical parameters of railway vehicles

Series number of railway vehicle	425.95	813-913
Drive arrangement	2'´Bo' 2"	1´A´ + 1’1’
Power system	1.5 kV DC	diesel
Power transmission	-	hydromechanical
Combustion engine	-	MAN D 2876 LUE 21
Design rate	602 kW	257 kW
Tare weight	41 t	39 t
Gross weight	56 t	53 t
Number of seats	88 + 20	78 + 5
Maximum number of standing passengers	92	120

Source: www.vlaky.net

5. PASSENGER CAR TRANSPORT

If we want to use a methodology for the calculation of energy intensity and GHG production in transport for passenger cars with different fuel types, it is suitable to use the following example.

Let us consider a vehicle frequently used in Slovakia which represents the middle class vehicle of an unnamed manufacturer who offers this type of vehicle with three types of propulsion – gasoline, gasoline/CNG and diesel with approximately the same engine power. Vehicle mark and model are not important in this case, but performance, weight parameters and fuel consumption of the vehicle are relevant. Curb weight of the vehicle is about 1,500 kg and the vehicle engine power is about 80 kW. For this type of the vehicle, fuel consumption may range from 6 to 7 litres of gasoline per 100 km; in the case of diesel engines it may be from 5 to 6 litres per 100 km and the vehicle consumption with CNG propulsion is about 5 kg/100 km [17, 18].

Fuel and energy consumptions stated by the manufacturer were used for the purposes of this calculation. The consumption was measured according to the standard. Consumption indicated by the manufacturer in the combined NEDC cycle is taken into account.

For comparison of other propulsion systems which are nowadays used in passenger cars, we chose the vehicles of the same category propelled by alternative technologies such as hybrid propulsion of gasoline/electric energy or fully electric cars.

Energy consumption and GHG production from a global aspect, thus primary as well as secondary impacts are taken into account. CNG is the cleanest from hydrocarbon fuels in terms of GHG production. In terms of energy consumption, however, it represents the least efficient fuel despite the fact that its production/modification is not subject to such procedures as in the case of gasoline or diesel. This is caused by a large content of energy in 1 kg of CNG and thus engines combusting CNG achieve lower efficiency than the engines designed for gasoline or diesel [19, 20].

When comparing the mentioned five vehicle propulsions, it is also necessary to particularly look at electric vehicles and vehicles with hybrid technology of propulsion. The resulting energy consumption (primary as well as secondary) of electric vehicles greatly depends on the country in which those vehicles are driven or the country from which the electricity is used. In this regard, the way of electricity production is important, and thus the efficiency during its production and GHG emissions already in the process of its acquisition [21, 22, 23].

In the case of hybrid vehicles, the resulting energy consumption may vary widely and thus also production of emissions, because this type of propulsion reaches greater differences in terms of the regime of vehicle operation. Vehicle consumption within urban areas may represent a very small amount. But, the use of hybrid vehicles on highways may result in equal or even higher vehicle consumption compared to comparable vehicles with conventional propulsion for combusting hydrocarbon fuels [24, 25].

6. EVALUATION

Table of the final evaluation (Table 3) shows the advantage of the large capacity which the electric train nr. 425 has. This unit is the most similar alternative to the unit nr. 813. It is often used on the railway with higher slope (mountains) in Slovakia thank to its higher power value.

Table 3 – Evaluation

Transport mode and vehicle type (nr., traction)	Railway vehicle		Passenger car				
	425	*813*	*gasoline*	*CNG*	*diesel*	*electric**	*hybrid***
Vehicle capacity usage (interval)	20 % - 100 %	20 % - 100 %	20 % - 100 %	20 % - 100 %	20 % - 100 %	20 % - 100 %	20 % - 100 %
Energy consumption (kJ/pskm)	*960 - 236*	1045 - 256	*2011 - 443*	2099 - 463	*1789 - 395*	2017 - 445	*1436 - 317*
GHG production (g/pskm)	*32.01 - 7.87*	79.28 - 19.40	*153.60 - 33.87*	128.65 - 28.37	*135.77 - 29.94*	62.27 - 13.73	*109.71 - 24.19*

Source: Calculation by the authors

* this applies only for the consumed electric energy produced in SK/CZ
** variable value; it depends on regime of vehicle operation (city, highways); the used type of hybrid technology

But the fact of using this nr. 425 causes higher total energy consumption. However, the capacity of the unit is up to 108 passengers, thus converted consumption per transported passengers at full occupancy is less than the diesel train consumption. But it is not possible to apply for the real operation because the average number of travelled passengers in train is much less.

The simulated fuel consumption of the diesel train was compared to the real consumption of this train operated on this track. This simulated result was validated because the simulation error was only -8 %. So every consumption results were increased of the value 8 % to be closer to the reality.

The electric train is not always the most environmental friendly transport mode. If we consider the energy consumption as the most important parameter, the diesel train reaches better results with lower energy intensity. The energy consumption of the electric train is not dependent only on the efficiency of the vehicle systems, but also on the efficiency of the electric energy production in the country.

In the case of real passenger number the diesel train reaches higher value of efficiency than the electric train, it consumed only circa 90 % of the electric train energy consumption. But if the trains is loaded fully than the electric train is more efficient. Diesel train consumption is now 118 % of the electric train consumption.

The results from the table 3 describe energy intension of chosen vehicle drives. Final intension depends on fuel consumption of the vehicle and currently on actual vehicle occupancy. The graphical results of the table 3 are given in the figures 1 and 2. The difference between all propulsions is visible there. The most intensive is passenger car driven by CNG in the consideration of the energy consumption but the gasoline car is the worst in the GHG production.

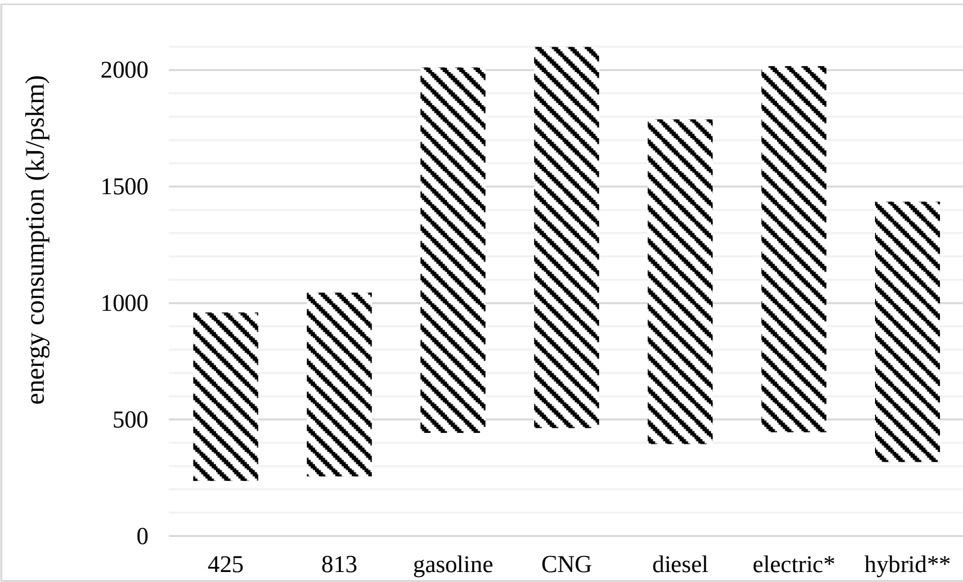

Figure 1 – Energy consumption
Source: Calculation by the authors

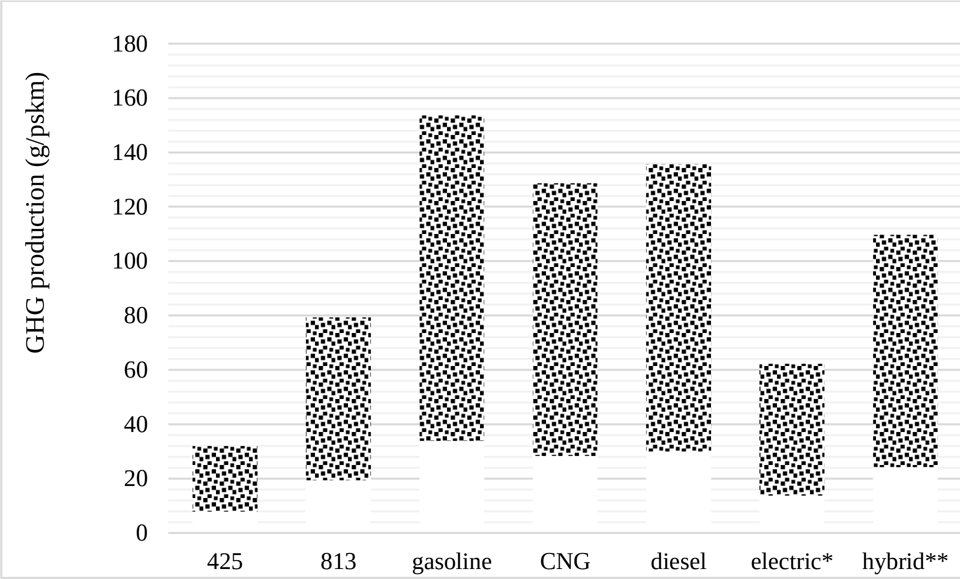

Figure 2 – GHG production
Source: Calculation by the authors

The results show that the usage of vehicle capacity is very important in the evaluation of energy intensity and GHG production per pskm. Trains (either electric driven or diesel driven) represent the most effective vehicles. Passenger cars can reach values of public transport vehicles only by 80 – 100 % occupancy. It testifies about the importance of the capacity usage which can be increased by tools such carpooling.

The emissions production has the opposite result as the energy consumption. In this case the electric train is friendlier to the environment then the diesel train. However, it is not possible to reach this scenario neither in all EU countries, nor in developing countries. Emissions production of electric traction is more dependent on the energy source mixture than the energy consumption. This study was calculated for Slovakia. Slovak energy source mixture is very friendly to the environment (production of the CO_2e) because of 50 % nuclear energy, 17 % water energy and only small share of energy from fossil fuels. The LCA factor in Slovakia is only 0.353 tCO_2e/MWh, while the EU average is 0.578. GHG production per capita of the electric train is 50 % of the diesel train in Slovakia. The electric train is not the "green" choice of transport everywhere, it would produce more GHG than the diesel train in countries with other source mixture, like Poland or Estonia (they use the fossil fuels as the biggest source of electric energy) with LCA factor up to 1.593 tCO_2e/MWh (almost 5-times more of the Slovak factor) [15].

7. CONCLUSION

The energy consumption per capita declares that individual road transport – passenger car – cold be less intense than the railway transport but only in the case of higher capacity usage. For example car occupied by 3 or more passengers reaches lower values of consumed energy per capita than trains with capacity usage below approximately 30 %.

Electric hybrid technology is the most energy effective passenger car traction investigated in this paper. Thanks to its efficiency and lower fossil fuel consumption reaches similar energy intensity than railway vehicles (in the higher capacity usage).

The emissions production is depended on the primary sources, too. Vehicles with electric traction produce much less GHG than the vehicles consuming fossil fuels. This is the case of Slovakia where the electric production is using sources with lower GHG production values. Resulting this fact the electric driven car (individual transport) reaches lower GHG production values than the diesel railway vehicle (public transport).

The results of this simulation do not determine which traction is better, greener or friendlier to the environment. It is not possible to do it, because the energy efficiency and GHG production is not dependent only on the type of fuel or traction but also on the capacity usage and electric energy sources. It is necessary to load the vehicles with the adequate number of passengers (suitable choice of the train according to the transport flow) and to use ecological produced electric energy. The transport efficiency with the low level of passengers is decreasing and without "green" electric energy the electric trains are not ecological as well.

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MEASUREMENT OF TRAFFIC CHARACTERISTICS USING BLUETOOTH SENSORS

ABSTRACT

The purpose of this article is to present the possibility of using Bluetooth sensors for measuring traffic characteristics. These devices are increasingly becoming components of urban ITS systems, and in particular Traffic Control subsystems. This fact contributed to conduct the traffic research using the devices. So, the main purpose of the research was to show the accuracy of the measured traffic characteristics needed to assess traffic conditions of the road intersections. Most publications describing research using Bluetooth sensors are about measurements of time, speed, and derivatives of these values (e.g. car queues). This article analyzes the compatibility of traffic intensities with respect to the directions at intersections. The study has been conducted at a traffic intersection located on a multilane street with the presence of traffic saturation. It is important from the point of view of the purpose of the article, because the measurements have been carried out under a variety of traffic conditions, i.e. both in free traffic conditions (with small queues of vehicles and average speeds of traffic flows at inlets close to the permissible velocity) and in saturated traffic conditions (large queues of vehicles and low average speeds of traffic flows at inlets). The article presents the detailed results of the statistical analysis of the obtained research material carried out at various levels of aggregation of data.

KEY WORDS

Bluetooth sensors; ITS; traffic characteristics; traffic measurements; multilane signalized intersections

1. INTRODUCTION

Traffic measurements are the basis for modeling, designing and managing road and street networks of cities and regions. The main goals of measuring traffic are [20]: planning and design of roads and intersections, organization of traffic, analysis of capacity and traffic conditions, economic analysis, road maintenance, accident analysis, and forecasting of environmental impacts.

The most important traffic parameters that are subjected to this study are: traffic flow volume, traffic density, speed, structure of vehicle types, measures assessing the traffic conditions (e.g. time delay, length of vehicle queues). In addition, it is often necessary to carry out studies on parking, public transport, traffic safety, environmental impacts or travel behavior. Such a diverse set of traffic characteristics requires the selection of the appropriate measurement methodology, and thus the measurement techniques. Of course, the choice of the right technique is determined by the factors such as [21, 22]:

- the cost of using a particular method or technique,
- the time of realization,
- the accuracy of the results,
- the form of the results.

With the development of technology, there is also a growing demand for more efficient and more accurate measuring devices, especially in the area of ITS services. Not without significance is the availability, cost and universality of their application, which moves to obtain better results of measurements used, among others, for traffic management and control. One of such devices are Bluetooth sensors being the subject of the research, and the results of which have been presented in this article.

2. LITERATURE REVIEW OF THE USE OF BLUETOOTH SENSORS FOR MEASUREMENT OF TRAFFIC CHARACTERISTICS

So far, the literature on the subject is dominated by the use of Bluetooth sensors to study travel time in a road and street network, an example of which is described in [7]. The article reports on the use of a Bluetooth based sensor both to capture the travel time data and to evaluate the reliability along two alternate routes in Chennai, India. This problem is also presented in publications [5, 8, 17]. Another example is the article [1], which compares the accuracy of the measurement of vehicle speed on a motorway in free flow, when traffic is in between free flow and congested and in congested traffic, using seven types of sensors, including Bluetooth sensors. In publication [1] was found that the vehicle speed studies give satisfactory results when using many types of sensors simultaneously, Bluetooth sensors and cell phones for example. The previous research by the authors described in [2] also focused on the comparison of vehicle speed data on the Toronto motorway using Bluetooth sensors, loop detectors, and GPS. An analysis has shown that using Bluetooth devices may improve the accuracy of traffic estimation obtained solely from loop detectors.

The second group of publications describing the use of Bluetooth sensors are those concerning their optimal location in the transportation network, with the aim of obtaining the highest accuracy of measurement with the smallest number of devices used. The paper [19] presents an algorithm to determine the optimal location of Bluetooth sensors from the point of view of the accuracy of the mapping of the traffic flows while minimizing the costs of their applications. The considerations presented in [11, 12, 13] have been used to develop the algorithm. In [23], the problem of the optimal number, as well as the location of Bluetooth sensors in the transportation network, has been presented in order to collect travel time data with high reliability. Two mathematical models have been proposed to solve this problem, which can be applied in dense transportation networks. In addition, different case studies on the actual network had been conducted, on the basis of which the results of both models have been compared. The developed models use, among others, assumptions contained in [3, 4, 10, 18].

The reviewed literature also deals with the use of algorithms indicating the optimal location of sensors for measuring traffic characteristics. For example, the paper [9] presents a method for locating sensors for assessing the variability of a travel demand matrix, and the article [15] – for the dynamic estimation of the OD matrix for motorway travel.

In contrast, the use of Bluetooth sensors for measuring the characteristics related to road traffic (e.g. traffic volume, structure of types of vehicle and traffic direction) is not common. This is due to the specific nature of the phenomenon of the occurrence of vehicles (or objects) equipped with Bluetooth devices in the total traffic of vehicles (objects) since, as stated in [1] vehicles equipped with Bluetooth devices account for a small share of total traffic. The results of the study presented in [14] concern measurement on road sections. They show that the number of detected vehicles equipped with Bluetooth devices is affected by the road function. Authors of [14] carried out research in Poland in Bielsko-Biała on the S69 road (motorway with a 2x2 cross section with a green belt, which is a bypass of the city Bielsko-Biała mainly serving outer traffic), on Zamkowa Street (highway with a cross section of 2x2 without a green belt serving mainly urban traffic) and on Cieszyńska Street (main road with a cross section of 1x2 serving mainly mixed traffic, i.e. urban and source-destination). The average share of identified vehicles (objects) equipped with Bluetooth sensors during the 3-hour measurements (15 minutes intervals) is 19.1% on the S69 road (motorway), 24% on Cieszyńska Street (main road) and 28.8% on Zamkowa street (highway). The calculated coefficient of variation of traffic share with Bluetooth sensors in the total traffic of vehicles does not exceed 0.25. Therefore, it is clear that the variability of the examined feature is small. This means that the average may well describe the studied phenomenon.

Based on the literature studies, there is not too much publications regarding the use of Bluetooth sensors to measure traffic characteristics at one intersection such as volume or traffic and direction of traffic at intersections. In publication [16] the review of main types of data collected by different sensor types (also Bluetooth) have been presented. Such analysis—filling the research gap in this area—is the main purpose of the article.

3. METHODOLOGY AND RESULTS OF MEASUREMENTS

3.1 General characteristics of subject of the study and research methodology

The intersection of Chorzowska Street with Złota Street and Bracka Street in Katowice in the Silesian Voivodeship in Poland has been selected for measurement. It is an intersection of four inlets, with traffic controlled by light signals. At this intersection, the occurrence of saturation states of traffic flows is often observed.

Chorzowska Street is the national road number 79, having its origin at the roundabout of General George Ziętek in Katowice. It is the main communication route connecting Chorzów with Katowice. Along the street from the north side of the intersection, there are tram tracks crossing Złota Street. Złota Street is a local road, which starts at the intersection with Chorzowska Street in Katowice. Złota Street along its whole length is the border between Chorzow and Katowice. At the intersection of the study, Złota Street has 3 lanes. Bracka Street is a local road that starts at the intersection with Chorzowska Street and Złota Street. It is one of the most important streets connecting the districts of Dąb and Załęże in Katowice. At the intersection of the study, Bracka Street has 4 lanes. Figure 1 shows the aerial view of the measured intersection with street names.

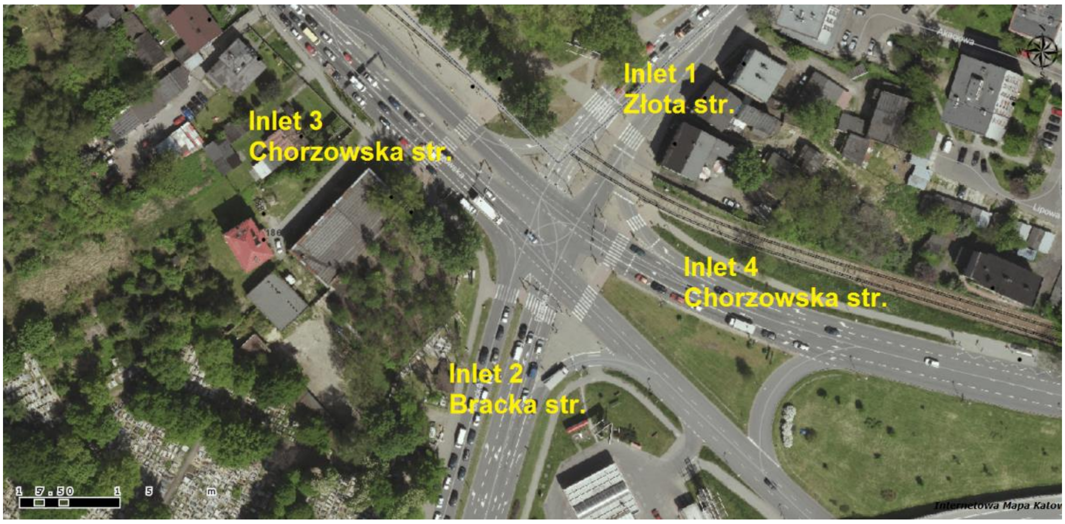


Figure 1 – Traffic organization on the measured intersection with names and numbers of legs
Source: own source on the basis of [25]

Research conducted in order to assess the possibility of using Bluetooth sensors for measuring the characteristics of road traffic at intersections was based on the use of On-Dynamic (Bluetooth sensors) and reference measurements. Studies using both systems were carried out at the same time, so the same traffic volumes have been measured.

The OnDynamic system is a Multimodal Road Traffic Monitoring System. This is a system developed in Poland. According to [26], it enables the collection and presentation of information obtained from Bluetooth sensors in real time on:

- time of passing through,
- average speed on selected section,
- traffic volume,
- current traffic conditions.

The system is based on maintenance-free sensors located at sections or intersections. Sensors collect data from Bluetooth devices installed in passing vehicles. The data is anonymized, i.e. processed in such a way as to prevent identification of sources. They are then filtered, analyzed and interpreted by software developed for this purpose. Properly processed information is presented through the graphic interface and archived in the database. The general idea of the OnDynamic system is shown in Figure 2. It consists of the following subsystems: data acquisition, processing information, data visualization.

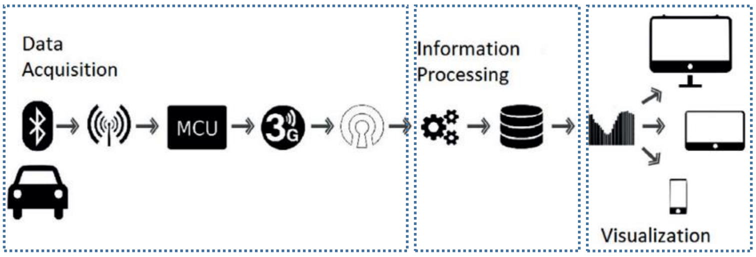


Figure 2 – OnDynamic system diagram
Source: own source on the basis of [6]

Figure 3 shows the locations of the five OnDynamic Bluetooth sensors at the intersection of the study.

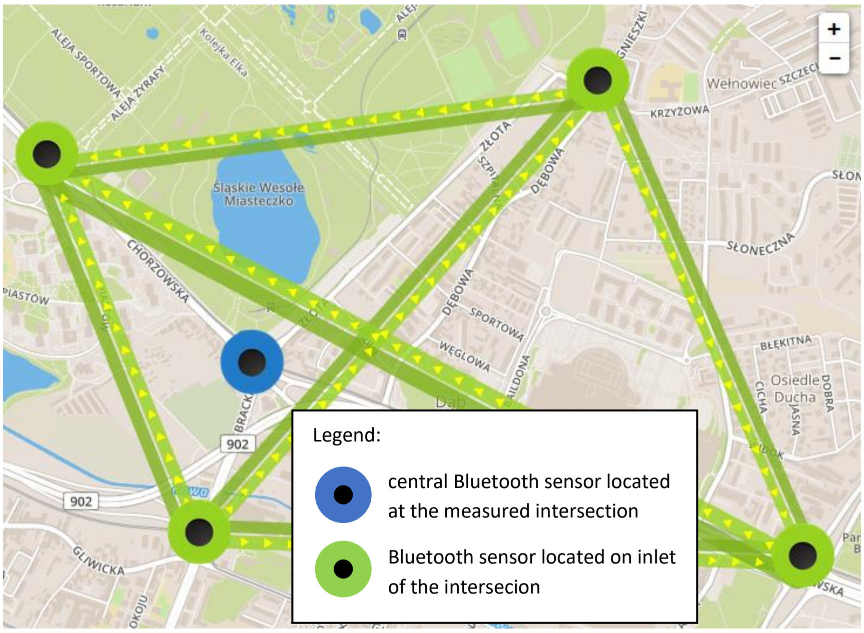
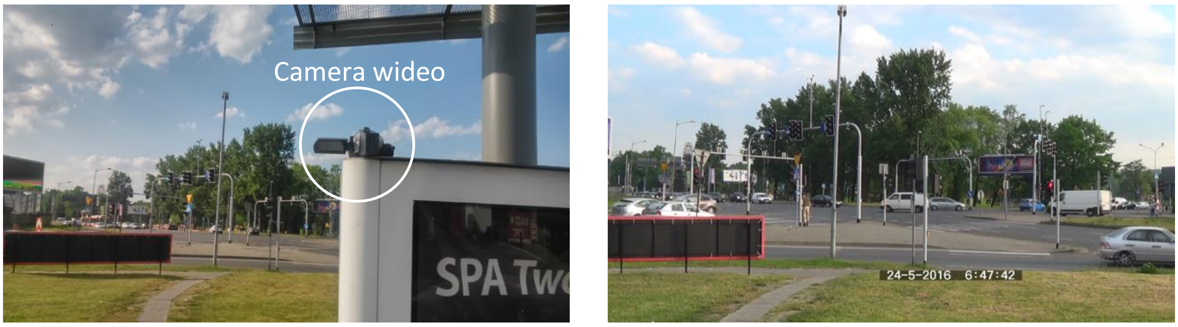


Figure 3 – Location of Bluetooth sensors of OnDynamic system
Source: map prepared by the APM PRO company –the owner of OnDynamic system

For reference measurements, video cameras have been used that have recorded traffic at intersection. The video camera image was analyzed by trained analysts. Figure 4A shows the location of one of the video cameras and Figure 4B - the image from the camera.



Location of the video camera | Image from the video camera

Figure4 – A. Location of the video camera; B. Image from the video camera
Source: [24]

Measurements using both systems have been carried out on May 24, 2016 (Tuesday) from 06:45 to 09:45 (morning measurement) and from 14:30 to 16:30 (afternoon measurement). When performing measurements with the use of video cameras (reference measurement) the traffic volume and the structure of vehicles (distinguishing the following group of vehicle types: SO - cars, LSC + SD - light trucks and vans, SC - trucks, SCP - trucks with trailers, A - buses, AP - articulated buses, M - motorcycles, R - bikes, T - trams, I - other) as well as the directional structure of traffic have been recorded. All these features were collected in 15 minutes intervals by writing them to a database prepared for this purpose.

Measurements using Bluetooth sensors have been made at the same intervals as the reference measurements. The traffic intensities of vehicles equipped with Bluetooth sensors, and the directional structure of traffic have been measured. For identification of the vehicle, its registration on the central sensor was required. However, the determination of the directional structure of the traffic required identification of the vehicles on the three sensors. Measurement of the structure of vehicle types with the Bluetooth sensors proved to be impossible.

The measurements were conducted without any interferences, at the intersection, there were no external factors that may affect the measurement results, e.g. road accident. The weather was good.

3.2 Results of the measurements

The proposed methodology of carrying out the research allowed to obtain the following results (separately for both measuring periods):

- distribution of traffic volume in time for each direction of traffic on inlets,
- distribution of traffic volume in time for individual inlets,
- distribution of traffic volume in time at the whole intersection.

These results have been presented both for the reference measurements and for the measurements with the use of Bluetooth devices. Based on them, the measurement errors were analyzed using the dependencies proposed in this article. The results are shown respectively in Figures 5 to 7.

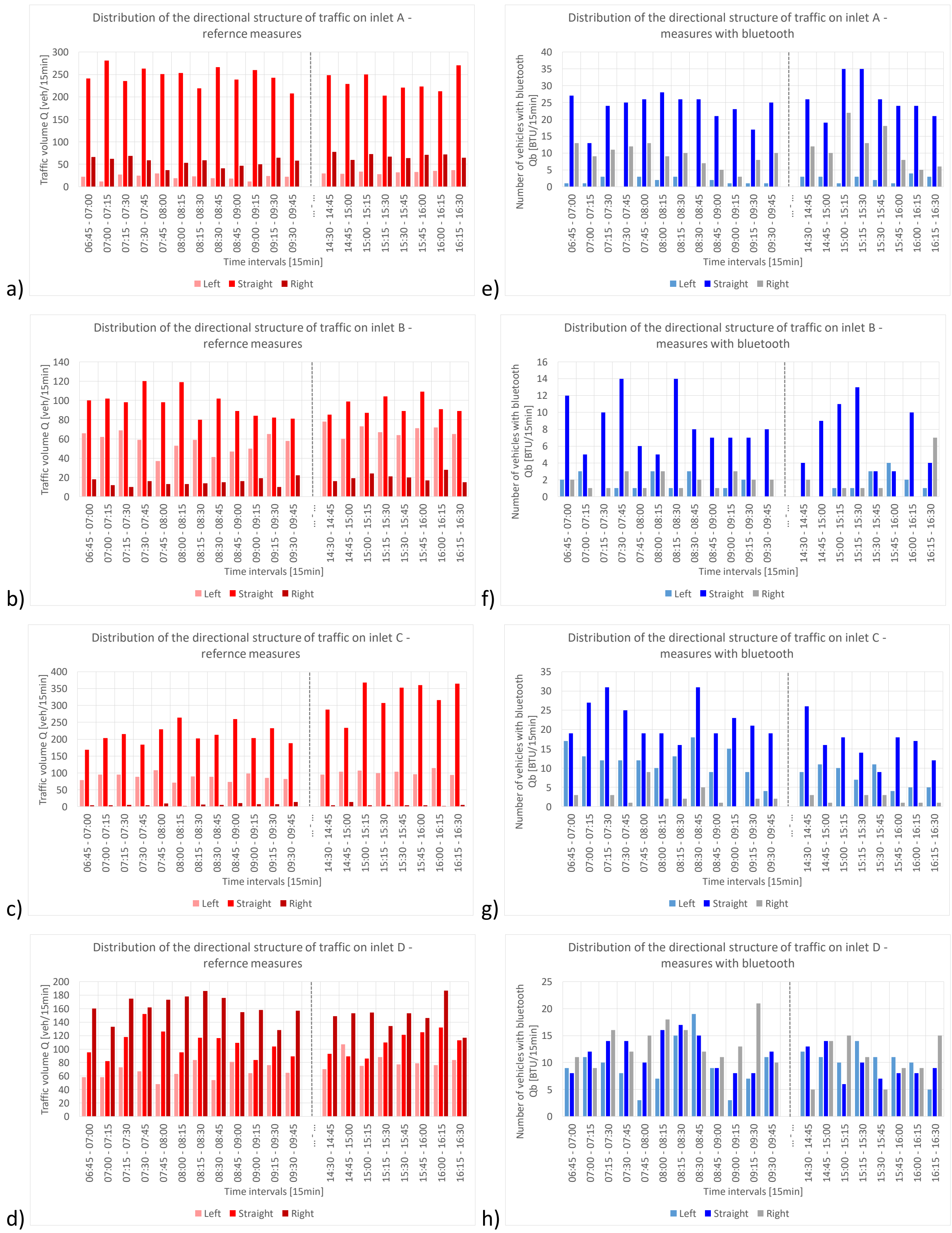


Figure 5 – Distribution of the directional structure of traffic on the inlets of the intersection; in Figures 5a-5d there are reference measurements, and in Figures 5e-5h there are measurements with Bluetooth sensors
Source: Made by the authors

The diagrams in the Figures 5 show that the dominant direction at the intersection is going straight. This fact is confirmed both by the measurements using Bluetooth sensors and by the reference measurements. Only on inlet D most vehicles turned right. However, when analyzing the graph in Figure 5h, it may not be clearly stated.

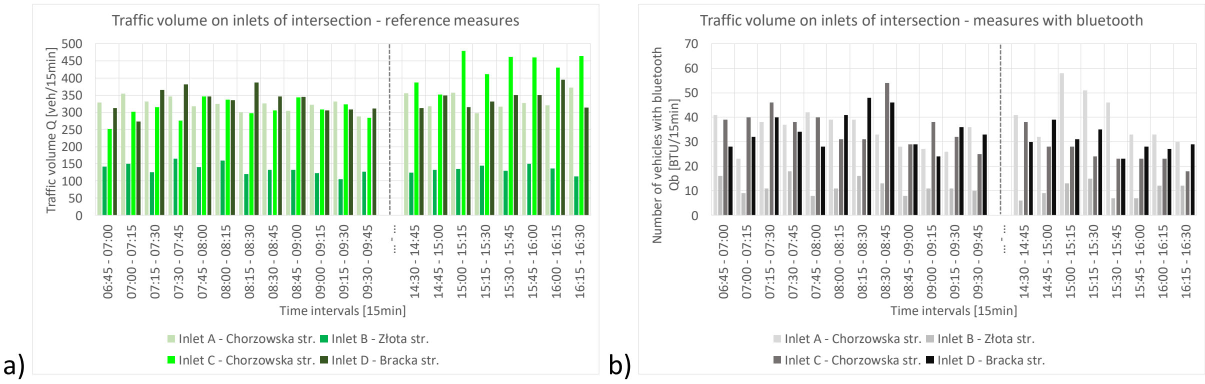


Figure 6 – Traffic volume on inlets of the intersection; in Figure 6a there are reference measurements, and in Figure 6b there are measurements with Bluetooth sensors
Source: Made by the authors

Most traffic in the afternoon measuring period occurs on the C inlet. However, during this period most vehicles equipped with Bluetooth sensors were recorded on the A inlet. In the morning measuring period, the traffic volume on the inlets A, C and D is at a similar level, which is also confirmed by the measurements using Bluetooth sensors.

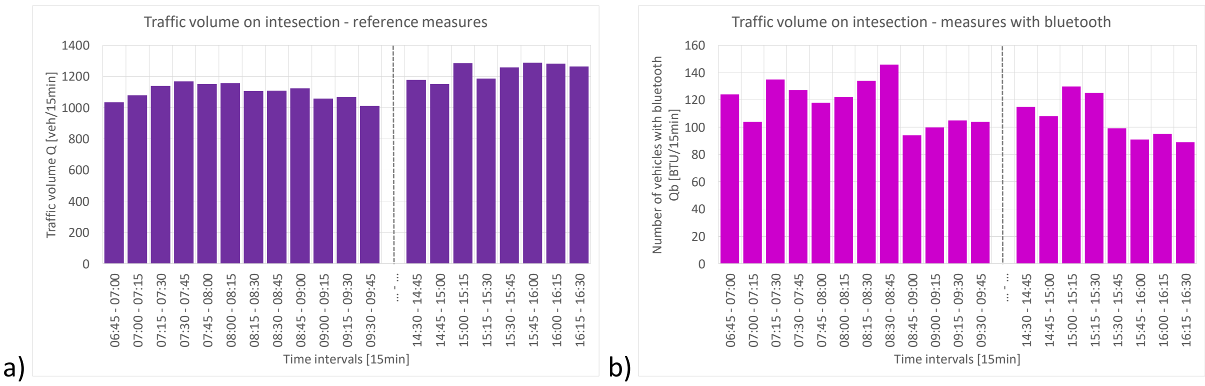


Figure 7 – Traffic volume at the intersection; in Figure 7a there are reference measurements, and in Figure 7b there are measurements with Bluetooth sensors
Source: Made by the authors

By analyzing the graphs shown in Figure 7, it can be stated that the higher traffic volumes have been observed in the afternoon measuring period, while the measurements using the Bluetooth sensors indicate that the opposite was true.

4. EVALUATION OF THE USEFULNESS OF THE MEASUREMENTS OF TRAFFIC CHARACTERISTICS WITH THE USE OF BLUETOOTH SENSORS

4.1 Mathematical model of the usefulness of the measurements using Bluetooth sensors

Evaluation of the usefulness of the measurements using Bluetooth sensors requires the development of specific measures. Due to the specifics of the measurements, the following sets have been introduced:

– a set containing consecutive time intervals of the same length:

$$\boldsymbol{T} = \left\{1, \ldots, t, \ldots, \overline{T}\right\}, \tag{1}$$

where $\overline{T}$ means the size of the set $\boldsymbol{T}$, i.e. numbers of analyzed time intervals,

– a set containing traffic directions at the intersection (directional relations):

$$\boldsymbol{K} = \{k \quad : k = l, w, p\}, \tag{2}$$

where l means turning left, w - going straight, and p - turning right.

– a set containing numbers of the inlets at the intersection of the study:

$$\boldsymbol{W} = \{w \quad : w = 1, 2, 3, 4\}, \tag{3}$$

Analysis of compliance of the results of the measurements using Bluetooth sensors with the results obtained from the reference measurements requires both measurements to be carried out simultaneously. Consequently, it is assumed that on the Cartesian product $\boldsymbol{W} \times \boldsymbol{K} \times \boldsymbol{T}$ the mapping x and y have been imposed, which elements of this product transform into elements of the set of positive integers $\mathrm{Z}^+ \cup \{0\}$, i.e.:

$$x : \boldsymbol{W} \times \boldsymbol{K} \times \boldsymbol{T} \longrightarrow \mathrm{Z}^+ \cup \{0\}, \tag{4}$$

$$y : \boldsymbol{W} \times \boldsymbol{K} \times \boldsymbol{T} \longrightarrow \mathrm{Z}^+ \cup \{0\}, \tag{5}$$

wherein $x_{w,k}(t) \in \mathrm{Z}^+ \cup \{0\}$ has an interpretation of the number of vehicles entering an intersection of the study from an inlet w traveling in directional relation k in time interval t determined by **the reference measurements**, while $y_{w,k}(t) \in \mathrm{Z}^+ \cup \{0\}$ means the number of vehicles entering an intersection of the study from an inlet w traveling in directional relation k in time interval t determined by **the measurements using Bluetooth sensors**.

Compliance analysis may be conducted at different levels of detail. As a result, the following **levels of data aggregation (reference levels)** have been distinguished:

– **Level I** – the reference units are the values of $x_{w,k}(t)$ and $y_{w,k}(t)$,

– **Level II** – the reference units are the values of $x_w(t)$ and $y_w(t)$, while:

$$x_w(t) = \sum_{k \in \boldsymbol{K}} x_{w,k}(t), \tag{6}$$

$$y_w(t) = \sum_{k \in \boldsymbol{K}} y_{w,k}(t), \tag{7}$$

– **Level III** – the reference units are the values of $x_{w,k}$ and $y_{w,k}$, while:

$$x_{w,k} = \sum_{t=1}^{\overline{T}} x_{w,k}(t), \tag{8}$$

$$y_{w,k} = \sum_{t=1}^{\overline{T}} y_{w,k}(t), \tag{9}$$

– **Level IV** – the reference units are the values of $x_k(t)$ and $y_k(t)$, while:

$$x_k(t) = \sum_{w=1}^{4} x_{w,k}(t), \tag{10}$$

$$y_k(t)=\sum_{w=1}^{4} y_{w,k}(t), \tag{11}$$

−**Level V** – the reference units are the values of x_w and y_w , while:

$$x_w=\sum_{t=1}^{\bar{T}} x_w(t), \tag{12}$$

$$y_w=\sum_{t=1}^{\bar{T}} y_w(t)\ , \tag{13}$$

−**Level VI** – the reference units are the values of x_k and y_k , while:

$$x_k=\sum_{w=1}^{4} x_{w,k}\ , \tag{14}$$

$$y_k=\sum_{w=1}^{4} y_{w,k}\ , \tag{15}$$

−**Level VII** – the reference units are the values of $x(t)$ and $y(t)$, while:

$$x(t)=\sum_{w=1}^{4} x_w(t), \tag{16}$$

$$y(t)=\sum_{w=1}^{4} y_w(t). \tag{17}$$

An important element of the analysis is the choice of appropriate measures of compliance. The basic measure is Absolute Error (AE) and Relative Percentage Error (RPE), which indicates how much and by what percentage the value determined on the basis of research conducted with the use of Bluetooth sensors differs from the value determined in the reference measurements. Table 1 contains methods for calculating these errors for different levels of data aggregation. Values based on them have been used in the construction of measures to assess the compliancy of measurement results.

Compliancy assessment has been carried out using the following measures:

- Mean Absolute Error (MAE),
- Mean Percentage Error (MPE),
- Root Mean Squared Error (RMSE),
- Root Mean Squared Percentage Error (RMSPE).

In addition, the standard deviations as well as the coefficients of variability of absolute and relative errors have been also determined:

- Standard Deviation of Absolute Errors (SDAE),
- Standard Deviation of Percentage Errors (SDPE),
- Coefficient of Variation of Absolute Errors (CVAE),
- Coefficient of Variation of Percentage Errors (CVPE).

Due to the different ranges of analyzes and reference levels, the methods of determining individual measures have been given in Tables 2-9.

Table 1 – Methods for calculating absolute and relative errors

Reference level	Absolute Error (AE)	Relative Percentage Error (RPE) [%]
I	$\Delta_{w,k}(t)=\lvert y_{w,k}(t)-x_{w,k}(t)\rvert$	$\delta_{w,k}(t)=100\cdot\frac{\lvert y_{w,k}(t)-x_{w,k}(t)\rvert}{x_{w,k}(t)}$
II	$\Delta_{w}(t)=\lvert y_{w}(t)-x_{w}(t)\rvert$	$\delta_{w}(t)=100\cdot\frac{\lvert y_{w}(t)-x_{w}(t)\rvert}{x_{w}(t)}$
III	$\Delta_{w,k}=\lvert y_{w,k}-x_{w,k}\rvert$	$\delta_{w,k}=100\cdot\frac{\lvert y_{w,k}-x_{w,k}\rvert}{x_{w,k}}$
IV	$\Delta_{k}(t)=\lvert y_{k}(t)-x_{k}(t)\rvert$	$\delta_{k}(t)=100\cdot\frac{\lvert y_{k}(t)-x_{k}(t)\rvert}{x_{k}(t)}$
V	$\Delta_{w}=\lvert y_{w}-x_{w}\rvert$	$\delta_{w}=100\cdot\frac{\lvert y_{w}-x_{w}\rvert}{x_{w}}$
VI	$\Delta_{k}=\lvert y_{k}-x_{k}\rvert$	$\delta_{k}=100\cdot\frac{\lvert y_{k}-x_{k}\rvert}{x_{k}}$
VII	$\Delta(t)=\lvert y(t)-x(t)\rvert$	$\delta(t)=100\cdot\frac{\lvert y(t)-x(t)\rvert}{x(t)}$

Table 2 – Methods for calculating MAE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$MAE^{\mathrm{I}}{}_{w,k}=\frac{1}{\overline{T}}\sum_{t=1}^{\overline{T}}\Delta_{w,k}(t)$	$MAE^{\mathrm{I}}{}_{w}=\frac{1}{3\cdot\overline{T}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{T}}\Delta_{w,k}(t)$	$MAE^{\mathrm{I}}=\frac{1}{12\cdot\overline{T}}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{T}}\Delta_{w,k}(t)$
II	-	$MAE^{\mathrm{II}}{}_{w}=\frac{1}{\overline{T}}\sum_{t=1}^{\overline{T}}\Delta_{w}(t)$	$MAE^{\mathrm{II}}=\frac{1}{4\cdot\overline{T}}\sum_{w\in\boldsymbol{W}}\sum_{t=1}^{\overline{T}}\Delta_{w}(t)$
III	-	$MAE^{\mathrm{III}}{}_{w}=\frac{1}{3}\sum_{k\in\boldsymbol{K}}\Delta_{w,k}$	$MAE^{\mathrm{III}}=\frac{1}{12}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\Delta_{w,k}$
IV	-	-	$MAE^{\mathrm{IV}}=\frac{1}{3\cdot\overline{T}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{T}}\Delta_{k}(t)$
V	-	-	$MAE^{\mathrm{V}}=\frac{1}{4}\sum_{w\in\boldsymbol{W}}\Delta_{w}$
VI	-	-	$MAE^{\mathrm{VI}}=\frac{1}{3}\sum_{k\in\boldsymbol{K}}\Delta_{k}$
VII	-	-	$MAE^{\mathrm{VII}}=\frac{1}{\overline{T}}\sum_{t=1}^{\overline{T}}\Delta(t)$

Table 3 – Methods for calculating MPE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$MPE^{\mathrm{I}}{}_{w,k}=\frac{1}{\overline{\overline{T}}}\sum_{t=1}^{\overline{\overline{T}}}\delta_{w,k}(t)$	$MPE^{\mathrm{I}}{}_{w}=\frac{1}{3\cdot\overline{\overline{T}}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{\overline{T}}}\delta_{w,k}(t)$	$MPE^{\mathrm{I}}=\frac{1}{12\cdot\overline{\overline{T}}}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{\overline{T}}}\delta_{w,k}(t)$
II	-	$MPE^{\mathrm{II}}{}_{w}=\frac{1}{\overline{\overline{T}}}\sum_{t=1}^{\overline{\overline{T}}}\delta_{w}(t)$	$MPE^{\mathrm{II}}=\frac{1}{4\cdot\overline{\overline{T}}}\sum_{w\in\boldsymbol{W}}\sum_{t=1}^{\overline{\overline{T}}}\delta_{w}(t)$
III	-	$MPE^{\mathrm{III}}{}_{w}=\frac{1}{3}\sum_{k\in\boldsymbol{K}}\delta_{w,k}$	$MPE^{\mathrm{III}}=\frac{1}{12}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\delta_{w,k}$
IV	-	-	$MPE^{\mathrm{IV}}=\frac{1}{3\cdot\overline{\overline{T}}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{\overline{T}}}\delta_{k}(t)$
V	-	-	$MPE^{\mathrm{V}}=\frac{1}{4}\sum_{w\in\boldsymbol{W}}\delta_{w}$
VI	-	-	$MPE^{\mathrm{VI}}=\frac{1}{3}\sum_{k\in\boldsymbol{K}}\delta_{k}$
VII	-	-	$MPE^{\mathrm{VII}}=\frac{1}{\overline{\overline{T}}}\sum_{t=1}^{\overline{\overline{T}}}\delta(t)$

Table 4 – Methods for calculating RMSE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$RMSE^{\mathrm{I}}{}_{w,k}=$ $=\sqrt{\frac{1}{\overline{\overline{T}}}\sum_{t=1}^{\overline{\overline{T}}}\left(\Delta_{w,k}(t)\right)^{2}}$	$RMSE^{\mathrm{I}}{}_{w}=$ $=\sqrt{\frac{1}{3\cdot\overline{\overline{T}}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{\overline{T}}}\left(\Delta_{w,k}(t)\right)^{2}}$	$RMSE^{\mathrm{I}}=$ $=\sqrt{\frac{1}{12\cdot\overline{\overline{T}}}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{\overline{T}}}\left(\Delta_{w,k}(t)\right)^{2}}$
II	-	$RMSE^{\mathrm{II}}{}_{w}=$ $=\sqrt{\frac{1}{\overline{\overline{T}}}\sum_{t=1}^{\overline{\overline{T}}}\left(\Delta_{w}(t)\right)^{2}}$	$RMSE^{\mathrm{II}}=$ $=\sqrt{\frac{1}{4\cdot\overline{\overline{T}}}\sum_{w\in\boldsymbol{W}}\sum_{t=1}^{\overline{\overline{T}}}\left(\Delta_{w}(t)\right)^{2}}$
III	-	$RMSE^{\mathrm{III}}{}_{w}=\sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\Delta_{w,k}\right)^{2}}$	$RMSE^{\mathrm{III}}=\sqrt{\frac{1}{12}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\left(\Delta_{w,k}\right)^{2}}$
IV	-	-	$RMSE^{\mathrm{IV}}=$ $=\sqrt{\frac{1}{3\cdot\overline{\overline{T}}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{\overline{T}}}\left(\Delta_{k}(t)\right)^{2}}$
V	-	-	$RMSE^{\mathrm{V}}=\sqrt{\frac{1}{4}\sum_{w\in\boldsymbol{W}}\left(\Delta_{w}\right)^{2}}$
VI	-	-	$RMSE^{\mathrm{VI}}=\sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\Delta_{k}\right)^{2}}$
VII	-	-	$RMSE^{\mathrm{VII}}=\sqrt{\frac{1}{\overline{\overline{T}}}\sum_{t=1}^{\overline{\overline{T}}}\left(\Delta(t)\right)^{2}}$

Table 5 – Methods for calculating RMSPE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$RMSPE^{\mathrm{I}}{}_{w,k} = \sqrt{\frac{1}{\bar{\bar{T}}}\sum_{t=1}^{\bar{\bar{T}}}\left(\delta_{w,k}(t)\right)^2}$	$RMSPE^{\mathrm{I}}{}_{w} = \sqrt{\frac{1}{3\cdot\bar{\bar{T}}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\bar{\bar{T}}}\left(\delta_{w,k}(t)\right)^2}$	$RMSPE^{\mathrm{I}} = \sqrt{\frac{1}{12\cdot\bar{\bar{T}}}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\bar{\bar{T}}}\left(\delta_{w,k}(t)\right)^2}$
II	-	$RMSPE^{\mathrm{II}}{}_{w} = \sqrt{\frac{1}{\bar{\bar{T}}}\sum_{t=1}^{\bar{\bar{T}}}\left(\delta_{w}(t)\right)^2}$	$RMSPE^{\mathrm{II}} = \sqrt{\frac{1}{4\cdot\bar{\bar{T}}}\sum_{w\in\boldsymbol{W}}\sum_{t=1}^{\bar{\bar{T}}}\left(\delta_{w}(t)\right)^2}$
III	-	$RMSPE^{\mathrm{III}}{}_{w} = \sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\delta_{w,k}\right)^2}$	$RMSPE^{\mathrm{III}} = \sqrt{\frac{1}{12}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\left(\delta_{w,k}\right)^2}$
IV	-	-	$RMSPE^{\mathrm{IV}} = \sqrt{\frac{1}{3\cdot\bar{\bar{T}}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\bar{\bar{T}}}\left(\delta_{k}(t)\right)^2}$
V	-	-	$RMSPE^{\mathrm{V}} = \sqrt{\frac{1}{4}\sum_{w\in\boldsymbol{W}}\left(\delta_{w}\right)^2}$
VI	-	-	$RMSPE^{\mathrm{VI}} = \sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\delta_{k}\right)^2}$
VII	-	-	$RMSPE^{\mathrm{VII}} = \sqrt{\frac{1}{\bar{\bar{T}}}\sum_{t=1}^{\bar{\bar{T}}}\left(\delta(t)\right)^2}$

Table 6 – Methods for calculating SDAE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$SDAE^{\mathrm{I}}{}_{w,k} = \sqrt{\frac{1}{\bar{T}}\sum_{t=1}^{\bar{T}}\left(\Delta_{w,k}(t)-MAE_{w,k}\right)^2}$	$SDAE^{\mathrm{I}}{}_{w} = \sqrt{\frac{1}{3\cdot\bar{T}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\bar{T}}\left(\Delta_{w,k}(t)-MAE_{w}\right)^2}$	$SDAE^{\mathrm{I}} = \sqrt{\frac{1}{12\cdot\bar{T}}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\bar{T}}\left(\Delta_{w,k}(t)-MAE\right)^2}$
II	-	$SDAE^{\mathrm{II}}{}_{w} = \sqrt{\frac{1}{\bar{T}}\sum_{t=1}^{\bar{T}}\left(\Delta_{w}(t)-MAE_{w}\right)^2}$	$SDAE^{\mathrm{II}} = \sqrt{\frac{1}{4\cdot\bar{T}}\sum_{w\in\boldsymbol{W}}\sum_{t=1}^{\bar{T}}\left(\Delta_{w}(t)-MAE\right)^2}$
III	-	$SDAE^{\mathrm{III}}{}_{w} = \sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\Delta_{w,k}-MAE_{w}\right)^2}$	$SDAE^{\mathrm{III}} = \sqrt{\frac{1}{12}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\left(\Delta_{w,k}-MAE\right)^2}$
IV	-	-	$SDAE^{\mathrm{IV}} = \sqrt{\frac{1}{3\cdot\bar{T}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\bar{T}}\left(\Delta_{k}(t)-MAE\right)^2}$
V	-	-	$SDAE^{\mathrm{V}} = \sqrt{\frac{1}{4}\sum_{w\in\boldsymbol{W}}\left(\Delta_{w}-MAE\right)^2}$
VI	-	-	$SDAE^{\mathrm{VI}} = \sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\Delta_{k}-MAE\right)^2}$
VII	-	-	$SDAE^{\mathrm{VII}} = \sqrt{\frac{1}{\bar{T}}\sum_{t=1}^{\bar{T}}\left(\Delta(t)-MAE\right)^2}$

Table 7 – Methods for calculating SDPE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$SDPE^{\mathrm{I}}{}_{w,k} = \sqrt{\frac{1}{\overline{T}}\sum_{t=1}^{\overline{T}}\left(\delta_{w,k}(t)-MPE_{w,k}\right)^2}$	$SDPE^{\mathrm{I}}{}_{w} = \sqrt{\frac{1}{3\cdot\overline{T}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{T}}\left(\delta_{w,k}(t)-MPE_{w}\right)^2}$	$SDPE^{\mathrm{I}} = \sqrt{\frac{1}{12\cdot\overline{T}}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{T}}\left(\delta_{w,k}(t)-MPE\right)^2}$
II	-	$SDPE^{\mathrm{II}}{}_{w} = \sqrt{\frac{1}{\overline{T}}\sum_{t=1}^{\overline{T}}\left(\delta_{w}(t)-MPE_{w}\right)^2}$	$SDPE^{\mathrm{II}} = \sqrt{\frac{1}{4\cdot\overline{T}}\sum_{w\in\boldsymbol{W}}\sum_{t=1}^{\overline{T}}\left(\delta_{w}(t)-MPE\right)^2}$
III	-	$SDPE^{\mathrm{III}}{}_{w} = \sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\delta_{w,k}-MPE_{w}\right)^2}$	$SDPE^{\mathrm{III}} = \sqrt{\frac{1}{12}\sum_{w\in\boldsymbol{W}}\sum_{k\in\boldsymbol{K}}\left(\delta_{w,k}-MPE\right)^2}$
IV	-	-	$SDPE^{\mathrm{IV}} = \sqrt{\frac{1}{3\cdot\overline{T}}\sum_{k\in\boldsymbol{K}}\sum_{t=1}^{\overline{T}}\left(\delta_{k}(t)-MPE\right)^2}$
V	-	-	$SDPE^{\mathrm{V}} = \sqrt{\frac{1}{4}\sum_{w\in\boldsymbol{W}}\left(\delta_{w}-MPE\right)^2}$
VI	-	-	$SDPE^{\mathrm{VI}} = \sqrt{\frac{1}{3}\sum_{k\in\boldsymbol{K}}\left(\delta_{k}-MPE\right)^2}$
VII	-	-	$SDPE^{\mathrm{VII}} = \sqrt{\frac{1}{\overline{T}}\sum_{t=1}^{\overline{T}}\left(\delta(t)-MPE\right)^2}$

Table 8 – Methods for calculating CVAE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$CVAE^{\mathrm{I}}{}_{w,k} = \frac{SDAE^{\mathrm{I}}{}_{w,k}}{MAE^{\mathrm{I}}{}_{w,k}}$	$CVAE^{\mathrm{I}}{}_{w} = \frac{SDAE^{\mathrm{I}}{}_{w}}{MAE^{\mathrm{I}}{}_{w}}$	$CVAE^{\mathrm{I}} = \frac{SDAE^{\mathrm{I}}}{MAE^{\mathrm{I}}}$
II	-	$CVAE^{\mathrm{II}}{}_{w} = \frac{SDAE^{\mathrm{II}}{}_{w}}{MAE^{\mathrm{II}}{}_{w}}$	$CVAE^{\mathrm{II}} = \frac{SDAE^{\mathrm{II}}}{MAE^{\mathrm{II}}}$
III	-	$CVAE^{\mathrm{III}}{}_{w} = \frac{SDAE^{\mathrm{III}}{}_{w}}{MAE^{\mathrm{III}}{}_{w}}$	$CVAE^{\mathrm{III}} = \frac{SDAE^{\mathrm{III}}}{MAE^{\mathrm{III}}}$
IV	-	-	$CVAE^{\mathrm{IV}} = \frac{SDAE^{\mathrm{IV}}}{MAE^{\mathrm{IV}}}$
V	-	-	$CVAE^{\mathrm{V}} = \frac{SDAE^{\mathrm{V}}}{MAE^{\mathrm{V}}}$
VI	-	-	$CVAE^{\mathrm{VI}} = \frac{SDAE^{\mathrm{VI}}}{MAE^{\mathrm{VI}}}$
VII	-	-	$CVAE^{\mathrm{VII}} = \frac{SDAE^{\mathrm{VII}}}{MAE^{\mathrm{VII}}}$

Table 9 – Methods for calculating CVPE

Reference level	For direction on the inlet	For the inlet	For the whole intersection
I	$CVPE^{\mathrm{I}}{}_{w,k} = \frac{SDPE^{\mathrm{I}}{}_{w,k}}{MPE^{\mathrm{I}}{}_{w,k}}$	$CVPE^{\mathrm{I}}{}_{w} = \frac{SDPE^{\mathrm{I}}{}_{w}}{MPE^{\mathrm{I}}{}_{w}}$	$CVPE^{\mathrm{I}} = \frac{SDPE^{\mathrm{I}}}{MPE^{\mathrm{I}}}$
II	-	$CVPE^{\mathrm{II}}{}_{w} = \frac{SDPE^{\mathrm{II}}{}_{w}}{MPE^{\mathrm{II}}{}_{w}}$	$CVPE^{\mathrm{II}} = \frac{SDPE^{\mathrm{II}}}{MPE^{\mathrm{II}}}$
III	-	$CVPE^{\mathrm{III}}{}_{w} = \frac{SDPE^{\mathrm{III}}{}_{w}}{MPE^{\mathrm{III}}{}_{w}}$	$CVPE^{\mathrm{III}} = \frac{SDPE^{\mathrm{III}}}{MPE^{\mathrm{III}}}$
IV	-	-	$CVPE^{\mathrm{IV}} = \frac{SDPE^{\mathrm{IV}}}{MPE^{\mathrm{IV}}}$
V	-	-	$CVPE^{\mathrm{V}} = \frac{SDPE^{\mathrm{V}}}{MPE^{\mathrm{V}}}$
VI	-	-	$CVPE^{\mathrm{VI}} = \frac{SDPE^{\mathrm{VI}}}{MPE^{\mathrm{VI}}}$
VII	-	-	$CVPE^{\mathrm{VII}} = \frac{SDPE^{\mathrm{VII}}}{MPE^{\mathrm{VII}}}$

4.2 Assessment of usefulness of the measurements of traffic characteristics using Bluetooth sensors

The usefulness assessment of the measurements of traffic characteristics using Bluetooth sensors has been carried out on seven reference levels according to the assumptions of the mathematical model previously presented. These analyzes have been made separately for the direction on inlet, for the inlet and for the whole intersection, depending on the reference level. The levels in question are:

- **Level I** – analysis has been carried out for the direction on inlet, for the inlet and for the whole intersection comparing the results of measurements aggregated to traffic directions on the inlets for each measurement interval,
- **Level II** – analysis has been carried out for the inlet and for the whole intersection comparing the results of measurements aggregated to the inlets for each measurement interval,
- **Level III** – analysis has been carried out for the inlet and for the whole intersection comparing the results of measurements aggregated to the inlets for the whole time interval,
- **Level IV** – analysis has been carried out for the whole intersection comparing the results of measurements aggregated to traffic directions on the whole intersection for each measurement interval,
- **Level V** – analysis has been carried out for the whole intersection comparing the results of measurements aggregated to the inlets for the whole time interval,
- **Level VI** – analysis has been carried out for the whole intersection comparing the results of measurements aggregated to the traffic directions on the whole intersection for the whole time interval,
- **Level VII** – analysis has been carried out for the whole intersection comparing the results of measurements aggregated to the whole intersection for each measurement interval.

Tables 10 to 12 show the measurement results for the specified reference levels. Gray background has been used for the measures based on relative error.

Table 10 – The usefulness assessment of the measurements of traffic characteristics using Bluetooth sensors regarding the traffic directions (for Level I)

Measure	Inlet A			Inlet B			Inlet C			Inlet D		
	Right	Straight	Left	Right	Straight	Left	Right	Straight	Left	Right	Straight	Left
MAE	23,65	216,25	50,60	20,65	87,40	15,20	82,90	237,70	3,75	62,55	96,90	144,35
MPE [%]	92,57	89,66	83,00	92,94	91,52	88,82	88,71	91,51	54,58	86,18	89,63	92,00
RMSE	24,54	217,52	51,58	21,58	88,18	16,03	83,82	247,17	5,30	63,89	98,60	145,57
RMSPE [%]	92,65	89,69	83,31	93,14	91,60	89,42	88,84	91,58	65,70	86,40	89,70	92,05
SDAE	6,57	23,50	10,02	6,26	11,73	5,09	12,40	67,76	3,74	13,03	18,25	18,80
SDPE [%]	3,86	2,56	7,20	6,07	3,71	10,33	4,69	3,60	36,57	6,26	3,43	2,92
CVAE	0,28	0,11	0,20	0,30	0,13	0,33	0,15	0,29	1,00	0,21	0,19	0,13
CVPE [%]	0,04	0,03	0,09	0,07	0,04	0,12	0,05	0,04	0,67	0,07	0,04	0,03

Source: Made by the authors

Table 11 – The usefulness assessment of the measurements of traffic characteristics using Bluetooth sensors regarding the inlets (for Levels I, II and III)

	Level I				Level II				Level III			
Measure	Inlet A	Inlet B	Inlet C	Inlet D	Inlet A	Inlet B	Inlet C	Inlet D	Inlet A	Inlet B	Inlet C	Inlet D
MAE	96,83	41,08	108,12	101,27	290,50	123,25	324,35	303,80	1936,67	821,67	2162,33	2025,33
MPE [%]	88,41	91,09	78,27	89,27	88,74	91,65	90,30	90,16	88,53	91,66	81,59	89,49
RMSE	129,85	53,23	150,72	108,00	291,42	124,06	332,91	305,18	2578,99	1051,74	2907,18	2133,51
RMSPE [%]	88,64	91,39	82,86	89,41	88,78	91,68	90,38	90,18	88,62	91,68	82,59	89,52
SDAE	15,23	8,22	39,83	16,89	23,19	14,18	74,99	29,04	1703,08	656,53	1943,20	670,74
SDPE [%]	4,94	7,24	21,39	4,45	2,67	2,40	3,83	1,86	3,92	1,43	12,82	2,33
CVAE	0,16	0,20	0,37	0,17	0,08	0,12	0,23	0,10	0,88	0,80	0,90	0,33
CVPE [%]	0,06	0,08	0,27	0,05	0,03	0,03	0,04	0,02	0,04	0,02	0,16	0,03

Source: Made by the authors

Table 12 – The usefulness assessment of the measurements of traffic characteristics using Bluetooth sensors regarding the whole intersection (for Levels I to VII)

Measure	Level I	Level II	Level III	Level IV	Level V	Level VI	Level VII
	Reference of intersection						
MAE	86,83	260,48	1736,50	347,30	5209,50	6946,00	86,83
MPE [%]	86,76	90,21	87,82	89,52	90,40	89,66	90,13
RMSE	116,27	275,81	2278,21	406,43	5450,49	8075,65	301,85
RMSPE [%]	88,13	90,26	88,16	89,57	90,41	89,66	90,14
SDAE	23,30	42,44	1374,54	211,10	1602,79	4119,38	276,88
SDPE [%]	11,77	2,79	6,84	2,94	1,07	0,92	1,66
CVAE	0,27	0,16	0,79	0,61	0,31	0,59	3,19
CVPE [%]	0,14	0,03	0,08	0,03	0,01	0,01	0,02

Source: Made by the authors

The values of the measures in Tables 10 to 12 allow to assess the quality of measurements of traffic flow using Bluetooth sensors at the intersection. It should be noted, however, that the method of determining the measures also affects the values obtained. It depends, inter alia, on how the data is aggregated (for traffic directions at inlets, for the inlets and for the whole intersections). This is evidenced by the MPE and MSPE measurement values, as well as by the values showing the assessment of the measurement errors i.e. SDPE and CVPE. In general, the measurement error value is about 90%. It may be unequivocally stated that these devices should not be used to measure the traffic volume at a single intersection.

The broadest range of comparisons of the effect of data aggregation on the size of the measurement error is obtained by analyzing the values for the whole intersection (reference levels I to VII). The range of variability of the MPE varies from 86.76% (level I) to 90.40% (level V), and of the RMSPE - from 88.13% (level I) to 90.41% (level V). However, the variation of the measurement errors is small, as evidenced by the SDPE and CVPE measures, ranging respectively from 0.92% (for level VI) to 11.77% (for level I) and 0.01% (for level V and VI) to 0.14% (for level I).

5. CONCLUSIONS

The decision to use Bluetooth sensors for traffic measurement should be taken with great care. The results of the study show that the measurement error in traffic measurement using these devices reaches up to 60%. Thus, it not entirely seems justified to use these devices - at least for the measurement of the traffic volume at a single intersection.

Of course, the specifics of the characteristics under study plays an important role. Furthermore, the fact that the number of users with Bluetooth sensors in total flow is a random phenomenon may have a great effect on obtained values. The total number of registered devices in traffic at the intersection under study have reached 10%, but the measurement error is about 90%. This is also confirmed by the values of the MPE and RMSPE. The lowest value of the former error is 54.58% for the reference level I (at C inlet for the left), and of the second error is about 88.16% for the reference level III. The lowest values for these errors were obtained for the highest levels of aggregation (for the greatest detail, i.e. for the direction of traffic on the inlets).

In addition, the article investigated the error values (MEA and RMSE) for other levels of data aggregation. It turned out that the variance of the determined errors is small, which proves the correctness of the proposed research methodology and, unfortunately, a large measurement error. It seems therefore that Bluetooth sensors can be used to measure traffic characteristics as the complementary devices (as evidenced by the values of such measures as SDPE and SCPE).

Lack of compatibility for traffic volume at different levels of detail and data aggregation forces the need for searching other features to evaluate which Bluetooth devices may be used. Further research by the Authors will focus on:

- the use of Bluetooth devices for validation of directional structure of traffic, speed testing, peak hour determination, and traffic assignment in transportation networks,
- the use of Bluetooth devices for estimating directional structure of traffic at intersection expressed in percentages,
- analysis of usefulness assessment of the measurements of traffic characteristics using Bluetooth sensors at intersection, expressed in 30, 45 and 60 minutes intervals,
- comparison of error distributions in function of time for directional structure of traffic.

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CURRENT LEVEL CROSSINGS SAFETY IN THE REPUBLIC OF CROATIA

ABSTRACT

Level crossings (LC's) represent a significant safety challenge for both road and railway traffic because they are often places with frequent accidents which results with human fatalities and significant material damages. Analysis of accident statistics have shown that main cause of all accidents is human behaviour of road users (pedestrians, cyclists and motor vehicle drivers) who didn't obey traffic rules, either intentionally or unintentionally. This paper shows current level crossing safety in the Republic of Croatia and proposes cost-effective measures for increasing level crossing safety.

KEY WORDS

level crossings; accidents; safety measures;

1. INTRODUCTION

Level crossings (LC) are crossing places of railway lines or industrial tracks with the road surface at the same level [1]. Due to the significant differences between road and rail vehicles (mass, stopping distances and manoeuvring capabilities), level crossings represent significant safety challenge for both road and railway traffic. Besides the technical characteristics of vehicles involved, safety challenge also lies in complex sociotechnical systems which involve interactions between many different types of road users (pedestrians, cyclists, motor vehicle drivers) and railway operators [2].

Accidents at level crossings increasingly attract the attention of the public, railway industry and relevant transport authorities [3], but unfortunately due to biased and inexpert media reporting, general perception in public is that accidents at level crossings are primarily railway sector problem even though statistical analyses of accidents shows that main cause of level crossing accidents is human behaviour of road users [4]. On average, fatalities at level crossing accidents represent almost one third of railway related fatalities, but only about 1% of overall road fatalities and because of that they didn't represent a significant issue for road sector authorities , but they are mayor obstacles for both traffic efficiency as well as rail safety [5].

There are several aspects from which level crossing safety can be addressed, but in general they can be divided into three distinctive categories: technical solutions of protecting LC's, national and international safety programs and educational campaigns [6]. Behaviour of road users is the main cause of all LC accidents; therefore, technical solutions are concentrated on ways to prevent road users to intentionally or unintentionally break traffic rules [7]. Some technical solutions uses advanced systems for scanning and recognition of license plates in order to punish drivers who are braking traffic rules on LC area [8]. Others uses obstacle laser detection systems which are only active during closed level crossing. They are monitoring predetermined LC area and giving real time information to train operators [9]. Speeding in LC area is another concern, so some authors suggest using low tech solutions in order to decrease road vehicles approaching speed such as reflective signs built into road pavement and rumble strips [10]. Unfortunately, technical solutions are only effective if they are correctly used and if the road users obey basic traffic rules. For that reason very important role falls on national and international educational campaigns such as Operation Lifesaver in the USA [11] and ILCAD – International Awareness Day [12]. Their main purpose is increasing road users awareness by providing and organising educational lectures, workshops, round tables and especially influencing popular social media such as Facebook and Twitter. Similar educational campaign also exits in the Republic of Croatia since 2000 when the Croatian Railways started their own campaign "Vlak je uvijek brži" (Eng.: "Train is always faster") in elementary schools across the country [13]. It included lectures, educational posters and pamphlets and since then expanded on all level crossing users as well as on social networks.

Aim of this paper is to analyse all relevant statistical data regarding level crossing accidents in Republic of Croatia. Based on those results, appropriate and cost-effective measures for increasing safety at LC will be suggested.

2. CLASSIFICATION OF LEVEL CROSSINGS IN THE REPUBLIC OF CROATIA

Since Lc's represent significant safety challenge, for both road and railway traffic, they need to be properly marked and protected with appropriate protection systems. Basic classification of protecting LC's is divided between passive and active protection. With passive systems road user is solely responsible for observing traffic situation (approaching train). In Croatia road traffic signs used for passive level crossings (traffic signs "Stop" and "St. Andrews Cross) stays unchanged and users should understand what they mean, then search/listen for trains, and respond accordingly to observed traffic situation. On the other hand, active protection changes its state to warn road users of approaching train (flashing light and sound and/or full or half barriers) [14]. Most common automatic LC's protection in Croatia is use of flashing lights and sound warning together with half barriers. Figure 1 shows classification of protection systems in the Republic of Croatia.

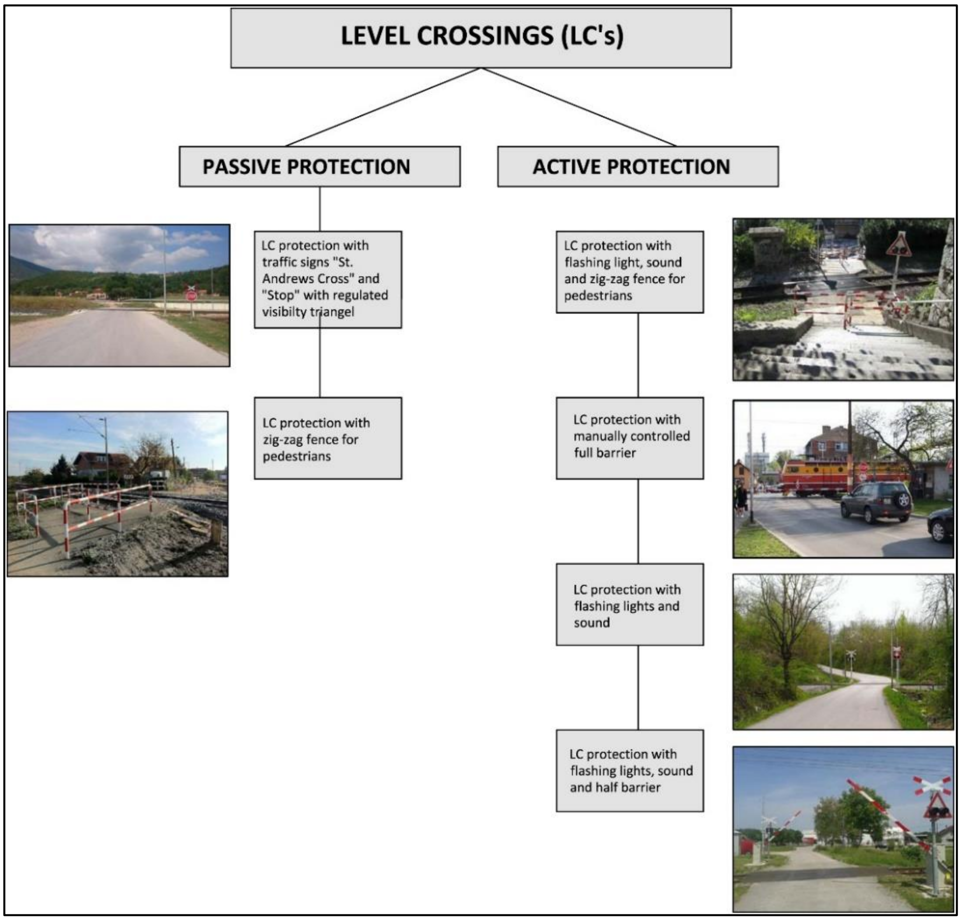

Figure 1 – Classification of LC's protection systems

The total length of railway lines in Croatia is 2.605 km, out of which 2.351 km are single track lines and 254 are double track lines. There are 980 km of electrified lines (977 km with 25kV/50 Hz A.C. system and 3km with 3kV D.C. system [15].

Every level crossing in Republic of Croatia is protected with a minimum passive protection and out of total 1.520 level crossings, 62,76% are protected with passive protection systems and remaining 37,24% with active protection systems as shown in Table 1 [16].

Table 1 – Classification and number of level crossings in the Republic of Croatia

Passive LC		**Active LC**				**Total**
Traffic signs + visibility triangle	Pedestrian crossings	Pedestrian crossings with sound and flashing lights warning	Manual full barriers	Sound and flashing lights with half-barrier	Sound and flashing lights	
895	59	11	65	349	141	**1,520**

Source: Made by the authors according to [16]

The total number of level crossings with passive protection systems in Croatia is considerably higher than the average of the rest of the EU countries. Currently there are 218,104 kilometres of railway tracks in the EU with 114,120 level crossings of which 51% have passive protection systems and remaining 49% have active protection systems [17]. Figure 2 shows the breakdown of EU level crossings by protection type.

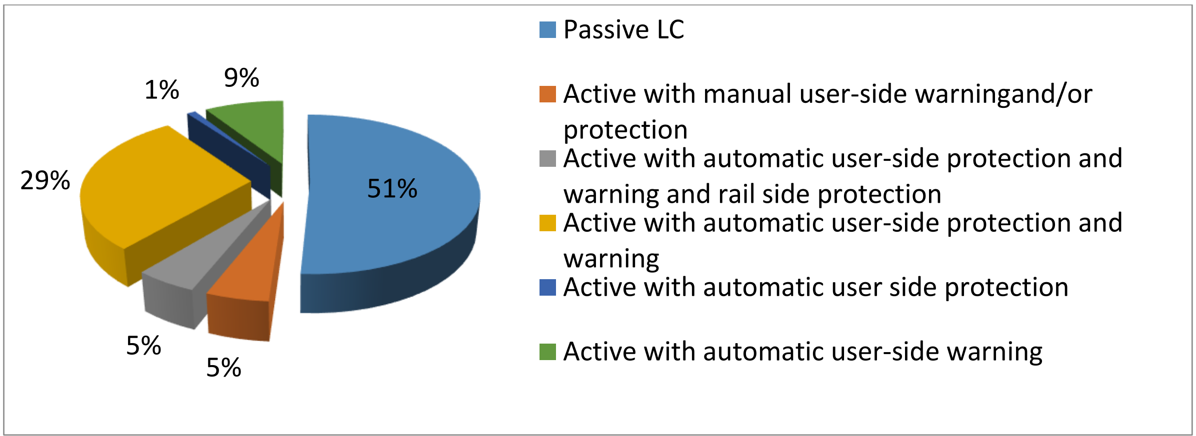

Figure 2 – Breakdown of EU level crossings by protection type
Source: Made by the authors according to [17]

From the Figure 2 it can be observed that on average, EU countries have higher percentage of level crossings with active protection systems than Croatia (37% in Croatia compared with 49% for EU).

3. LEVEL CROSSING ACCIDENTS STATISTCS

For purpose of this article level crossings accident statistics was analysed from 2007 up to 2016. Unfortunately, official data is only available up to 2014 because that was the last year that HŽ Infrastructure issued their annual safety report. Partial data, but only for level crossings, for 2015 and 2016 was obtained unofficially from HŽ Infrastructure employers and it will be included in the overall accident statistics.

Analysing the data for the last 10 years, in the last observed year (2016) there were total of 24 LC's accidents in Croatia which is a significant 43.92% drop in comparison with the 10-year average. Furthermore, it can be observed from Table 2 that 36,92% of all accidents happened on level crossings with active protection systems which is alarming and obviously shows very poor traffic culture in the Republic of Croatia [18].

Table 2 – Level crossing accidents by protection system in the Republic of Croatia (2007-2016)

Type of LC / Number of accidents	Year									
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Active LC	19	15	25	12	21	21	16	12	12	5
Passive LC	53	23	45	29	24	24	20	24	16	19
Pedestrian LC	0	1	0	0	1	0	0	1	0	0
TOTAL	**72**	**39**	**60**	**41**	**46**	**45**	**36**	**37**	**28**	**24**

Source: Made by the authors according to [18]

When we look at the consequences of these accidents it can be observed that the overall number of fatalities is dropping even though there are spikes in some observed years. Figure 3 shows detailed number of fatalities according to LC protection systems. What is concerning is the fact that almost half of fatalities (48,42%) in 10-year span happened on level crossings with active protection systems which worked properly at the time of the accidents.

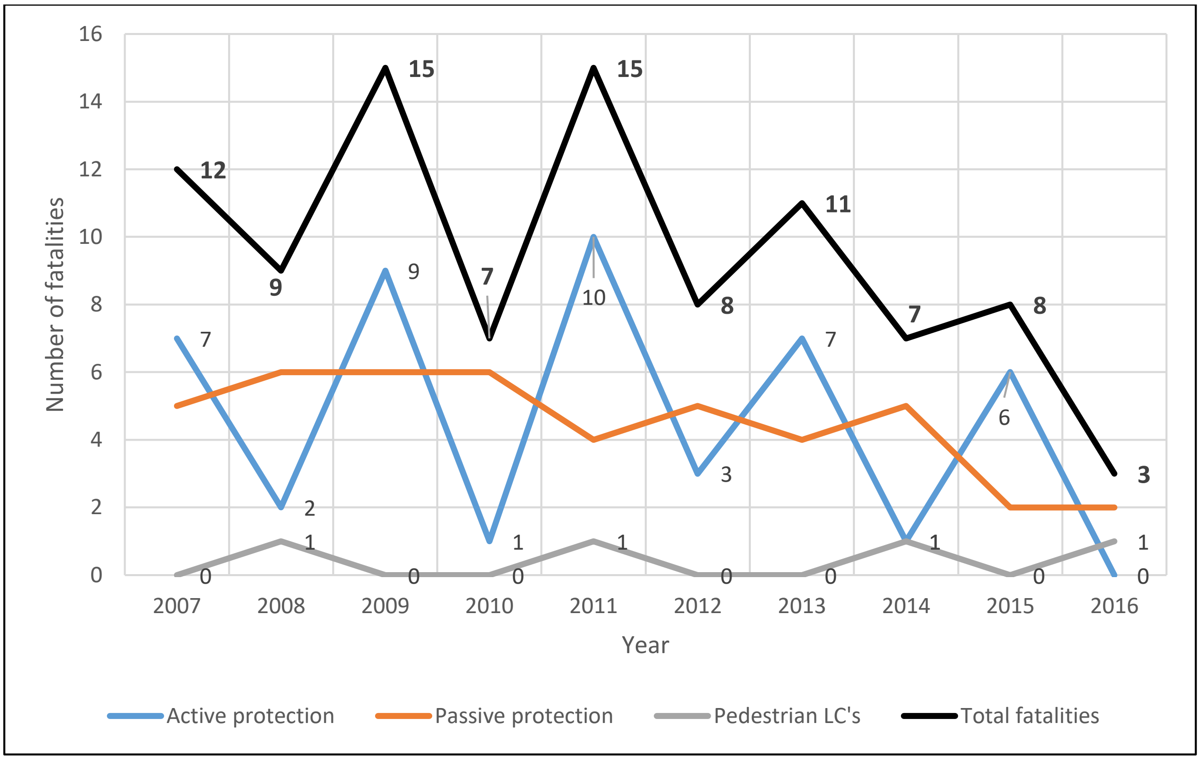

Figure 3 – Level crossing fatalities by protection system in the Republic of Croatia (2007-2016)
Source: Made by the authors according to [18]

This is another proof of very poor traffic culture in Croatia, because all fatalities are road users who clearly didn't obey visible road traffic signs, especially on LC's with active protection systems. Unfortunately, accidents and fatalities at level crossings are not a primary concern of road sector or proper national authorities because they represent only a small fraction of all road traffic accidents and fatalities in the Republic of Croatia, even though the behaviour of road users is the main reason for all accidents at level crossings [19]. Figure 4 shows detailed comparison of overall road fatalities with level crossings fatalities with expressed ratio of LC's fatalities.

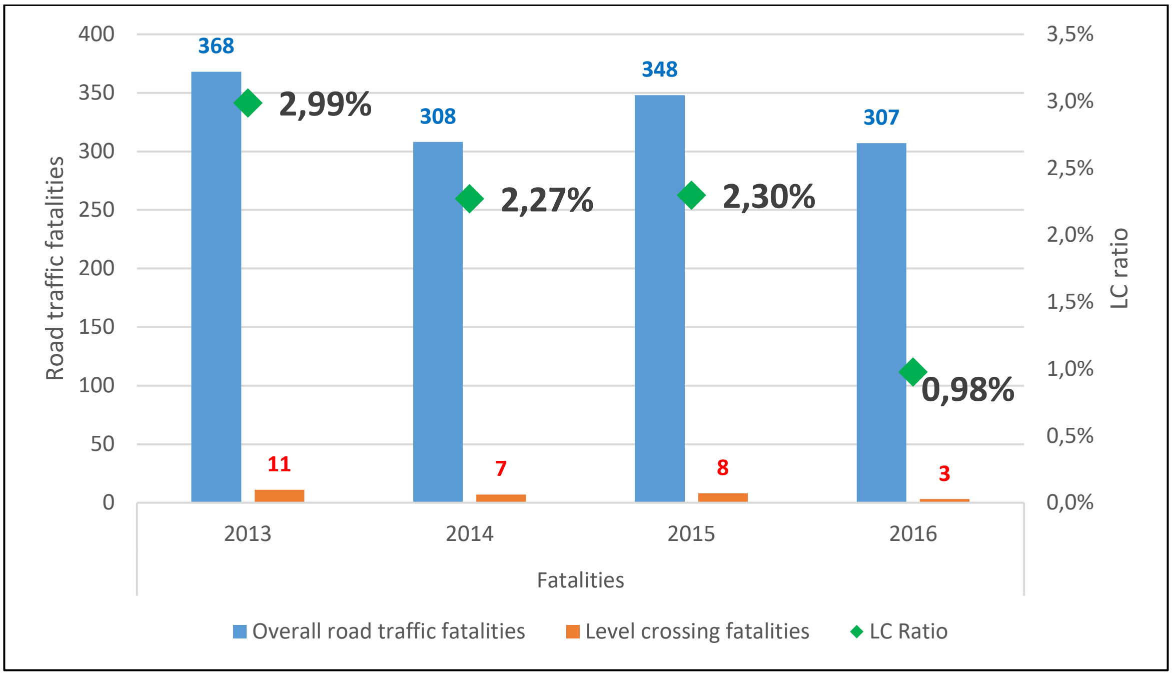

Figure 4 – Comparison of road and LC fatalities in the Republic of Croatia (2013-2016)
Source: Made by the authors according to [18] and [19]

Currently there are 414 level crossings in Croatia that uses full or half-barriers so it is of great concern a large number of broken or damaged barriers by road users. This presents significant safety issue because every incident where road drivers ran into barriers could lead to a potential serious accident. Figure 5 shows the breakdown of all broken or damaged barriers from 2017 until 2016. It can be observed that the number is decreasing but it is still too high and it is another testament for poor traffic culture in Croatia.

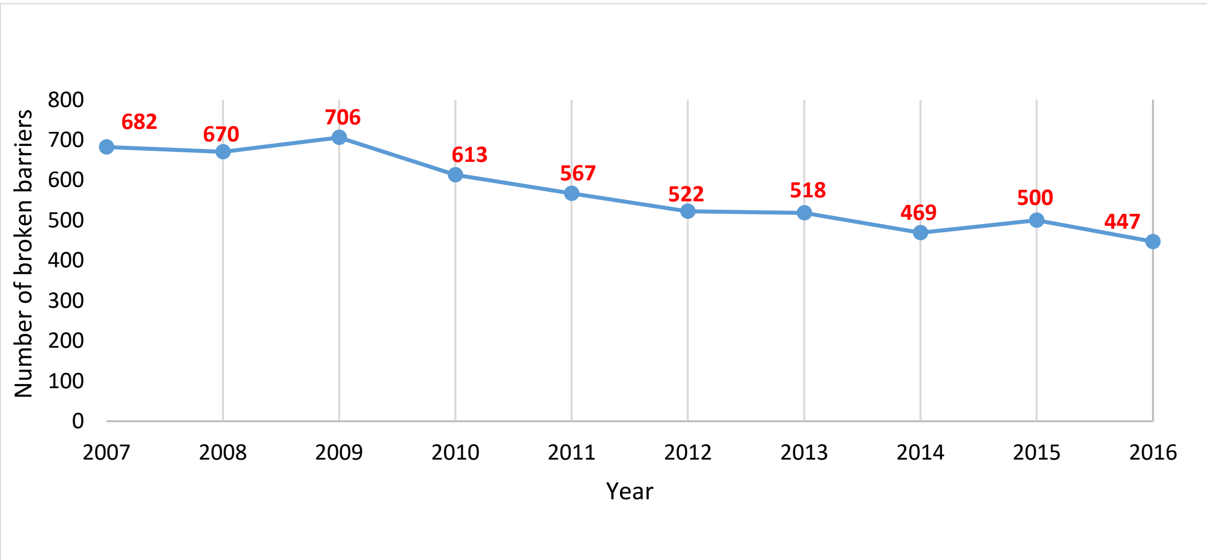

Figure 5 – Broken or damaged barriers on LC's in the Republic of Croatia (2007-2016)
Source: Made by the authors according to [18]

Unfortunately, only broken barriers are reported to proper authorities, so it is not known how many road users are intentionally driving around lowered barriers and thus cause a protentional dangerous situation.

4. MESAURES FOR INCREASING SAFETY ON LEVEL CROSSINGS

The only real solution for completely removing possible occurrence of accidents at level crossings is to separate road and railway traffic in two levels by either building an overpass or underpass. Due to the high costs of such infrastructure projects, separating road and railway traffic is reserved for only those LC's with highest traffic volumes or significant accident history and after a lengthy process that includes both road and railway authorities as well as local communities.

For that reason, there is a need for a more cost-effective solution that can be applied rather fast than lengthy infrastructure processes. Upgrading protection systems from passive to active should be first step in increasing safety, but even most advanced active protection systems will not be effective if the road users don't obey traffic rules and observing common sense when crossing over railway tracks.

Since human behaviour is the main cause of all LC accidents, the emphasis should be on proper education of all level crossing users regarding dangers when crossing railway tracks. First step to achieve this goal is to widen curriculum in driving schools so that young drivers will be more prepared for level crossing dangers and parallel with that, there should be a continuous national campaign throughout media and social networks with ads and posters explaining the dangers and consequences of illegal behaviour on level crossings. Furthermore, big poster panels with the same information could be installed in the close vicinity of level crossings with higher traffic volume and/or accident history [16].

Proper maintenance of visibility triangle on LC's with passive protection systems is of outmost importance because vegetation around railway tracks, especially from spring to autumn, can severely diminished road users visibility on an oncoming train. Since majority of LC's in Croatia are passive, regular maintenance of visibility triangle should be one of the highest priorities.

Another low-cost solution for LC's with half-barriers is road lane separators for directional traffic on the approaches to level crossing. Reason for that is because road users are intentionally driving around lowered barriers which is a significant safety issue. Separators should be installed on the road centreline leading right next to lowered half-barrier in the length of at least 10 meters from the half-barrier so that it is impossible for road user to go around lowered half-barriers [20]. They could be built from relatively cheap and easy to replace plastic components and main purpose would be a deterrent for drivers to brake traffic rules by going around half-barriers.

5. CONSLUSION

Level crossings represent a significant safety challenge for both road and railway traffic, even though railway traffic is among safest transportation modes. Even though there is a trend of diminishing level crossing accidents and fatalities in the Republic of Croatia, accident statistics still shows very poor traffic culture. Since more than one third of railway related fatalities happens on level crossings, a wrong public perception exists that LC's accidents are mainly a railway sector problem. But, analyses of accident statistics show that main cause of all accidents is human behaviour of road users. Unfortunately, accidents and fatalities at level crossings do not represent high priority for road traffic sector even though road users are main cause of LC accidents. Reason for that is overall road traffic statistics where LC fatalities represent only a small fraction of overall road traffic accidents.

Since the main cause of LC accident will remain human behaviour of all road users (pedestrians, cyclist and motor vehicle drivers), every safety measure should be targeted at ways to completely, or as much as possible, remove possibility of road users bad decisions regarding crossing railway tracks. Of course, the only real solution is grade separation of railway and road traffic, but high costs of such solutions are reserved for LC's with significant traffic volumes and/or accident history.

Unfortunately, a large number of accidents in Croatia happens on LC's with active protection systems which leads to a conclusion of poor traffic culture of road users. For that reason, it is important to increase the educational campaigns throughout the whole county for all LC users, but together with increased repression policies.

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THE IDENTIFICATION OF KEY ELEMENTS IN THE DEVELOPMENT OF LOGISTIC OPERATORS

ABSTRACT

For logistics operators to develop and increase their competitiveness on today's rapidly changing market, it is necessary to invest in processes, technology, staff and other resources of which a company consists. Logistics processes are increasingly present in everyday life, while companies engaged in logistics activities, with the optimal logistics processes planning, generate more profit and hold a more stable position in the globalized market. Because of a complex, systematic and networking access logistics today increases the speed and efficiency of operations and significantly impacts the reduction of costs, thus fulfilling one of the basic strategic functions, which consists of creating the necessary core competences of a company. The aim of this paper is to identify, present and describe the information and communication (IT) technology, logistics strategies and human resources as key factors in the development of logistics operators.

KEY WORDS

logistics operators; IT technology; logistics strategy; human resources;

1. INTRODUCTION

Many companies today want to improve their business, which includes the processes of procurement, distribution, transportation, storage, respectively all the processes within the supply chain. Market development and market relations have, with a very marked competition, imposed the need for enterprises to significantly change and adapt their business policy in order to produce and distribute market-friendly products. The need and the trend of ''cost reduction'' in contemporary economic systems have set new terms and conditions in companies' management. Therefore, the importance of having logistics and optimization of supply chains is increasing. The introduction of appropriate optimization models, such as IT technology, new logistics strategies and investment in human resources, which can be applied within the logistics processes in daily management, has become the primary task of modern enterprises and logistics operators respectively.

A logistics operator is a factor that successfully designs and optimizes the logistics network that is increasingly integrated into the global economic system, and performs a variety of logistic activities from the delivery to the receipt point, all with minimal resources invested and the maximum met requirements on the market. With the development and specialization of business activities the development of the concept of a logistics operator is visible, from a 1PL to 5PL operator which is aimed to providing complete logistics solutions of the whole supply chain and it represents an advanced supply chain management as an integration of all activities related to the circulation of goods in modern logistic networks.

A purpose of this paper is to present and analyze the key factors and directions of logistics operator development using IT technology, logistics strategies and human resources investment. The main objective of this research is to identify the key elements that enable the improvement of logistic processes. The questionnaire about importance and influence of IT technologies, logistics strategies and human resources on logistics operators' business was conducted among logistics operators. The result of this questionnaire is presented in this paper.

2. KEY FACTORS AND THE COURSE OF DEVELOPMENT OF LOGISTICS OPERATORS

With the development of the global logistics market the role of logistics operators spreads at equal speed. In the time of globalization, logistics operators offer transport, but also storage services, information technology, and in certain cases, even production, and global performance. Therefore, in these conditions, logistics operators must complete the task of enabling global companies by combining domestic and international resources in a way that will enable effective and efficient implementation of their business ventures within the global traffic, logistics and economic system. To acquire such results, it is necessary to invest in information technology (IT), to introduce strategies for development and investment in human resources [1].

Large transport companies (1PL) provided their limited services to a transport chain that had limited services of physical transport. First Party Logistics (1PL) are companies, which do their own logistics activities. In logistics first party companies do not get help from outsourcing companies [2]. With time, through the expansion of freight forwarding logistics (2PL) the field and the diversity of logistics services expanded (by providing additional services). A Second Party Logistics (2PL) provider specializes on one area of the supply chain, usually transporting goods from one point to another [2]. The mentioned trend has continued, so that today it is increasingly affirmed by providing so-called advanced services, which are more complex, of better quality, faster, more reliable and more flexible. One of the most important links in the supply chain is the responsibility of modern operators for a larger part of the transport chain, from production to the customer. The development of logistics outsourcing has led to a growing demand of manufacturing companies for logistics services, as well as their increasing demands. This had a decisive impact on systematic logistics operators (3PL), where they had to begin to organize and propose additional logistics operations that would increase the value of the total logistics service: the development, introduction and use of information and communication systems, the development of strategies that can contribute to better logistical planning and the investment in human resources [3].

2.1 IT technology and logistics operators

Contemporary logistics requires the cooperation and communication of logistics processes in order to be effective. Information technology is an essential link to all logistic chain processes and allows a continuous communication in real time. It has become a core technology that ensures an efficient flow of products, services and information through the logistics chain.

The key factor for the success and efficiency of a logistics chain is the cooperation and joint action between various participants. All this leads to a necessary synchronization between activities within the logistics chain. This level of coordination refers to the integration of logistics processes through the field of information exchange, joint planning, business flow coordination and the acceptance of new models and technologies of business [4].

The integration of the logistic chain takes place through four areas [5]:

- The exchange of information among the members of the logistics system - early identification of problems, rapid response, building trust and reliability;

- Joint planning, monitoring, updating and design - reduction of costs (material, operational), higher utilization of capacity, a higher level of customer service;
- Coordinated work flow and operations - efficient logistics services, faster response to client requests, service improvement, convergence of services to the market;
- Adoption of new business models and technologies – new market entry, new services offer, efficiency improvement, mass customization.

One of the important terms that relate to the relationship logistics operator - carrier is that they have to conform to the agreement on the manner in which they set their business objectives, roles and responsibilities, and that they have a wide range of strategic and operational issues. A study from 2016 by C. John Langley Jr., Randolph P. Ryerson and other, under the title ''Third-Party Logistics '', aimed at exploring the improvement and strengthening of openness, transparency and effective communication between logistics operators and carriers, as well as the ability of both parties to be sufficiently agile and flexible in order to better respond to current and future business needs and challenges. For carriers to reduce costs and improve their business, the usage of the possibility of outsourcing of certain logistics activities is rising, as shown in Table 1 [6].

Table 1 – Percentage of users who use outsourcing logistics services

Outsourcing of logistics services	Percentage of users
Domestic transport	80 %
Storage	66 %
International transport	60 %
Forwarding	48 %
Customs intermediation	45 %
Reverse logistics	34 %
Cross-docking	33 %
Statutory audits of cargo and payments	31 %
Transportation planning and management	28 %
Inventory management	25 %
Product labeling, packaging	22 %
Order and delivery management	19 %
Service logistics	12 %
Fleet management system	12 %
Information Technology (IT)	11 %
Supply chain consultations	11 %
User services	7 %
LLP/4PL services	6 %

Source: [6]

Table 1 shows that the logistics services most common in outsourcing are the following: domestic transportation (80%), storage (66%), international transportation (60%), shipping (48%) and customs intermediation (45%). On the other hand, it is evident that the services that are strategically focused on the needs of clients and on more intensive use of IT technologies have less need for outsourcing. For example, the included services are: service logistics (12%), fleet management system (12%), IT services (11%), supply chain consultations (11%), customer service (7%) and LLP / 4PL services (6%).

For logistics operators to successfully provide services to clients (customers) they mostly use IT technologies that have the capacity for more performances and transactions. Some of these technologies are: the warehouse managing system / distribution centre (WMS), transportation managing system (TMS), visibility, RFID system, barcode system, a system for electronic data interchange (EDI) and GPS tracking system.

The conducted study by C. John Langley Jr., Randolph P. Ryerson and others, ''Third-Party Logistics 2016'', examined attitudes among operators whether the information technology is a necessary element of 3PL operators and if they are satisfied with the abilities and the services that are provided by 3PL operators using information technology. The results of the study (*Figure 1*) for 2015 showed that 93% of respondents agreed that IT technology is a necessary element of 3PL operators, while 59% of respondents agreed that they are satisfied with the capabilities of 3PL operators using IT technology.

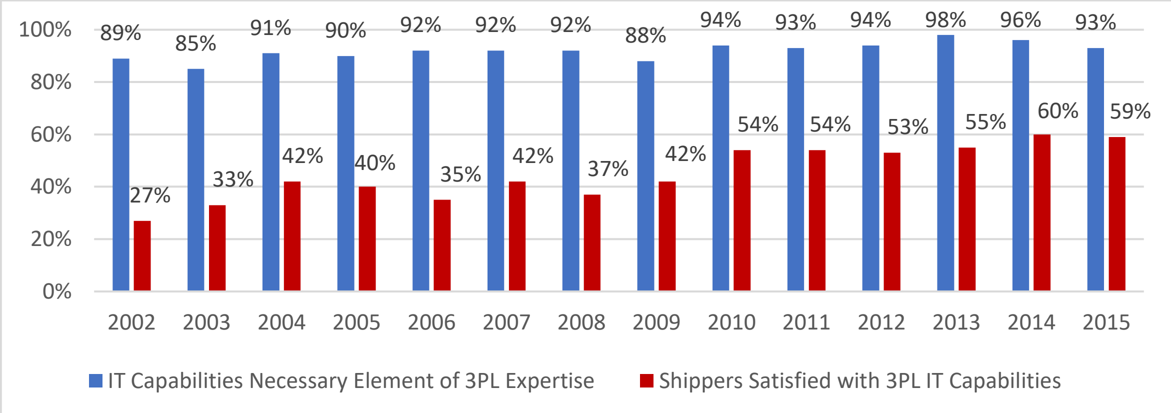

Figure 1 – The contentment of using 3PL operators which use IT technology and their ability
Source: [6]

2.2 Logistic strategies

The strategy attempts to set up, generate and integrate knowledge and belief of the company and the environment, form complex movement in the environment and tries to predict the course of action taken and needed to be taken, and to set priority tasks and the time of realization. There is no 'magic algorithm' that will guarantee the strategy of complete success, but in theory there are certain rules that need to be followed when making a strategy (form a clear strategy, involve all executors in forming of the strategy, form a management team, consider together all the functions of operations, readiness to change old ways of business, reduce operating costs, quick change response, etc.) [7]. The factors of a competitive strategy require the following: knowledge of users, service and quality differentiation, finding the placement of services on the market, determination of clear business objectives, general and comprehensive strategies, control of key technology (processes), partnerships with other businesses, creating of flexible technological and organizational solutions, reduction of fluctuations within the financial plan, and other.

For companies to successfully operate on today's rapidly changing market, achieve greater flexibility in the distribution of goods within the supply chains, respond faster and in a short period of time to customer demands and increase their competitiveness, it is necessary to introduce strategies with which this can be achieved. Today, there is a number of strategies, such as Lean, Agile, Just in Time, Quick Response, Cross-docking, Make or Buy, etc., that improve processes in various segments of the supply chain and in the very processes of business enterprises. For the changes to be made it is important to first define the strategic objectives of the development and improvement of the process, to define some key elements and based on that choose a strategy that suits the set objectives. By implementing the optimal strategy, the company will achieve its goals, thus increase its competitiveness and its position on the market and provide greater satisfaction to users and obtain their loyalty [8].

2.3 Human resources investment

The trends of the development of human resources management in the era of the globalization of the market indicate that this sector occupies a growingly important place in the development of contemporary enterprises that seek to self-develop and have a competitive market position. The impact of the development and management of human resources in terms of achieving the objectives of the company becomes a strategic activity with which one connects the strategic objectives of the company with the organizational structure, human resources and the technological development of the company. In that sense, while concerning the human factor, the research suggests that personal interests of individuals and groups must be submitted to the organizational goals of the company in which they operate. Often it happens that there is an optimal cooperation between different departments that oversee the management of human resources at the enterprise level, which can lead to delayed reactions and to the development of irreversible damage [9].

Human resources management is an organizational function within companies, whose aim is achieving the designated strategic goals of the company. For that to be achieved, human resources management provides guidance and advice for solving all problems faced by the people in organization. It employs employees, ensures safety, but also benefits for the employees, their motivation, communication in the office, solves administration, but also sends employees to further education and training which helps them to performing everyday work more easily. Good human resources management helps enterprises employees to efficiently and productively assist in achieving the objectives of the company. It tries to increase the performance and satisfaction of employees by providing them with the necessary knowledge and skills to perform their jobs better and create conditions that encourage and guide employees toward the objectives of the organization [10].

Between company competition excels in the ability to change, create and use new knowledge, skills of differentiating one’s products and services and the amount of built-in knowledge and human imagination in these skills. The ability to learn becomes more important than the experience. This can be supported by the fact that today's logistics operators who have access to high technology have the best, most creative and highly educated work force, and are willing to invest substantial resources in the further education of their employees.

3. THE ANALYSIS OF THE EFFECT OF IT TECHNOLOGY, LOGISTICS STRATEGIES AND HUMAN RESOURCES ON LOGISTIC OPERATORS’ BUSINESS

According to previous research, with the trend of globalization more and more various products and services appear, which results in a tendency for companies looking for the increase of competitiveness and the power to maintain their position on the market. Companies that want to achieve a good performance should improve the quality of its services by investing in modern IT technology, effectively managing all processes within the supply chain and reducing overall costs by introducing logistic strategies and ultimately by educating and motivating the working staff for implementing the concept of continuous improvement, i.e. invest human resources development. Based on that a research was carried out by a questionnaire, at the Faculty of Transport and Traffic Sciences, to analyze the impact of IT technology, strategies and human resources for the development of logistics operators. The survey was conducted on the regional level, involving 36 logistics operators.

In the first part of the survey a research was conducted on the use of IT technology within the logistics processes. The first question referred to the importance of using IT technology for improving operational processes, where 71% of respondents said that for their business IT technology had a very important role, 28% said that it was of medium importance, while 1% of respondents believed that IT technology it is not important for their business.

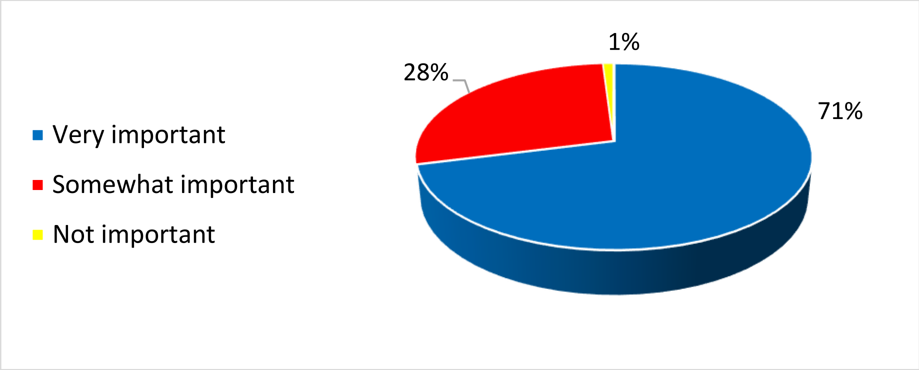

Figure 2 – How important is improving IT technology to your business?

When respondents were asked about what kind of IT technology they currently use and / or they are planning to implement in their business (*Figure 3*), most of them (62.3%) said they currently use GPS technology, and the least (30.4%) said that they use WMS technology. On the other hand, in the future, 64.2% of them mostly plan to implement bar codes technology, and the least, 32.4% of respondents the RFID technology.

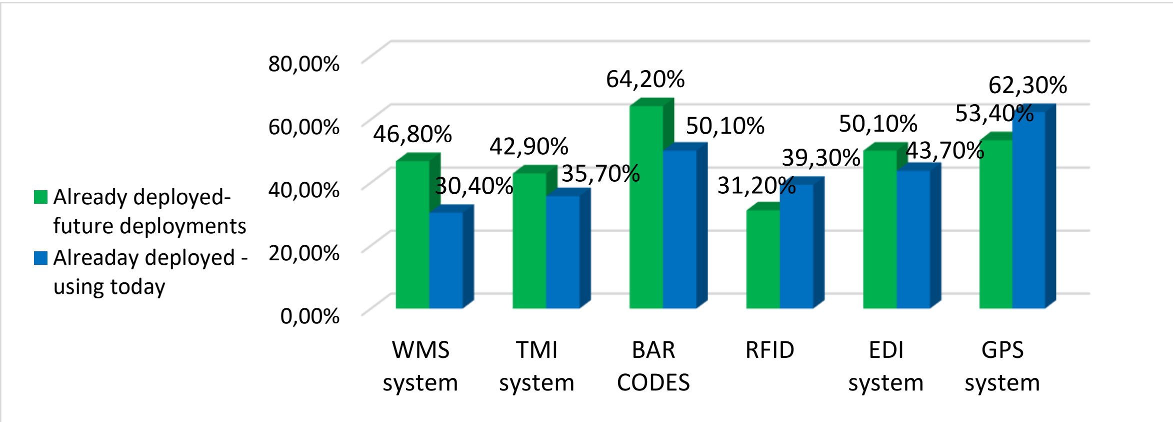

Figure 3 – IT technologies currently used and/or planned to be implemented within the logistic operator's business

In the second part of the survey a research was conducted on logistics strategies which are one of the key factors for the development of logistics operators (*Figure 4*). Through the survey the obtained results showed that companies (respondents) used two or more strategies, depending on the type of goods: 58.7% use Just in Time, Cross-docking is used by 37.00%, Quick Response by 18.50%, Make or Buy by 6.30%, 4.00% uses Lean, Agile is used by 1.80% and others by 1.30%. From the above it can be concluded that most logistics operators use the Just in Time and Cross-docking strategies in their businesses.

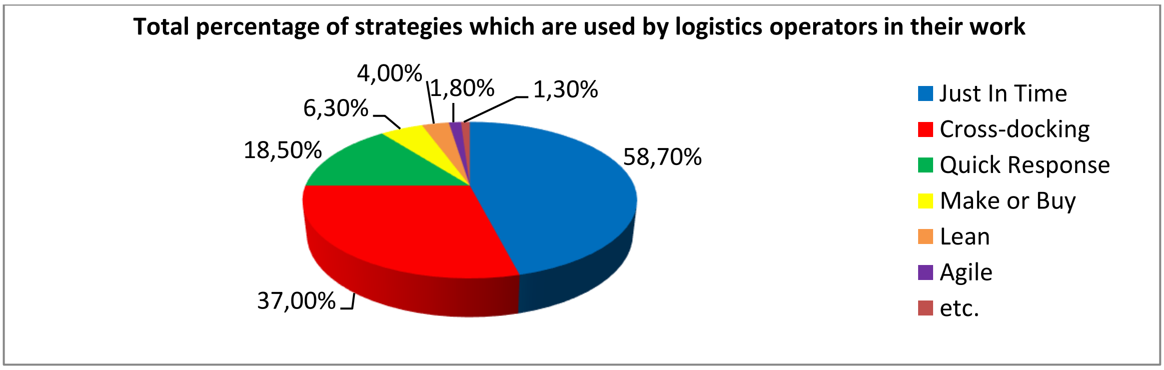

Figure 4 – Strategies used by logistics operators with the purpose of optimizing business processes

Based on the implementation of the strategy it can be concluded that the development and implementation of strategies brings many benefits to businesses. Therefore, respondents in the study listed some of the most common results which they have achieved by using certain logistics strategies (*Table 2*).

Table 2 – Most often realized results as a result of introducing logistics strategies

Which are the most common results achieved in business processes after the implementation of the strategy?
Decrease of supplies
stronger relationship between businesses and customers / users
repeated orders
faster flow of goods
flexible response to the demands of customers / users
predictability of the production processes
fast and accurate adjustment to market changes
improved planning system
increase of profits
increase of competitiveness

With the implementation of the logistics strategy it is very important to coordinate all activities on the basis of shared information, to cooperate with all participants in the supply chain, to manage all processes and strive to reduce the complexity of the system.

In the last part of the survey a research was conducted on the investment and the importance of human resources, which are an indispensable part for the development of logistics operators. An adequate program with which the engagement of employees is measured and raised (motivation, education and retention of employees) has 71% of respondents, while 29% of subjects have a program which defines the culture of the employee's work (*Figure 5*).

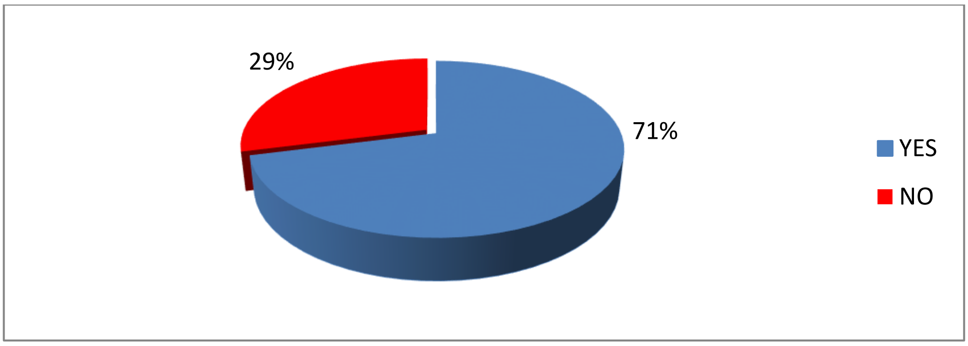

Figure 5 – Percentage of usage of adequate programs for employee engagement

Aware of the fact that the general lack of skills can stand in the way of business growth, many companies put education and development at the top of priorities. Therefore, in the survey questionnaire, a question was served to the respondents: "In which of the mentioned elements of the human resources (additional training, motivation, team work etc.) do they usually invest?", where it was possible to choose multiple responses (*Figure 6*).

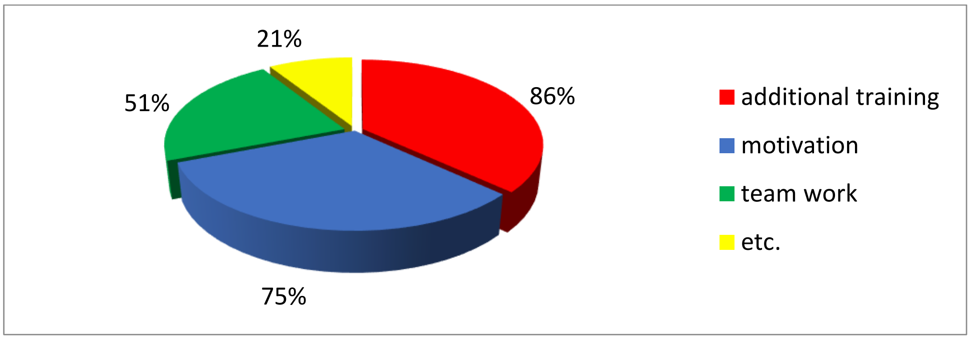

Figure 6 – Percentage of elements of human resources mostly invested in by companies

On this basis, respondents said that 86% of them usually invest in additional training, 75% in motivation, 51% in team work, while 21% invest in some other elements of human resources. In view of the radical demographic and technological changes, the application of existing methods to new trends in human resources management will not give the desired results. If companies want to retain and develop the right talents, organizations, especially the leaders of human resources, need to adapt more to new conditions on the market.

4. CONCLUSION

Today, in conditions of adverse global economic conditions and rapid market changes, it is necessary to invest in the business processes in order to achieve a profit and increase market competitiveness. Therefore, it is very important for logistics operators to invest in modern IT technology that allows them quick transfer of information and facilitates communication within the supply chains. Also, to achieve the development of the company itself, it is necessary to create strategic objectives and on the basis of them select the optimal logistics strategies that can enable process optimization, reduce costs, a faster turn inventory, increase competitiveness, increase profits and increase customer satisfaction and loyalty. For all the logistics company to work, human resources have huge importance. By developing new and advanced human resources management systems various opportunities to improve operations and increase productivity are offered, and through methods of learning and education for the working staff it is contributed to the development of new models, principles and methods of treatment and organizing. Nowadays it can be said that for a successful business enterprise a constant introduction of new methods and strategies for the management and human resources management is required, and the major role in the implementation of the same is added to the strategic management of any organization.

Based on the conducted survey it can be concluded that key elements such as IT technology, logistics strategies and human resources have a very important role in the development of logistics operators in the present and the future. According to the survey results, it is visible that companies are willing to invest the most in IT technology that simplifies and accelerates all logistics processes, and with possession of modern technology, they also invest in logistics strategies that play a crucial role in improving the process and the strategic development of logistics operators. But in order for the investment in IT technology and logistics strategy to make sense, they also invest in human resources in a way that most employees are sent to additional education and are motivated by the company as well. Therefore, it can be concluded that by investing in these three key elements, development and better business through increased competitiveness, increase of profits and ultimately reduced costs of services of logistics operators are achieved.

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REVIEW OF ECOLABELS: IMPACT ON GREENING THE SUPPLY CHAINS

ABSTRACT

Paper focuses on environmental labels which indicates product's environmental performance. Products that have earned ecolabel, meet certain criteria regarding energy consumption, water pollution, use of hazardous materials etc. and this is an indication to consumers to choose products which cause less environmental impacts. In the modern world, environmental awareness is increasing but information on environmental performance of products are very limited. This means that objective of environmental labeling should be informing people about importance of ecolabels, learning them about the differences between less and more eco-friendly products as well as to encourage them to choose environmentally better alternative. Environmental labels could be divided on voluntary and mandatory labels. Main subject of the research is to study well known ecolabels divided in different groups and cross compare them according to implementation criteria. It was found that type I labels are the most established and are showing consumers simple and accurate guidance of environmental performance. In European Union the most accepted is EU Ecolabel, indicating products that meet strict environmental criteria and cover a wide range of product groups however it is still not widely used.

KEY WORDS

Ecolabels, environmental management; greening, environmental awareness;

1. INTRODUCTION

Nowadays companies are faced with complexity of the green market, which includes different knowledge and awareness of costumers about environmental problems, market needs, products and production processes, regulations and dilemma how to properly mark sustainable or green products and services. There are already many different environmental labels available for companies, but not all of them are appropriate for each and every type of product. They have different standards and rules for implementation, because they are focusing on different goals, sectors and sustainable development paradigm.[1]

Main goal of ecolabel(s) is to help consumers (sometimes companies in cases of B2B) choose eco-friendly product, by educating them about importance and meaning of environmental problems and how implemented ecolabels help saving our environment. Ecolabels evaluate and include the whole life cycle from origin (how raw materials are produced and transported etc.) to consumption and disposal in the end (with tendency to recycle)[2]. With implementation of ecolabels, companies can gain added value of their products, especially with implementation of well-established and independently regulated (by different organisations and specialists from different sectors) ecolabels, which consumers can trust. This kind of ecolabels are classified under ISO I standard, which have the highest integrity.

Very important advantage of many ecolabels that needs to be pointed out is definitely their focus on further development of production processes, which consequently improve product quality and extend its life cycle. This presents a very important aspect of costumer's decision, when they are choosing between different options of similar products, produced by different manufacturers.

As it was already mentioned, the main goal of ecolabels is to inform customers and simplify their decision to make a "green purchase", in order to reduce time and effort, which is needed to find information about product (how it was produced, its effect on environment etc.) and its recyclability (how it should be disposed to minimize effect on nature). However, it was discovered that ecolabels alone aren't enough, because they need marketing background, which promotes ecolabels and their purpose as well as basic ecological problems. This is very important, because knowledge about ecolabels and ecological problems positively affects consumer's attitude towards environmental problems.[3]

Although the basic essence of ecolabels is very positive, there is still some lack of interest on the costumer side. Manufacturers' and retailers' mistrust in their economic sense is the main reason why ecolabels aren't more frequent. Rex & Baumann discovered in their study [4] that there are only 11 % of "extremely green consumers", who would buy eco-friendly products no matter the cost. There are only 5 % of consumers, who are willing to buy eco-friendly products, but are not ready to change their behaviour for it and 33 % of them, who are willing to pay just a bit more for products with ecolabels. Consequently, there is half of costumers left, who don't care about their effect on environment which is released through their choice of product.[4] This results take us back to previous paragraph and the fact that change can only come with customer awareness, which can only be achieved with additional effort to inform consumers about environmental problems (eg. through education) and promotion of sustainable way of living. The answer for both lies in marketing and specifically in ecolabels.

When considering introduction of ecolabels, companies also have to consider the differences in cost of their implementation. For example, some ecolabels have higher initial costs, but are cheaper when considering mass production, because of lower cost per product. There are clearly ecolabels, which are opposite and are cheaper, when company produces lower number of products, because of significantly lower implementation cost. There are also some differences connected to recognition of ecolabels on different markets (or parts of the world) and that has to be important criteria, when deciding between different options.[1] Some companies also decide to start their own "self-declaration" ecolabels, which are much cheaper, but have considerably smaller effect. Therefore different aspects of ecolabel implementation should be considered and special importance should be given to marketing and economic ones.

2. METHODOLOGY

By examination of different eco labels and changes brought along with their implementation, we managed to analyse and study different scientific and professional literature. Results were synthesized to present overall condition of ecolabels and their implementation procedures. This paper describes qualitative research methods – studying multiple examples simultaneously, followed by comparison and comparative analysis. Several examples of good practices consisting of introduction of various ecolabels in different companies and changes were also studied as well as the situation before and after implementation.

Information on ecolabels and their features (usage, criteria for introduction and implementation) was collected through different data bases, i.e. Wiley, Springer Link, Science Direct, Scopus, Sage, Econlid and Emerald. Qualitative method was used to gather data, allowing us to recognize the enormity of a widely occurring environmental problems. To define a theoretical framework and importance of various eco labels in detail, we used descriptive approach of analysing literature. Research includes eco labels Nordic Swan, Blue Angel, FSC, EU Ecolabel and Energy tags – Energy Star and EU Energy Label. Classification method was used to determine the concept of ecolabel and compilation method to integrate diversified points of view concerning the significance of ecolabels and to present their importance for businesses.

3. ECOLABELING OVERVIEW

According to ISO standards there are three different types of environmental labels: Type I, Type II and Type III environmental label. Type I labelling is eco-labelling, for which stakeholders set criteria with use of a consultative process that must involve industry and consumer. They refer to the environmental quality of a product for its whole life cycle. Type I label are voluntary. Type II labelling refers to “recyclable” or “ozone friendly”. They could be in a written or symbolic form. Type II are self-declarations and refer only to specific features of the products. Type III labelling is testified by an independent third party, who has life-cycle data and product rating in term of environmental indicators. They are rarely found in the environmental field.[5,6]

3.1 Nordic Swan

Nordic Swan is the internationally known label for the environment in the Scandinavian countries and is classified in the Type I label. It is the mark for all paper products and specify the criteria about emissions, use of energy, origin of raw materials and specific chemical.[7]

The Nordic Swan was established in 1989 in the Nordics countries. From the beginning to nowadays it is one of the most popular and most successful label in the environmental field. Currently there are criteria for more than 60 products developed. The national office, responsible for the implementation of Nordic Swan has each of the Nordic countries (Netherlands, Sweden, Finland, Island, Denmark). The offices have responsibility to develop criteria, license, marketing and revision about the label.[8]

The mission of Nordic Swan is to contribute the sustainable consumption with the choice of products or services, which are labelled with Nordic Swan label and to encourage the manufacturer to develop environmentally friendly products and services.[9] The criteria for the implementation of Nordic Swan are the same in all Nordic countries. They have been determinate by the board of Nordic Ecolabelling. The standards for implementing have very high demands. They all refer to quality, health and functionality [10]. In the process of developing the criteria for the implementation Nordic Swan label several of environmental criteria are included: the use of energy, climate aspects, the use of water, sources of raw materials, the use of chemicals, hazardous waste water, packaging and waste.[9]

The steps to implement it are[10]:

- the life-cycle of products is evaluated; it covers a full lifetime of products from raw material to waste;
- many factors are analysed and many previous studies are done;
- environmental problems connected to the product are researching:
- product improvement on environmental are analysed;

- the possibility that Nordic Swan would have the impact on product development and its impact on the environment.

3.2 Blue Angel

The Blue Angel was established in 1978 in Germany by the German Federal Minister of Interior and approved by the Ministers of the Environment for the German federal states. The Blue Angel is used as the role model for the ISO 14024 standard. The label is voluntary for the companies and has potential to be implemented before legal regulations are introduced. For companies it means that could highlight their pioneering role in the specific area.[11] Products who acquire the Blue Angel have high standards in environmental, health and performance field. The products are evaluated across their entire life-cycle. Criteria for implementation the Blue Angel are specified from the Federal Environmental Agency every three to four years. That means constant improvement of environmental friendliness for all products over time.[12]

Products and services awarded with the Blue Angel are less harmful because of [13]:

- resources saved during the production and disposal;
- no use of dangerous substances for the human's health and environment;
- products are easy to repair and recycle;
- caused emissions are low;
- more sustainable raw materials are used.

Product that acquires the Blue Angel label can be classified in one of four groups that based on their protection goals: protects the environment and the health, protects the climate, protects the resources and protects the water.[14]

3.3 FSC

FSC (The Forest Stewardship Council) is the international non-profit organization, established in 1993 with the purpose of promotion responsible management world's forest. It is world's most respected system of forest certification. They strive for environment properly, socially useful and economically acceptable manage of forest.[15] The label is bonded just on a product only and not on a company.

FSC edit two different certifications [16]:

- Forest Management Certification (for the forest manager or owners);
- Chain of Custody Certification (for the manufacturer and seller FSC certificated products, it confirms that FSC certificated product is handled correctly).

FSC labels come in three different types [17]:

- FSC 100 % (wood in the product comes from FSC-certified forest completely);
- FSC recycled (wood or paper in the product is from re-used material);
- FSC MIX (wood is from FSC-certified material, re-used material or controlled wood).

3.4 EU Ecolabel (Flower)

The EU Ecolabel flower is awarded for products and services that have reduced their impact on the environment. It was launched in 1992 by the European Commission. The product or service impact is evaluated across its entire life-cycle. Evaluation is done from the independent professionals.[18, 19]

The advantage of Ecolabel flower from the B2C (business-to-customer) point of view is visibility and popularity among consumers. From the B2B (business-to-business) point of view, the pressure on suppliers to cooperate with manufacturer that have this label is very important. The standards for implementing the Ecolabel flower are designed in the way that 10 to 20 percent of products on the market correspond to the criteria to acquire the label.[20]

The EU Ecolabel flower could be awarded for a wide range of product groups. The criteria are revised every four years, which means products with the label stand for the highest environmental performance. The old licence for Ecolabel flower lose their validity after a transition period when the criteria are revised [18], [19].

Criteria of Ecolabel flower refer to the important environmental impacts [21]:

- raw materials selection;
- production;
- usage and waste product.

3.5 EU Energy Star

Energy star was introduced in 1992 by the US Environmental Protection Agency (EPA) as a voluntary government program which reduces air pollution through increased energy efficiency and is mostly implemented in the USA. Energy star was designed to inform businesses and consumers about energy-efficient solutions and to help save the money and protect the environment for future generations.[22] The Energy star label can be found on appliances, office equipment, lighting, buildings and more. It is a nationally recognized symbol of energy efficiency. Behind every label is a product, building or home that is independently certified to use less energy and cause fewer of the emissions that contribute to climate change. It is evaluated that Energy star has helped save $362 billion on utility bills, while reducing gas emissions by 2.4 billion metric tons.[23]

EPA offers many tools and materials to promote energy efficiency, which include [23]:

- the Energy star marks;
- public service announcements;
- promotional and campaign materials;
- performance rating systems;
- sales training materials;
- educational brochures and
- awards in recognition of excellence.

3.6 EU Energy label

The intention of the EU Energy label is to provide information about the usage of energy, efficiency and other important information about the household electronic device. The label classified the devices in the energy efficiency classes. For all products in the same category, the label is the same, the information included, based on the EU legislation. The label is determined by law and if it is not on the electronic device the costumer can demand to see it.[24]

The label is the same in in all EU Member States and do not need to be translated into the official national language. The energy efficiency classes are coloured in the different colours from dark green to red, which is the less efficiency.[24] Electric energy use in kilowatt-hour (kWh) is written on the label and energy labels for different types of products consist of additional information relevant for the consumers. The information enables the comparison of the different models.[24]

In figure 1 overview of most important information on described labels is presented with the purpose to summarize their core similarities and differences.

	Nordic Swan	Blue Angel	FSC	EU Ecolabel Flower	EU Energy Label	Energy Star
Application	Car and boat products, cleaning products, coffe services, construction and facade panels, cosmetic products, disposable products, floor products, heat pumps, sanitary products, textile products and services	Home living, electric devices, construction, office equipment, energy heating, garden leisure, business services	Furniture, paper, flooring, decking, dors, toilet tissue, in fact most things made from wood	Personal care, cleaners, clothes & footwear, "do it yourself" products, electroic equipmnet, floor coverings, furniture, gardening, home products, lubricants, paper, holiday services	Refrigerators, dishwashers, washing machines, televisions, air conditioners, tumble driers, vacuum cleaners, water heaters, ovens	Appliances, building products, commercial food service equipmnet, electronics, heating & cooling devices, lighting, office equipmnet, water heaters, other
Criteria of implementation	The label chooses product areas from three perspectives namely: • relevance; • potential for environmental improvements; • steering the production of the product or the establishment of the service.	• Applicable life cycle and supply chain phases; • social and environmental attributes; • mutual recognition with other eco labels; • standard details, including standard document, review frequency	• Verify your supplier; • verify your product certificates; • never mix FSC and non-FSC materials; • keep documented evidence; • pass on the COC to your customer	The strategy consists of five elements: • policy development and coherence; • product group criteria development and maintenance; • increased and effective communication; • greater coordination with other schemes; • financing and resources for the scheme.	• Mandatory for all electronic devices in EU; • Submission of technical documentation; • producers must provide labels for their products; • label must be visible	• Product categories must contribute significant energy savings nationwide; • products must deliver the features and performance demanded by consumers; • if certified products are more expensive, purchasers will recover their investment in increased energy effiecency through utility bill savings; • product energy consumption and performance can be measured and verified; • labeling effectively differentiates products and is visible for purchasers

Figure 1 – Comparison of different well-known ecolabels

4. DISCUSSION AND CONCLUSION

In this paper basic classification of ecolabels according to three different ISO standards was analysed. Most of analysed ecolabels are in accordance with ISO standard, which is the most respected by consumers and producers because standards are set and controlled by independent organizations that consist of various experts for different sectors and product types. They also differ from one another by their main focuses, e.g. reduction of paper waste, emissions reduction, content of toxic materials, recyclability etc.

Focus of the research was on established eco-labels such as Nordic Swan, which has the highest recognition in Scandinavian countries, but is also suitable for the whole European market. With this establishment in 1989, it is one of the most recognizable ecolabels on the market covering wide range of product types (more than 60). Blue Angel which originates from Germany is even more recognizable and is one of the pioneers of ecolabel industry (est. 1978) was also studied. Within Blue Angel product types are separated in four main categories: protection of environment and health, climate, resources or water. We continued with analysis of FSC, which was established specially for promotion of responsible forest management around the world. It is one of the most common and recognizable ecolabels on the market, assigned to individual products, not company. Being part of the European Union, companies should also consider implementation of EU Ecolabel ("Flower") because of its popularity on the European market. In order to get endorsement from independent professionals of EU Ecolabel organization, it is necessary to prove that the product is »green« through its entire life cycle. We also took a closer look at the USA market, where one of the most popular ecolabels is Energy Star that focuses mainly on energy-efficient solutions. At the end we also took a look at one of the mandatory labels – EU Energy Label – that shows product's energy efficiency with coloured scale and other information. It is the same for all European countries and does not require translations.

All in all, there is wide range of ecolabels on the market to choose from. When deciding for implementation of ecolabel, we have to take into account all of described parameters, such as target market, recognition of ecolabel, product type, criteria, cost of implementation and cost per product. When all of the factors are chosen correctly, ecolabels can serve as successfull marketing tool as well as a guarantee for costumers' satisfaction, which can provide competitive advantage.

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LOGISTICS IN THE SLOVENIAN AUTOMOTIVE INDUSTRY

ABSTRACT

The automotive sector is characterized by intense competition among car manufacturers, which is why constant demands for process improvement are passed on to the suppliers, who must excel in various business areas. One of these areas is logistics management, since, due to the high degree of global integration in the automotive industry, logistics represents an important tool in ensuring the effective flow of material and information at the lowest cost and, ultimately, customer satisfaction. The article undertakes a statistical analysis of logistics in the Slovenian companies that are suppliers of the international automotive industry, the results of which show that the companies that took part in the study still have plenty of room for improvement in all areas of logistics: the organisational aspect, human resources, training and cost.

KEY WORDS

logistics; logistics analysis; automotive industry; case study

1. INTRODUCTION

The supply chain in the automotive industry is unique in its complexity, as a modern car is manufactured using 15,000 different parts originating from approximately 200 to 400 different suppliers, which in turn have their own sub-suppliers [1]. Over time, the organization of the automotive industry has therefore reached a level of development that makes it a reference point for other industrial sectors in terms of process management and cost management, as well as in terms of strengthening relationships in the supply chain. Being part of such an industry has many advantages, but also entails a lot of responsibility, because the demand for business process improvement is passed down the supply chain from the end-customers [2].

The global automotive sector is constantly evolving. Intense competition puts a lot of pressure on companies, which is why companies must excel in various business areas, including cost, design, functionality, manufacturing and quality [3]. In addition to expectations in terms of quality management, first-tier suppliers in the automotive industry are particularly prone to strategic requirements, which are indirectly related to the implementation and strengthening of the concept of lean production [4].

Due to the complexity of business operations and international competition, both typical of the automotive industry, logistics plays a crucial role in supply chain management and in strengthening the concept of lean manufacturing. The basic role of logistics in the supply chain is to act as a connecting element between individual entities, activities and functions, with a view to ensuring the smooth flow of materials and information. Any change in the logistics supply to the customer also affects the cost of logistics, which is often dependent upon the complexity of the customer's requirements, as well as affecting the organization of the supply chain. Suppliers are thus confronted with the significant challenge to meet customers' needs and desires, while simultaneously managing logistics processes in a rational manner [5].

The article presents a survey conducted on a sample of thirty Slovenian companies that are suppliers to the international automotive industry, with the purpose of analysing logistics management in these companies. Slovenian companies have a long tradition of cooperation in the international automotive industry. Therefore, any proposal aimed at improving the management of logistics represents an important basis for ensuring a better organization and efficiency of logistics processes, which can be applied to other companies as well.

2. THE IMPORTANCE OF LOGISTICS MANAGEMENT - LITERATURE REVIEW

One of the major studies on the management of logistics processes in companies was carried out in a company that operates in the automotive industry - General Motors [6]. The authors analysed the deliveries of goods from 20,000 suppliers to 160 General Motors manufacturing plants. The resulting database enabled the researchers to set a framework for the reduction of the total logistics costs by using the decision-support tool Transpart. The model enabled them to streamline transport processes and reduce overall logistics costs for companies by 26%. The study laid the foundation for the later use of the system in various manufacturing companies in the United States.

A wider-reaching study was conducted by Engblom et al. [7] in 2005 and 2008 on a sample of 241 production and sales companies in Finland. The authors focused on the differences in logistics costs in manufacturing and trading companies, export-oriented companies and companies focused on the domestic market and between large and small businesses. The study also included an analysis of the changes in the management of logistics costs between the years 2005 and 2008. The authors also highlighted the interdependence of logistics costs. A similar study was carried out by Ojala et al. [8], who examined the state of logistics in seven countries of the Baltic Sea Region. Part of the study was dedicated to logistics cost management in manufacturing and trading enterprises. The same study also concluded that, due to economies of scale, larger businesses have lower total logistics costs, compared to smaller businesses and that the share of logistics costs in sales revenues in manufacturing companies differs from the share of logistics costs in sales revenues in trading companies. At the same time, the study concluded that transport costs and stockholding costs represent the largest individual cost component in both sectors. The study also found that absolute logistics costs, especially those of transport, were expected to increase in all regions, especially in the EU's New Member States. Pettersson and Segerstedt [9] conducted a study in thirty different companies and in ten different industry sectors. The authors examined how the companies in the sample measured the costs of the supply chain and compared the results with the model they developed. They found that logistics costs account for the largest part of the cost structure of the supply chain and that companies have many reservations when it comes to managing logistics costs.

Several authors have analysed the various logistical aspects and relationships within companies that affect logistics cost management. Lambert et al. [10] highlighted the impact of the reduction of logistics costs on a company's revenues. They pointed out that reduced logistics costs have a much greater effect on a company than an increase in sales volume. Ballou [11], Lambert & Burduroglu [12], Stock & Lambert [13] and Shang [14] highlighted the impact of the quality of logistics services on the level of logistics costs and concluded that higher quality logistics services for the customer result in increased customer satisfaction, but also in higher logistics costs. Research also points out that logistics costs are interdependent [11, 15, 16], since the reduction of the cost of one logistics activity leads to an increase in the cost of other logistics activities, which ultimately results in higher overall costs.

Stock & Lambert [13] emphasize the fact that when logistics experts focus solely on reducing costs to justify their existence, the management is more prone to view logistics as an area for cost reduction. If logistics experts want to be appreciated for their achievements, they should focus on building a logistics system that will include elements of rationality and quality.

3. METHODOLOGY

The survey conducted among companies operating in the Slovenian automotive industry was developed in collaboration with the GIZ ACS (a business association based on economic interest, uniting Slovenian automotive suppliers and manufacturers). Of the forty companies that were asked to take part in the survey, 10 companies opted not to participate. The final sample therefore comprised 30 companies. For the purpose of the survey, an online questionnaire was set up, which was mostly completed by heads of logistics departments. The descriptive variables are presented as frequencies and shares in the results. Ordinal variables, where respondents ranked the answers are presented as median, minimum and maximum values and numeric variables are presented as average, median and standard deviation. The statistical analysis of the data obtained through the survey was done using the statistical program SPSS 22.0 IBM.

4. RESULTS

Table 1 shows the sample of companies included in the survey, which comprised 2 companies with 11 to 50 employees (6.7%), 13 companies with 51 to 250 employees (43.3%) and 15 companies with more than 250 employees (50 %).

Table 1 – The number of employees in the surveyed companies

	f	f %
11 - 50	2	6.7
51 - 250	13	43.3
over 250	15	50.0
Total	30	100.0

** f = frequency; f % = share (%)*
Source: Authors.

Figure 1 illustrates the organization of logistics in companies. 19 companies have centralised logistics in a separate department, representing 63.3% of the companies included in the sample, 10 companies or 33.3% of the sample have decentralised logistics, while only one of the companies has partly centralised and partly decentralised logistics. The question was answered by all 30 companies surveyed.

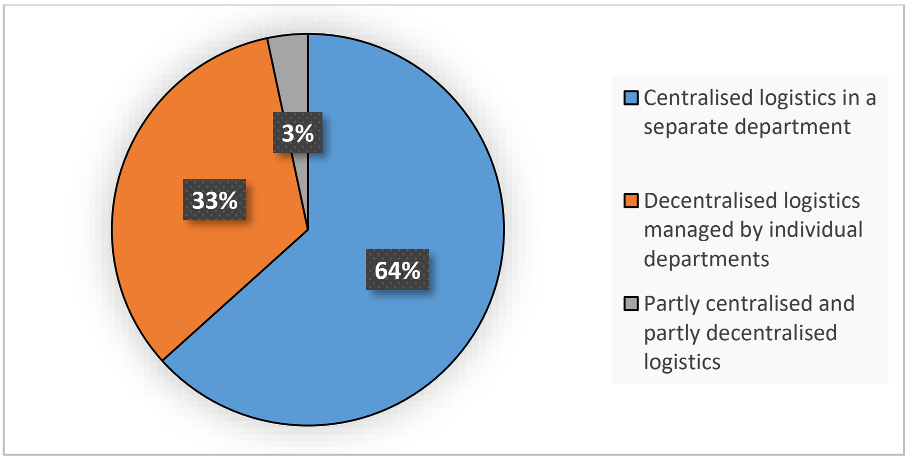

Figure 1 – Organization of logistics in companies
Source: Authors.

In the companies included in the sample, 1059 employees in total work in logistics. Figure 2 shows the number of these employees by level of education. The logistics departments employ 12.4% of employees who have completed primary education, 60.6% with vocational or secondary education and 27% with tertiary education.

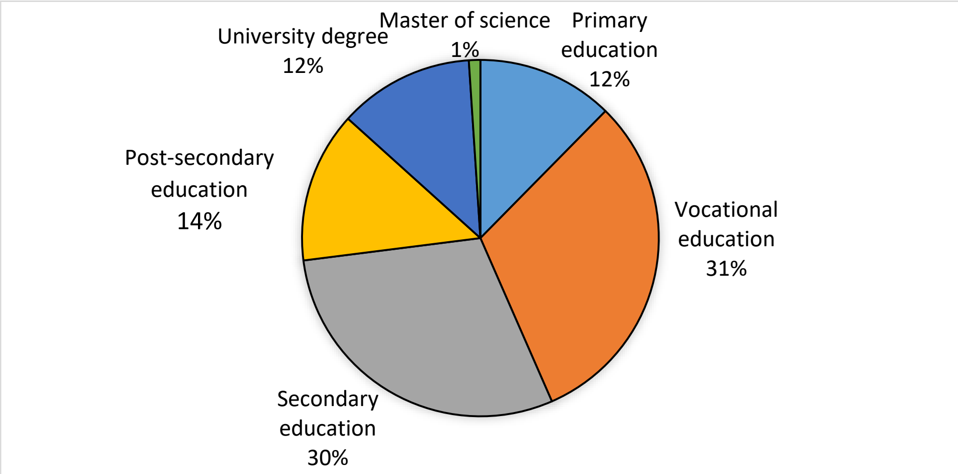

Figure 2 – The number of employees in logistics by level of education
Source: Authors

The largest share of companies in the sample, which represents 86.7% of all surveyed companies (Table 2), understand the concept of logistics cost management as having an optimal balance between the quality of service for the customers and the company's level of logistical costs. To 3 of the companies surveyed (10.0%), logistics cost management represents the reduction of the costs that represent the largest share of the total logistics costs. Only one of the companies (3.3%) surveyed understands the concept of logistics cost management as the reduction of all logistics costs.

Table 2 – Understanding the concept of logistics cost management

	f	f %
Reducing all logistics costs.	1	3.3
Reducing only the costs that represent the largest share of the total logistics costs.	3	10.0
The optimal ratio between the quality of service for the customers and the level of the logistics costs of a company.	26	86.7
Total	30	100.0

** f = frequency; f % = share (%)*
Source: Authors

Figure 3 shows the number of companies that have a system for controlling logistics costs implemented throughout the company. Of the surveyed companies, 19 (63.3%) have a system in place, while 11 (36.7%) of the companies do not have such a system in place.

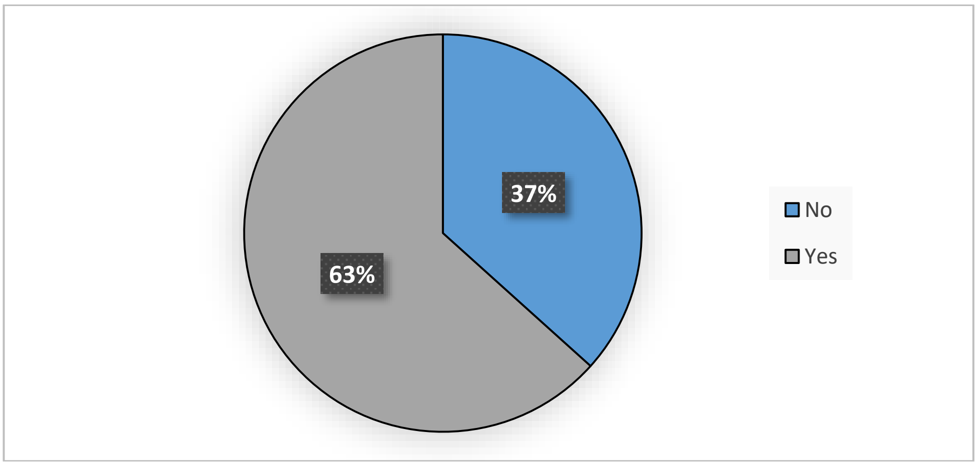

Figure 3 – Number of companies with a company-wide system for controlling logistics costs
Source: Authors

Table 3 shows the lowest and highest ranking attributed to a particular reason why the company lacks a system for controlling logistics costs and the median value of the ranking. 50% of respondents ranked the reason with a value smaller or equal to the median. The minimum value indicates the most important reason for not having a system for controlling logistics costs, while the highest value indicates the least important reason. The sampled data show that having costs managed by each individual department is the most important reason for not having a system for controlling logistics costs, followed by the financial investment required for implementing such a system, followed by a lack of knowledge and experience and in last place, the least important reason, which is simply not attributing a lot of importance to logistics cost management.

Table 3 – The reasons for not having a logistics cost management system ranked

	Min	**Max**	**Me**	**n**
Costs are managed by individual departments (sales, purchasing, logistics, etc ...), which results in not having a clear insight into the entire system of logistics cost management.	1	4	1	11
Too large a financial investment for the implementation of a system for controlling logistics costs.	1	3	2	10
Lack of knowledge and experience in the area of logistics costs.	1	4	3	10
Logistics cost management is not important for our company.	1	4	4	10

** Min = minimum value; max = maximum value; Me = median; n = number of respondents*
Source: Authors

Figure 4 shows the assessment of the effectiveness of the system for controlling logistics costs. Of the 19 companies that have a system for controlling logistics costs, 10 believe their system to be effective, while the rest of the companies selected the other option (neither effective nor ineffective).

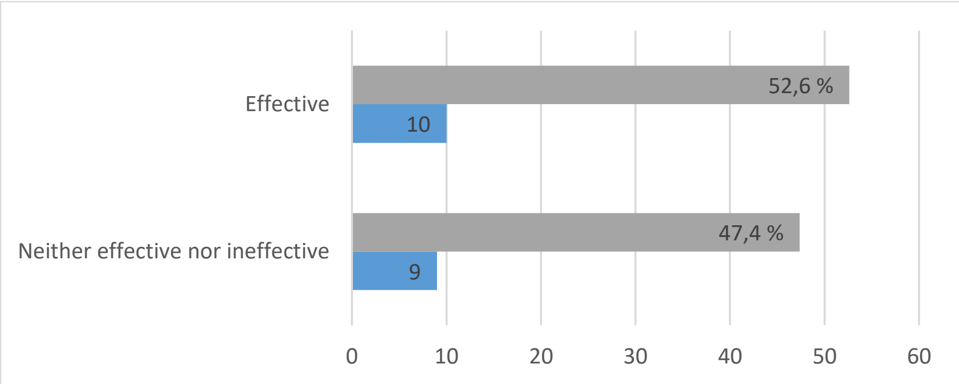

Figure 4 – Assessment of the effectiveness of the system for controlling logistics costs
Source: Authors

Figure 5 shows the share of logistics costs in relation to revenues. In 19 of the companies surveyed (63.3%) the share of logistics costs in sales revenue is less than 5%, while in 5 of the companies surveyed (16.7%) the share ranges from 5% to 9%. In 3 of the companies surveyed (10%) the share of logistics costs ranges from 10% to 20% and in only one of the companies surveyed (3.3%) the share is more than 20%. Two of the companies surveyed (6.7%) do not account for logistics costs separately.

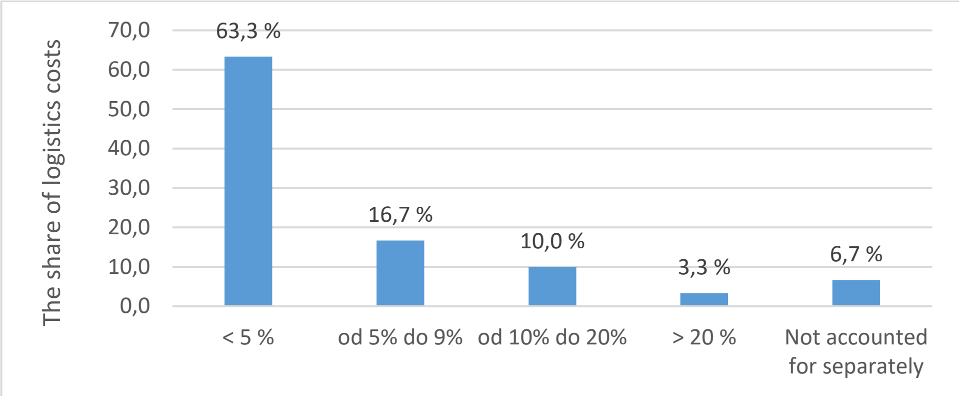

Figure 5 – The share of logistics costs in relation to sales revenues
Source: Authors

In 10 of the companies surveyed (34.5%) the share of transport costs in the total logistics costs is less than 15%, in 7 of the companies (24.1%) the share ranges from 15% to 29% and in 4 of the companies (13.8%) the share ranges from 30% to 60% (Figure 6). In 3 of the companies surveyed (17.2%) the share of logistics costs amounts to more than 60% of the total logistics costs. Five of the companies do not account for transport costs separately.

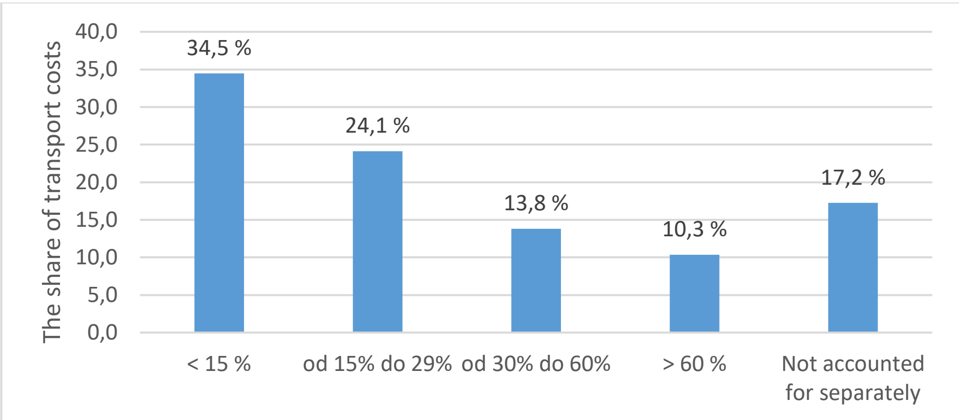

Figure 6 – The share of transport costs (internal and external) in the structure of all logistics costs combined
Source: Authors

In 18 of the companies surveyed (62.1 %) the share of warehousing costs in the total logistics costs is less than 15%, in 3 of the companies (10.3 %) the share ranges from 15% to 29% and in 2 of the companies (6.9 %) the share ranges from 30% to 60% (Figure 7). Six of the companies surveyed (20.7 %) do not account for warehousing costs separately.

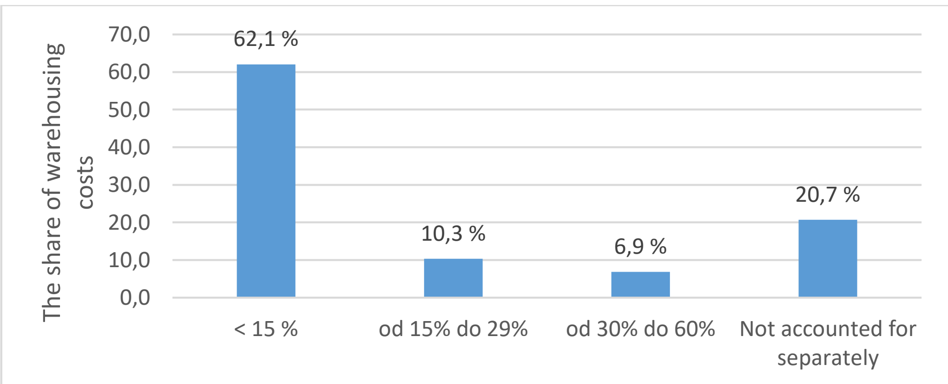

Figure 7 – The share of warehousing costs in the structure of all logistics costs combined
Source: Authors

In 7 of the companies surveyed (24.1%) the share of all other logistics costs in the structure of logistics costs is less than 5%, in 6 of the companies surveyed (20.7%) the share ranges from 5% to 9%, in 10 of the companies surveyed (34.5%) the share ranges from 10% to 20% and in 2 of the companies surveyed (6.9%) it is less than 20% (Figure 8). Four of the companies surveyed (13.8%) do not account separately for all the remaining logistics costs in the total logistics costs structure.

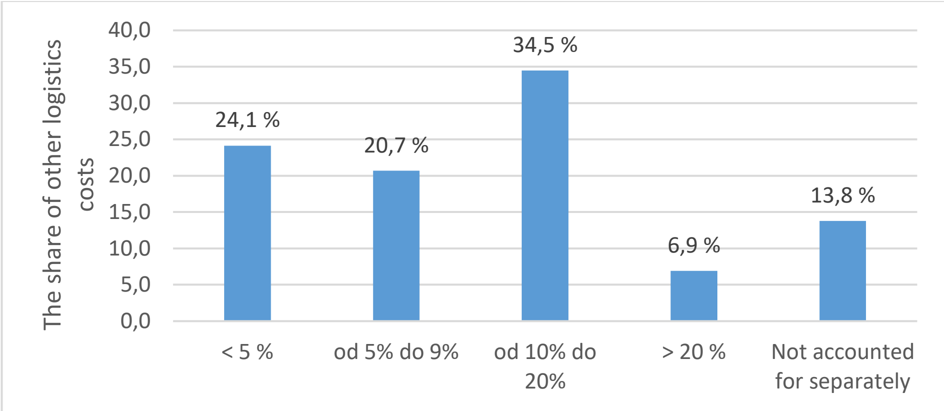

Figure 8 – The share of the other logistics costs in the structure of all logistics costs combined
Source: Authors

Respondents rated the strength of the tendency to reduce individual logistics costs on a five-point scale. Strictly, the scale used is an ordinal scale, which is considered by some researchers as an interval scale, which is why it also features the average value and standard deviation. Strictly, the most suitable mean value for each statement on the Likert scale is the median. The data in Table 4 show that the strongest tendency is the tendency to reduce transport costs and the costs of inventories.

Table 4 – The strength of the tendency to reduce individual logistics costs

	Min	Max	AM	Me	SD	n
Transport costs	1	5	4.2	4.0	1.0	29
Cost of inventories	1	5	4.2	4.0	1.0	29
Warehouse costs	1	5	3.3	3.0	1.1	29
Operational staff costs	1	5	3.1	3.0	1.0	29
Other logistics costs	1	4	2.7	3.0	0.8	29
Information System costs	1	5	2.6	3.0	1.1	29

** f = frequency; f =% share (%)*
Source: Authors

Respondents assessed the level of logistics expertise of employees from other departments as medium (Me = 3), indicating the potential for improvement in this area (Table 5).

Table 5 – Assessment of the level of logistics expertise of employees from other departments

	Min	Max	AM	Me	SD	n
The level of logistics expertise demonstrated by the employees from other departments	2	5	3.1	3.0	0.8	29

** Min = minimum value; max = maximum value; AM = arithmetic mean; Me = median; SD = standard deviation; n = number of respondents*
Source: Authors

5. DISCUSSION

The majority of the companies used in the sample are medium-sized and large companies. This is a reflection of the high likelihood of Slovenian companies to participate in the international automotive industry, where large production capacities and adequate financial and human resources are crucial.

Centralised logistics allows companies to unite all the logistics activities that were previously managed by different departments (e.g. sales, purchasing, production, etc.) under a single management. This kind of organisational approach is more likely to help companies achieve operational synergy in all their logistics processes, which could reduce logistics costs and increase the time required to respond to the demands of the different actors in the supply chain. Only 63.3% of the companies included in the sample have centralised logistics in a separate department, while the remaining 37.7% of the companies have decentralised logistics. The results suggest that most companies are not aware of the importance of the systemisation of logistics, since especially larger businesses tend to opt for centralised logistics.

Car manufacturers are increasingly focusing on their core business and redirecting all their other secondary activities to the suppliers. This increases the expectations for greater expertise and different competences, which also applies to the field of logistics. Among the employees of Slovenian companies that work in logistics, 73% have a level of education that is below post-secondary education, which suggests a clear pathway for future improvements in this area.

Various authors [10, 13, 14, 15] define the concept of logistics cost management of as an optimal balance between the quality of service for the customers and the logistics costs of the company. The majority of the companies surveyed also share this understanding of the concept (86.7%), which implies a certain degree of knowledge of logistics processes management.

Slovenian suppliers of the international automotive industry achieved the most significant improvements in the area of systematic logistics cost management. Among the companies surveyed, 37% do not have a system for controlling logistics costs used company-wide. That is mainly because cost management is left up to the individual departments (sales, purchasing, logistics, etc ...) and do not have a clear insight into the entire logistics cost management system.

In most of the companies surveyed, the share of logistics costs in relation to sales revenue is less than 5%, which is a smaller percentage than the one reported by comparable studies [7, 8, 17].

The respondents assessed the level of logistics expertise of employees from other departments as medium, which suggest that there is potential for significant improvements. Individual business functions (e.g. sales, purchasing, production and development) have a major impact on how a company's logistics system is built, because they are in direct contact with the customers as early as in the product development phase. A high level of logistics expertise of employees from other departments can therefore improve the management of logistics processes, since a lack of understanding of the interdependence of logistics costs in upstream and downstream activities can lead to disruptions in a company's functioning as an element of the modern supply chain.

6. CONCLUSION

The companies that took part in the survey operate in the automotive industry, which is the world's leading high-tech industry and an important factor of economic development, competitiveness and innovation. Thus, they constitute an important source of information for understanding how the Slovenian automotive industry approaches logistics management. The results of the analysis suggest the need for improvements in the Slovenian automotive industry, especially in the following areas:

- organisation (centralisation of logistics under a separate department)
- human resources (strengthening the training of logistics personnel)
- costs (the need for a systemic approach to managing logistics than can be used company-wide) and
- expertise (logistics training for employees from other departments).

The findings represent an important starting point for the development of high-quality, efficient logistics processes in the Slovenian automotive industry and in other manufacturing sectors.

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RECENT TRENDS IN PREMIUM AIR TRAVEL

ABSTRACT

Premium travel by air is closely related to business activities, such as international trade of good and services and it is very important market segment that supports airline financial performance. The paper examines the drivers of recent premium air travel that determine the size of premium travel markets between country pairs and changes caused by economic developments in different geographic regions. Advances in cabin designs and amenities offered by airlines to compete for business and first class passengers are elaborated as well as new premium-class products offered by legacy carriers and low cost carriers. The innovations in business class seating incorporate features previously exclusive to first class, while first class features tend to be like those of premium hotels. Trends in premium air travel over the period of last decade and its dependence on economic changes for main traffic route areas are analysed in the paper and it is shown that business passengers, contrary to the opinion of being inelastic with respect to fares, expressed significant downgrading behaviour, particularly in the short haul market. The paper brings some important specific guidelines for airlines to keep and increase their premium travel volumes and improve their financial performance.

KEY WORDS

Premium class travel; business passengers; low-cost airlines; legacy airlines; passenger yield

1. INTRODUCTION

Demand for airline premium travel is a key source of revenue and profit for many scheduled carriers. Business and First class passengers tend to place relatively high value on time, available flight frequency and quality of service and are, in general, less price sensitive than leisure passengers. They have a relatively high willingness to pay (WTP) for travelling in premium classes or to pay a premium for ticket flexibility, late booking or cancellation with refund possibility. Thus, this source of demand has an influence on some airlines' pricing and operational strategies out of proportion to the number of travellers. Premium air travel is an important aspect of international trade and economic development. With an increasingly globalised and financially integrated world economy that led to fast increases in the flow of goods, services and capital between nations, changes in the international business environment, air transport services are necessary for moving people and goods swiftly within and between nations, and the increased liberalisation and deregulation of international air transport markets has facilitated this. Consequently, the size and potential for flows of international trade, investment, finance and other business activities reflect the size and potential of premium travel markets between country pairs.

Airlines identify different segments of the total demand for air travel and offer multiple “fare products” with different characteristics to different demand segments assumed to have varying levels of price and time sensitivity, as well as WTP. The service amenities designed to make higher-priced fare products more attractive to consumers with a higher WTP include extra seating space and premium meals to physically differentiate the first and business-class products. To achieve the required demand segmentation in practice, airlines physically differentiate their fare products by offering clearly identifiable different products with different quality of service, such as first class, business class, economy class and premium economy class.

The aim of the paper is to examine and analyse trends in premium air travel over the period of last decade and its dependence on economic changes as well as to discern disparities in premium travel growth rates across the main premium traffic route areas, particularly to assess the widely accepted assumption that business or time sensitive passengers are inelastic with respect to fares. The paper reviews advances in aircraft cabin designs and shifts in different class products as well as forces that affect demand for premium air travel and recovery patterns after recession and financial crises.

2. AIRCRAFT CABIN DESIGN ADVANCEMENTS

Traditionally, air carriers provide the premium-class passengers with additional services improving the comfort of the air trip. On board of the aircraft, the business-class passengers are offered special services, gourmet meals and excellent wines, cabin is separated from the economy class cabin and equipped with more comfortable and functional seats. The main types of long haul business class seats are:

- **Cradle seats** (seats with around 150-160 degrees of recline, usual seat pitch range from 140–160 cm, still common in business class on shorter routes);
- **Angled lie flat seats** (recline 170 degrees to provide a flat but not parallel to the floor of the aircraft sleeping surface, seat pitch typically ranges from 140 to 170 cm;
- **Fully flat seats** (recline into a flat sleeping surface which is parallel to the floor); many airlines offer such seats in international first class but retain inferior seating in business class to differentiate the two products and fares (British Airways was among the first airlines to introduce fully flat business class seats with its Club World product in 1999);
- **Cabin seats** are designed to give the business class traveller the most privacy they can attain while in flight, typically positioned in a 1 - 2 - 1 arrangement on a wide body jet with and separated with a privacy panel about 120 cm feet in height, offer the best ergonomic comfort on long haul business class flights.

Business class is a much more significant upgrade from economy class for long haul flights, in contrast to a regional or domestic flight where business class offers few advantages over economy class. The innovations in business class seating, incorporating features previously exclusive to First class, has narrowed the comfort and amenities gap with First class. These advances and added features, as well as the late 2000s recession, have caused some airlines to remove or not install First class seating in their aircraft. Business class has started to disappear from some short/medium haul routes, to be replaced with full fare economy and discount economy. On these routes, the seats are the same for all passengers, only the flexibility of the ticket and the food and beverage service differs. On shorter routes (less than one hour) many airlines have removed business class entirely.

With business class seating moving upmarket, some airlines are modelling their first-class section as suites (Singapore Airlines, Cathay Pacific, Emirates, Etihad Airways). First-class seats vary from large reclining seats with more legroom and width than other classes to suites with a fully reclining seat, workstation and TV surrounded by privacy dividers, usually at least one lavatory for their exclusive use.

Singapore Airlines markets its highest class on its A380s as "suites", with the tagline "A class above first." The 2 m bed is separate from the seat and folds out from the back wall. Other A380 operators like Emirates also have a suite-like first class with similar amenities but the bed and chair are integrated where a button is pushed to turn the seat into a bed in seconds and vice versa. Etihad Airways introduced a three-room suite called "The Residence" in December 2014 when it added the Airbus A380 to its fleet.

Flexible aircraft cabins (the concept allows for seat pitch to be quickly increased), removal of overhead bins, foam seat cushions that allows passengers to adjust the firmness of their seat with the push of a button, introduction of in-flight social zones, suites with double beds, a smart seat which remembers passenger preferences are new trends in the evolution of aircraft cabin design that make air travel more comfortable and familiar. Icelandair's Boeing 757 Hekla Aurora aircraft, Thomson Airways' 'Beach Snack Bar' concept, KLM's Boeing 787-9 business class, and Finnair's A350 XWB serve as insightful examples of how inventive cabin design can be used to enhance the in-flight experience [1].

3. PREMIUM TRAVEL AND LOW-COST AIRLINES

Low-cost carriers (LCCs) have their biggest impact on short- and medium-haul flights, as shown in the Figure 1 but during the last few years they are expanding into long-haul service offering business-class products with more seating space and enhanced on-board passenger service.

In Europe, Norwegian Air Shuttle has for three years flown Boeing 787s from major European cities to multiple destinations in the United States and a few in Asia. According to their web site, their premium class features include: lounge access at selected airports, comfortable seat in the Premium cabin with 1.16 metres legroom, 2 checked bags x 20 kg included, seat reservation, complimentary drinks before departure, pre-dinner drinks, 3-course dinner including drinks, breakfast, USB charger and power outlet by your seat and state-of-the-art touch screen entertainment system. By this summer, Norwegian Air launches 10 new routes from three smaller U.S. airports — Stewart International Airport in New York's Southern Hudson Valley about 65 miles north of Manhattan, Hartford Bradley International Airport in Central Connecticut, and T.F. Green Airport in Providence, Rhode Island. Norwegian will operate all flights with a new single-aisle airplane, the Boeing 737 Max, charging only $69 for one-way ticket between the U.S. and Europe [3].

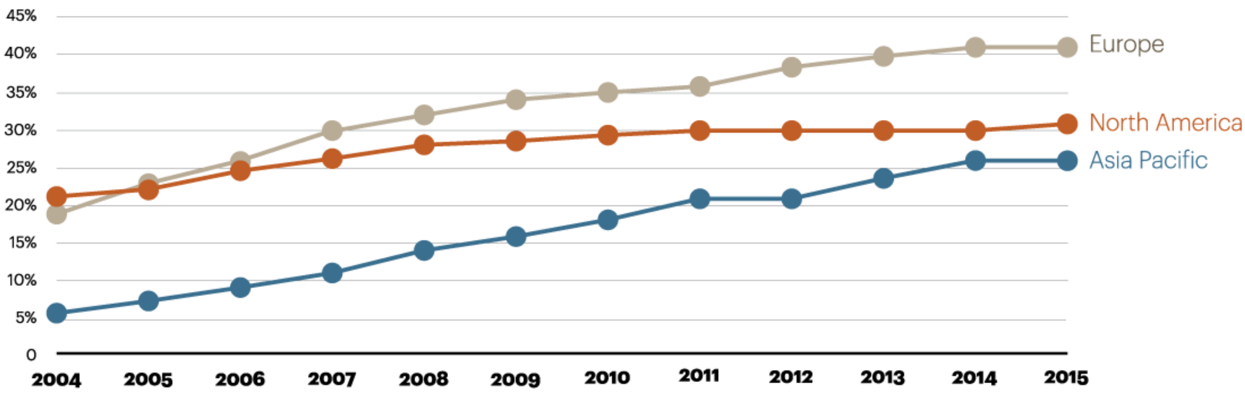

Figure 1 – Low-Cost Carriers Share of Short and Medium-Haul Flights
Source: Kerney, AT. Low-Cost Air Travel Enters the Next Stage, 2016, [cited 2017 Mar 22]. Available from: https://www.atkearney.com/documents/10192/7849535/Low-Cost+Air+Travel+Enters+the+Next+Stage.pdf/82879799-c94b-410c-a219-7104df388c9a

Ryanair introduced Business Plus class in 2014, a service providing seating, check-in and luggage benefits thus expanding its offerings in the business travel market. Starting at $99.59, Business Plus tickets afford customers a free carry-on bag under 20kg, flexibility on ticket changes, expedited security check-ins and premium seating.

Similarly, easyJet offers business passengers the opportunity to pay one price for an all-inclusive ticket, which will entitle them to choose their seat, place their bag in the hold, and pay by credit card. Their *FLEXI* fares promise speedy boarding, allocated seating, Fast Track security, one piece of cabin luggage and a second smaller piece of cabin luggage (handbag/ laptop), one piece of hold luggage, no extra booking fees, free route changes and unlimited free date changes in a 4 -week period - from 1 week before to 3 weeks after the original travel date.

Advantages of LCC business model may be applied for long-haul service, even it is not expected that the cost savings would be close to those achieved on short and medium haul flights. Only some of the favourable cost advantages that LCCs enjoy over network carriers readily apply to long-haul operations. With longer flight lengths, LCCs' productivity advantage is harder to maintain, but the other advantages like lower labour costs and reduced airport, handling, and other service expenses still apply and might bring a 20% cost advantage on long-haul routes [2].

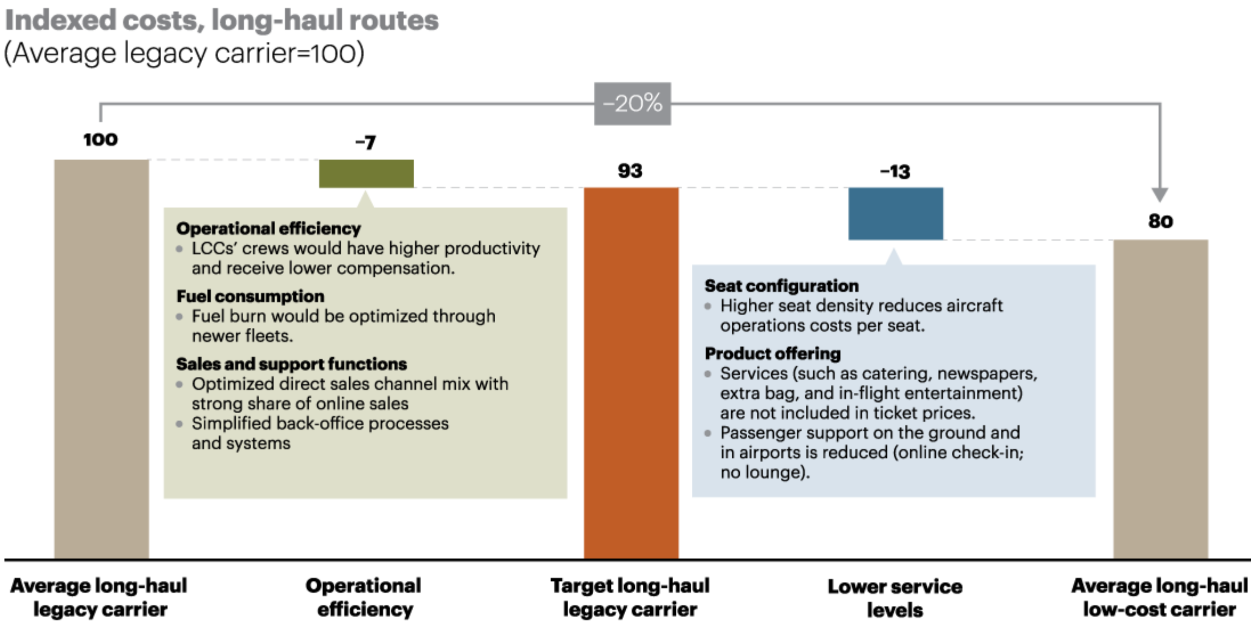

Figure 2 – Estimate of LCC's Cost Advantage on Long-Haul Routes
Source: Low-Cost Air Travel Enters the Next Stage, A.T. Kearney, March 2016, https://www.atkearney.com/documents/10192/7849535/Low-Cost+Air+Travel+Enters+the+Next+Stage.pdf/82879799-c94b-410c-a219-7104df388c9a

4. PREMIUM TRAVEL DRIVERS

The premium travel segment is recognized as an important travel market segment, particularly for hotels and network airlines, but also for others in the travel and tourism value chain. For example, international air passengers travelling on premium seats represent 8% of traffic but 26% of passenger revenue [4].

According to research done by IATA [4], there is a positive relationship between the number of premium passengers travelling between a country pair and the size of the economies at either end of the flow. Still, there are some interesting country-pairs outliers to that relationship:

- those with a relative small number of premium passengers but large economies at both origin and destination (such as United States - Russia)
- those with a high number of premium travellers but small economies (such as United Arab Emirates-Bahrain).

Over the last decade, the United Kingdom was the country with the greatest number of premium travellers, followed by United States and Japan. Several examples show that economic size, at both origin and destination, is not the only factor that drives premium passengers. The same research identified the following factors as the most important business travel drivers determining the size of premium travel markets between country pairs:

- the relationship between travel and distance (business travel, all other things being equal, tend to diminish with distance)
- historical relationship (for example, premium travel market between Australia and the United Kingdom is about 3 times larger than Singapore - United States)
- regulatory framework of a country (how well property rights are protected and the cost of setting up a business)
- the quality of the information communication and technologies infrastructure
- price competitiveness (purchasing power parity, airfare ticket taxes, taxation level in the country.

Many countries have a great potential to increase the number of business travellers over and above the flows implied by economic size and distance, by improving one or several of these drivers. Basic findings of IATA's research could be summarized as follows [4]:

- economic size at both origin and destination is the most significant factor in explaining differences between country-pairs
- all other things being equal, if GDP rises by 10%, number of business passengers will increase by 6%
- any 10% improvement in policy rules and regulations, ICT infrastructure and price competitiveness would lead to an increase of 4.5%, 2.2% and 13.8% in number of business travellers
- for every 10% increase in distance between economies, premium travel markets, all other things being equal, will be 9% smaller.

5. ANALYSIS OF PREMIUM TRAFFIC TRENDS OVER THE PAST DECADE

This chapter provides an analysis of high-yield traffic growth based on IATA Premium Monitor reports from January 2008 to December 2015 and IATA Airlines Financial Monitor reports from 2014 to 2017.

5.1 Analysis of High-Yield Traffic Growth by Major Market from 2007-2014

The slowdown in premium travel was widespread across the world through most of 2007. The largest falls in growth were recorded in markets linked to the troubled US economy. The impact of Open Skies across the North Atlantic was an offset to that slowdown, providing a structural boost to business travel through the introduction of new services and the impact on fares from increased competition resulting in premium revenues slowing more sharply than volumes on this market. Another boost to the premium travel market was provided by the services offered on many long-haul markets by the Middle Eastern airlines and Middle Eastern hubs [6].

According to IATA, international premium traffic began to fall in July 2008 and the monthly traffic decline has been particularly steep since November 2008, leading to a 21% fall in premium passengers worldwide in February 2009 compared with February 2008 [5]. Following years brought recovery, as shown in Figure 3 which illustrates changes in premium passenger growth and world trade growth since 2008 when economic downturn had affected negatively the volume of premium travel and average fares.

Figure 3 – Premium Passengers and World Trade Growth
Source: Airlines Premium Traffic Monitor December 2105, IATA; Montreal, 2016, p. 2

Premium passenger traffic data provided by IATA Premium Monitor reports from January 2008 to December 2015 were deeply analysed and growth rates for major routes over the 2007-2014 period are illustrated in Figure 4.

Premium travel fell sharply from September 2008, as the Lehman Brothers bankruptcy marked the start of the collapse in the banking sector. Business travel, being highly sensitive to economic growth and developments in international trade and investment was so far less sensitive to fare levels. The fact that average premium fares were falling faster than discounted economy fares on some markets, e.g. within Europe, witnessed about severity of the downturn in business travel during 2008. For network airlines, focussed on serving this passenger segment, the decline in premium revenues damaged overall profitability [7].

Premium travel numbers fell 16% in 2009. The decline in premium travel matched very closely the decline in world trade so when world trade started to pick up at a robust pace from the middle of 2009, premium passenger numbers followed that upturn very closely. A steady shift of business travellers from premium to economy seats on the within-Europe market was recorded, but this was less evident on long-haul markets. There were large geographical differences in passenger growth. Very strong growth was recorded in Within-Far East and Asian markets, while the weakest large premium market was within-Europe where premium travel numbers were down on the previous year by 25% [8].

Over the 2010, premium travel continued to be on an underlying trend growth rate and premium travel markets expand by 9.1% [9].

During the 2011, premium travel markets grew 5.5%, a slowdown to 2010 results. While first 8 months sow a nearly flat trend, premium travel strengthened at the end of 2011. Despite financial instability in the Eurozone, travel markets within Europe expanded by 5.1% in 2011 [10]. Growth on all the larger routes continued at a robust pace with no significant areas of weakness.

During 2012, expansion in economy and premium travel numbers slowed from the faster growth trend seen in late 2011. For the year as a whole, premium travel expanded 4.8%. Among the major markets, air travel across the North Atlantic and within Europe experienced largest decline in 2012. Recession in many European economies contributed to premium travel numbers expanding for only 1.0% within Europe. By contrast, Far East contributed more than any other market to overall growth in premium travel in 2012 [11].

The growth trend continued in 2013 with number of passengers traveling in premium seats on international markets expanded by a solid 4.2% mostly due to positive developments in the business environment in the second half of the year. The largest share of the rise in premium travel in 2013 was attributed to the within Far East market which expanded 7.2% in 2013 [12].

In 2014, annual growth was 3.4% for premium international air travel and 3.5% for economy class. While in 2013 and during first months of 2014 premium travel expanded at a faster pace than economy travel, in 2014 there has been no further gain in premium's share of total traffic [13].

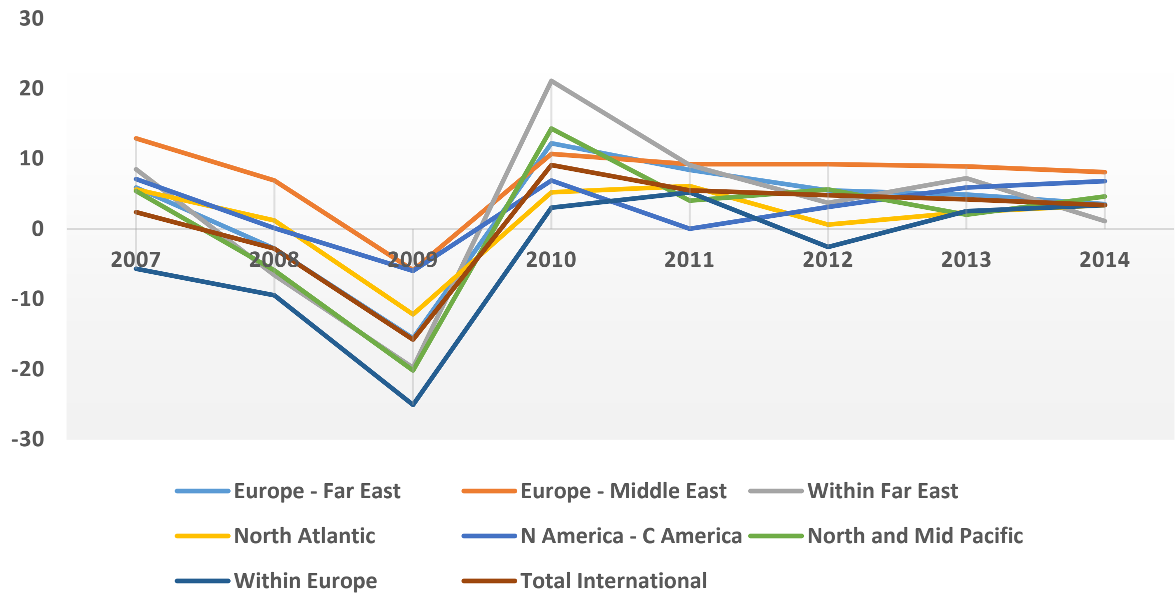

Figure 4 – International Traffic Growth by Route 2007- 2014
Source: Airlines Premium Traffic Monitor, January 2008-January 2015

The impact of the most recent global recession of 2008 – 2009 on premium and economy travel was remarkably different with premium traffic suffering a structural loss in demand afterwards. Premium traffic started to fall before economy traffic, as corporations anticipating the recession started to cut travel budgets. While economy traffic recovered strongly a year after the worst negative growth rates were recorded, premium traffic needed years to stabilise growth rates and for many years grew slower than economy traffic. Economy travel regained its pre-recessionary levels in early 2010, but premium traffic did not recover to these levels until late 2012.

5.2 Recent Changes in Premium Traffic and Premium Yields

Before the recession, premium represented around 9.5% of total passengers, while in the 2015 it was around 8,1 (Table 1). Given that premium fares are much higher than economy fares, the loss in revenue is significant.

In 2013 and early 2014 premium travel was expanding at a faster pace than economy travel which was positive for airline yield growth and revenues. That trend reversed in 2015, with relatively stronger growth in economy class travel placing downward pressure on the share of premium seats from the total. Premium traffic volumes grew by an estimated 3.7% in 2015 thanks to upward trend recorded in the first months of 2015. The easing in the upward trend of premium traffic over the second half of 2015 relates to broad-based weakness in the drivers of premium travel demand, including the ongoing uneven pattern of global economic growth and the emergence of key economic risks proving that trade growth tends to correlate with business-related premium travel demand. Comparatively strong economic performance in advanced economies has supported premium traffic on the North Atlantic, but slowing growth, and even recession, in a number of large emerging markets such as China and

Brazil, has weighted on premium traffic growth in many markets [14]. International passenger traffic by cabin class and geographic region for 2015 are reported in Table 1. Figure 5 shows how the share of premium international traffic varies by region.

Table 1 – International Passenger Traffic by Cabin Class

Region of Airline Domicile	RPKs[1] (millions)					
	Premium Classes[2]		Economy Class		Total	
	2015	% Growth	2015	% Growth	2015	% Growth
Africa	8,020	-0.4	116,269	-0.5	124,289	-0.5
Asia Pacific	95,876	3.7	1,096,651	10.7	1,192,527	10.1
Europe	108,247	2.6	1,492,915	6.1	1,601,161	5.9
Latin America	13,347	3.3	163,723	11.2	177,057	10.6
Middle East	53,862	9.8	534,994	10.8	588,856	10.7
North America	63756	1.2	488,842	3.9	552,598	3.6
Industry	**343,093**	**3.7**	**3,893,394**	**7.7**	**4,236,488**	**7.4**

Source: IATA WATS (World Air Transport Statistics) 2016, IATA, Montreal 2016, p. 37

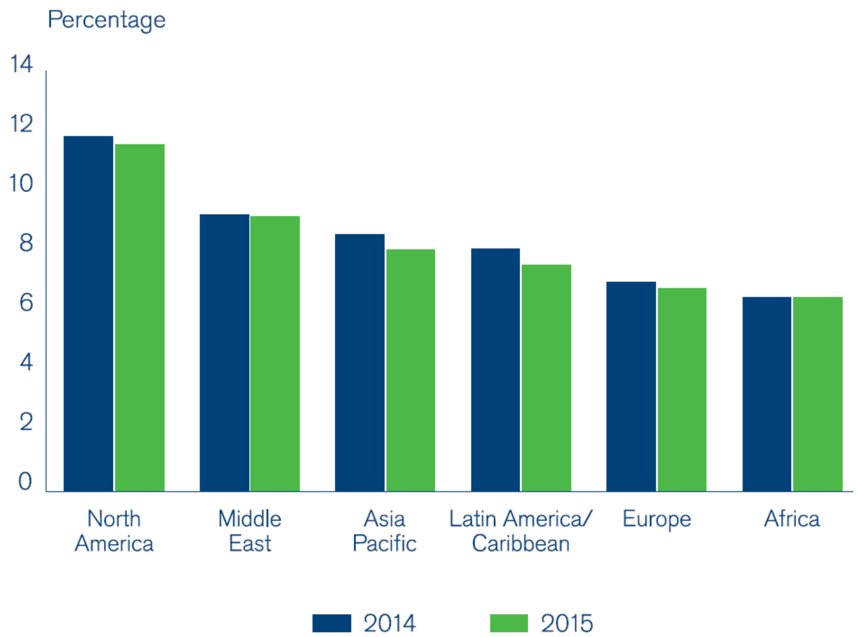

Figure 5 – Share of Premium International Traffic, 2014–2015
Source: IATA WATS (World Air Transport Statistics) 2016, IATA, Montreal 2016, p. 38

According to IATA Airlines Financial monitor issued in February 2017, premium cabin airfares generally held up better than economy airfares in 2016. At the same time, premium's share of revenues increased on a number of key routes thus supporting airline financial performance. Still, average passenger yields have trended downwards since late-2014, and fell by 8.8% in 2016 compared to the previous year as shown by Figure 6. The main reason for these developments lies in upward trend in oil and jet fuel prices and rising labour costs in some key markets. Industry-wide passenger yields have trended downwards since late-2014, and fell by 8.8% in 2016 compared to the previous year. Given that the yield data are denominated in US$, the significant swings in that currency over the past 2-3 years impact the results. Correcting for this effect, the constant exchange rate series (the blue

[1] RPKs-revenue passenger kilometres

[2] Traffic for the premium classes refers to the combination of First Class and Business Class. Premium Economy (or similar) classes are included under Economy Class.

line on the chart) shows that yields increased in seasonally adjusted terms in December 2016 for the first time in six months [15].

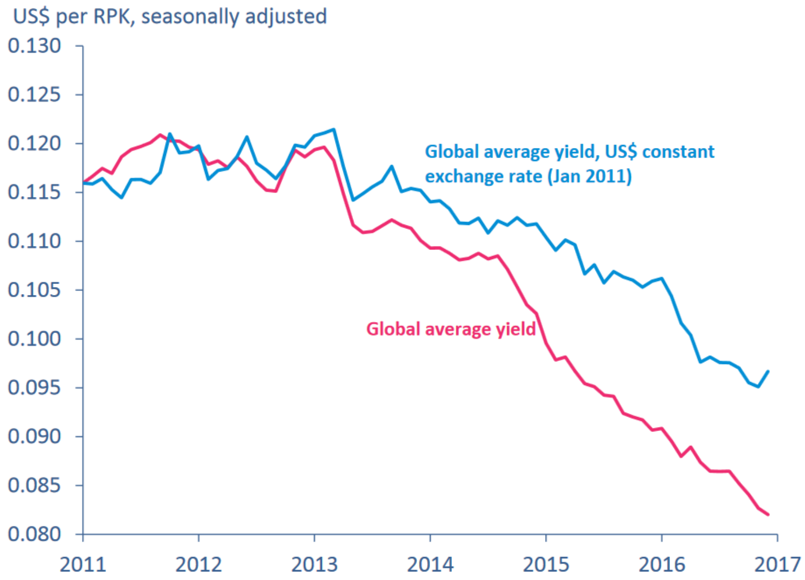

Figure 6 – Airlines' Global Average Yield
Source: Airlines Financial Monitor January 2017 – February 2017, IATA, Montreal 2017, p. 2

Figure 6 shows that annual growth in premium passenger traffic typically lagged behind its economy counterpart on the top -10 premium international markets in 2016 (market between Asia and the Southwest Pacific was the only exception).

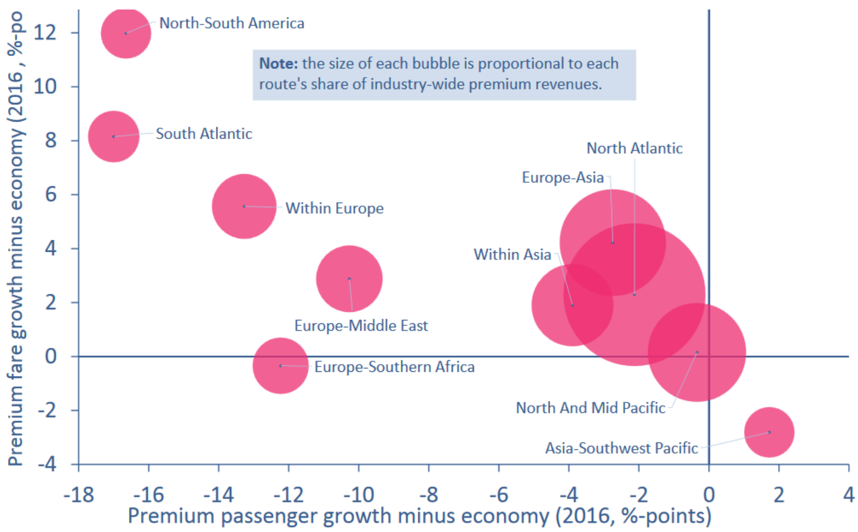

Figure 6 – The Premium Traffic Segment Annual Growth on the Top -10 Premium International Markets in 2016
Source: Airlines Financial Monitor January 2017 – February 2017, IATA, Montreal 2017, p. 3

Premium O-D international journeys accounted for 5.2% of the global total over last year as a whole, down from 5.6% in 2015. Despite having fallen by 7% on average on the key routes in 2016, premium airfares generally held up better than those in economy last year. As a result, premium's share of revenues increased on the important Transatlantic and Europe-Asia markets, and this has helped to support airlines' overall financial performance [15].

6. CONCLUSION

Premium travel demand has an influence on many airlines' pricing and operational strategies out of proportion to the number of travellers. Reduced business travel budgets and substantial cutbacks in airline passenger service quality led more premium passengers to look for alternatives to paying premium airfares: teleconferencing and other travel substitutes, alternative travel modes and, especially, low-fare airlines. Airlines are competing for premium class passengers throw better differentiation of premium class products, advanced cabin designs and better airport amenities. The trend toward lie-flat seats in business class, along with other amenities that are similar to first class, might diminish the value of first class, but airlines count on passenger's segment that appreciate the privacy of suits offered in first class.

Premium travel demand tends to be highly correlated with world economic performance. Historically, *business air travel demand* tends to be slightly inelastic, i.e. the volume of demand does not change by as much as a change in price (in percentage terms). The 2008-2009 slowdown in the economy has led to a reassessment of the assumption that business or time sensitive passengers are inelastic with respect to fares and that they would be prepared to pay high fares for a high quality of service including attractive flight schedules and frequencies, flexibility, and comfortable seats. Analyses of premium air traffic data from IATA shows that whilst long-haul (intercontinental) premium traffic recovered quickly and robustly from the financial crisis - particularly that connecting advanced to emerging markets - short-haul travel demand has been much more sluggish.

To avoid decrease of premium passenger travel and improve their financial performance airlines should:

- understand and recognize all relevant factors that drive demand for premium market segment (e. g. demographic shifts among passengers, the growing use of global communication like video conferencing, corporate travel restrictions or *corporate or* restrictions *on* travel *issued by* government*)* and estimate underlying demand growth at the route, country and regional level
- revise their reliance on passengers willing to pay a premium for travelling business and first class and stop taking them for granted
- better understand individual customers' preferences by capturing rich data about passengers' preferences at each point of interaction between the passenger and the airline with an aim of exceeding their expectations, improving their travel experience and ensure their loyalty
- envisage airplane requirements for each region served (for example, Middle East airlines continue to favour wide body airplanes and premium passenger services to benefit from area's geographic advantages and prominence in business travel).

Recent trends show that premium's share of revenues increased on a number of key routes thus supporting airline financial performance. Still, upward trend in oil and jet fuel prices and rising labour costs in some key markets caused that average passenger yields have trended downwards since late-2014.

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IMPORTANCE OF ROAD MARKINGS QUALITY FOR AUTONOMOUS VEHICLES

ABSTRACT

In this proceeding we provide a short overview of some of the systems for autonomous driving and their implementation along with short pointers on the quality a road infrastructure needs to achieve to allow safe navigation for such vehicles. Autonomous systems have become a hype in the public with the emergence of the Google autonomous vehicle systems. There are many elements needed to allow such vehicle to move around independently. One of the more important elements is the need for a highly accurate map representing the roads and its infrastructure. To achieve this, a certain level of quality needs to be present when we talk about road markings on the existing roads. One such element is the road marking retroreflectivity values since they assure the visibility of the markings in day or night and various weather conditions.

KEY WORDS

Autonomous vehicles; retroreflectivity; road mapping

1. INTRODUCTION

Recently, a large sum of companies began to experiment with autonomous vehicles and related technologies. Starting with the DARPA Urban Challenge [1], a significant increase of prototype development is evident. These vehicles contain a plethora of technological elements allowing them to autonomously navigate roads (GPS devices, LiDAR and RADAR elements, Cameras and ultrasonic sensors). One of the remaining challenges is the notion of highly accurate navigational maps. To completely understand its surrounding, the on-board processing unit must have a precise road map with all the containing markings in vertical and horizontal spread. Apart from standard road lane elements (lane position, orientation), the map needs to contain very detailed spatial information on the road markings, traffic signs, curb height, etc. This is important to assure seamless execution of the autonomous navigation within the real-world environment. One of the important elements that contribute to the effectiveness of the mapping approaches is the retroreflectivity of the markings since it directly influences the quality of the final, obtained, result.

2. SHORT OVERVIEW OF SOME OF THE APPROACHES WITHIN AUTONOMOUS SYSTEMS

Spatial data and extracted information carry the load of the autonomous system (*Figure 1*). They provide the most basic source of data for the core function – spatial navigation. Franke et al. [2] made a notion of the need to have a fully autonomous driving system that would be able to navigate through various scenarios and not be limited to highways only. They called it "Stop&Go" system and it should be able to: detect leading vehicles and estimate their speed and distance, define the lane track even in the case of low quality painted markings, detect and recognise small traffic signs in a hard-to-interpret zone, recognise and detect pedestrians and bicycles, and finally, detect obstacles.

Figure 1 – Google autonomous vehicle
Source: Litman (2014)

Kolski et al. [3] developed an approach to autonomous driving based on two solutions. In first case, the autonomous system recognizes lanes and marking thus navigating the environment. Second case evolves around the need to navigate when no obvious lanes are present. As it is case in the other approaches, autonomous vehicle needs an active map containing all the necessary information for safe navigation and obstacle avoidance. This map is additionally populated with information on the go. Built in sensors detect elements like road blocks, vehicles in surroundings, pedestrians etc. Geiger et al. [4] took upon the challenge of solving one of the main problems in the modern autonomous vehicle industry, the lack of realistic benchmarking environment scenarios. Evaluation showed that some of the top-ranking algorithms did not yield high results within their scenarios even though that was not the case with other benchmarks. Their scenario focused on stereo matching, optical flow estimation, visual odometry/SLAM, object detection and orientation estimation.

Schreiber et al. [5] mentioned in their work the need for pre-generated road maps containing information as road lane markings and curbs. Their approach to road lane extraction was based on data recording, GNSS data processing, Bird Eye View image generation, Lane marking extraction and finally manual review. Early adapted systems used only sensory data as the main input elements but in the past few years there is a sharp increase in utilizing maps as the main component for the navigation. Choi et al. [6] developed their own two-part solution for rural and off-road areas. First part utilises cameras for lane, speed-bump and pedestrian-crossing detection whilst LiDAR technology performs obstacle detection. Their lane detection algorithm contains segment for lane marking detection based on the dark-light-dark transitions detected on inverse perspective mapped imagery. Levinson et al. [7] presented an evolved version of their autonomous vehicle called "Junior". Within their framework, they implemented new elements for navigation and mapping in the open environments which corresponded more closely to the real scenarios. High accuracy maps were produced based on automatic calibration of 64-beam rotating LiDAR using a trio of unsupervised algorithms bringing them to a centimetre accuracy. Advantage of such system is the possibility to operate during day or night, sun or rain. Litman [8] provided the most recent predictions for the autonomous driving systems. Based on his report, the real possibility of seeing a fully autonomous system is the 2030s but the aftermath effects of reduced pollution and traffic jams won't be seen before 2040s or even 2060s.

3. ROAD MARKINGS AND THEIR DETECTION

Road markings represent a communication channel system that allows drivers to better understand the driving environment and easily navigate through the road network. They provide information on where to position your vehicle during your ride, provide a warning on upcoming conditions and indicate where passing is allowed or not. They are a part of a larger communication network consisting of traffic signs and traffic signals [9]. As such, road markings represent an important element of vehicle localisation in autonomous driving environments. Stroila et al. [10] applied a patent describing the use of retroreflectivity as to determine travel path features. They linked the retroreflectivity values of the road markings with the intensity values obtained from a LiDAR sensor on their vehicle. Based on this connection they could automatically identify road markings on the road and classify them thus to generate necessary map data to be used in autonomous navigation at a later point. From the collected data, they generated a data model which was then stored for future uses. Mocanu et al. [11] performed a web survey on the question of technical readiness and performance influencing factors for autonomous driving. They had 67% of R&D experts, 24% from academia, 15% from automotive and supplier industry and 13% from other fields as public authorities, consultants etc. The results of their queries are provided in the *Figure 2 and 3*. Based on the obtained result, and in regards to road markings, Mocanu et al. concluded that to allow autonomous systems to be utilised on the roads it is important that the road planning and design consider these requirements:

- Clear visibility of lane markings, regardless of the weather conditions
- Harmonised characteristics of lane markings at a transnational level when it comes to colour, luminance, shape, etc.
- Proper road works markings which need to be clearly recognisable when compared to the normal lane markings
- Well removed remnants of the old road lane markings.

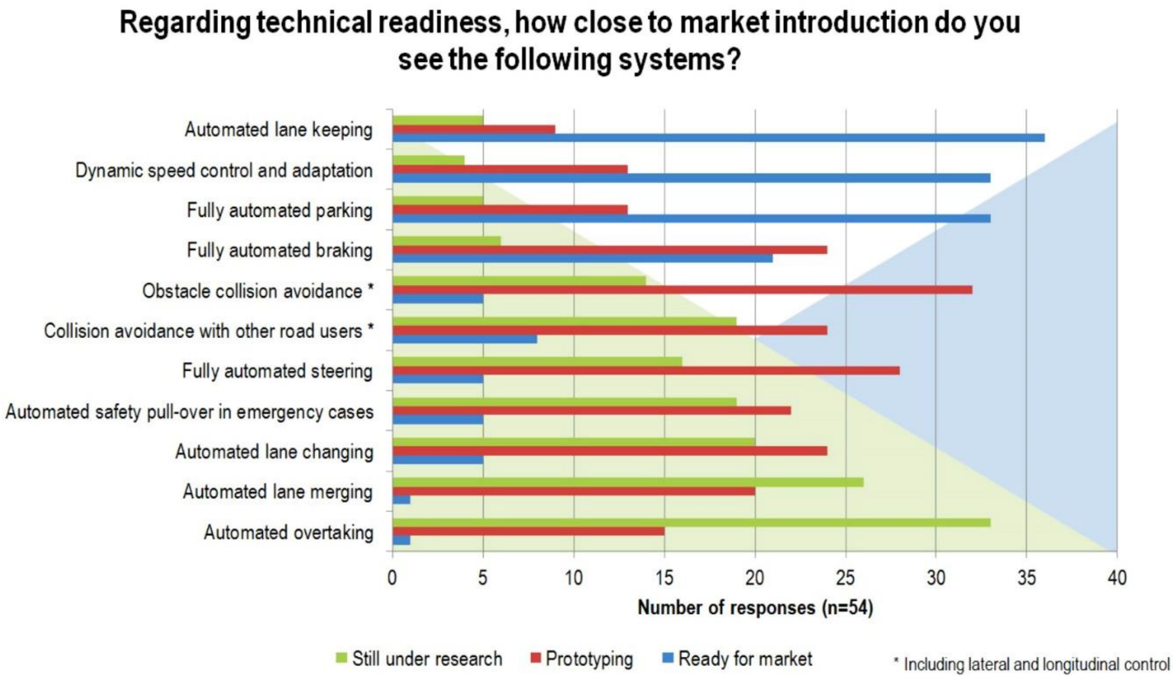

Figure 2 – Survey results based on Mocanu et al.
Source: Mocanu et al. (2015)

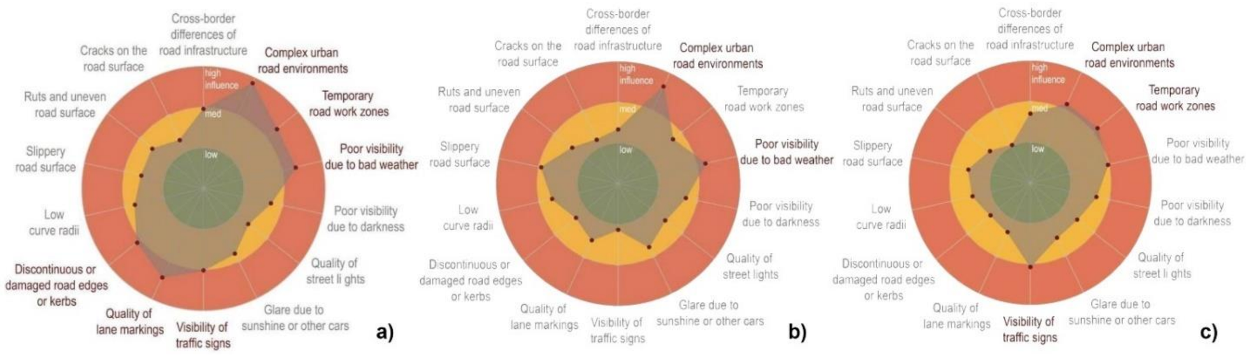

Figure 3 – Based on Mocanu et al. Factors influencing the performance of: a) lane assistance systems, b) collision avoidance systems and c) speed control systems
Source: Mocanu et al. (2015)

In March last year Reuters reported on a problem that autonomous vehicles encountered on shabby US roadways [12]. An autonomous Volvo car prototype refused to work during a press event since it was unable to locate and recognise road lane markings because of their poor quality. The same problem was encountered with Tesla company vehicles. This problem requires the manufacturers to implement even more sensors into the vehicles to compensate for the problem. This in return results in an up to 4000$ increase in the price per unit. Davies [13] presented a set of questions that directly deal with road markings quality:

- How does pavement marking elements (retroreflectivity, contrast ration and width) affect the performance of machine vision?
- Are the key pavement marking factors different in a day versus night scenarios?
- Are the key pavement marking factors different in a dry versus wet scenarios?

For his experiment, he equipped a car with machine vision system and tested the outcomes of various scenarios based on the pre-mentioned questions. He concluded that during the day there is no significant impact of retroreflectivity on the machine vision opposed to the night where the impact was very high. Mathibela et al. [14] developed their own approach to automated process of understanding the painted road signs. They wanted to mimic the understanding of the road signs which comes natural to humans by applying probabilistic RUSBoost and Conditional Random Field (CRF) classification framework. This allowed them to jointly classify extracted road markings (*Figure 4*).

Figure 4 – Various colours show a different type of markings recognised from the scene
Source: Mathibela et al. (2015)

If we talk about road lane detection algorithms in general then it is important to note a few additional elements. Gradient based algorithms can be found in the literature; however, such algorithms are sensitive to noise and result in an increased number of outliers from clutter and shadows. Additionally, they are limited to local view thus ignoring the shape of road line markings.

Other, more advanced variants, based on image gradient have been proposed in the literature. They are less sensitive to the noise. The steerable filter [15] and ridge detector [16] are some of those algorithms. Another set of algorithms attempts to detect road line markings from a different perspective, searching for low-high-low intensity pattern along image rows. The most common being the box filter.

Based on Hillel et al. [17], a majority of lane line detection algorithms combine three common steps: firstly, lane line feature extraction, by edge detection [18,19] and colour [20,21], or by learning algorithms such as SVM [22], or by boost classification [23,24]; secondly, fitting the pixels into different models like straight lines [25,26], parabolas [15,27], hyperbolas [28,29]; and thirdly, estimating the vehicle pose based on the fitted model. A fourth time integration step may exist before the vehicle pose estimation in order to impose temporal continuity, where the detection result in the current frame is used to guide the next search through filter mechanisms, such as Kalman filter [18,30] and particle filter [22,31]. The main purpose of lane line feature extraction is to identify the pixels belonging to road line markings and eliminate non-road line marking pixels.

It is important to note that clear majority of approaches in the literature are based on the observations that road markings have high contrast compared to road pavement. Vehicle manufacturers may consider that existing road-marking, marker and sign standards are all that is needed for autonomous vehicles to perform safely and efficiently, provided the minimum standards are enforced. The standards CEN EN1436 and ASTM E 1710 were created to assess the night-time visibility of road markings. Road markings that adhere to these standards are visibly distinct in daytime and night-time driving.

4. CONCLUSION

As we can see from the main text, there is an existing problem with lack of proper infrastructure for autonomous vehicles to perform at its peak level. Some of the bigger mapping companies have started their own mapping project in a quest to generate HD navigational maps which are then being used as an additional source of information. They use a vehicle loaded with LiDAR, cameras, GPS and other sensors to collect high amounts of data. This data is then being processed either manually or using neural networks as to produce final maps containing even the slightest details. Another problem they are facing is the problem of locating the car within less than 30cm accuracy. GPS devices have a maximum accuracy of around 5m which is not suitable for navigation on a 5-lane road network or similar. Same problem arises in the case when the signal is lost because of tunnels or deteriorated due to multipath effect in urban environments with high buildings.

Based on the short description of the autonomous systems and the connecting elements that provide the infrastructure needed for their safe operation, we can conclude that not only that the new sensors and methods are a great part of the autonomous vehicles success but also the quality of the pre-existing elements on the roads plays an important role. The quality of the road markings and the materials used to produce them will have, and has, an impact on the mapping accuracy. Retroreflectivity of the road markings provides a good insight on their visibility under various conditions and it should become one of the important markers in evaluating the road quality when it comes to autonomous vehicles.

Markings, like everything on a road surface, are subject to wear and tear caused by traffic and environmental conditions. The constantly changing condition means it is often difficult and time-consuming to monitor their quality. To maintain accurate maps of road-marking quality will require road authorities and road maintenance companies to perform regular periodic surveys, perhaps several times a year. When autonomous vehicle manufacturers finally decide upon the quality and visibility of road markings necessary for safe passage, these road-marking maps will have to be maintained (this will probably be mandated by the regulating authority). Road authorities and road maintenance companies will require systems to continually access and monitor the retroreflectivity of road markings, to ensure they are safe, economically and environmentally friendly and legible at all traffic speeds, causing no interference to traffic flows.

Even though the true era of autonomous vehicles has not yet begun, future efforts should be made to assure that the materials used and approaches implemented to road marking application allow for increased retroreflectivity over a longer period to assure readiness without the need for large modification interventions once the autonomous vehicles become part of everyday life. This way, long term planning will allow smoother transition and reduce the financial stress of the implementation.

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EVALUATION OF LOCAL MUSCULAR LOAD APPLICABLE IN THE LOGISTIC COMPANIES

ABSTRACT

This paper is focused on the comparison of currently available methods how to evaluate Local Muscular Load. Our article offers an overview some other functional methods that we can use for evaluation of Local Muscular Load not only in Czech Republic, but in the world. Furthermore, we described completely new and innovative method developed by Tomas Bata University in Zlin, in cooperation with other Czech universities and Institutions. This method obtained Utility model in Czech Republic and it was patented.

There is so many practical view a suitable work environment as a tool towards fulfilling corporate needs: maximum output at minimum cost. In connection with the development of work-related injuries or occupational diseases, there are several groups affected by costs: those workers where a loss of earnings, damages for pain and suffering, costs associated with treatment and material damage may occur; those employers affected by an adequate share of sickness, pensions, healthcare, costs of occupational care etc., and finally the insurance companies and the state involved in healthcare. However, the work environment is also viewed as one determiner of the quality of work, performance, satisfaction, work efficiency, work-related stress and also the worker's creativity also in logistic companies and processes.

KEY-WORDS

ergonomics; datalogger; local muscular load; electromyography; logistics

1. INTRODUCTION

Ergonomics as a science uses optimization of working conditions. It plays a main role in the reduction of health costs and also in the elimination of negative influences of the work environment [1]. The results are also obvious in maximizing human health, comfort and well-being while working [2].

Ergonomics believes that the human body is limited by range of motion, speed, endurance and strength; therefore, the goal of ergonomics is to evaluate the person, work environment and working task and then to set to meet the worker's needs [3]. Basically, the aim of ergonomics is to understand the relation between the human and the system, which means the working environment with its risk factors, method of working, working tools, machine, technologies etc., and to fit the task to the individual, not the individual to the task [4]. Apart from to cost reduction and health protection, ergonomics has been involved in improving the worker's productivity, quality, job satisfaction, loyalty and absenteeism.

2. HEALTH COSTS

Worldwide, healthcare is a very hot issue, in particular its funding. Health costs represent one part of corporate and government spending and their trend is constantly growing. Many of the reasons of increasing health costs can be defined as longer life expectancy [5] aging population [6], obesity and obesity-related diseases [7] diabetes [8], standard of living, new technologies or the work environment which is not always well defined.

In the 1990s, Becker [9] started to examine the relationship between the work environment and the health condition of employees. He named an unsuitable work environment as being a cause of health problems of employees. He also claimed that the work environment was a crucial and often neglected part of working conditions. Dul and Ceylan [10] view a suitable work environment as a tool towards fulfilling corporate needs: maximum output at minimum cost. The rising costs associated with work-related injuries or occupational diseases are the most significant impacts of an inappropriate working environment [1]. In connection with the development of work-related injuries or occupational diseases, there are several groups affected by costs: those workers where a loss of earnings, damages for pain and suffering, costs associated with treatment and material damage may occur; those employers affected by an adequate share of sickness, pensions, healthcare, costs of occupational care etc., and finally the insurance companies and the state involved in healthcare.

The consequences of inappropriate working conditions are easily defined as worsening of the worker's health and economic impact on a micro and macroeconomics level. However, the work environment is also viewed as one determiner of the quality of work, performance, satisfaction, work efficiency, work-related stress [11,12], and also the worker's creativity [10,13].

3. PROBLEM SOLUTION

3.1 The local muscular load

The local muscular load is a load on small muscle groups during the work performance of the upper limbs [14]. It is the involvement of fingers, hands and forearms while working. Most often, the local muscular load is developed by a work characterized by fine motor skills, monotony, work in unsuitable working positions of the upper limbs or by the presence of other factors (cold, vibration, etc.). The local muscular load is also viewed as a long-term, excessive and unilateral overload of muscle and outside-muscle structures of the elbow to the fingertips of the upper limbs, it is called as RSI - Repetitive Strain Injury.

Especially in the Czech Republic, very often local muscular load causes the most common occupational diseases [15].This is the carpal tunnel syndrome, the most common neuropathy [16]. The term neuropathy is used in connection with an indication of disease of the nervous system, specifically peripheral nerves that connect the central nervous system with organs and tissues throughout the body.

3.2 The Carpal Tunnel Syndrome

During the carpal tunnel syndrome, a compression of the median nerve, situated in the carpal tunnel in the wrist, occurs. Carpal tunnel is the space at the bottom and on the sides defined by wrist bones. The central nerve is the strongest nerve innervating the upper limbs. It provides the ability to bend and rotation of the hand, fingers and thumb [17]. When the median nerve is compressed, limited innervations leads to limitations of sensitivity and movement of the fingers. Other symptoms include tingling, pain and weakness of the whole hand. Currently, the carpal tunnel syndrome is connected with profession, is thus a professional neuropathy. Other reasons for its emergence may be an inherited predisposition to carpal tunnel shallow, diabetes, rheumatoid arthritis, hypothyroidism, a hormonal disease or fracture of mandrel forearm bones.

Statistics show that to 30% of workers in high-risk groups suffer from carpal tunnel syndrome [17]. The most vulnerable group are definitely women in middle-age (between 40 and 50 years).

3.3. The Integrated Electromyography

So far in the Czech Republic, integrated electromyography (EMG) is the only official method for measuring of local muscular load. Only the entities having the special permission can realize these measurements.

The expended muscle strength, the number of movements and the operating position of the limbs are identified and judged during the evaluation of local muscular load, depending on the extent of the static and dynamic parts of a person´s work during an average eight-hour shift. Equipment that is used for the measurement is a non-invasive electromyography using a Holter EMG. This personal device enables the observation of the (potential) electrical activity in the individual muscle groups of the forearm in real time. The device then stores this activity and exports it to a PC. The Holter EMG (i.e. data collection station) is shown in Figure 1.

Figure 1 – Holter EMG [18]

Five electrodes are placed on both upper limbs to scan the muscle activity. As the Figure 2 shows, two electrodes are located on the extensors (muscle groups on the top of the hand), two electrodes are placed on the flexors (muscle groups at the bottom of the hand) and one ground electrode on the tendon in the elbow. Concurrently, the ultrasound gel is applied to the electrodes to ensure flawless skin contact and conductivity of signals.

Figure 1 – EMG electrodes placed on the arm (Source: authors)

Prior to starting to take measurements, it is necessary to individually determine the maximum muscle strength for each upper limb. Each limb is put into a predetermined position (upper arm parallel to the body, with the forearm held at a right angle). Measurement is performed by the analog dynamometer.

The highest activity of electrical potential is recorded as 100% Fmax for measuring the muscle groups of the flexors and extensors of the forearm. With special software (see Figure 3) it was possible to evaluate individual EMG signals, to separate them in time, calculate the average expended muscle forces (% Fmax), show the frequency analysis of individual muscle forces (0-100% Fmax), etc. is possible through the special software presented in Figure 3. This Figure also shows the output of flexors and extensors of both upper limbs.

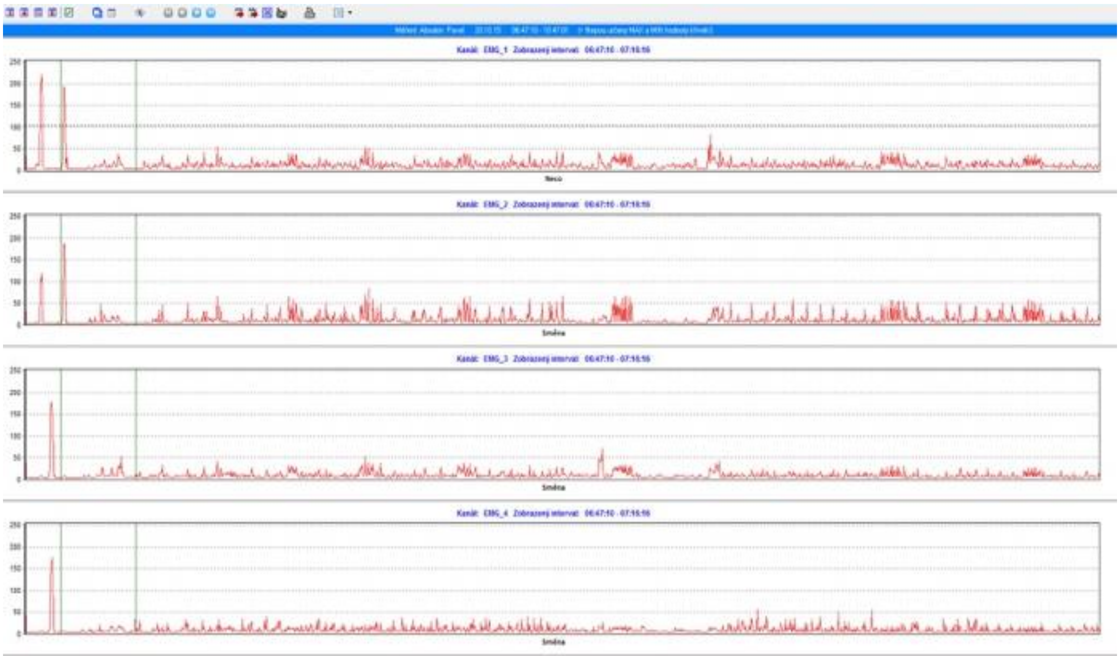

Figure 3 – Output from the EMG Holter (Source: authors)

Expended muscle group in one of the two required parameters for measurement of local muscular load. The second required parameter is number movement conducted per work shift. The number of movements of the hand and forearm were determined separately for each upper limb. This activity is done directly in the workplace, or later through the analysis of audio-visual recordings made during the monitored work. The obtained values is time-weighted per average work shift, based on the time frame or by the number of finished products (the real performance, standard).

After the measurement is taken, the risk factors associated with local muscular load are objectified. The evaluation of the measured results is carried out by comparing them to the health and safety limits specified in §25 of Government Decree No. 361/2007 Coll., as amended. The health and safety limits for local muscular load are represented by the value of the expended muscle strength; the number of movements of the hand and forearm during the shift (these movements are relative to the average shift time-weighted value for expended muscle strength); and the average minute counts of movements of the small muscles of the hand and fingers in an average eight-hour shift [19]. The determination of work as being hazardous or non-hazardous is based on whether the work in question complied with or exceeded the legally stipulated health and safety limits [20 -23]. Local muscular load is often detected in production companies (final assembly etc.) and also logistics companies [24-25]. Cohen and Gjessing [26] remark that the scope of Local muscular load and ergonomics is much broader.

3.4. The Datalogger

In 2013 we started in Czech Republic with testing evaluating and using of new measuring device and method. Before this method obtained Utility model in Czech Republic and before we started the patent process, we tested out datalogger in laboratory conditions. Datalogger is a small compact device recording data from the sensors attached. It is based on press sensors (see Figure 4). Type FSR 400 and 402 were used for taking measurements; for our process of testing, a three-finger grasp was chosen at first. Based on the defense carried out, the Industrial Property Office subsequently issued a letters patent for the invention with a number PV 2015-820, in February 2017.

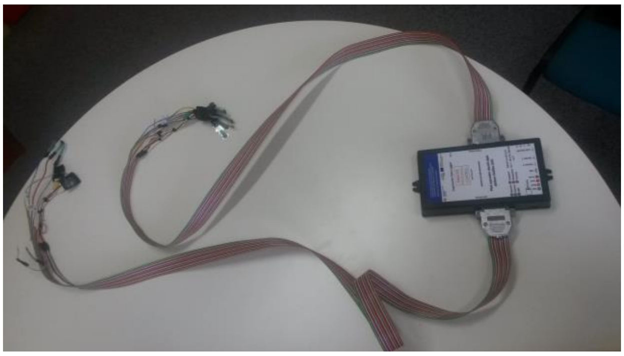

Figure 4 – Datalogger and measuring sensors FSR 400 and 402 (Source: authors)

But in practice the probands (operators) can use all five/ten fingers. The principals with using all five (ten) fingers are the same. The following fingers were used for the measurement: a thumb, index finger and middle finger, ring finger.

Each of the probands was asked to lift one of the cylinders before the attachment of sensors (as a practice). According to the type of grasp, or better to say a contact surface of fingers, the sensors were attached – every individual sensor was secured by one layer of the adhesive tape (Omnifilm). The thickness of the tape securing the sensor is important – using more layers can distort the results.

All connecting cables were secured by putting a tubular bandage over them on the forearm. Each of the probands received a bag to be attached around his/her waist to have the measuring device placed at the back of the body.

4. DISCUSSION

These evaluations were carried out without any support of a later-developed SW application. The aim was to find dependency between the EMG measurements and the muscle force recorded by the datalogger. The value averaging set per every minute was later confirmed to be very close to an optimal sampling frequency. As an illustration, the records of two probands are mentioned below. But in total we tested more than 100 probands and for about 30 operators at the production lines (see f.g. Figure 5). The rest of elevations, in a form of unprocessed data, was added on the CD-ROM enclosed (together with the application developed). All this data were handed to the Moravian-Silesian Automotive Cluster c.a. (hereinafter referred to as MAK) and Ministry of Industry and trade Czech Republic and (MIT CR), and to The Industrial Property Office in Czech Republic (IPO CZ) too.

In the future, we expect to attach so-called IMU units – location sensors (accelerometer, magnetometer and gyroscope all together) to the proband´s hand. The second sensor of the same character will be attached to the wrist. The location sensor on the hand should be highlighted by using the yellow tape to see well.

To obtain valid data, it was essential to synchronize beginning of a measuring process done by EMG as well as the measuring device. A camera was switched on before the start of testing itself. Then, the measuring device was switched on (a side button – light is on) and started recording (Log ON button – it flashes!). Other lights must be off at this stage (if not, there is something wrong with attachment of sensors, or cabling on upper limbs). Following the instructions (time signal), Marker button of EMG and the measuring device was pressed at the same time – starting the process of measurement. This measurement takes 20 minutes. Then, Marker is pressed again, signalling the end of measurement. The gloves were put on, covering the sensors, and a further measurement of 20 minutes was taken when the beginning and the end was indicated by Marker.

Consequently, the video recording was finished and the sensors of the measuring device detached. Once again, the elevation measurement of a maximum muscle force was done in order to identify potential muscle fatigue. In addition, the EMG holter electrodes were detached and all the data from the EMG holter as well as the measuring device were exported to a personal computer where their final check-up was done. In the course of the measurement itself, a non-stop check-up of the data obtained was done in order to have a continuous monitoring.

Figure 5 – Measuring in factory: dependency between the EMG measurements and the muscle force recorded by datalogger: Operator in ITT holding Ostrava (own processing)

The datalogger data recorded on SD card are then divided on a personal computer by using EGParser application into 7 files. The analogue data, keeping record of AD non-dimensional values, are part of one file only.

Processing, the datalogger and EMG holter evaluation of values and the dependency analysis are done in MS Excel. The information regarding muscle forces used in the course of measurement is presented in the form of analogue data one after another in six columns for LUL (left upper limb) and six columns for RUL (right upper limb) for every individual sensor. Every record starts with a time code – in the first column, consisting of a number defined by seconds; in the following column of an order number in particular second.

The statistical data processing from the datalogger starts by a thorough check-up of the records kept throughout the whole period of measurements. As standard, the device keeps record of between 99% to 100% of data, which represents a record loss of 0 – 1000 lines (0 – 10 seconds) per 100 thousand lines of a record.

5. CONCLUSION

Ergonomics brings many rules which should be followed when designing a workplace and work environment. These rules based on our research we can successfully apply in so many types of operations: in production processes, assembly, stocking and apply them in services, production companies and logistics companies also.

It regards the rules to the size of the workplace (table height, amount of floor space, reach distances etc.), manual handling of loads, working positions, local muscular load, physical factors (lighting, noise, dust), chemicals and mixtures and many others. Ergonomics also offers a range of tools to evaluate the work environment and to implement ergonomics principles – checklists, RULA (Rapid Upper Limb Assessment), OWAS (Ovako Working Posture Analysis System) etc. To be able to effectively implement ergonomics principles, the knowledge of many sciences such as anthropology, physiology, medicine, occupational therapy, psychology, tool design etc. are needed.

Based on our experiences and some specialists in ergonomics, prevention plays a crucial part. Exploring ergonomics after a health issue, occupational injury or illness has occurred is a very wrong strategy. Prevention programmes must be included within all activities. Ergonomics prevention prevents and decreases the risks of developing a serious health problem. An effective way of prevention in the working environment is through continuous ergonomics screening.

The mentioned claims unequivocally confirm the fact that the work environment is a key element in business and working processes, and helps to cost reduction, health improvement, productivity, effectiveness growth etc. The implementation of ergonomics rules into corporate activities is a highly topical issue and ergonomics is an excellent tool to care for the working environment and should become an essential part of all processes.

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THE BENEFITS OF ADAPTIVE TRAFFIC CONTROL FOR EMISSION REDUCTION IN URBAN AREAS

ABSTRACT

In urban areas one of the most important causes of pollution (that directly affects climate changes and air quality) is traffic, considering that almost 50% of delays are produced on signalized intersections. Modern methods for the reduction of the exhaust emission are focused on advanced traffic control in order to decrease travel times and the number of stop-and-go actions. In this research, the application of adaptive traffic control on signalized intersections is considered and a simulation model of demonstration corridor in the city of Zagreb was made (with real traffic data implemented in the model). The main goal of this research is to demonstrate the significance of adaptive traffic control on the road vehicles energy efficiency. The algorithms used to address optimization in harmonization and increasing of traffic flow was made. This method outperforms traditional fixed cycle management of intersections, which use predetermined green time split. The case study illustrates the benefits of using adaptive control algorithm, which controls green time splits on demand. The impact of adaptive traffic control is measured on two scenarios – fixed control and adaptive control and their comparison on a signalized grid of seven intersections. The expected benefits are: increased vehicle speed; reduced fuel consumption; exhaust emission and average delays.

KEY WORDS

energy efficiency; fuel consumption; intelligent traffic control;

1. INTRODUCTION

Rapid increase of the number of vehicles in urban areas directly affects traffic quality because of the limitations of road capacity. Frequent congestions in the cities cause the increase of delays, stop-and-go actions and travel times especially, so the overall quality of living in cities is decreasing. International Energy Agency (IEA) is estimating that by 2050. more than 50% of spent fuel will be caused by traffic and transport. That number could be doubled [1]. European Environment Agency (EEA) has determined that traffic in urban areas causes 40% of CO_2 emission and over 70% of other exhaust emission [2]. It is necessary to react on traffic system quality increase (especially in urban areas where the population is bigger and the consequences of traffic are increasing exponentially). Exhaust emissions have different causes; according to the paper [3], 22% of spent fuel is the consequence of ineffective acceleration and deceleration, with the lack of traffic predictions. Congestions cause 15% of exhaust emission and excessive speed, inefficient traffic control, incidents, etc. cause additional 11%.

Rational usage of time and energy means that the research must be oriented to modern traffic control strategies and technologies. The research within the eCoMove project shows a great development and progress in the mentioned area – "beyond-state-of-the-art" strategies are defined with the implementation of the cooperative systems (*vehicle-to-vehicle* and *vehicle-to-infrastructure* communication). A part of the eCoMove project was to develop a simulation model in the city of Rotterdam using PTV VISSIM and EnViVer simulation software and to prove that with speed recommendations only, major improvement of CO_2 and NO_X emission can be achieved [4]. Further research within the eCoMove project is presented through the "green priority strategies", where a part of the urban network was controlled by UTOPIA (Urban Traffic Optimization by Integrated Automation) software and similar results were gathered [5]. According to the authors [6], a different focus was selected – better vehicle routing in the urban traffic network can impact fuel consumption and CO_2 emission. The CVIS (Cooperative Vehicle-Infrastructure Systems) project defines that the efficiency of the system is drastically increased with the number of vehicles that are equipped with the new ITS applications [7]. According to the project results [8], by the implementation of the cooperative approach and the generic algorithms, the improvements were achieved at the stop-and-go actions and the average delay decrease which is directly related to exhaust emissions. The paper [9] says that the benefits of the combination of analytical and simulation data were presented in the means of average travel time and overall fuel consumption. Simulation based optimization was used on the model of the city of Lausanne, Switzerland, and a microscopic evaluation model of fuel consumption was implemented in the Aimsun simulation software. The presented research upgrade was made by the integration of the q-learning algorithms (model-free reinforcement learning technique) in the SUMO (Simulation of Urban MObility) simulation software, where the improvements in CO_2 reduction and the number of vehicles in queue length were presented [10]. With the integration of collected traffic data, PTV VISSIM micro simulation software and MOVES (MOtor Vehicle Emission Simulator), another research [11] presented the difference between a macro simulation tool (which calculates emissions according to average vehicle speed) and a micro simulation tool (which calculates emissions according to current vehicle speed and acceleration), considering the results of the exhaust emissions. The research [12] proved that the evaluation of the exhaust emissions is more accurate using second-by-second model examination because of the emission sensitivity on stop-and-go actions, acceleration/deceleration and idle engine state. The possibilities of integration of the micro simulation models with the exhaust emission models was presented in [13] where the reduction in the emission of CO_2, NO_X and particulate matter (PM) was achieved with the implementation of *k*-means and LOESS (Locally Weighted Scatterplot Smoothing) algorithms. Authors in the paper [14] presented the improvements of CO emissions and overall travel time by integrating emission model VT-micro, model predictive control (MPC) and dynamic speed limit control on a motorway model. The research [15] presented an impact of the implementation of the adaptive priority strategies on the travel time's reduction in urban areas regarding public transport.

The main purpose of this research is to present the implementation of the adaptive traffic control algorithm's benefits with a direct impact on the stop-and-go actions reduction, vehicle delay and exhaust emission. Adaptive traffic control algorithms were developed and implemented in a simulation model with the demonstration corridor in the city of Zagreb which is presented in the second chapter. Improvements was made regarding reduced emissions of CO_2, NO_X and PM_{10} gases, queue lengths, maximum queue lengths and increased traffic flow at high traffic congestion. The description of the developed algorithms is presented in the third chapter, while the results and the implementation are presented in the fourth chapter. Conclusions and further research plans are presented in the last chapter.

2. RESEARCH DESCRIPTION

The first phase of this research consisted of selecting an eligible demonstration corridor. When a demonstration corridor was selected, relevant traffic data was gathered and analyzed. Afternoon peak hour was taken as relevant for this research. Physical components (the number of lanes, the position of signal heads, signal plans for selected time intervals, etc.) were measured within the creation of a simulation model. After it was completed, the simulation model was calibrated according to the existing traffic situation.

The main problem in the city of Zagreb is traffic fluctuation (westbound and eastbound) in the morning and afternoon peak hours. The defined demonstration corridor is located in the west part of the arterial route which is important for connecting the west part of the city with its center. The defined demonstration corridor with its signalized intersections is presented in the Figure 1.

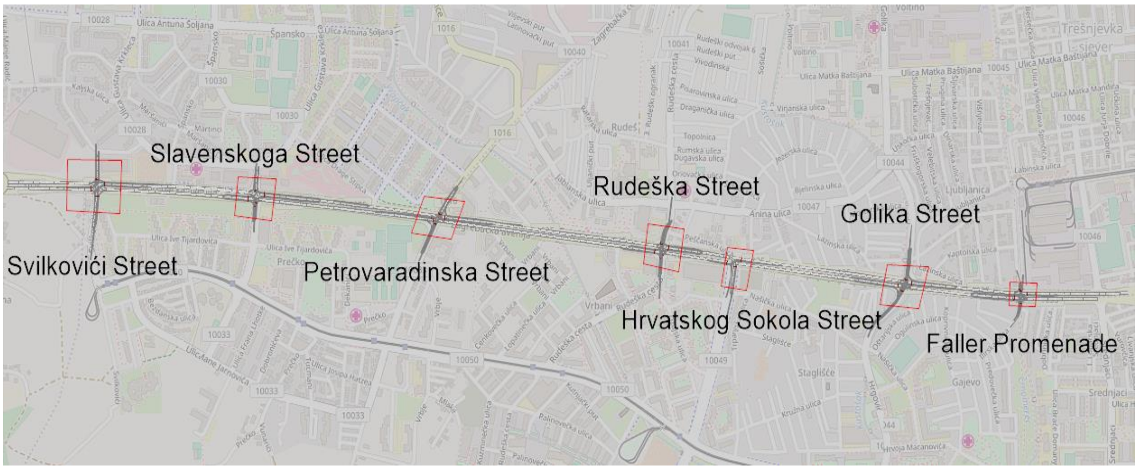

Figure 1 – Demonstration corridor: Zagrebačka Avenue in the city of Zagreb with its signalized intersections
Source: Made by the authors

The demonstration corridor is 3500 [m] long and is consisted of seven signalized intersections where six of them have four approaches and one of them has three approaches. The average distance between intersections is 500 [m]. The main corridor path consists of two-direction roads with three lanes in each direction. On every intersection there are separate approaches for left-turns on main corridor paths. The side approaches on every intersection are problematic regarding traffic demand, so the algorithm had to be personalized for each intersection. The existing traffic control situation has fixed signal plans. The main direction has a green-wave simulation from both sides (offset). Every intersection signal cycle is 150 [s] long, with the implemented intergreen matrix regarding pedestrians. In this research, the pedestrian flow was not generated, but it was included in the calculations.

After the collection of the traffic data, the afternoon peak hour (4 PM - 5 PM) was selected as relevant for simulation modeling because of major traffic demand. The traffic data was collected on every signalized intersection simultaneously and two major road vehicles categories were defined - personal vehicles (PV) and heavy duty vehicles (HDV). Regarding vehicle composition, personal vehicles make 95,95%, while heavy duty vehicles make 4,05%. The OD matrices were made for every intersection individually and for the entire corridor. The speed limits on the selected corridor are set to 60 [km/h]. Traffic flow saturation was calculated, so the capacity of the defined demonstration corridor could be compared with the gathered traffic flow data. Traffic flow saturation was calculated according to the paper [16]:

$$S = s_0 * N * f_W * f_{HV} * f_g * f_p * f_{bb} * f_a * f_{LT} * f_{RT} \quad (1)$$

The parameters are:

S - The number of vehicles on the saturated traffic flow,
s_0 - The number of vehicles on the ideal traffic flow,
N - The number of lanes

The defined correction factors are:

f_W - The lane width factor,
f_{HV} - The group of vehicles homogeneity factor,

f_g - The longitudinal tilt factor,
f_p - The parking factor,
f_{bb} - The public transit vehicles factor,
f_a - The area type factor (urban area, motorway, etc.),
f_{LT} - The left-turn vehicles factor,
f_{RT} - The right-turn vehicles factor.

According to the previously defined equation, the gathered traffic on the defined demonstration corridor is oversaturated. According to the fixed traffic control of the defined corridor's signalized intersections, the main path flow is oversaturated by 32,5% westbound and by 26,3% eastbound. Oversaturation is detected on the north approaches (21%), while on the south approaches the saturation is within limitations.

The exhaust emission regarding vehicle categorization was defined in an emission modeling tool EnViVer. EnViVer is a statistical emission model which is able to calculate CO_2, NO_X and PM_{10} emission based on the vehicle categorization and a simulation model made in PTV VISSIM. According to the gathered traffic data (vehicle number, speed, acceleration/deceleration, etc.), EnViVer can calculate presented data. A basic emission evaluation model is based on Dutch statistics, where the average fuel consumption and vehicle categorization are set by default [17] as shown in Figure 2.

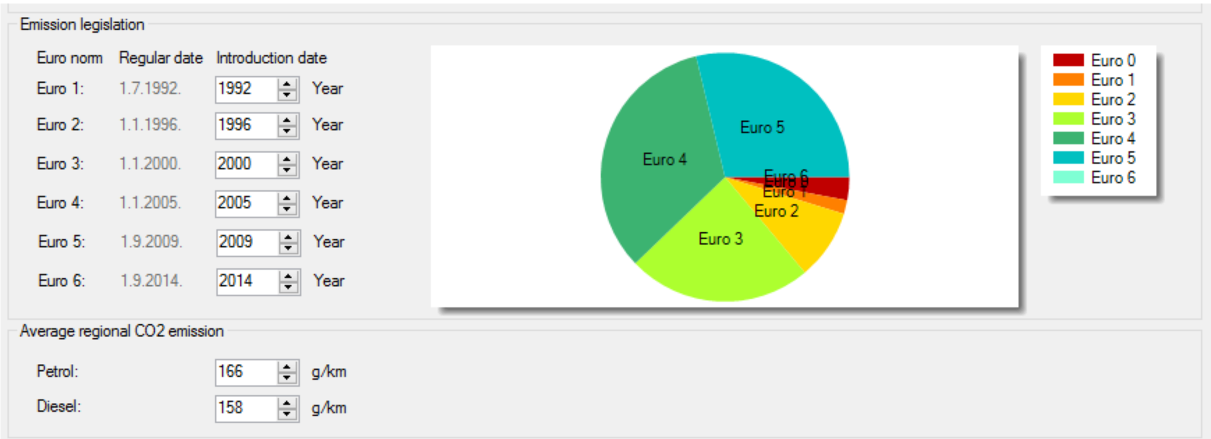

Figure 2 – Vehicle categorization in the Republic of Croatia
Source: Made by the authors

The definition of EURO norms for the emission evaluation is based on the average age of the group of vehicles, where the oldest group belongs to EURO 0 norms and has the biggest impact on the pollution. The youngest group belongs to EURO 6 norms and has the lowest impact on the pollution. The distribution of Dutch and Croatian vehicle fleet regarding EURO norms defers, so changes were made. Vehicle categorization and configuration regarding EURO norms was calibrated in EnViVer according to the authors [18] as shown in Table 1.

Table 1 – Distribution of fleet regarding EURO norms

[%]	**EURO 0-1**	**EURO 2**	**EURO 3**	**EURO 4**	**EURO 5**
PV	37,73	28,72	23,83	9,61	0,11
HDV	37,55	26,62	27,04	8,51	0,28

Source: Made by the authors according to [18]

The average CO_2 emission of 166 [g/km] for petrol engines and 158 [g/km] for diesel engines was selected as a basic parameter for emission evaluation.

Vehicle acceleration/deceleration and the correlation with speed has great impact on exhaust emission. When the vehicle is in the state of starting/braking, smoother acceleration/deceleration will produce less exhaust gases, while in the sudden acceleration/deceleration, the vehicle will produce more exhaust gases. According to the authors of the paper [17], the calculation of exhaust emission is based on the vehicle speed and acceleration/deceleration.

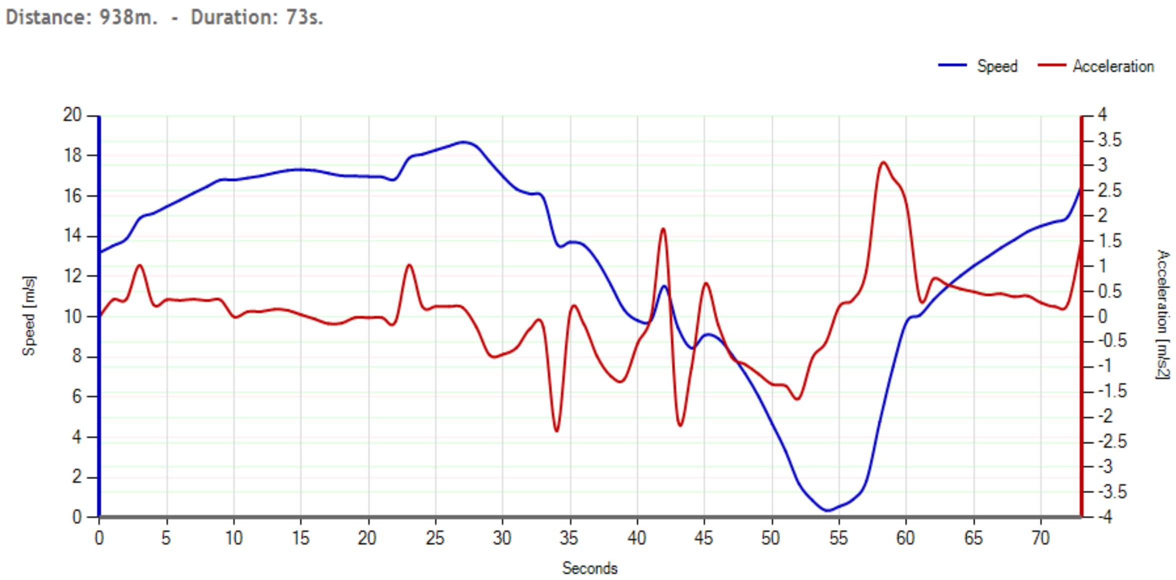

Figure 3 – Relations between the exhaust emission and vehicle acceleration/deceleration
Source: Made by the authors

Figure 3 presents the evaluation of the exhaust emission based on current vehicle speed, where the results are more accurate and precise than the results of macro simulated emissions that evaluate emission based on the average vehicle speed.

3. ALGORITHM DEVELOPMENT

The algorithms for adaptive traffic control were developed for each signalized intersection separately because of different physical situations on the intersections (the number of signal phases, the duration of phases, etc.). There are two levels of traffic control for the whole demonstration corridor – the global and the local level. The global level of traffic control is based on the distance between the intersections and speed limitations (60 [km/h]). The global level of traffic control is essential for the maintenance of the "green wave" on the main path throughout the corridor. This kind of control is significant for traffic flow harmonization and the elimination of unnecessary stop-and-go-actions. Figure 4 presents the global level and the requirements for maintaining a "green wave" within the algorithm.

The global level of the algorithm is consisted of three parts in which the first part sets a "green wave". The values measured in seconds are depending on the distance between signal controllers. After the first requirement is met, the second part initializes the cycle within the individual signal control. The last part of the global level is testing the conditions of the given parameters on the local level where the time factor is the first condition. If the maximal cycle second is not fulfilled, the algorithm continues to check the local level. Otherwise the algorithm returns to the beginning.

The local level of traffic control is programmed according to the maximum utilization of effective green times. A real-time traffic situation is monitored through the detectors that are located on the approaches on every intersection. The detectors monitor traffic demand on each segment of every approach so the optimal distribution of green times can be achieved. The example of the detector implementation is presented on Figure 5.

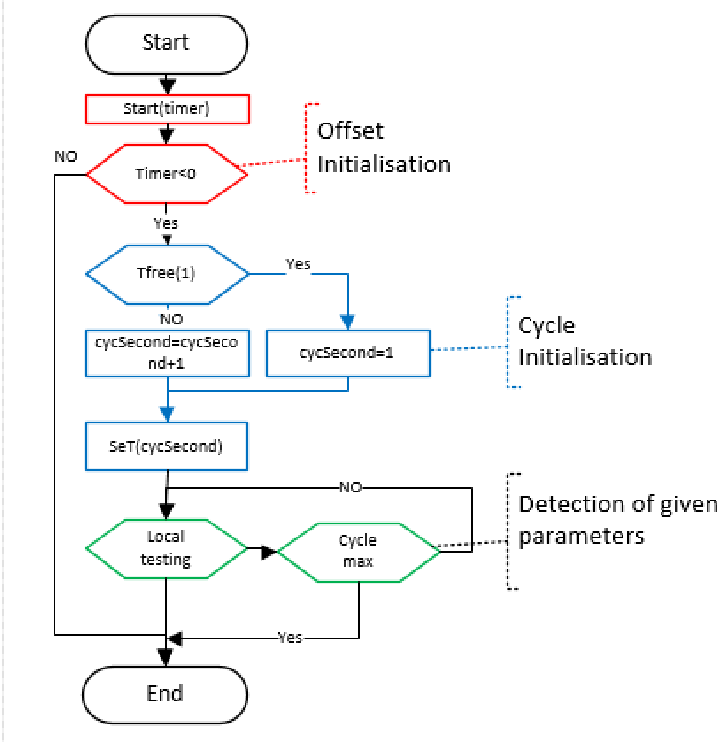

Figure 4 – The global level of the algorithm
Source: Made by the authors

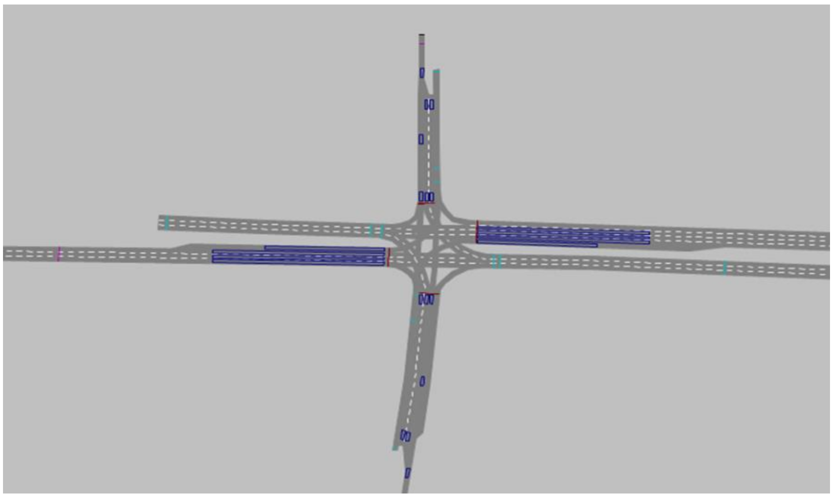

Figure 5 – The example of the detector implementation on every approach
Source: Made by the authors

Local level of the algorithm is divided to phases. Every phase has a certain sets of conditions, where the main phase is the "master" phase which decides the order of green lights for other phases. In example corridor the advantage is given to main direction, where the secondary phases (phases in which north and south bounds have green lights), are tested after meeting the conditions in primary "master" phase. The priorities of activation of the next phase are defined with the order of detection in algorithms (firstly, main approaches are examined, than the left-turn approaches on main path, etc.).

The sequence of phase activation is not predetermined; algorithm is adapting phase activation according to traffic demand on each approach, but with accent on main path approaches. In other phases on each signalized intersection after the examination of minimum green times, the conditions which are defined on global level are analyzed. Regarding existing traffic situation and calculated saturation, data priorities were defined in algorithms so the first priority is allocated to main path lanes (westbound and eastbound directions), after the completion of adaptive traffic control on main path, north approaches are the second level of calculation, and finally, south approaches have the minimum advantages regarding phase activation correction. This allows the reduction of stop-and-go actions on main path approaches and the group of vehicles is released through the corridor. Figure 6 presents the local level and conditions within algorithm.

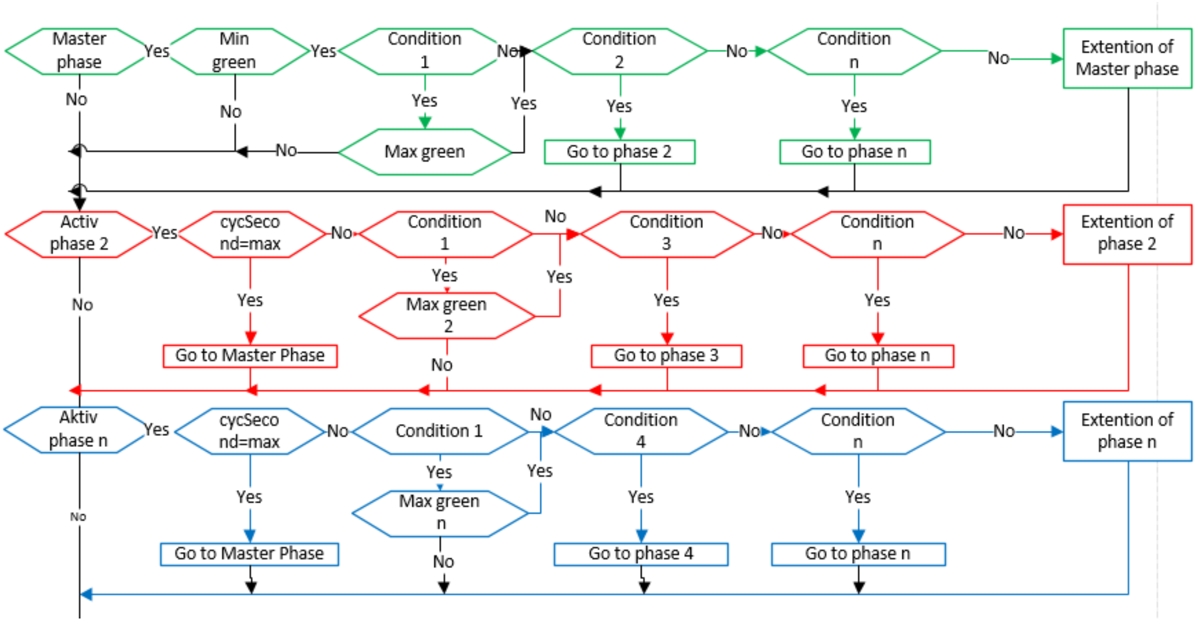

Figure 6 – The local level of the algorithm
Source: Made by the authors

When there are no special traffic demands on the detectors, the algorithm works as defined on every intersection in the fixed time signal plan. In every phase, signal groups that are not in conflict are "opened", but minimum green times are calculated regarding minimum pedestrian crossing times on every signalized intersection. When vehicles are detected on each approach detector, green times extend upon repeated detection or the expiry of maximum green time for the selected approach/phase. The algorithm ensures that all of the phases get activated in every cycle without exceeding the psychological barrier of 120 [s]. The traffic situation on every approach of each signalized intersection is monitored in every second of the cycle.

4. SIMULATION RESULTS AND EVALUATION

After the development of the defined demonstration corridor simulation model, the evaluation parameters were selected. The simulation was conducted ten times for each defined scenario with the random seed number increment of 1. The simulation duration was set on 4500 [s] where the data from the last 3600 [s] was collected considering 900[s] for network charging. Apart from the parameters regarding the exhaust emission, other relevant parameters that directly affect the quality of traffic system on demonstration corridor were defined. The defined parameters for the measurement of the quality of the traffic network are:

- The average queue length [veh],
- The maximum queue length [veh],
- The traffic flow [veh/h],
- The number of stops,
- The delay on the intersection/Level of Service [s].

After gathering the simulation results (regarding the exhaust emissions), the data for the existing traffic situation and the proposed adaptive traffic control were gathered. The results are presented in the Tables 2 and 3.

Table 2 – The results of the exhaust emission for the existing traffic situation

	CO_2	**NO_x**	**PM_{10}**
PV	294,4483 [g/km]	677,6785 [mg/km]	54,7952 [mg/km]
HDV	1867,5229 [g/km]	12,2948 [g/km]	273,0529 [mg/km]

Source: Made by the authors

Table 3 – The results of the exhaust emission for the proposed traffic situation with the implemented adaptive traffic control algorithms

	CO_2	**NO_x**	**PM_{10}**
PV	287,6693 [g/km]	655,4248 [mg/km]	54,0686 [mg/km]
HDV	1811,0881 [g/km]	11,9348 [g/km]	271,0046 [mg/km]

Source: Made by the authors

Tables 2 and 3 show the reduction of CO_2 emission by 2,302%, for NO_X it is 3,283% and for PM_{10} it is 1,32% regarding personal vehicles (PV), while for heavy duty vehicles(HDV) the reduction CO_2 emission is 3,02%, for NO_X it is 2,982% and for PM it is 0,75%. It should be noted that these results are based on a one hour simulation, so by observing a longer period of time, the reductions are multiplied.

The secondary element of the adaptive traffic control impact was the overall variation on the traffic network quality which is directly assigned to the relevant parameters defined before. The methods of data collection and the analysis are based on standard equations of TRANSYT 7-F tool for a signal program optimization [20]. The selected corridor consists of 178 links on seven signalized intersections which produce a vast amount of traffic data.

For example, the data below is presented for just one intersection (Zagrebačka Avenue – Faller Promenade). This is the first intersection of the corridor (westbound). With previously defined parameters, Tables 4 and 5 present the results of the existing traffic situation and the results of the traffic situation with the adaptive traffic control algorithms.

Table 4 – Relevant parameters on a selected intersection for the existing traffic situation

	Q-length average [veh]	**Q-length max [veh]**	**Traffic flow [veh/h]**
Link 1	6,2700	53,9523	2651
Link 2	3,4970	31,2601	90
Link 3	229,4365	384,9527	3098
Link 4	13,7685	71,4647	31
Node evaluation	31,6199	384,9572	6355

Source: Made by the authors

Table 5 – Relevant parameters on a selected intersection for a proposed traffic situation with the implemented adaptive control algorithms

	Q-length average [veh]	**Q-length max [veh]**	**Traffic flow [veh/h]**
Link 1	12,0206	99,7778	2730
Link 2	12,6240	56,9432	89
Link 3	53,9323	309,7049	3190
Link 4	17,3631	70,9112	32
Node evaluation	14,7319	309,7049	6534

Source: Made by the authors

The presented results show that the traffic flow on the main approaches has increased and the secondary approaches are unmodified. A total number of vehicles have increased by 2,884 % westbound and 2,889 % eastbound, a significant improvement considering the percentage of the oversaturation. The average Q-length (the number of vehicles in a queue) is increased on Link 2 by 9 vehicles and on Link 4 by 4 vehicles. The reason for that is a different green time distribution considering the same traffic flow on both links with fixed and adaptive control. Link 1 has increased values of average vehicles in the line by 6 vehicles, which is a slight impairment considering the increscent traffic flow. Link 3 has the best performance with a high increase of all the performance factors. Although the average number of vehicles in the queue on the secondary approaches has increased, the total traffic flow on the intersection has increased by 2,7%. The reduction of the average Q-length is 53,4% and the reduction in maximum Q-length is 19,54%, considering all links in node. The main contributor to that result is the traffic flow from link 3 which has the highest traffic flow as shown in table 5.

5. CONCLUSION AND DISCUSSION

A sustainable growth of traffic in urban areas is not possible without the advanced intelligent transport systems applications. The results of this research show that the impact of the adaptive traffic control affects the quality of urban traffic network, which is demonstrated through a simulation model of the selected corridor in the city of Zagreb. The corridor, consisting of several signalized intersections, has been simulated with the adaptive traffic control algorithms, which ensure green lights to dedicated groups of vehicles. The algorithm enables giving partial green times to defined groups of vehicles and with this concept, the "lost" green times are minimized. The calculated signal cycle enables a partial green wave concept through an offset but the oversaturation of the corridor increases fuel consumption, overall delays, queue lengths, etc. With adaptive management improvement was made, and traffic flow was increased with minimization of stop-and- go action and total Q-length which resulted in emission reduction up to 3,28%. The future research is focused on the upgrade of the existing algorithms with the intelligent systems that develop their own knowledge according to the previously gathered data and decisions.

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WHAT WILL UNLOCK THE POTENTIAL OF INTERMODAL TRANSPORT? GREAT INTERMODAL SURVEY RESULTS

ABSTRACT

From many years, intermodal transport reports continuous improvement. There are permanently created new concepts of functioning, new ways of implementation processes and new technologies. Documents and policies stand chances in intermodal transport. However, intermodal transport is also seen as new, very serious challenge. These challenges are just before them. One of them is linked with road transport utilization and its significant reduction until 2050. It won't be easy without coordination of the activities of players-partners in intermodal chain, country-specific policies and statement with the needs of clients. In fact, the clients decide about the results of modes of transport utilization until 2050. On the other hand, intermodal transport is still in need: the need for scientific improvements and need for balance between quality and economy.

KEY WORDS

intermodal transport; great intermodal survey; inland terminals;

1. INTRODUCTION

The proper functioning of the intermodal chain is possible thanks to the effective working of the intermodal chain players. There is a need to pay attention that each of the participants in the intermediate carries out its own services to other participants, while being the client. The good functioning of this chain, which very often is forgotten having regard to the only purely technical aspects of the processes is determined by the profitability of each entities. This means that each player working on efficient, reliable, smooth transport process should score the profit. Eventually it creates need to define the value chain of the intermodal transport process. Usually, the players only deal with running own business, while the value chain is left to the scientists. Considering development in technical meaning, developing society, good functioning of intermodal transport and its individual players rely on [16, 17]:

- creating adequate business models, suitable to current market situation: reasonable everyday business,
- technology branch marking due to stepping changes of environmental needs and society requirements, polices and politics changes, etc.,
- fulfilment of customer's requirements.

The third element, although it meets only the final customer, should be considered by each participant in the intermodal chain. It should be realized that this buyer-power is the foundation, the driving force behind the success of intermodal transport. There is strong question why so little attention is focused on customer requirements? On the other hand, lots of attention is given to the optimum intermodal network planning, movements optimization on terminals, and prove that utilization of hybrid engine locomotives will rapidly increase the volume of transported TEUs. These topics are important, development of mentioned aspects has a great meaning, however, causes the loss of most important values, which meet the needs of the client.

This searching for answers pushed to establish program entitled as Great Intermodal Survey (GIS). GIS is action carried out by Wroclaw University of Science and Technology (Poland). This is a set of tests carried out throughout Europe, which aims to find solutions and answers, how to conduct the actions and improve measures in order to achieve the desired level of intermodal transport utilisation in the year 2050. Currently, intermodal transport is treated as a process being carried out separately by each of the operators, while the transport should be integrated. This is one of points GIS, to answer, what should be done or take place to make intermodal transport integrated.

The aim of article meets the point of GIS, issues connected to the program are presented. After showing the results of survey discussion about the results is presented. Final part of the article are conclusions for the future.

2. LITERATURE OVERVIEW

Intermodal transport is still growing: the number of transported TEUs is raising, number of cargo fleet is growing. Authors contributions on intermodal transport is oriented on models and methodologies to improve the efficiency of intermodal transport. Modern container terminal is not just the yard to make physical movement of the cargo, but is must be agile organization of services integrated with a physical plant that meets the business needs of a specific marketplace [2]. For example, the paper [12] shows the trends in the intermodal transport development. In recent years' customer satisfaction with quality of service was mentioned in paper. There are two approaches applied. The authors of the first approach say that better planning, improving the efficiency and integration of the whole supply chain, increase customer satisfaction with the quality of the carriage, for example [4, 6, 10]. The applications of proposed approaches result in costs reduction and increase of customer satisfaction. In the second approach, the authors consider that customer satisfaction increase can be obtained by fulfilment of customer's requirements, especially through the application of multicriterial methods, e.g. [9]. The aim of the literature overview is to present state of the art in increasing intermodal client satisfaction.

In the paper [18] authors present the model applied to Dutch intermodal terminals net. The aim of the model is to solve the problem of intermodal terminal network modelling. The economic model was settled in GAs method (genetic algorithms); and is considering CO2 emission, emission costs and other economics' aspects. In following papers [3, 17] linear programming was applied to create new models to indicate profits coming from intermodal transportation network optimization. Authors of [3] proposed a Green Intermodal Service Network Design Problem with Travel Time Uncertainty (GISND-TTU) for combined offline intermodal routing decisions of multiple commodities. This stochastic method allows to achieve transportation plans according to different objectives (i.e. time, cost, and greenhouse gas (GHG) emissions) taking uncertainties in travel times. Authors focused on possible delays. The results show that this algorithm is effective in finding good-quality and robust solutions on instances with up to 20 locations and 500 transportation services. In the paper [17] a tool to use the truck appointment system to increase the service quality of trucks was created. However, the tool could be used to service barges, vessels and trains. The aim of the model is to determine the number of truck appointments to offer and an allocation of straddle carriers in order to minimized overall delays at the terminal. Workload by the number of arriving vehicles per transport mode and per time period is defined in this paper. The results show that application of the method can increase efficiency of terminal operations and will lower the number of delays noted by means of transport. Paper [7] meets issue of truck scheduling where containers need to be transported between customers (shippers or receivers) and container terminals (rail or maritime) and vice versa. Proposed approach is allowing to manage empty and loaded containers. Main assumption relies on constant delivery time, excluding any disturbances and means of transport are not various for transport of the single container.

Additionally, truck starts and end tours at a predefined and an arbitrary depot, respectively. The method minimized the total truck operating time of all trucks in use. Previous approach presented in [12] consider Inland Container Transportation Problem (ICT) which describes the movement of full and empty containers among a number of terminals, depots and customers in a hinterland region. The aim of model is to minimize the total operating time of all trucks. Authors assume transportation of single 40-feet-containers, using a homogeneous fleet of vehicles. Each vehicle begins and end process in assigned depot. Additionally, vehicle can start and end its route to depot at any time. As the result, level of effectiveness and efficiency of the process strongly increase. In last years in many papers methods or approaches on determining the optimal allocation of containers to all available inland transportation services, considering capacity, costs, lead times and emissions were presented. The paper [8] based on a real-time DSS (decision trees), which includes real-time decision support for allocating incoming transport orders directly to available inland services. In this method, the routing decision is made per container, by applying the tree to the properties of the container transportation order (i.e. booking). The approach divides three error types: the historic data error, the misclassification error and the over-capacity error. The quality of DSS can be obtained by error assessment. This method can increase the effectiveness of manual planning, without extensive IT development, while decreasing transport costs. In the next papers authors try to include errors caused by lack of information. The approach about lack of information demand data for road freight transport is presented in paper [13]. Presented model could allow to simulate both direct cargo transport from origins to destinations and cargo movement by trucks, translocation trains and relational trains in order to optimize goods transport. Model deals with the modal split separately for the cargo transported presently on railways and cargo transported presently on roads. In the paper [4] authors claim that a more customer-orientated service can also be achieved by further deregulation of rail. Effectiveness development can be reached by innovative semi/ fully automated loading/ unloading equipment in container terminals. At the same time, dependable service, a reduction in operating costs will be applied by better timetable planning, signalling systems and infrastructure improvements.

Mentioned studies were focused on better efficiency and productivity. Presented methods and models allows reduction of number of operations, the number of delays, etc. Unfortunately, in those approaches customer satisfaction there is not taken into account directly. There is lack of information how the implementation of the above models and methods will affect on service level.

Considering second approach, fulfilment of customer requirements, following papers are presented. SPECTRUM study [5] consist of rail freight customer requirements, which are: reliability of service, lower operational costs of door-to-door delivery, service availability, safety and security and environmentally friendly transport service. Next paper [9] evaluated the criteria used for deciding on suitable locations for intermodal terminals in Croatia. Basing on those indicators and European traffic policy for effective intermodal transport, those criteria were formed and evaluated: goods flows, legislative, environmental, technical-technological, organizational and spatial. Later criteria were divided and evaluated using muticriteria method AHP (analytical hierarchy process). Lower quality of service and higher price for customer are caused by in proper infrastructure, to long time of waiting on service (due to previous delays), high terminal costs and unexpected disruptions [1]. This study concludes, that defined criteria have great impact on the quality and price of the entire process. Next study [1] shows indicators of performance, quality and excellence of intermodal transport with the aim of quantifying the characteristics of the competitiveness of intermodal transport in the Republic of Croatia. The problems of intermodal transport in the Republic of Croatia were described, e.g. discrepancies between data on the transport/traffic, availability of statistical data, obstacles in the preparation, signing and implementation of research and development projects. For transport sector the total quality management is defined by following criteria: frequency, availability to correct and reliable information, possibility of resolving border-crossing procedures, possibility to negotiate price-quality relation of the service. Authors of the study use analysis of External Quality Assessment (EQA) criteria context. It is proposed that terminals should introduced the EQA criteria in business to increase profits and other advantages (increase of effectiveness, reliability of service, etc.).

The second approach is closer to the idea of fulfilling customer requirements. However, this approach did not bring the answer how intermodal transport players see the development. In the further part of this paper the survey and its results are showed. The aim of survey was to find the answers how innovation is perceived by the participants of the intermodal transport chain and whether innovation can help to increase satisfaction with services. Questions are also relating to the direction of the stream of subsidies.

3. GREAT INTERMODAL SURVEY

3.1 Assumption of the research

At the beginning of 2017 a study called Great Intermodal Survey were conducted in several European countries. The survey aimed at uncovering attitudes towards intermodal transport sent to participants in the supply chain. The survey was related to quality aspects and the questions of determining the subsidies flow. In following part, the questions and their meaning are showed.

1. Does your organization is a business dependent on the railway company?

In accordance with the EU directive, intermodal carriers and terminal operators may not be the same entity, or the carrier isn't operating on the terminal. Hence, in many cases, excluded subsidiary are not engaged in freight services. However, this is not the rule. If there is a relationship between the terminal operator and the carrier, the first often doesn't pay attention to its financial performance, treats the customer acquisition "at any price" as a top priority. On the one hand, this may seem positive (increasing the level of quality), but at all costs leads to underreporting of the rates and consequently ruining the market. Very often those players offer low price and low quality.

2. Does your daily work creates new challenges in competition in the field of customer service?

In the case of subsidiaries, the entities could follow different objectives, e.g., to achieve high revenue, gaining market, or acquiring volume for the parent company. Is the quality of customer service the top goal or minor idea? Is there a tool or the goal?

3. Do you think that investing in the development of modern technologies on terminals corresponds to the number of new customers of intermodal transport?

The sources of investment and the range of new technologies are not described. Regarding general awareness of the binding introduction of new technologies as a driving force for improving the quality of customer service. A negative response is declining opinion confirming that the investment in innovation is associated with improving the quality of customer service.

4. Do you think that investing in the development of modern technologies on terminals corresponds to the lowering the cost of provided services?

Again, the source of the investment does not specify what are the new technologies. Clue of the question is making relations between quality and service costs.

5. Do you think that the lower price of intermodal transport service than in alternative transport (e.g., road or a typical rail transport) is the key driving force of demand for this kind of service?

The question includes assumption, that the price, and not for example quality is the basis for decision making when selecting the bidder services. What is more important to customer: price or quality?

6. Do you think that a better coordination of the information flow between participants in the intermodal chain affects the service quality development for the customers?

Insufficient quality of customer service is often caused by lack of information about the state of the process. Road transport is equipped with tracking & tracing tools for years. In intermodal transport this is a challenge that requires considerable work.

7. Do you think it would be better subsidizing the intermodal transport forwarders or the target customers?

Changing the funding mechanisms of intermodal transport: is it important? If the current way of funding is the appropriate instrument of financial support?

8. Do you think that the investment in modern handling equipment is a better investment in the customer quality than to acquire modern IT solutions?

This question is about the direction of the logistics systems development: is the operation technology sufficiently expanded compared to the flexibility required by the customers.

9. How many cargo from the Terminal on which you work is delivered to the client with all quality standards?

The last question concerns the current processes execution.

3.2 Results of the survey

The survey was sent to 1524 subjects via e-mail with ask to fill forms available online. The recipients were employees of container terminals, freight forwarders involved in the carriage of cargo by intermodal transport. The e-mail receivers were from Belgium, Czech Republic, France, Germany, Hungary, Netherland, Italy, Poland, Spain and UK. These studies obtained 154 replies, which represents just over 10% of all recipients. The survey was developed in such a way to explore several areas of intermodal transport functioning. The form contains with 9 questions, most questions allowed to answer "Yes" or "No". Questions 1 and 9 were designed to characterize the investigated company; the results obtained are shown in Table 1 and Figure 1.

Table 1 – Characteristics of the surveyed companies

Number of Question	Possible answers	No. of answers	%
1	Yes	84	55
	No	70	45
9	to 20 %	7	4
	20% - 50%	4	3
	50% - 80%	46	30
	above 80%	97	63

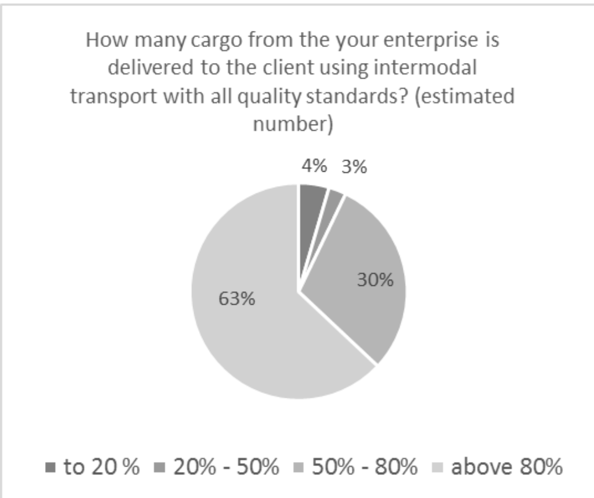

Figure 1 – The volume of intermodal transport in the surveyed companies

The answers were obtained mostly from large companies (over 92%) in which the intermodal transport takes 50% of all goods transport. More than 54% of these are carrier dependent entities.

Questions 2-6 are relate to the evaluation of the services quality, includes price reductions and the development of modern technology.

Table 2 – Responses of subjects on the transport quality

Number of Question	Possible answers	No. of answers	%
2	Yes	148	96
	No	6	4
3	Yes	144	94
	No	10	6
4	Yes	98	64
	No	56	36
5	Yes	132	86
	No	22	14
6	Yes	128	83
	No	26	17

From the responses on the quality of freight services 96% of subjects replied that their daily work is focused on customer service. The vast majority of subjects (94%) also said that the development of modern technologies in the transhipment points will increase the number of customers for the services of intermodal transport. The 64% of subjects (30% less than in the previous question) responded that the development of modern technology affects the reduction of the service cost rendered. More than 80% of the interviewed subjects consider that the introduction of lower prices in intermodal transport compared to road and rail transport will result in an increase in the demand for services in the intermodal transport. Quite a common problem is reflected in the studies [14, 15].

The studies are related to the carriage of intermodal cargo and the flow of information between the intermodal subjects. Therefore, the next question was precisely the information flows. Over 80% of the interviewed subjects believe that improved information flows will affect the clients service quality. Elimination of errors in information flows, definitely will reduce the risk of mistakes, as well as reduce the operations time, which directly translate into customer satisfaction. The last group of questions concerns funding for transport in intermodal, as well as what they think of the subjects on the development of modern information technology in companies.

Table 3 – Responses about subsidies' direction

Number of Question	Possible answers	No. of answers	%
7	Forwarders	82	53
	Customers	72	47
8	Yes	80	52
	No	74	48

The results from table 3 are slightly different from the previous, because the answers are not in any way prevailing on one of the answers. In this case, the responses are very close to each other. To a question about funding for forwarders or customers, 53% of those surveyed responded that better funding should be oriented to forwarders. Currently, this situation has changed a few years ago, which means a changed awareness in companies. In the case of question concerning whether is the better funding the cargo equipment or information systems, here the opinion is divided. The 52% of interviewed entities believed that it is better to invest in cargo equipment, while 48% of interviewed subject think that is better to invest in the information systems.

4. DISCUSSION

As is apparent from the responses of the participant in the survey of intermodal chain are aware of the changes and the requirements dictated by the customers. They understand they need to increase the qualitative potential, improve its own methods and investments in innovation. However, it should be noted that the interviewed subjects have concerns whether these investments are conducive to lowering the service costs. This question is the basis for a deeper analysis of the situation, especially in combination with the subsidization of intermodal transport. As noted in the introduction, the popularity of intermodal transport is the result of decisions taken by the transport organizers. It is they who decide whether they choose intermodal transport or e.g. maritime package stacked, etc.

Each of the modes of transport is carried out with greater or lesser regard to quality policy, but intermodal transport without respect into the financial issues may have a problem with the correct operations. So far, the incentive to use intermodal transport in many European countries were done by subsidizing each transported container granted to railway carrier. The subsidize had the form of a co-financing the cost of access to the infrastructure. However, if we look at the size of those subsidies, it turns out that the final customer could score a little advantage. In a relation of Asia-Europe transport cost of access to the railway infrastructure, in Europe is just about 5% of the total transport costs. Lower rates of access to infrastructure payed by carriers allow to only a symbolic lowering of the price paid by the client. Completely different value may be obtained by granting the client directly. In respect to value chain it could allow strongly reduce prices and putting the real dilemma of choice how to transport the cargo. What's more, by transferring real decision power to the customer will generally improve the conditions of carriage, increased competition and the further contention of the clients. It will also still effectively run the new transport links with less popular today ports in CEE and SEE instead of the standard use of Western European ports. Consequently, it will also increase the income related to the operations of the port facilities, ships service, customs clearance wraps, etc. The significant change to customers of intermodal transport can be big step to unlock the potential of intermodal transport for the future.

5. CONCLUSION

As is apparent from conducted study an important element of the strategy for the future of intermodal transport is changing in subsiding's direction (in the form of discounts on access to the railway infrastructure for intermodal transport), which today is consumed mainly by the land transit and is used for indirect financing of ports and railway companies. Paradoxically, current model of subsiding's drains intermodal transport in the transit countries. Proposed changes allow to create new intermodal transport corridors, with long routes, allowing the participation of a greater number of European ports. The change of corridors that begins in Western European ports to CEE and SEE ports may include new few hundred thousand of TEU container loaded in the ports and shipped to final costumer by means of intermodal transport. A potential change exists and it remains only to insert stimulus, which will cover the costs of the changes occurring to customers. The stimulus would be a significant subsidy for each transported container. In addition, the size of the "new" volume should not also cause perturbation in „old corridors".

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