ZIRP 2020

International Scientific Conference
The Science and Development of Transport
Znanost i razvitak prometa

ISSN 2718-5605

Proceedings of the International Scientific Conference "The Science and Development of Transport" (ZIRP 2020)

Topic: Transformation of Transportation

ORGANIZER

University of Zagreb
Faculty of Transport and Traffic Sciences

CO-ORGANIZERS

Wrocław University of Science and Technology

Universität Bremen

IRF GLOBAL

FSB

POLITEHNICA 200 ani 1818

United Nations Educational, Scientific and Cultural Organization · UNESCO Chair on Engineering for Society, University Politehnica of Bucharest, Romania

University of Zagreb Faculty of Economics & Business

European Platform of Transport Sciences

AMAC-FSC 2002.

CONFERENCE SPONSOR

CENTAR ZA VOZILA HRVATSKE

29th - 30 th September 2020
ON-LINE CONFERENCE



INTERNATIONAL SCIENTIFIC CONFERENCE

THE SCIENCE AND DEVELOPMENT OF TRANSPORT

TRANSFORMATION OF TRANSPORTATION

29th – 30th September, ON-LINE CONFERENCE

Editors

Edouard Ivanjko, Ph.D.
Ratko Stanković, Ph.D.

Chairman of Programme Committee

Edouard Ivanjko, Ph.D., HRV

Programme Committee

Marjana Petrović, Ph.D., HRV, Co-Chairman
Adam Szelag, Ph.D., POL
Aleksandar Trajkov, Ph.D., MKD
Almir Karabegović, Ph.D., BiH
André Luiz Cunha, Ph.D., BRA
Artur Kierzkowski, Ph.D., POL
Aura Rusca, Ph.D., ROM
Bernhard Ruger, Ph.D., AUT
Casandra Venera Pietreanu, Ph.D., ROM
Essam Radwan, Ph.D., USA
Daniela Nečoska-Koltovska, Ph.D., MKD
Dario Babić, Ph.D., HRV
Darko Babić, Ph.D., HRV
Davor Sumpor, Ph.D., HRV
Dora Naletina, Ph.D., HRV
Doris Novak, Ph.D., HRV
Dragan Peraković, Ph.D., HRV
Dragana Macura, Ph.D., SRB
Elen Twrdy, Ph.D., SLO
Florin Nemtanu, Ph.D., ROM
Florin Valentin Rusca, Ph.D., ROM
Franciszek Restel, Ph.D., POL
Goran Đukić, Ph.D., HRV
Goran Zovak, Ph.D., HRV
Gunnar Prause, Ph.D., EST
Hans-Dietrich Haasis, Ph.D., DEU
Herbert Kopfer, Ph.D., DEU
Hrvoje Haramina, Ph.D., HRV
Ivan Grgurević, Ph.D., HRV
Ivana Plazibat, Ph.D., HRV
Ivona Bajor, Ph.D., HRV
Jurica Pavičić, Ph.D., HRV
Jörn Schönberger, Ph.D., GER
Katarina Mostarac, Ph.D., HRV
Kerstin Lange, Ph.D., GER
Kristijan Rogić, Ph.D., HRV
Kristina Petljak, Ph.D., HRV
Kristijan Rogić, Ph.D., HRV
Kristina Petljak, Ph.D., HRV
Lahorka Crnković, HRV
Lucas Assirati, Ph.D., BRA
Luka Novačko, Ph.D., HRV
Ljupko Šimunović, Ph.D., HRV
Marcin Seredynski, Ph.D., LUX
Marija Malenkovska Todorova, Ph.D., MKD
Marinko Jurčević, Ph.D., HRV
Mario Anžek, Ph.D., HRV
Mario Ćosić, Ph.D., HRV
Mario Muštra, Ph.D., HRV
Marko Ševrović, Ph.D., HRV
Martin Gregurić, Ph.D., HRV
Mateusz Zajac, Ph.D., POL
Mihaela Tabak, HRV
Milica Selmić, Ph.D., SRB
Mladen Nikšić, Ph.D., HRV
Nagui Rouphail, Ph.D., USA
Nguyen Khoi Tran, Ph.D., FRA
Niko Jelušić, Ph.D., HRV
Olja Čokorilo, Ph.D., SRB
Patricija Bajec, Ph.D., SLO
Paulina Golinska, Ph.D., POL
Pawel Zajac, Ph.D., POL
René Schumann, Ph.D., CHE
Rajko Horvat, Ph.D., HRV
Ratko Stanković, Ph.D., HRV
Ružica Škurla Babić, Ph.D., HRV
Sanda Renko, Ph.D., HRV
Sanja Sever Mališ, Ph.D., HRV
Slavko Vesković, Ph.D., SRB
Stefan Popescu, Ph.D., ROM
Stjepan Lakušić, Ph.D., HRV
Tihomir Opetuk, Ph.D., HRV
Tiziana Campisi, Ph.D., ITA
Tomislav Fratrović, Ph.D., HRV
Tomislav Radišić, Ph.D., HRV
Tomasz Kisiel, Ph.D., POL
Tomislav Rožić, Ph.D., HRV
Valentin Silivestru, Ph.D., ROM
Valentina Mirović, Ph.D., SRB
Vera Karadjova, Ph.D., MKD
Vladimir Đorić, Ph.D., SRB
Vlatka Stupalo, Ph.D., HRV
Željko Šarić, Ph.D., HRV

President of Organising Committee

Mario Šafran, Ph.D., HRV

Organising Committee

Doris Novak, Ph.D., Vice-President, HRV
Tomislav Rožić, Ph.D., Vice-President, HRV
Tomislav. J. Mlinarić, Ph.D., HRV
Anđelko Ščukanec, Ph.D., HRV
Borna Abramović, Ph.D., HRV
Darko Babić, Ph.D., HRV
Darko Kužić, HRV
Dominik Cvetek, HRV
Edouard Ivanjko, Ph.D., HRV
Hans-Dietrich Haasis, Ph.D., DEU
Hrvoje Gold, Ph.D., HRV
Luka Novačko, Ph.D., HRV
Kristijan Rogić, Ph.D., HR
Kristina Bradvica Šančić, HRV
Marjana Petrović, Ph.D., HRV
Ratko Stanković, Ph.D., HRV
Sorin Eugen Zaharia, Ph.D., ROM
Tomasz Nowakowski, Ph.D., POL

Managing Editors

Ante Kulušić
Marjana Petrović, Ph.D.
Luka Novačko, Ph.D.

Production Editor & Computer Text Design

Ante Kulušić

URL

http://www.fpz.unizg.hr/zirp/

Publisher

Faculty of Transport and Traffic Sciences
University of Zagreb

ZIRP 2020

International Scientific Conference
THE SCIENCE AND DEVELOPMENT OF TRANSPORT
TRANSFORMATION OF TRANSPORTATION
29th – 30th September, ON-LINE CONFERENCE

	Authors	Papers	Page
1.	P. Bajec D. Tuljak-Suban	**MOST FREQUENTLY USED MULTI-CRITERIA DECISION MAKING MODELS IN LOGISTICS SERVICE PROVIDER SELECTION: A COMPARATIVE PERFORMANCE ANALYSIS OF A REAL CASE STUDY**	**1-9**
2.	V. Bogdanović V. Mirović J. Mitrović Smić N. Guranović M. Počuč	**ACCESSIBILITY ANALYSIS AT SIGNALIZED INTERSECTIONS IN NOVI SAD**	**11-22**
3.	P. Brlek Lj. Krpan I. Cvitković M. Kodžaga	**ELECTROMOBILITY: EUROPE, CROATIA – CITY OF KOPRIVNICA**	**23-33**
4.	M. Drljača P. Repnjak	**SUPPLY CHAINS IN THE CONTEXT OF THE COVID-19**	**35-46**
5.	B. Duvnjak T. J. Mlinarić H. Haramina	**IMPROVEMENT OF PASSENGER SERVICE QUALITY BY APPLICATION OF THE NEW MODEL OF RAILWAY SYSTEM (ON THE RAILWAY LINE ZAGREB MAIN STATION – DUGO SELO)**	**47-55**
6.	M. Emanović M. Ćosić E. Missoni J. Jurak M. Sikirić	**ANALYSIS OF TRAFFIC POLICY MEASURES IN THE RESTRICTION OF THE USE OF OLDER FOSSIL - POWERED MOTOR VEHICLES CONSIDERING EUROPEAN UNION AND THE REPUBLIC OF CROATIA**	**57-65**
7.	M. Emanović J. Jurak I. Jelić	**SAFETY OF PEDESTRIAN CHILDREN IN PRIMARY SCHOOL ZONES**	**67-72**
8.	M. Emanović Lj. Šimunović J. Jurak M. Sikirić	**ANALYSIS OF PEDESTRIAN TRAFFIC ACCIDENTS USING THE MULTIPLE-CRITERIA DECISION-MAKING METHOD - CASE STUDY OF THE CITY OF ZAGREB**	**73-82**

	Authors	Papers	Page
9.	K. Evdjenić L. Bukvić J. Pašagić Škrinjar	**INTERMODAL ROUTES ANALYSIS OF TRANSPORT ORGANIZATION FROM GOTHENBURG TO ZAGREB**	**83-97**
10.	M. Goluban M. Petrović J. Blašković Zavada T. J. Mlinarić	**SIMULATION OF PASSENGER TRANSPORT ON RAILWAY SECTION ZAGREB MAIN STATION - ZABOK**	**99-109**
11.	H. Haramina A. Wagner I. Belobrajdić	**A MODEL OF AN EXPERT SYSTEM FOR TRAIN PRIORITY ASSIGNING IN RAILWAY TRAFFIC CONTROL PROCESS**	**111-119**
12.	T. Lukanić D. Šipuš B. Abramović	**CROATIAN TRANSPORT DEVELOPMENT STRATEGY: A REVIEW ON RAILWAY SECTOR**	**121-128**
13.	M. Matulin Š. Mrvelj S. Martirosov	**QUALITY OF OMNIDIRECTIONAL VIDEO STREAMING SERVICE: A STUDY OF USER QUALITY OF EXPERIENCE**	**129-137**
14.	M. Mikulčić I. Ljubaj T. J. Mlinarić	**PROGRESS IN THE ERTMS INTEGRATION OF CROATIAN RAILWAYS WITHIN EUROPE**	**139-148**
15.	N. Munitić	**COMPETITIVENESS AS A FACTOR OF SEAPORT MANAGEMENT EFFICIENCY**	**149-155**
16.	M. Nikšić J. Blašković Zavada K. Vidović	**ANALYSIS OF INTRODUCING URBAN RAIL SYSTEMS IN LARGE CITIES – CASE STUDY SEOUL**	**157-165**
17.	Z. Rezo S. Steiner C. Piccioni	**APPLICATION OF CONVENTIONAL METHOD IN DYNAMIC BUSINESS ENVIRONMENT: EXAMPLE FROM AIR TRAFFIC MANAGEMENT DOMAIN**	**167-177**

	Authors	Papers	Page
18.	Z. Rezo S. Steiner A. Tikvica	**AUTOMATED AERONAUTICAL DATA PROCESSING: RECOMMENDATIONS REVIEW AND LESSONS LEARNED**	**179-189**
19.	E. A. Roman V. Dragu M. Popa E. Roşca	**SATISFYING FUTURE TRANSPORTATION NEEDS BY MEANS OF PUBLIC TRANSPORTATION**	**191-202**
20.	B. Rüger	**IMPROVED OPERATING QUALITY THROUGH OPTIMIZED VEHICLE LAYOUTS BY MEANS OF SIMULATION**	**203-211**
21.	F. Rusca E. Rosca M. Azmat H. Perez-Acebo A. Rusca S. Olteanu	**MODELING THE TRANSIT OF CONTAINERS THROUGH QUAY BUFFER STORAGE ZONE IN MARITIME TERMINALS**	**213-224**
22.	M. Slavulj D. Brčić S. Inić M. Sikirić	**ANALYSIS AND PROPOSAL OF SOLUTIONS FOR PUBLIC TRANSPORT IN THE AREA OF STUPNIK MUNICIPALITY**	**225-235**
23.	V. Stupalo T. Franc A. Dávid A. Mrvica	**PRODUCTIVITY ANALYSIS OF SOLID BULK CARGO TERMINAL: CASE STUDY PORT OF SPLIT**	**237-247**
24.	T. Sunko L. Mihanović T. Mišković D. Vodopija	**THE ROLE OF HUMAN FACTOR IN RECENT ACCIDENTS OF US NAVAL SHIPS**	**249-260**
25.	J. Šarić A. Vidović I. Štimac T. Mihetec	**SPECIFICITY OF THE FRANJO TUĐMAN AIRPORT POSITION IN THE FUNCTION OF INCREASING REGIONAL COMPETITIVENESS**	**261-273**

	Authors	Papers	Page
26.	M. Šoštarić M. Ševrović M. Jakovljević M. Švajda	**PARKING LOT MANAGEMENT IN FUNCTION OF REDUCING GREENHOUSE GAS EMISSIONS**	**275-283**
27.	K. Tečec D. Šipuš B. Abramović	**ANALYSIS OF DIAGNOSTIC SYSTEMS IN INTEGRATED PASSENGER TRANSPORT**	**285-291**
28.	L. Tišljarić D. Cvetek M. Muštra N. Jelušić	**MIXED IMPACT OF THE COVID-19 PANDEMIC AND THE EARTHQUAKE ON TRAFFIC FLOW IN THE NARROW CITY CENTER: A CASE STUDY FOR ZAGREB-CROATIA**	**293-300**
29.	A. Wasiak M. Obrecht	**ANALYSING SINGLE TRANSPORT MODES TO REDUCE FOOD MILES**	**301-306**
30.	V. B. Wildhaber	**TOWARDS A CONCEPTUAL FRAMEWORK FOR LOADSPACE SHIPMENT SHARING**	**307-320**

PATRICIJA BAJEC, Ph.D[1]
(Corresponding author) E-mail: patricija.bajec@fpp.uni-lj.si
DANIJELA TULJAK-SUBAN, Ph.D[1]
E-mail: danijela.tuljak@fpp.uni-lj.si
[1] University of Ljubljana, Faculty of Maritime Studies and Transport
Pot pomorščakov 4, 6320 Portorož, Slovenia

MOST FREQUENTLY USED MULTI-CRITERIA DECISION MAKING MODELS IN LOGISTICS SERVICE PROVIDER SELECTION: A COMPARATIVE PERFORMANCE ANALYSIS OF A REAL CASE STUDY

ABSTRACT

Multi-criteria decision making (MCDM) methods are becoming increasingly popular in LP selection issues. Many MCDM methods of different characteristics have been used so far, but very little attempt has been given to comparing and critically evaluating the performance and results of the MCDM methods applied. Therefore, in this paper, the use of the two most frequently used MCDM methods (AHP and ANP) and PROMETHEE are considered in regard to a real case study of a local spare parts company - dealing with construction and agricultural machinery - that decided to outsource distribution logistics to one or at most two logistics providers. The objective of this paper is not to determine which MCDM method is most appropriate for selecting the appropriate LP, but to emphasize whether the use of various MCDM methods can highlights different alternatives as the most appropriate. Moreover, some reasons which lead to different results will be highlighted as well.

KEY WORDS

logistics service provider; multi-criteria decision making; selection process; comparative analysis

1. INTRODUCTION AND BACKGROUND

The growing needs for developing sustainable competitive advantage and more responsive customer services, together with a growing awareness that the competitive advantages come from the logistics services and not only products (1), upgraded logistics to a strategic function, which consequently resulted in the evolution of logistics outsourcing (2).

Logistics outsourcing is a logistics service provided by an outside provider - a logistics provider (LP) - on a contractual basis. The selection of the LP able to meet a customer's requirements in a highly competitive environment is now becoming a challenging task for several reasons. Firstly, LPs with varying capabilities in terms of services, infrastructure, suprastructure and diversification are now available on the logistics market. Secondly, there are numerous criteria that are to be considered while selecting an LP. Forty-four selection criteria which consider the requirements of an external competitive environment were detected by Bajec and Tuljak-Suban (2017). Among them, costs, information technology and accurate delivery time are considered to be vital criteria. Flexibility, staff quality, network coverage, reputation, culture recognition and experience are found to be important criteria. Service level, information exchange, customer satisfaction, accurate delivery place, risk management, transport services, accurate quantity and quality and financial stability are important criteria. The group of less important criteria includes storage, breadth of services, reliability, value-added services, flexibility, order processing, human resource management, responsiveness, recycling – and related criteria. Some of these criteria are quantitative, some qualitative. Some of the latter are uncertain, while many qualitative as well as quantitative criteria are conflicting.

Thirdly, numerous MCDM methods were applied in the past to solve the problems regarding selection factors. Of 108 articles on the third party logistics provider selection problem, systematically reviewed by Bajec and Tuljak-Suban (2017a) the third party logistics provider selection process was analysed (4); the AHP method was used in 38 cases, followed by TOPSIS (22 times), ANP (16 times), Linear programming (10 times), DEA and VIKOR (9 times), DEMATEL (6 times), QFD (5 times), ELECTRE, PROMETHEE, ISM (4 times). SMART, ANN, CBR/RBR, DCA were used less frequently.

Each MCDM method used so far has its advantages and disadvantages (5). Methods are, moreover, of very different characteristics (6-8) which may consequently lead to different results (9, 10). Methods in addition differ in the approach used to determine the most appropriate alternative, have different aggregation procedures and different treatment for cost and benefit criteria (11). »Each method may also provide its own computation in consolidating the diverse measurement units and different normalization techniques may yield different solutions« (7).

The presence of many MCDM methods confuses decision-makers in the LP selection process, resulting in the difficulty of selecting the method which will give results in the form that decision makers want. The logistic selection process consequently takes more time, is more uncertain and, in the case that the final selection of the LP is not appropriate (due to the application of an inappropriate method), even risky. However, very little attempt has been given to compare the performance of MCDM methods applied and their results (appropriate alternative(s), LP(s).

AHP, TOPSIS, ELECTRE and Grey Theory were compared and then applied on the warehouse selection problem (12). A comparative study of multi criteria decision making approaches, analytical network process (ANP) and a multi-objective optimisation by ratio analysis (MOORA) technique was performed for risk assessment in the supply chain and determined the best alternatives (13). Browne & Ryan (2011) examined and compared cost-benefit analysis (CBA), cost-effectiveness analysis (CEA) and multi-criteria decision analysis (MCDA), used to measure the impact of transport policies and programmes as part of a strategic environmental assessment (SEA) or sustainability appraisal. VIKOR and TOPSIS were compared with the concordance analysis to evaluate which performs best in identifying critical sections in a road network (15). As far as the authors are aware, a comparative analysis in the field of application of the MCDM and LP selections process has not yet been made.

Accordingly, two research questions (RQ) were developed to cover the detected gaps:

- *RQ1*: Are the results significantly different according to the use of the selected MCDM method (AHP, ANP and PROMETHEE)?
- *RQ2*: Which are the reasons that lead to different results?

The objective of this paper is not to detect which method is most appropriate for selecting the appropriate LP, rather to find out whether various MCDM methods produce different results and to detect the reasons for such differences.

To answer the paper's RQs the rest of the paper is arranged as follows: Section 2 presents a comparative analysis and a brief presentation of three MCDM methods, followed by a case study to detect differences in procedures of methods as well as potential differences in results. The paper ends with a discussion of the results and the conclusion.

2. COMPARATIVE ANALYSIS OF THE THREE MOST FREQUENTLY USED MCDM METHODS

The comparative performance of two (most) frequently used MCDM methods – AHP, ANP and PROMETHEE are investigated in this section. The methods were selected according to two criteria: importance and possibility of integration of methods from different categories of MCDM methods.

AHP and ANP belong to the group of linear weighting models. PROMETHEE comes from the family of outranking methods. The selected methods differ in their basic principles as presented in Table 1.

Table 1 – Comparison of selected MCDM methods on the basis of common criteria

	CRITERIA							
MCDM method	**Type of results**	**Kind of info**	**Feature of info**	**Type of problem statement**	**Preference of elucidation mode**	**Compensation**	**Complexity**	**Software solutions**
AHP	numerical value	mixed	deterministic and non-deterministic	choice, ranking	pairwise comparison	yes, partially	low complexity/ time consuming	yes
ANP	numerical value	mixed	deterministic and non-deterministic	choice, ranking	pairwise comparison	yes, partially	high complexity/ time consuming	yes
PROMETHEE	ranking	mixed	deterministic /extensions are possible for non-deterministic	ranking	pairwise comparison	yes, partially	intermediate complexity/ time consuming	yes

Source: (16-20)

2.1 The AHP method

MCDM method defines a hierarchy between alternatives $(\mathrm{A}_1, \ldots, \mathrm{A}_\mathrm{m})$ subject to different criteria $(\mathrm{C}_1, \ldots, \mathrm{C}_\mathrm{n})$. The method is based on a pairwise comparison of the independent criteria using a nine stage linguistic comparison scale proposed by (21). Evaluations are matched in a square comparison matrix A=[a_{ij}] of dimension n. The relevance of criteria is expressed by weights $(\mathrm{w}_1, \ldots, \mathrm{w}_\mathrm{n})$, which are computed by normalizing the Eigen vector using the arithmetic mean:

$$w_i = \frac{1}{\mathrm{n}} \sum_{j=1}^{\mathrm{n}} \frac{a_{ij}}{A_j} \text{ for } i = 1, \ldots, \mathrm{n} \quad (1)$$

where $A_j = \sum_{i=1}^{\mathrm{n}} a_{ij}$ for $j = 1, \ldots, \mathrm{n}$.

An approximation of the maximum eigenvalue is computed as:

$$\lambda_{max} = \sum_{i=1}^{\mathrm{n}} A_i \cdot w_i. \quad (2)$$

On the base of the characteristics of the comparison matrix, the method consistency can be checked using the consistency index defined as:

$$CI = \frac{\lambda_{max} - n}{n-1}. \quad (3)$$

Then the consistency ratio $\frac{CI}{RI}$ is computed and in case of consistency it must be less or equal to 0.1. RI is the random consistency index computed by Saaty (22).

2.1 The ANP Method

The Analytic Network Process (ANP) is a generalization of the AHP method defined by (23) in case the criteria are not independent. The hierarchic structure of the AHP method is expanded in a network structure, where feedback is possible. Due to the generalization the method becomes more complex and requires software to evaluate the weights of criteria.

On the basis of a pairwise comparison a limit block super-matrix is computed and the weights are defined. In this also case a nine stage linguistic comparison scale proposed by (21) is used.

2.2 The PROMETHEE Method

The Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) was developed by J.P. Brans and presented for the first time in 1982, (24, 25).

Like in AHP, a set of alternatives $A = \{a_1, a_2, \dots, a_n\}$ are evaluated with respect of a set of criteria $C = \{c_1, c_2, \dots, c_k\}$. Evaluations are based on scale, like in AHP, and $f_i(a_j)$ is the evaluation of alternative a_j with respect of criteria c_i.

For each pair of alternatives a_i, a_j the preference degree $\pi_k(a_i, a_j)$ is defined (24):

$$\pi_k(a_i, a_j) = P_k[d_k(a_i, a_j)], \tag{4}$$

where $d_k(a_i, a_j) = f_k(a_i) - f_k(a_j)$ are the deviations between criteria and P_k is a predefined linear non-decreasing preference function between 0 and 1. Six different shapes of preference function can be used: Usual, U-shape, V-shape, Level, Linear and Gaussia (24).

The Liner shape function is a generalization of the V-shape preference function and both are generally used in the case of quantitative criteria. The Usual preference function, Level preference function and the U-shape, as a special case of the Level function, are generally used in cases of qualitative criteria. The Gaussian preference function is less often used, since it is more difficult to define (24).

The multi-criteria preference degree is defined as:

$$\pi(a_i, a_j) = \sum_{k=1}^{m} \pi_k(a_i, a_j) w_k, \tag{5}$$

where $w_k$is the weight associated to criterion c_k.

Each alternative is compared with the other (n-1) alternatives of A. So preference flows can be split into two outranking flows as:

i. the positive outranking flow, that quantifies how a given action is globally preferred

$$\phi^+(a) = \frac{1}{n-1} \sum_{i=1}^{n} \pi(a, a_i), \text{ and} \tag{6}$$

ii. the negative outranking flow, that quantifies how a criterion is being globally preferred by all the other actions

$$\phi^-(a) = \frac{1}{n-1} \sum_{i=1}^{n} \pi(a_i, a). \tag{7}$$

The final ranking is obtained by ordering the actions with respect to the decreasing values of the net flow scores (24):

$$\phi(a) = \phi^+(a) - \phi^-(a);\ \phi(a) \epsilon [0,1]. \tag{8}$$

3. CASE STUDY

The proposed analysis presented in this paper was applied in a single case study of a local spare parts company dealing with construction machinery. The company dispatches a very large number of product packages to end customers, mainly located in Slovenia and other territories of the former Yugoslavia, on a daily basis. The company does not have its own fleet or storage capacity.

Thus far five different parcel distributors were used for this purpose (POŠTA SI, UPS, DPD, GLS and DHL). »Due to a large number of contacts, different pricing, operating conditions and even quality of

services, the situation can be quite chaotic at times. The dealer, therefore, decided to cooperate with one or at most two logistics providers who are favourable, offer a high quality of service, particularly in terms of time, quality and quantity of package accuracy, flexibility, responsiveness, high frequency of delivery, etc. « (26).

3.1 The Decision Making Objective and Selection Alternatives

A spare parts dealer intends to select one or at most two LPs that are able to offer cost-effective and high quality transport and warehouse services in terms of time, quality and quantity of package accuracy, flexibility, responsiveness, high frequency of delivery, etc. The selection alternatives are the same package distributors that the company has worked with so far: POŠTA SI, UPS, DPD, GLS, DHL. There are two reasons: (1) the low number of package distributors in Slovenia and (2) the relatively positive experience and knowledge of the above five package distributors.

3.2 The Selection of Criteria

To identify the appropriate criteria, the list of the most frequently used criteria detected by Bajec and Tuljak-Suban (2016) was submitted to the management of the spare parts dealer. The list of criteria includes five different groups (operational capability, service level, costs, logistics provider status and environmental capability), further divided into several subgroups. The operational capability is further divided into eight criteria (transport services, distribution services, warehouse services, value-added services, innovation capability, breadth of services, information technology application and technical and technological capability). Service level includes nine criteria (accurate delivery time, accurate quality and quantity, accurate place, flexibility, responsiveness, customer satisfaction, network coverage, information exchange and risk management). Fixed price and variable price belong to the costs group of criteria. Logistics provider status counts seven criteria (culture recognition, financial stability, degree of reputation, experience, staff quality, empathy and employee satisfaction) and environmental capability five criteria (pollutant released, energy consumption, clean material and energy use, waste disposal capabilities and value-added reverse logistics services) (27).

According to spare parts dealer management requirements nine criteria (C_1, ..., C_9) were selected. C_1 – costs are the total costs of logistics outsourcing (transportation costs, warehousing costs, freight forwarding, packaging costs, value-added costs, etc.). C_2 – warehouse services refers to the ability of the LP to store goods and perform added value services, such as packaging, labelling, repackaging, which is C_3. C_4 – accurate time refers to number of shipments performed in an agreed time, while accurate quality and quantity describes the number of shipments performed without damage and loss. Flexibility (C_5) in delivery and performance is characterized by »the ability to meet the customer's changing needs including specific and non-routine business requirements or personalized customer needs. Responsiveness (C_6) is the ability of a LP to react quickly to unexpected events and emergencies. This may include urgent deliveries because of a sudden rise in product demand« (27). Frequency of delivery (C_7) describes the frequency of delivery within a certain time frame to a specific area. Staff quality criterion (C_8) is measurable with the help of two indicators: the level of education in a particular field and the quantifiable applicable learning in the field of logistics and transport. Information sharing ability (C_9) relates to providing high quality information between the company and the LP by using software tools (efficient resource planning, management system, warehouse management system). It is calculated in numbers of software tools used by LP.

Based on the objective, criteria, and alternatives the most intuitive (for decision maker) decision making model was designed (Figure 1).

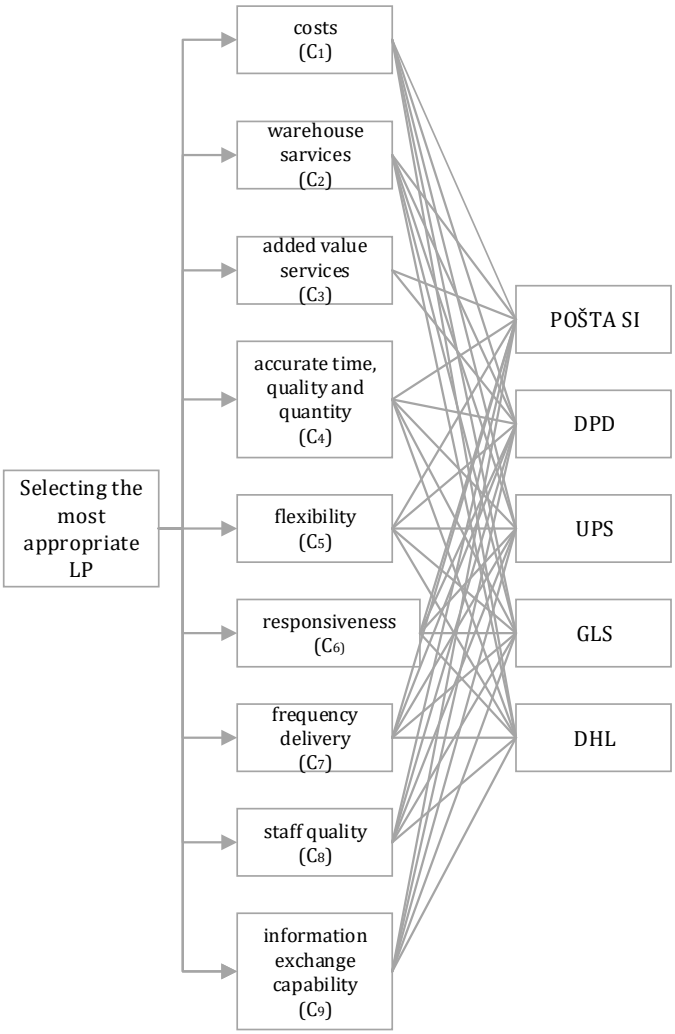


Figure 1 – Intuitive decision making model structure
Source: own

3.3 The Selection of the MCDM Method

The selection of the MCDM method should depend on specific characteristics of the decision making problem, characteristics of MCMD methods and resource constraints (19, 28-31). To select an appropriate MCDM method all three groups of the above mentioned characteristics should correspond among themselves and correspondence should be established in accord with common criteria (limits, conditions of application for the MCDM method) (19, 28, 29, 31).

However, in the present case study the methods (AHP, ANP and PROMETHEE) were selected according to the importance and possibility of integration of methods from different categories of MCDM methods.

3.4 Results

Firstly, using a five step scale, where 1 was the lowest point on the scale and 5 was the highest point on the scale, the alternatives were evaluated by managers of the spare parts company in accordance with the selected criteria. The results are presented in Table 2.

Table 2 – Alternatives evaluation using a five step scale

Alternatives / Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
TNT	3	5	5	3.5	4	3	3	4	4
DHL	3	5	4	4	4	3	4	4	4
GLS	3	5	4	3.5	3	3	4	4	4
POŠTA SI	4	4	3	3	3	2	3	4	3
FEDEX	3	5	4	3.5	3	3	3	4	4

Source: own

Then, using the AHP, ANP and PROMETHEE methods proposed alternatives were evaluated. The PROMETHEE method was computed using weights detected by AHP and ANP. Regarding the preference function P_k, see equation (4), defined as usual between 0 and 1, since the criteria used are prevalently quantitative and are evaluated by a discrete numerical scale with a small (<= 5) number of possible values that are perceived as quite different from each other. The results are presented in Table 3.

Table 3 – Ranking of alternatives by the AHP, ANP and PROMETHEE method

Alternatives	AHP weights eq. (1)	AHP ranking	ANP weights	ANP ranking	PROMETHEE ϕ eq. (8) using AHP	PROMETHEE ranking - AHP	PROMETHEE ϕ eq. (8) using ANP	PROMETHEE ranking - ANP
DHL	3.72	1	0.1077	1	0.4050	1	0.2908	1
GLS	3.51	2	0.071	2	0.0675	3	0.1747	3
TNT	3.50	3	0.070	3	0.03	2	0.2066	2
FEDEX	3.34	4	0.0396	5	-0.1575	4	0.1110	4
POŠTA SI	3.24	5	0.0448	4	-0.3454	5	0.0783	5

Source: own

It is possible to note that all the methods determinate DHL as the best alternative, despite the fact that the condition of independence between the criteria could not be considered in a proper way.

The rankings differ in the positions of the last two alternatives (FEDEX, POŠTA SI) between AHP and ANP, while the PROMETHEE method proposes a univocal evaluation independent of the effectiveness of the initial weights computed with AHP or ANP.

4. DISCUSSION AND CONCLUSION

This paper's aim was to determine whether the application of the selected three MCDM methods can highlight different alternatives as the most appropriate in the selection of an LP and what the reasons are for any difference.

Unlike previous articles on this topic in which numerical examples were shown using only individual methods or only a theoretical comparative analysis was done, the existing article analyses the method's procedures and the final results of the three MCDM methods (AHP, ANP and PROMETHEE) in a real case study of a small Slovene trader (buyer of logistics outsourcing).

The option of DHL was highlighted as the most appropriate alternative in all three analyses. A different order of ranking was only detected in the case of AHP and ANP, where FEDEX and POŠTA SI changed positions. These results answers RQ1.

As regards RQ2, the reasons that lead to different results can be many, certainly the most important is the improper use of the MCDM methods. These are used without taking into account mathematical assumptions, which are the basis for an effective and objective evaluation: (1) hierarchical structure of the AHP (Figure 1), (2) network structure of the ANP, (3) selection of the appropriate preference function P_k (eq. 4).

Moreover, some methods, especially those based on pairwise comparisons, like AHP and ANP, require a great deal of precision from the evaluators and the ability of define a proper local valuation that is not in contradiction with global results. Such methods require (include) a consistency check, which generally guarantees a formally consistent valuation, which however is not entirely in line with the experts' wishes for evaluation, since they correct pairwise evaluation to reach the consistency effort.

On the other hand, it seems that the PROMETHEE method was not influenced by the possibly of an inappropriate ranking of criteria by AHP or ANP. This leads to a new question: It is really necessary to take care to establish the independence of criteria or is it better to combine methods from different categories that could minimize this problem?

The authors believe that this study is a contribution to the selection process of LP and represents the potential of great support for decision-makers. All three methods can also be applied in decision making problems with more criteria and more alternatives, as in our case. However, it is recommended to limit criteria in the case of the AHP method to a maximum of nine (21). Besides, increasing the number of criteria and alternatives increases the complexity of calculations (more comparisons) and consequently requires more time. The authors hope that the results will encourage more decision makers to greater acceptance and adoption of MCDM methods in the selection process of LPs.

However, to extend the set of evaluated methods from which decision makers can choose, further comparative analyses of methods are needed. Moreover, more case studies and examples are needed to increase the external validity and generalisation.

A sensitivity analysis could also be performed in order to evaluate the robustness of these methods with respect to uncertainties in interpretation values or criteria weights.

REFERENCES

[1] Muller E. Selling the process, not just the product. Distribution. 1991;90(1):40-2.
[2] Abdur Razzaque M, Chen Sheng C. Outsourcing of logistics functions: a literature survey. International Journal of Physical Distribution & Logistics Management. 1998;28(2):89-107.
[3] Bajec P, Tuljak-Suban D. Selecting a logistics service provider: A definition of criteria that consider the requirements of an external competitive environment. Transport problems. 2017;12(Special Edition):157-68.
[4] Bajec P, Tuljak-Suban D, editors. MULTI-CRITERIA DECISION MAKING APPLICATIONS TO INTEGRATE SUSTAINABILITY INITIATIVE INTO THE THIRD PARTY LOGISTICS PROVIDER SELECTION PROCESS: A. 3rd Logistics International Conference; 2017; Belgrade: Faculty of Transport and Traffic Engineering.
[5] Lee H-C, Chang C-T. Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan. Renewable and Sustainable Energy Reviews. 2018;92:883-96.
[6] Hwang B-N, Shen Y-C. Decision making for Third Party Logistics Supplier Selection in Semiconductor Manufacturing Industry: A Non-Additive Fuzzy Integral Approach.
[7] Yazdani M, Zavadskas EK, Ignatius J, Abad MD. Sensitivity analysis in MADM methods: application of material selection. Engineering Economics. 2016;27(4):382-91.
[8] Pamucar D, Chatterjee K, Zavadskas EK. Assessment of third-party logistics provider using multi-criteria decision-making approach based on interval rough numbers. Computers & Industrial Engineering. 2018.

[9] Amine ME, Pailhes J, Perry N. Critical Review of Multi-criteria Decision Aid Methods in Conceptual Design Phases: Application to the Development of a Solar Collector Structure. Procedia CIRP. 2014;21:497-502.
[10] Zanakis SH, Solomon A, Wishart N, Dublish S. Multi-attribute decision making: a simulation comparison of select methods. European journal of operational research. 1998;107(3):507-29.
[11] Stanujkić D, Đorđević B, Đorđević M. Comparative analysis of some prominent MCDM methods: A case of ranking Serbian banks. Serbian Journal of Management. 2013;8(2):213-41.
[12] Özcan T, Çelebi N, Esnaf Ş. Comparative analysis of multi-criteria decision making methodologies and implementation of a warehouse location selection problem. Expert Systems with Applications. 2011;38(8):9773-9.
[13] Chand M, Raj T, Shankar R. A comparative study of multi criteria decision making approaches for risks assessment in supply chain. IJBIS. 2015;18(1):67-84.
[14] Browne D, Ryan L. Comparative analysis of evaluation techniques for transport policies. Environmental Impact Assessment Review. 2011;31(3):226-33.
[15] Fancello G, Carta M, Fadda P. Road intersections ranking for road safety improvement: Comparative analysis of multi-criteria decision making methods. Transport Policy. 2018.
[16] Munda G. The issue of consistency: Basic discrete multi-criteria "Methods". Berlin: Springer-Verlag Berlin Heidelberg; 2008. XVII, 210 p.
[17] Polatidis H, Haralambopoulos DA, Munda G, Vreeker R. Selecting an appropriate multi-criteria decision analysis technique for renewable energy planning. Energy Sources, Part B. 2006;1(2):181-93.
[18] Roy B, Słowiński R. Questions guiding the choice of a multicriteria decision aiding method. EURO Journal on Decision Processes. 2013;1(1):69-97.
[19] Teghem J, Delhaye C, Kunsch PL. An interactive decision support system (IDSS) for multicriteria decision aid. Mathematical and Computer Modelling. 1989;12(10):1311-20.
[20] Cinelli M, Coles SR, Kirwan K. Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment. Ecological Indicators. 2014;46:138-48.
[21] Saaty RW. The analytic hierarchy process—what it is and how it is used. Mathematical Modelling. 1987;9(3–5):161-76.
[22] Saaty TL. Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process: RWS Publications; 1994.
[23] Saaty TL. Decision Making with Dependence and Feedback: The Analytic Network Process : the Organization and Prioritization of Complexity: Rws Publications; 2001.
[24] Greco S, Ehrgott M, Figueira JR. Multiple Criteria Decision Analysis: State of the Art Surveys: Springer New York; 2016.
[25] Brans JP, Vincke P, Mareschal B. How to select and how to rank projects: The Promethee method. European Journal of Operational Research. 1986;24(2):228-38.
[26] Bajec P, Tuljak-Suban D. A framework for detecting the proper multi criteria decision making method (MCDM) taking into account the characteristics of third party logistics (3PL), the requirements of managers, and the type of input data [Article]. In press 2018.
[27] Bajec P, Tuljak-Suban D. Identification of Environmental Criteria for Selecting a Logistics Service Provider: A Step Forward towards Green Supply Chain Management. In: Krmac E, editor. Sustainable Supply Chain Management. Rijeka: InTech; 2016.
[28] El Amine M, Pailhes Jm, Perry N. Selection and use of a multi-criteria decision aiding method in the context of conceptual design with imprecise information: Application to a solar collector development. Concurrent Engineering. 2016;24(1):35-47.
[29] Laaribi A, Chevallier JJ, Martel JM. A spatial decision aid: A multicriterion evaluation approach. Computers, Environment and Urban Systems. 1996;20(6):351-66.
[30] Belton V, Stewart T. Multiple criteria decision analysis: an integrated approach: Springer US; 2002. XIX, 372 p.
[31] Guitouni A, Martel J-M. Tentative guidelines to help choosing an appropriate MCDA method. European Journal of Operational Research. 1998;109(2):501-21.

VUK BOGDANOVIĆ, Ph.D.[1]
E-mail: vuk@uns.ac.rs
VALENTINA MIROVIĆ, Ph.D.[1]
E-mail: plast@uns.ac.rs
JELENA MITROVIĆ SIMIĆ, Ph.D.[1]
E-mail: mjelena@uns.ac.rs
NEMANJA GARUNOVIĆ, M.Sc. [1]
E-mail: garunovic@uns.ac.rs
MIODRAG POČUČ, M.Sc.[2]
E-mail: miodrag.pocuc@adomne.rs
[1] University of Novi Sad
Faculty of Technical Sciences, Department of Traffic Engineering
Republic of Serbia, 21000 Novi Sad, Trg Dositeja Obradovića 6
[2] ADOMNE d.o.o
Republic of Serbia, 21000 Novi Sad, Šumadijska 16b

ACCESSIBILITY ANALYSIS AT SIGNALIZED INTERSECTIONS IN NOVI SAD

ABSTRACT

This paper shows the results of the research on elements of accessibility at pedestrian crossings in Novi Sad in 2019. The analysis included data on devices for sound signals emitting, countdown signals and tactile surfaces on approaches to pedestrian crossings. The applied accessibility criteria were availability, functionality, equipment and safety. The analysis is a part of a wider research which was conducted at the signalized intersections with intensive pedestrian traffic with the aim to analyze the level of service of the pedestrian flows at peak hours and to propose solutions which will positively affect the improvement of the level of service of pedestrian flows.

KEY WORDS

Pedestrians; pedestrian crossings; accessibility; sound signals; countdown signals; tactile surfaces

1. INTRODUCTION

Walking as the most accessible and the healthiest way of travelling has a special position and significance in sustainable mobility plans. In most small and mid-sized cities walking is the most frequent way of travelling, and apart from a certain number of bicycle journeys, all others start and finish with walking. Walking is the right of all citizens. Therefore, it is equally used by all residential categories, even those most vulnerable in traffic. Even though the pedestrian infrastructure and the equipment of pedestrian paths and pedestrian crossings are incomparably cheaper than the infrastructure necessary for all other modes of transportation, the least attention and investment are provided for the improvement of pedestrian traffic conditions.

The quality of walking, especially for vulnerable participants and persons with disabilities in traffic, is also affected by pedestrian crossings equipment and arrangement. Lack of pedestrian traffic lights at pedestrian corridors can represent an insurmountable barrier and endanger safety in traffic, especially for the blind or the visually impaired people. Most previous research studies and contemporary solutions in the field of accessibility at signalized intersections referred to the improvement of the access to the pedestrian crossings and introduction of sound signals [1,2,3], while other activities were not considered. Namely, for involving persons with disabilities into a traffic system, it is necessary to ensure accessibility and having all users informed with all the contents which surround the very persons. One of the current topics in this field is definitely the development of

different software tools which would improve accessibility of the traffic system to the persons with disabilities, and in that way contribute to the existing barriers surmounting [4,5,6]. In the paper of a group of authors [7] user demands of the visually impaired persons were analyzed according to the needs of movement in the road network. In accordance with the obtained results it was suggested to apply an information-communication solution through a model which enables precise and updated data when the user is navigated and redirected through the street network. Specifically, the visually impaired persons create their travel plan via the Internet page and they receive the information in real time on their mobile terminal or application. When the model efficiency was checked among the users, it was determined that a sense of safety when traveling increased for 87%.

Novi Sad traditionally has a great share of walking in modal split. According to research studies from 2018 [8], the share of walking journeys was 39.98% in relation to the total number of journeys during the day by all other means of transport. Data collecting methodology, data types and processing method were formed so that they enable the comparison of basic characteristics of the journeys with the data obtained in the research studies from 2009 [9]. Regarding the year of 2009, the share of pedestrian journeys was 48.5%. The reduction of pedestrian traffic can be linked with journeys redistribution which resulted in a higher share of passenger car use, as well as bicycle, but also in aggravation of pedestrian traffic conditions at certain location on the territory of City of Novi Sad, which implies the necessity for researching the possibilities of increasing the quality of traffic conditions for pedestrians.

Based on the results of previous studies, locations with intensive pedestrian flows were determined. In this paper, the authors will analyze pedestrian traffic and the operation of traffic lights from the aspect of accessibility to signalized intersections. The results of the research of geometric characteristics of intersections, equipment, arrangement and signals functioning method were used for the assessment of the current state and for defining the measures for the improvement of traffic conditions. The analysis shown in this paper is a part of a wider research study whose aim was to analyze the level of service of pedestrian flows in peak hours at signalized intersections with intensive pedestrian traffic, using professional software packages and engineering tools, and to propose solutions which will positively affect the improvement of level of service of pedestrian flows [10].

2. RESEARCH METHODOLOGY

The data collected on the locations of signalized intersections and separate pedestrian crossings were used to form a data base for this analysis. Twenty-seven signalized intersections, as well as four separate pedestrian crossings on the territory of City of Novi Sad were chosen. The chosen locations are located at the crossings of two or more streets (boulevards) (Table 1).

The existence of pedestrian traffic lights on walking corridors can represent a barrier for persons with disabilities and it can endanger their safety in traffic. Considering this, it was necessary to analyze pedestrian movement characteristics, particularly blind and visually impaired participants, as well as to consider pedestrian traffic lights operating modes, from the aspect of their accessibility, so as to additionally advance safety and to provide free movement. Free movement (in the context of this article) denotes every person's right to movement, without facing any barriers or limitations in the built environment. All potential travelers should reach as high autonomy and independence degree as possible, thereby not encounter any physical and/or information obstacles.

The Figure 1 shows the position of these locations in the street network of Novi Sad.

Table 1 – A list of locations

R1:	Rumenačka - Partizanska - Kornelija Stankovića	R17:	Bulevar Evrope - Futoški put
R2:	Hajduk Veljkova - Futoška - Cara Dušana	R18:	Futoški put - Bulevar kneza Miloša - Bulevar patrijarha Pavla
R3:	Bulevar cara Lazara - Cara Dušana - Ive Andrića	R19:	Bulevar Jaše Tomića - Kisačka
R4:	Novosadskog sajma - Hajduk Veljkova	R20:	Partizanska - Temerinska
R5:	Bulevar kralja Petra I - Hajduk Veljkova - Braće Popović	R21:	Sentandrejski put - Teodora Mandića - Put novosadskog partzan. odreda
R6:	Bulevar oslobođenja - Maksima Gorkog	R22:	Bulevar Evrope - Hadži Ruvimova - Radomira Raše Radujkova
R7:	Bulevar kralja Petra I - Kisačka - Dositejeva	R23:	Bulevar patrijarha Pavla - Vršačka - Feješ Klare
R8:	Jovana Subotića - Kisačka - Temerinska	R24:	Bulevar oslobođenja - Bulevar cara Lazara
R9:	Bulevar Jaše Tomića - Bulevar oslobođenja	R25:	Bulevar oslobođenja - Novosadskog sajma - Papa Pavla
R10:	Bulevar Slobodana Jovanovića - Futoški put - Vršačka	R26:	Bulevar oslobođenja - Bulevar kralja Petra I
R11:	Rumenačka - Bulevar Jaše Tomića - Janka Veselinovića	R27:	Bulevar Mihajla Pupina - Žarka Zrenjanina - Modene
R12:	Bulevar Mihajla Pupina - Jevrejska	R28:	Puškinova - Bulevar cara Lazara - Šekspirova
R14:	Bulevar oslobođenja - Narodnog fronta	IP1:	Bulevar oslobođenja (Stadium)
R15:	Bulevar cara Lazara - Stražilovska	IP2:	Bulevar oslobođenja (Dalton)
R16:	Bulevar oslobođenja - Futoška - Jevrejska	IP3:	Bulevar cara Lazara (Student cafeteria)
		IP4:	Hajduk Veljkova (Hospital)

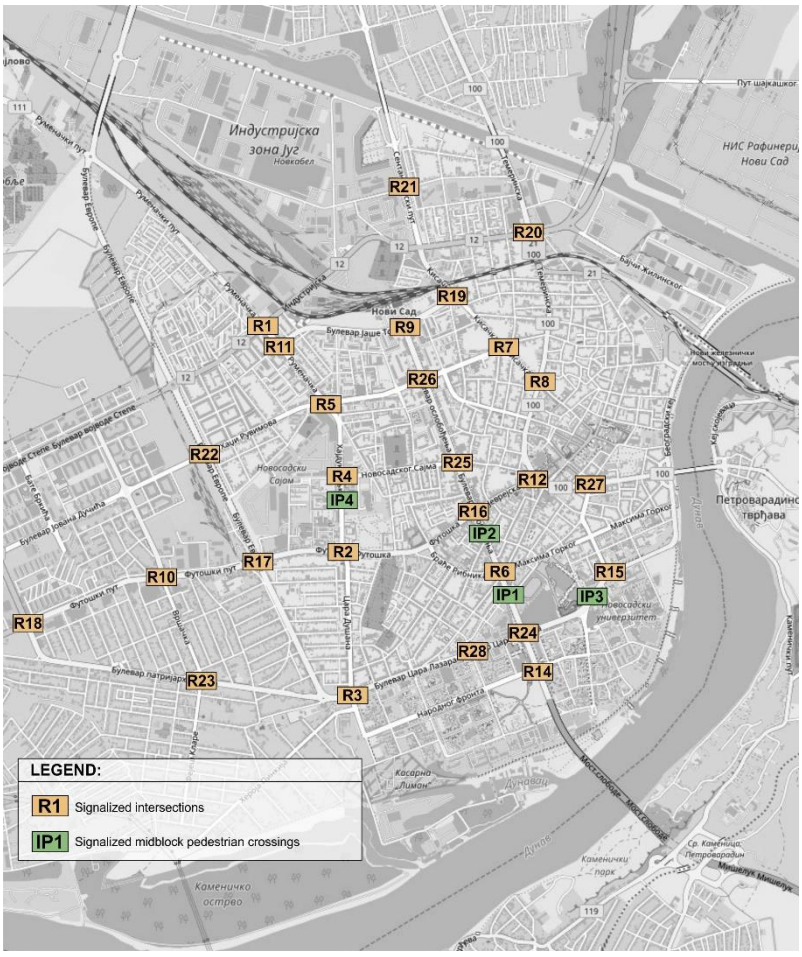


Figure 1 – The position of the analyzed locations in the street network of Novi Sad

The analysis of pedestrian movement and pedestrian traffic lights, from the aspect of accessibility, meant criteria control such as: accessibility, functionality, equipment and safety.

The aforementioned criteria can be briefly described as:

Accessibility - implies the possibility of reaching the traffic lights device and providing appropriate accessible surfaces;

Functionality - implies the usability of a certain surface or devices being used;

Equipment - implies the existence of necessary installations, devices and equipment necessary for achieving the basic traffic function;

Safety – implies the use of all stated elements without endangering the user.

3. THE ANALYSIS OF ACCESSIBILITY AT SIGNALIZED INTERSECTIONS

Within the analysis of accessibility at signalized intersections the following basic and additional elements were analyzed:

- A sound device for signals of light phases;
- The position of the traffic lights pole in relation to the pedestrian crossing;
- Tactile plan of the pedestrian crossing;
- General accessibility of the accumulation zone.

The aforementioned elements are interdependent, which means that only with the existence of all listed elements, maximum accessibility and user safety can be guaranteed.

3.1 Sound Devices for Signals of Light Phases

Sound traffic light, basically, represents a pedestrian traffic light which apart from standard light signals also has an appropriate acoustic signal of light phases, given exclusively in the form of different sound frequencies or rhythms for the red and the green phase.

After the equipment check of the existing pedestrian traffic lights included in the analysis, with acoustic devices, the following characteristics can be separated:

There are pedestrian traffic lights with acoustic devices at 11 intersections (40.7%), out of total 27, as well as at 3 out of totally 4 separate pedestrian crossings (75%). On the other hand, according to the data from the traffic study from 2018 [11], out of the total number of the intersections with traffic lights and the separate pedestrian crossings on the territory of City of Novi Sad (106), at 24 intersections or separate pedestrian crossings there was an acoustic device, with the coverage of 18%.

In most cases sound traffic lights were set in relation to the representative facilities (attractions) and in relation to the significance and traffic at the intersection or pedestrian crossing. Also, the acoustic devices were not installed at all approaches of every intersection, but only at some of them.



Figure 2 – An example of a pedestrian traffic light with an acoustic device



Figure 3 – The appearance of the pedestrian traffic lights with an acoustic device, the intersection of H.Veljkova St. (Hospital)-Futoška St.

A relatively low presence of sound signals in relation to the total number of light signalized crossings can affect the complete reduction or narrowing of possibilities for the blind to move on the desired route.

Since this is only about the information format given to the users at pedestrian traffic lights which already exist, from the aspect of accessibility and safety of users in traffic, it is recommended that each pedestrian crossing regulated by light signals, apart from light, should also have the appropriate sound signalization.

It can be carried out in the following phases, that is, priorities:

Phase 1: Installation of sound traffic lights at separate pedestrian crossings since pedestrians are the most vulnerable there;

Phase 2: Installation of sound signals at certain approaches to intersections, where partly there already are sound traffic lights installed;

Phase 3: Installation of sound traffic lights at other light-signaled pedestrian crossings.

The information format should be of a universal type so as to be understood by different users regardless of the fact whether they know the city or the language they speak (for instance, tourists). For this reason it is particularly significant to avoid sound signals with speech information in the form of a recorded sentence which is repeated (for example voice information in Serbian or a minority group language).

3.2 The Position of the Traffic Lights Pole

The position of the traffic lights pole in relation to the pedestrian crossing has a special significance from the aspect of accessibility. Namely, blind or visually impaired participants use the traffic lights pole so as to get orientated in space in an appropriate way, obtain data on the appearance of the pedestrian crossing by touching the tactile information on the auxiliary device on the pole (the so-called tactile plan of crossing) and take the appropriate initial position for crossing the roadway.





Figure 4 – Examples of the appropriate position of the traffic lights pole from the aspect of accessibility, in the middle of the pedestrian crossing width, R25 and R9

Holding onto the pole of the traffic lights device during waiting for the green phase provides the users with the necessary feeling of safety.

With the insight into the current state it was noticed that there is a relatively homogeneous way of setting the traffic lights pole in the middle of the total width of the pedestrian crossing.

A smaller number of poles was set on the left side, observed in relation to the direction of pedestrians movement, and these are: R25 - approach from P. Pavla St., R26 - Bulevar oslobođenja in the direction towards the station (approach from Bulevar kralja Petra), R27 – Bulevar M. Pupina (approach from Modena), IP2, IP3). This situation is most probably conditioned by different technical limitations in the sense of space possibilities and /or underground installations for each location separately.





Figure 5 – Examples of inappropriate position of the traffic lights pole from the aspect of accessibility, set from the left side, observed in relation to the direction of pedestrian movement - R27 and IP1

The ideal position of the pole of the traffic lights device is in the middle of the pedestrian crossing width. In that case users shift from the right side of the pole, wherewith maximum pedestrian safety is provided by the vehicle approaching from their left side. Simultaneously, maximum tolerance of passing by a pedestrian during the very crossing is enabled, which is particularly significant at crossings with a higher density of pedestrians.

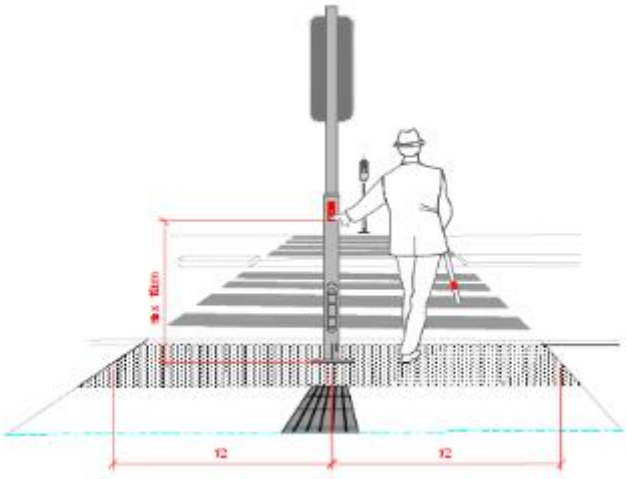


Figure 6 – Example of setting the traffic lights pole in relation to the pedestrian crossing

The position of the traffic lights pole can also be on the right side of the pedestrian crossing, observed in relation to the direction of pedestrian movement.

The position on the left side is not accessible due to the occurrence of numerous crossings of pedestrian flows and creation of unnecessary conflict points, both in the zone of accumulation and at the very crossing across the roadway, which is especially unfavorable from the aspect of safety of all traffic participants.

In the situations when the position of the traffic lights pole is not unified, it seems confusing to the users, it requires additional exerts for detection of the traffic lights pole and additional devices, and it endangers general safety of participants.

Regarding traffic lights described in this analysis, the most common problem is non-unified position of the pole at all approaches in order to reduce the possibility of confusing the user.

3.3 Tactile Plan of the Pedestrian Crossing

Tactile plan of the crossing is a device on the traffic lights pole, and its role is to inform the user on the type and appearance of the crossing (for example, crossing over one or more lanes, crossing with or without pedestrian island and similar), as well as to imply to the user the direction of the pedestrian crossing spreading (straight or at an angle - left or right), when crossing the roadway.



Figure 7 – An example of setting a device with a tactile plan of the crossing - R26



Figure 8 – Appearance of different devices with a tactile plan of crossing in Novi Sad

With the insight into the current situation in the field it was noticed that the tactile plan of crossing does not exist at most locations, only occasionally.

The device was installed at totally 4 analyzed positions at the following intersections: R9, R12, R26 and a separate pedestrian crossing - IP4.

The existence of this keyboard device does not have any effect if the user cannot find and detect it. In that sense, its functionality to a considerable extent depends on the existence of appropriate tactile paths, in the zone of accumulation.

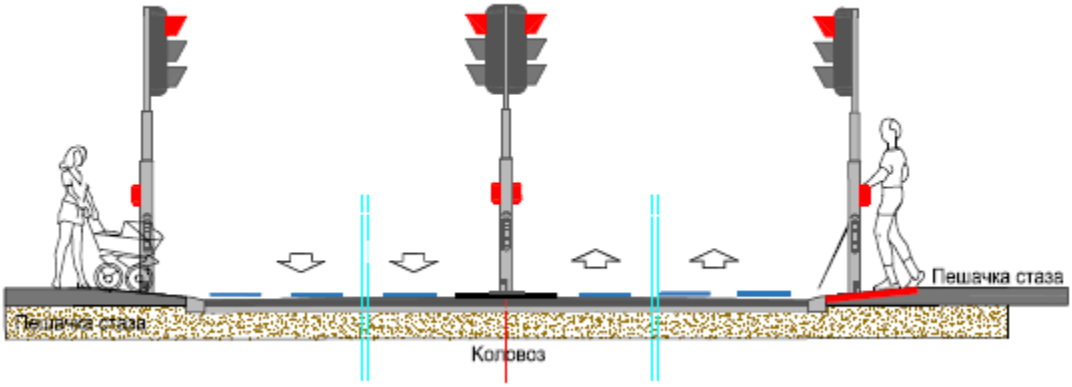


Figure 9 – An example of the device setting - cross section

Since the sound traffic lights cannot provide users with the information about the movement direction (crossing direction across the roadway), type and category of the pedestrian crossing which users come across, the proposal of measures relates to the necessity of installation of this additional device at all light-signaled pedestrian crossings.

3.4 General Accessibility of the Accumulation Zone

General accessibility of the accumulation zone means adaptation of construction elements in the zone, in order to increase availability of all devices, functionality and safety of the users in the crossing zone.

What is especially important is the equipment of the zone with appropriate tactile systems of orientation and leveling with the roadway.

3.4.1 Horizontal tactile systems of orientation and information

Horizontal tactile systems of users' orientation and information represent the final relief processing of a part of the pedestrian path/pavement, which are set in the accumulation zone of crossing, in order to inform, orientate, guide or warn the blind traffic users, and through the touch, that is, their tactile sensation through the users' feet.

Bearing in mind their significance for the safety of blind participants in traffic, they are considered an element of traffic signalization (horizontal), and especially for the reason they represent the main source of information for this group of traffic participants.

The most common problems related to the tactile paths in the accumulation zone of crossing are reflected in:

- Non-existence at the places where they are necessary,
- inadequate/inappropriate setting of tactile plates,
- Inequality of tactile information.

The stated problems lead to unnecessary confusion of users, their different "reading" and understanding tactile information. Most commonly that is the consequence of non-existence of appropriate standards, rules and norms which precisely define all technical elements for design, production and setting tactile marking in the Republic of Serbia.



Figure 10 – An example of inappropriate tactile guiding lines in the accumulation zone



Figure 11 – An example of appropriate tactile guiding lines in the accumulation zone

In the accumulation zone of the pedestrian crossing the existence of the appropriate tactile guiding line and tactile safety area is especially important.

Tactile guiding lines - should enable adequate availability of the users to the pole of the traffic lights, that is, to the device with the tactile plan of the pedestrian crossing. Withal, tactile guiding line should

direct the movement of pedestrians (that is, to imply to the user the direction of pedestrian crossing spreading) in a way the user can go across the roadway at a certain angle, on the marked pedestrian crossing.

Tactile safety areas - should enable complete user safety when they wait for the green phase in the accumulation zone (immediately before the roadway) and to prevent the possible pedestrian going onto the roadway. They are especially necessary in cases when the pavement at the place of pedestrian crossing is lowered to the level of roadway, that is, when users cannot detect the border between the pavement and the roadway in a tactile manner. The aforementioned tactile markings should be set in valeur or in contrast (in a certain color), with the rest of the path.

3.4.2 Leveled pedestrian crossings

In the analysis of the state it was noticed that a large number of light-signaled crossings does not have appropriate building elements (lowered path to the roadway level) which will provide undisturbed crossing for all groups of users. Taking everything stated into account, it is necessary to carry out appropriate leveling of all pedestrian crossings between pavements /paths and roadway, as well as between the pavement and cycling paths, so as to provide undisturbed approach and roadway crossing, without obstacles. Pedestrian paths and pavements should be lowered to the level of roadway in its full width, with a tactile safety area and without any fixed obstacles (for example, posts).



Figure 12 – An example of unapproachable and unsafe accumulation zone



Figure 13 – An example of good leveling of the zone with a roadway and a cycling path

4. ASSESSMENT OF ACCESSIBILITY AT SIGNALIZED PEDESTRIAN CROSSINGS

Assessment of the state of accessibility was determined on the basis of the analysis of intersection equipment in the form of tactile plates and devices for giving sound signals marking pedestrian phases. Although devices for pedestrian phases counting down do not belong directly to the devices or equipment which improve accessibility, they are taken into consideration when assessing the state due to the reason they affect the pedestrian behavior and the feeling of comfort, especially for the pedestrians which have movement difficulties. The analysis was carried out on the basis of the research studies performed to determine the characteristics of the locations, wherewith it was determined that only at one location (IP3) all accessibility criteria were met.

At 4 intersections two criteria were met, and at 4 intersections one of the defined criteria of accessibility. At the other 22 researched locations there are no devices or equipment whose existence enables accessibility, comfort and the sense of pedestrian safety when going across the pedestrian crossing, or these devices are set only at a certain number of approaches to the intersection (e.g. at one approach to the intersection R24 there is not the counting down signal and the sound signal).

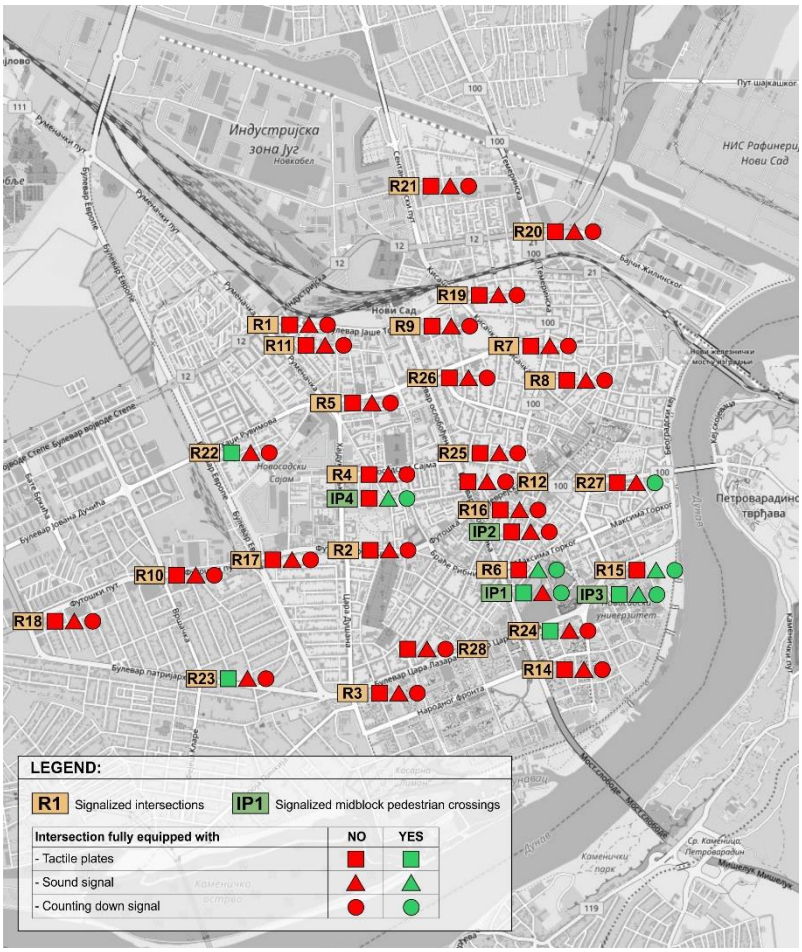


Figure 14 – Spatial distribution of the intersections and the existence of the equipment for accessibility improvement

Table 2 – Intersection equipment and devices which enable better accessibility

Marking	Intersection	Tactile plates	Sound signal	Counting down signal
R6:	Bul. oslobođenja – M. Gorkog			
R15:	Bul. cara Lazara - Stražilovska			
R22:	Bul. Evrope - Hadži Ruvimova – R.R. Radujkova			
R23:	Bul. patr. Pavla - Vršačka – F. Klare			
R24:	Bul. oslobođenja – Bul. cara Lazara			
R27:	Bul. M. Pupina – Ž. Zrenjanina - Modene			
IP1:	Bul. oslobođenja (Stadium)			
IP3:	Bul. cara Lazara (Student cafeteria)			
IP4:	Hajduk Veljkova (Hospital)			

Legend:

	There is a device or equipment at the intersection
	There is no device or equipment at the intersection

5. CONCLUSION

The research on accessibility elements was carried out at 31 locations where there are 98 pedestrian crossings. The data on intersection equipment and devices for accessibility improvement were collected. Within this part of the research the following data were collected: on the existence of the device for sound signals, counting down signals emitting and on tactile surfaces on the approaches to pedestrian crossings. The analysis and assessment of the state of accessibility at pedestrian crossings showed that a majority of pedestrian crossings is not equipped with the appropriate equipment and devices, that is, most intersections do not have appropriate equipment which would improve accessibility and increase comfort to pedestrians, especially the vulnerable categories of traffic participants. Namely, only at one researched locations all the devices and equipment, which enables better accessibility to all pedestrian categories, were installed. In order to improve accessibility, the measures relating to completing the missing equipment and devices were proposed. In that sense, the proposal is to install them at all signalized intersections and the pedestrian crossings without it. Apart from the noticed deficiencies and the proposal of measures related to the improvement of accessibility at signalized intersections, it is necessary to strive for the implementation of other measures of traffic policy which urge sustainable urban mobility so as to achieve the improvement of the quality of traffic conditions of pedestrian flows.

REFERENCES

[1] Barlow, J. M., Scott, A. C., Bentzen, B. L., Guth, D., & Graham, J. Effectiveness of Audible and Tactile Heading Cues at Complex Intersections for Pedestrians who are Blind. *Transportation Research Record.* 2013; 2393(1): 147–154.

[2] Scott, A. C., Barlow, J. M., Bentzen, B. L., Bond, T. L. Y., & Gubbe, D. Accessible Pedestrian Signals at Complex Intersections: Effects on Blind Pedestrians. *Transportation Research Record*. 2008; 2073(1): 94–103.

[3] M. Muhsinzoda, C. C. Corona, D. A. Pelta and J. L. Verdegay. Activating accessible pedestrian signals by voice using keyword spotting systems. *Proceedings of the IEEE International Smart Cities Conference (ISC2)*, 14-17 October 2019, Casablanca, Morocco; 2019. p. 531-534

[4] Hakobyan, L., Lumsden, J., O'Sullivan, D., Bartlett, H. Mobile assistive technologies for the visually impaired. *Survey of ophthalmology.* 2013; 58: 513-528

[5] Azenkot, S., Fortun,a E. Improving public transit usability for blind and deaf-blind people by connecting a braille display to a smartphone. *Proceedings of the 12th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'10);* 25-27 October 2010, Orlando, FL, USA; p. 317-18

[6] Periša, M., Margović, G., Kolarovszk,i P., Madlenak, R. Proposal of a conceptual architecture system for informing the user in the iot environment. *Promet – Traffic & Transportation*. 2019; Vol. 31, No. 1: 37-47

[7] Periša, M., Peraković, D., Šarić, S. Conceptual model of providing traffic navigation services to visually impaired persons. *Promet – Traffic&Transportation*. 2014; Vol. 26, No. 3: 209-218

[8] Smart plan – prikupljanje podataka „prva faza", Fakultet tehničkih nauka Novi Sad, ADOMNE d.o.o., Novi Sad, 2018. Serbian

[9] JP Urbanizam. Saobraćajna studija Grada Novog Sada sa dinamikom uređenja saobraćaja – NOSTRAM. 2009. Serbian

[10] ADOMNE d.o.o, Novi Sad. Definisanje rada pešačkih semafora, Knjiga 2: Analiza postojećeg stanja sa predlogom mera za unapređenje pešačkog saobraćaja. 2019. Serbian

[11] ADOMNE d.o.o., Novi Sad. Primena koncepta dizajn za sve na javnim saobraćajnim površinama i u javnom prevozu iz ugla bezbednosti saobraćaja na putevima na teritoriji Grada Novog Sada. 2018. Serbian

PREDRAG BRLEK, assist. prof.[1]
E-mail: pbrlek@unin.hr
LJUDEVIT KRPAN, full prof.[1]
E-mail: ljkrpan@unin.hr
IVAN CVITKOVIĆ, mag.ing.traff.[1]
E-mail: icvitkovic@unin.hr
MAJDA KODŽAGA, bacc.inf.[1]
E-mail: makodzaga@unin.hr
[1] University North, Koprivnica
Žarko Dolinar Square 1, 48000 Koprivnica, Croatia

ELECTROMOBILITY: EUROPE, CROATIA – CITY OF KOPRIVNICA

ABSTRACT

This article is giving representation of the results of researching scientific and electrically dilatation from field of electromobility. It is briefly discussed about the development of electromobility, followed by a survey of the current state of electromobility in the European Union, the Republic of Croatia and the City of Koprivnica. The article also discusses the types of charging stations and the charging prices. The information provided is about the current state and trends in the field of electromobility, and the situation in the City of Koprivnica is particularly emphasized. Finally, proposals were made to improve the vehicle fleet in the public city transport system in the City of Koprivnica.

KEY WORDS

Electromobility; Koprivnica; charger; cost

1. INTRODUCTION

Looking globally, transport is experiencing daily changes. Every day, transport technology, modes of transport and means of transport are changing. From former carriages drawn by horses through fossil fuel vehicles to today's electric and hybrid vehicles. Looking at the history of the development of transport and means of transport, it can be seen that the first means of transport were completely environmentally friendly, but also rather slow, and as the world evolved, so did more and more non-environmentally friendly vehicles. Today, it has come to the point that new transport technologies are actually needed where CO2 footprint will be minimal or usable and electrification will be considered as the foremost alternative: provided that the electricity production is decarbonized[1]. [1] As more and more of them strive to conserve nature every day, environmentally friendly means of transportation are being developed that will meet the needs of their users and also contribute to sustainable development. In order for all this to be possible, there had to be mobility as a feature that ensured the initial adaptation and then the acceptance of new forms of traffic by users.

Mobility is a characteristic human trait that encourages people to move and create new ideas that will be the focus of attention, and contribute to the development of new solutions. In order to gain insight into the solutions that are changing very quickly and appearing on the transport scene, throughout the paper, a survey was conducted on the state of electromobility in parts of the European Union (EU), the Republic of Croatia (RH) itself and ultimately in the city of Koprivnica. [2] The study was designed to show and compare the level of electromobility in different areas of the EU. The focus and targets of the research are focused on the efficiency of electromobility in the city of Koprivnica. White paper (2011) indicates that the future prosperity of society will depend precisely

[1] Decarbonisation is the process of internal cleaning of the engine from the deposits of the grime and soot and is applied to all types of internal combustion engines regardless of engine type.

on the ability of regions, of individual entities to successfully integrate transport into the world economy and make it efficient, since transport itself is of great importance for further development.

The paper consists a total of 6 chapters. The first chapter is the introductory part of the paper which briefly describes the development of transport and the importance of human mobility. This is followed by the second chapter, which deals with electromobility in general and technologies related to electromobility. The third chapter discusses electromobility in the European union, number of electric vehicles and national incentives and benefits for electric vehicles and electric chargers. The fourth chapter contains information on electromobility in the Republic of Croatia, while the fifth chapter focuses exclusively on electromobility in the city of Koprivnica. In the last sixth chapter, conclusions are presented and potential proposals for increasing the percentage of electromobility.

2. ELECTROMOBILITY

Electromobility can be defined from several different points of view, one of them is that the road transport system is based on electric vehicles. (Chalmers, 2013) While from a different point of view, this is a topic that appears in political programs as an option that will reduce the adverse environmental impact. [3] Moreover, electromobility is actually a new concept used in urban areas to create a life-friendly environment that will ensure sustainable development. The very beginnings of electromobility date back to 1899 when Belgian driver Camille Jenatzy performed with his electric car at “Le Jamais Contente”. Then, in the early 1970s, an era of electric cars and the development of electromobility began in Greece, where “ENFIELD NEORION Ltd” produced three mini electric cars based on English E465 car model. However, after this period the production of electric cars stopped and electromobility did not continue to develop in Greece. [4]

Encouraging electromobility in cities will enable the achievement of the aforementioned target, thereby ensuring the achievement and impact on at least one component of sustainable development (the ecological component), while affecting the economic component and, to a lesser extent, the social component. White Paper (2011) also points to the need to create as many projects as possible involving electromobility and to include infrastructure for intelligent transport systems. This can further contribute to the development of urban areas where the air quality level is low or very poor. Namely, electromobility can do a lot of good for the transport system and transport technologies, but the damage it can do must also be borne in mind (e.g. excessive consumption of electricity not coming from renewable energy sources). [5]

Electromobility technologies can be divided into those used by e-cars, e-bikes, e-buses, etc. e-vehicles. However, electromobility-related technologies not only apply to systems that are broken down by vehicle type, but also to battery types by their duration. Therefore, technologies can also be divided into [6]: Long-Range Battery, Limited-Range Battery, Range-Extended Plug-in, Minimal Plug-in. The Long-Range Battery allows vehicles to travel hundreds of miles with just one battery charge, and can then be recharged very quickly. [6]

In addition to batteries in electric cars, there are also chargers or charging stations that must be adapted to a specific type of electric car or battery in the car. Before embarking on a detailed elaboration of the type of charging stations, it is necessary to know the terms used for charging stations [7]: charging station, charging plug, charging outlet, charging port, electric vehicle supply, equipment, charger ect. In addition to various names for electric charging stations, there are different types of charging stations, some of which are [8]:

- Charger station for all types of electric vehicles;
- Charger station for hybrid electric vehicles;

Charger stations for all types of electric vehicles are suitable for households with two cars and for those who are fans of electric vehicles with shorter travel distances. When it comes to hybrid electric charging stations, they are just as good for households as charging stations for all types of electric

vehicles. However, they make it impossible to charge vehicles that are only electrically powered, as vehicles using such a charging station are powered by electricity and a gasoline engine. [8]

Of course, according to Drive Electric Vermont Company (2020) there are also different types of charging: level one charging or 120 Volt AC, level two charging or 240 Volt AC and DC fast charging. Types of charging today are increasingly striving for faster charging time (less time consuming). Level one charging allows the use of up to 120 volts of electricity, which is also the current found in households and/or household outlets in some countries. This form of charging is relatively slow and charging takes place within 3 to 5 miles per hour. [8] Level two charging uses double voltage to allow batteries to be charged as quickly as possible. The benefits of this form of charging are from 10 to 20 miles per hour. [8] DC fast charge is charged in 30 to 60 minutes. If we remember the beginnings of electric cars and charging stations, charging took longer than the duration of driving a car. Today, this is completely different with the help of technologies that are being developed on a daily basis. There are following types of charging: standard charging, semi-fast charging and fast charging. Nemry and Brons (2010) each of these types of charging has its own characteristics. Thus, standard charging requires infrastructure containing cable from electricity charger to the vehicle, semi-fast charger requires stationary charger as well as fast charger. We can't forget the wireless charging type for electric and hybrid cars that exist, however, it is still more in development than in use. [9]

In addition to the mentioned technologies, there are also payment technologies that are still under development in the Republic of Croatia, that is, they are not yet deployed in the Republic of Croatia. The cost of a charging at home in the United Kingdom is around €9.17 when it comes to a 60 kWh car with a range of 200 miles. Average domestic consumption is around 14p per kWh. In the United Kingdom, when you want to charge your car in a public place, you have to pay. Charging stations are very often available in supermarket and public parking lots. If the car is to be refuelled as fast as it can, it can be done at petrol stations at a cost of €7.10 for 30 minutes or up to 100 miles. [10] Based on the foregoing, the following conclusion is reached, namely that the 2018 Nissan LEAF car model with a 40 kWh battery and 150 miles range to fully charge will generate a cost of €6.11 which is, 3.7p per mile. At the same time, a Mitsubishi Outlander PHEV (2019) with a 13.8 kWh battery and a 23-mile range will cause a cost of €2.11 or 8.4p per mile. [11] Based on Compare The Market (2020) data, Chile is the country with the lowest car charging cost of €0.06 per kWh, followed by Australia with €6.23 per full battery/tank, while at third place Canada with as much price as Australia. Table 1 shows the Top 10 countries from the lowest to the most expensive price per kWh and full tank. Denmark is considered to be the country where the cost of charging is the most expensive as €0.3 per kWh and €30.26 per full tank. [13] The prices shown in the table are based on a car model with a 100 kWh battery and a range of 259 miles.

In the United Kingdom, by March 2020, 31,460 car charging connectors were recorded, most in London (25.6%), while the lowest in Wales (3.2%). In the past year, over 10,000 outlets in 20 locations have been installed in the United Kingdom. From 2011-2019 in the United Kingdom, there was an increase in the number of fast chargers with over 7,000 installed in 2,157 locations. [13]

Table 1 – Ten countries with the lowest price for electric car charging

	Country	Price per kWh (€)	Price per full battery (€)
1.	Chile	0.06	6.23
2.	Australia	0.10	9.79
3.	Canada	0.10	9.79
4.	Korea	0.11	10.68
5.	Estonia	0.12	11.57
6.	Hungary	0.12	11.57
7.	United States	0.12	11.57
8.	Czech Republic	0.12	12.46
9.	Lithuania	0.12	12.46
10.	Iceland	0.13	13.35

Source: [12]

3. ELECTROMOBILITY IN THE EUROPEAN UNION

There were 134,871 registered electric vehicles (BEVs) in the European Union in 2017, and 155,261 hybrid electric vehicles (PHEVs), while in 2010 there were only 1,410 registered electric vehicles and 2 hybrid electric vehicles. Until 2012, electric vehicles predominated in the market, while from 2012 to 2015, hybrid electric vehicles were the best-selling ones. [13] In the case of electric buses, the largest number of such buses is in the United Kingdom (200), while the smallest number is in Bulgaria (0). The Netherlands has slightly fewer electric buses than the United Kingdom, followed by Belgium (approx. 145), Germany (90), Austria (70) and Poland (65). [14]

Germany has set a goal of having 1,000,000 electric vehicles on the streets by 2020. Specifically, Germans believe that electromobility is the key to technology for replacing fossil fuels with new technologies, e.g. electric vehicles. They consider the battery in an electric vehicle a key element to increase the number of purchases and use of electric vehicles. [15]

Germany has set itself the task of making the most of its positive environmental impact through the use of modern technologies, primarily in public transport and then in private. The electricity needed for all means of transport would be provided from renewable energy sources. At the same time, Germany wants to become the market leader in electromobility, and given that the German energy system is one of the most efficient in the world, it has a large space for electromobility manoeuvre. [15]

Sweden is one of the few countries in the European Union to have its own Centre for Electromobility which is responsible for monitoring the development of electromobility in Sweden, as well as implementation of the research. Of course, research is from the field of electromobility, but also from stored energy, interaction between drivers and the network, but particular emphasis is placed on electromobility in society. [16]

According to the European Environment Agency, as of the end of 2019, the largest number of BEV vehicles was in Germany, accounting for 34,280 vehicles. Germany was followed by the United Kingdom, which had more PHEV vehicles than Germany, with 44,334 thousand. Table 1 shows data on electric vehicles in EU countries that had more than 4,000 registered vehicles in 2018. While Table 2 shows an overview by type of vehicle in 2018 for EU-28. Table 2 shows that the largest share of electric and hybrid vehicles is in 2018, with 294,352 vehicles operating, which is 293,618 more than in 2010 (+ 99.75%). [17]

Table 2 – Number of BEVs and PHEVs in individual EU countries

Country	BEV	PHEV
Germany	34,280	26,562
United Kingdom	15,430	44,334
France	32,654	13,900
Sweden	7,041	21,754
Netherlands	24,185	3,665
Belgium	3,587	9,758
Spain	5,896	5,076
Austria	6,718	2,254
Portugal	4,429	3,920
Finland	773	4,845
Italy	4,963	402
Denmark	1,484	3,182

Source: [17]

Some countries in the European Union have introduced incentives to buy electric vehicles and install electric chargers, some of them are Denmark, Belgium, Sweden, United Kingdom, Spain, Italy, France, Finland, Norway ect. Belgium offers incentives of up to 30% of the purchase price of an electric vehicle, which is up to a maximum of €3,500 or €4,000, depending on which province you live

in. In addition to the usual cash incentives, Belgium also provides tax breaks when it comes to vehicle registration or when the car is fully electric then the owners are 100% exempt from property tax in the province of Flanders. Businesses operating in the corporate income tax system can achieve annual savings of up to €14,375.00. [18]

Denmark has a slightly different approach, it gives its citizens tax benefits, and so tax deduction for registration was introduced in 2017 for electric vehicles. Property taxes are kept to a minimum and paid according to fuel consumption and weight. In addition, Denmark has one local benefit that allows anyone with electric cars to park for free up to 5,000 DKK, and affordable tariffs for charging electric buses. [18]

Incentives of up to €6,000 is provided by France for vehicles emitting 20g CO2/km or less. Of course, if one owns a car older than 2001 with a diesel engine or since 1997 with a gasoline engine, the state will support up to €5,000 to buy a new environmentally friendly vehicle. France, just like Denmark and Belgium, gives tax breaks to all those who have electric vehicles, and the amount of tax relief depends on the region in which the entrepreneur is located. However, compared to the previous two countries, France is giving support to municipalities and cities that set up electrical infrastructure and the maximum amount of support may be €2,160 per charging station. [18]

Table 3 – Number of electric vehicles in the EU 28 from 2010 to 2018

Year	Battery electric	Electric plug-in	Total vehicles	Sher of electric vehicles
2010	734	0	13,181,154	0.006
2011	7,759	0	12,829,535	0.06
2012	13,986	9,000	12,031,054	0.191
2013	24,175	31,167	11,868,737	0.466
2014	37,855	68,180	12,541,978	0.845
2015	56,756	103,553	13,770,826	1.074
2016	64,316	93,707	14,714,327	1.164
2017	97,143	126,898	15,129,296	1.481
2018	148,454	145,898	14,701,753	2.002

Source: [17]

The incentives that the Swedish state gives its residents are tax cuts for electric vehicles and an increase for petrol and diesel fuel. Possibility of exemption of a five-year vehicle tax and incentives of up to €6,000 for the purchase of electric vehicles or plug-in hybrid vehicles. As an additional incentive, citizens and companies with electric vehicles will receive free parking, and there is a "Charge at Home" program that encourages individuals to buy home chargers and thus receive support of €960 for hardware. [18]

Germany offers its residents the option of buying electric vehicles with a subsidy of €4,000 for fully electric vehicles and up to €3,000 for hybrid vehicles, however, it is projected to increase to €6,000 in 2020 for electric vehicles and to €5,000 for hybrid vehicles. For all vehicles purchased and registered between 2011 and 2025, owners don't have to pay tax for 10 years. Local incentives provided by Germany for all electric car owners are free parking, reservation of parking space and use of the bus lane. [18]

4. ELECTROMOBILITY IN THE REPUBLIC OF CROATIA

At the end of 2018, the implementation of the Easte project was completed, with a total value of €5,05 million, and this project ensured the procurement of installations and commissioning of 27 multi-standard rapid charging stations, procurement, installations and commissioning of ICT solutions for charging station management, billing system, establishment of roaming platform with 11 countries, building a respectable competitive advantage, localization of EU best practices, etc.

BigEVdata and NEXT-E are projects that are currently implementing in the Republic of Croatia. The BigEVdata project, with a value of 7,684,366.57 HRK, was funded by the European Union from the IRI Fund, with a project duration till February 2021. The project will provide the following infrastructure: 12 rapid charging stations (50 kW), 10 fast charging stations (22 kW), 10 wireless charging stations and 10 wallbox charging stations. [19]

The NEXT-E project runs until the end of 2020 and has a total value of €18,84 million, with activities related to: support for national e-mobility plans and EV expansion strategies in the region, development of sustainable vehicle charging solutions, evaluation integrating renewable energy, introducing innovative business processes and consumer packages to reduce oil dependency, reducing CO2 emissions in Europe, establishing cooperation with transport ministries, the European Commission and policymakers to ensure the implementation of what is learned with a view to introducing pan-cohesion charging infrastructure EVs, presenting best strategies and approaches to infrastructure and service utilization, supporting the spread of EV use in the region - bringing Western and Pan-Cohesion Europe together to provide a seamless and enjoyable long-distance, fully electric-based driving experience, conducting network plans and ICT studies to enable a pilot project to set up fast and ultra-fast charging stations in two phases which will result in a pan-cohesion plan and a guide for the widespread use of electric vehicles. [19] According to the latest data from March 2020, only 730 fully electric vehicles are registered in Croatia, while in Norway there are as many as 215,000, which is a huge difference, thus indicating that the number of electric vehicles is completely negligible compared to most EU countries, and which is evident in chapter 3. When it comes to hybrid vehicles, there are 5,899 registered in the Republic of Croatia, and 207,000 in Norway. In relation to motor vehicles, hybrid and electric vehicles in the Republic of Croatia account for 0.38%, which is a negligible percentage in relation to the total number of vehicles. [20] Table 4 shows the number of vehicles per drive in the period from 2010 to 2019 in the Republic of Croatia. The table shows that the number of electric, hybrid and hybrid vehicles with external charging, for which records have been kept only since 2013, is growing every year. Thus, it can be concluded that although very slowly in the Republic of Croatia, the number of more environmentally friendly vehicles is growing every year. According to the data in the table, the Republic of Croatia has 6,629 electric and hybrid vehicles (including externally charged vehicles). [21] At the end of 2019, there were 272 registered e-charger locations in Croatia with 693 connections, which at that time was almost like electric cars. [22]

Table 4 – The number of vehicles per drive in the period from 2010 to 2019 in the Republic of Croatia

Type of drive	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
ELECTRIC drive	3	7	13	24	74	156	224	277	452	730
HYBRID drive - total	211	280	354	446	873	1,347	1,843	2,500	3,552	5,547
HYBRID drive – externally charged hybrid cehicle	0	0	0	12	33	70	96	132	230	352

Source: [21]

There is also a MULTI-E project which should be implemented in four European countries in Croatia, Slovakia, Italy and Slovenia. The value of the project is €12,9 million funded by the Connecting Europe Facility (CEF). The project will invest in the transport infrastructure in these countries with the purpose of electrification of urban and regional bus lines. Also, the project will fund 16 CNG chargers, 24 fast chargers, 349 AC chargers, 5 charging centres and 6 bus charging stations. [22]

5. ELECTRIC MOBILITY IN THE CITY OF KOPRIVNICA

Since 2014, the City of Koprivnica has been intensively working on the development of electromobility, but also on raising citizen's awareness of the environmental impact of CO2. There are three aspects through which the City of Koprivnica (hereafter referred to as the City) develops

electromobility: electric buses, electric cars and electric bicycles [23]. Everything started in the City with the implementation of the CIVITAS DYN@MO project, which is also the largest and most demanding project in which the City participated as a partner with its local businesses and had a budget of 920,000.00 €. The project included six measures [23]: public transport planning, a sustainable urban transport plan, low-emission public transport, zero CO2 campus, development of a sustainable transport curriculum for the University of Koprivnica, electric city car sharing program.

One of the main problems and also the reasons why the City decided to participate in the project is the problem with the efficiency of the use of transport and vehicles. Through the project, 7 innovative and energy efficient vehicles were purchased and infrastructure was set up to charge them. At the same time, in order to achieve additional cost optimization, the City has developed a car-sharing system that optimizes the use of purchased vehicles and aims to increase the number of electric vehicles [23]. Of course, in cooperation with the HEP d.d. (Croatian electricity company) a system of five high-speed electric chargers (ELANs) is built and established to allow faster and more efficient charging of electric vehicles. That this was a good move is indicative of a 25% reduction in CO2 emissions and a reduction in the operating costs of the City fleet by 28%. The intensive promotion of the measure has contributed to the continued increase in the use of electric vehicles by the citizens of that industry [23]. In addition to the aforementioned project, there is a project from the University North called Low Carb which target was to improve, plan and manage sustainable urban mobility while transforming the hinterland and urban areas into functional urban areas. The project also emphasized the role of public transport in supporting sustainable and efficient mobility systems, including electromobility. As a result of the project, a multimodal site will be created that combines renewable energy in the form of a photovoltaic system, on-campus e-vehicle and e-bike charging stations and a battery tank. So far, 9 electric charging stations have been installed in the town of Koprivnica, and so far, none of them has been charging any cost for charging. [23]

In addition to purchasing electric cars, electric bikes (e-bikes) and terminals were installed, which can accommodate 10 electric bikes. A total of 60 public bicycles (Bicko system) and 10 e-bikes have been erected and funded through the CIVITAS DYN@MO project. Within the Bicko system, there are seven terminals in the city area where e-bikes can be taken or dropped off.



Figure 1 – E-terminal, e-bike and e-bus in City of Koprivnica
Source: [23], photo: Ante Klečina (2015)

Another aspect through which the City has invested in the development of electromobility is electric buses. The types of electric buses that have been purchased have the capacity to carry up to 12 passengers and range from 90 to 130 kilometres, while the power of the electric motors is 100 kW and the speed is limited to 90 km/h. Public transport by electric buses was also introduced through the CIVITAS DYN@MO project, called BusKo. The introduction of the e-bus enabled urban and suburban transport, which is also free of charge and is used year after year by an increasing number of citizens, and by February 2019 3,140 persons were transported. [24]

Electric charging stations in the city of Koprivnica in 2017, 2018 and 2019 were installed at nine locations: Mosna 15, Zrinski trg 1, Trg dr. Žarka Dolinara 1, Ulica Ante Starčevića 32, Ulica Antuna Mihanovića, Trg Eugen Kumičića on Trg kralja Zvonimira and at the Cerina pool. According to the data from 2017 and 2018, it is visible that the consumption of electricity at lower and higher tariffs at the following charging stations in the city of Koprivnica is growing or falling (chart 1) [24]:

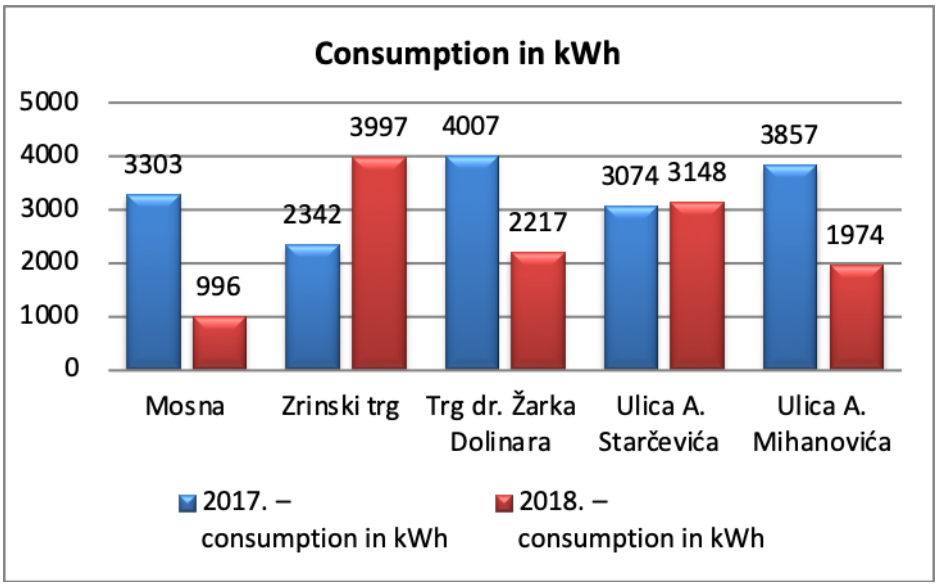


Chart 1 – Consumption in kWh in the City of Koprivnica
Source: [23]

The graph shows that in certain locations in 2018 there was an increase in electricity consumption at electric charging stations, while in some there was a significant decrease. Looking at the total, we can see that in 2018 there was a drop of 4,251 kWh which does not give a positive picture of electromobility in the city itself. Graphs 2 and 3 show how the higher and lower tariff consumption used to be. [22] The graph shows that the higher tariff consumption was significantly higher than the lower tariff consumption, which is expected given that consumption at a higher tariff takes place in the period from 07:00 to 21:00 in winter and in summer from 08:00 to 22:00, and this is also the period in which most vehicles move at the mentioned locations.

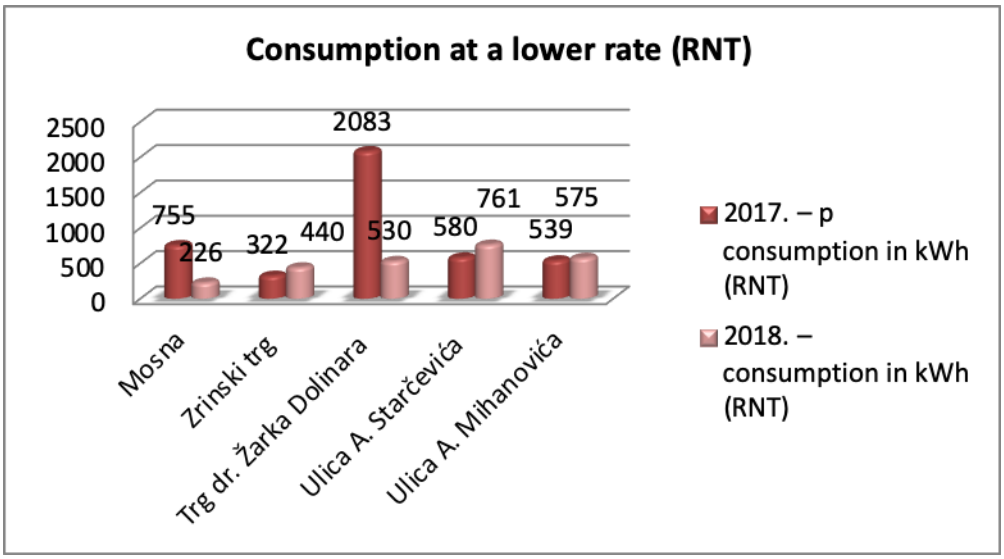


Chart 2 – Consumption at a lower rate in the City of Koprivnica
Source: [23]

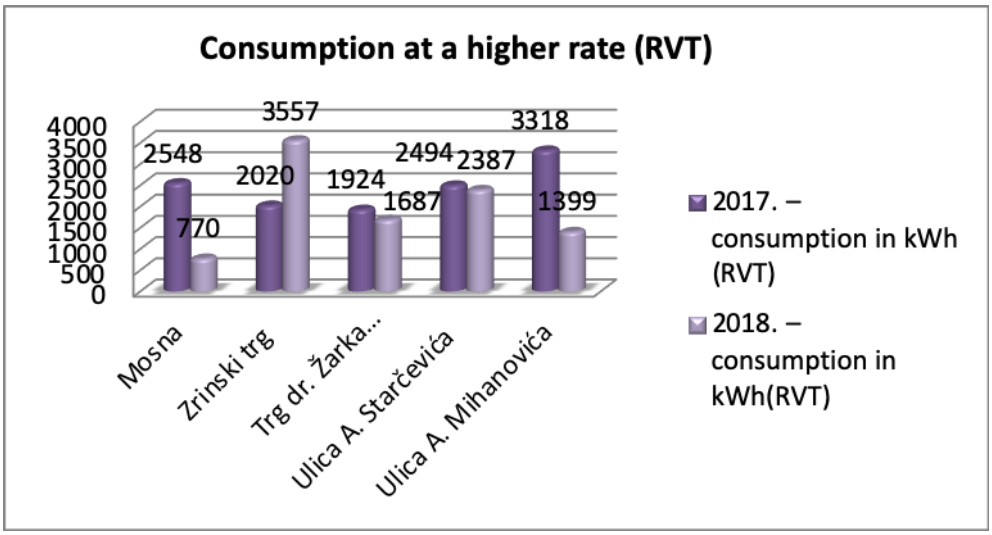


Chart 3 – Consumption at the higher rate in the City of Koprivnica
Source: [23]

With all the aforementioned electric vehicles, the City of Koprivnica has significantly reduced the cost of public transport, and has also provided free bus for urban and suburban services with BusKo. This is certainly not enough and a good example from Switzerland can be used to improve the electric public transportation system. In Switzerland, a project is currently underway to electrify the entire Lake Zurich bus fleet. [25] In order to carry out this project, it was necessary to study the analysis of transit tickets and to develop a plan for the gradual procurement of electrified vehicles, e.g. e-buses. The plan is to electrify the entire fleet of buses by 2035, as electric buses are significantly better than those with a diesel engine. Specifically, the challenges that can arise at any time, or caused by the e-bus itself, such as shorter driving distances, the cost of e-vehicle procurement and charging stations, are still high, very fast technological developments that are difficult to keep track of, long delivery times for e-buses etc. It is precisely with the aforementioned challenges that the public transport company in Zurich also faces. [25] Certainly, if the City of Koprivnica was to embark on such a challenge, it would be necessary to check whether it was feasible at all before embarking on it. It is important to question whether it will be possible to map existing daily routes when the bus fleet is electrified and what the demand for public transport will be. In order not to miss completely. Ultimately, if the City of Koprivnica wants to become as sustainable and environmentally friendly as possible, it is recommended that a strategy be developed that will cover electric vehicles or the development of electromobility in the city.

6. CONCLUSION

This paper provides an overview of existing technologies in the field of electromobility and the situation in the European Union, the Republic of Croatia, and in particular in the city of Koprivnica. The paper deals with several countries that belong to the European Union and have developed electromobility. The general conclusion is that, for now, there is still not enough primarily electric and then hybrid vehicles on the streets if it is to have an impact on sustainable development, especially on the environmental component, but on the development of electromobility as well. Coordinated measures need to be taken to increase the percentage of electric vehicles, whether electric bikes, electric buses, electric cars, etc.

The paper also presents a positive example of the development of electromobility in Switzerland, which can be applied in many other cities or help create new ways to raise the level of use of electric vehicles. In addition to Switzerland, there is Sweden, which has its own electromobility centre, which can also be used as a good example not only for the city of Koprivnica but also for other cities in the Republic of Croatia and the world.

Some other EU countries (Denmark, Germany, etc.) are mentioned in the paper, which have "soft activity", which is incentive measures for the purchase of electric vehicles and a charging station. Of course, we should not forget that the Republic of Croatia has them, but to a lesser extent than the other countries mentioned. The City of Koprivnica still lacks such incentive measures, and the measures mentioned in this paper can serve as an example for creating ownership.

REFERENCES

[1] Altenburg T, Schamp E, W., Chaudhary A. The emergence of electromobility: Comparing technological pathways in France, Germany, China and India. [Internet]. 2015 Oct Available from: https://academic.oup.com/spp/article/43/4/464/2514627 [Accessed 24th March 2020]

[2] Chalmers. System perspectives on Electromobility. Göteborg: Chalmers University of Technology; 2014.

[3] Auvinen H, Järvi T, Kloetzke M, Kugler U, Bühne J, Heinl F, Kurte J, Esser K. Electromobility Scenarios: Research Findings to Inform Policy. Transportation Research Arena. 2016. doi: https://doi.org/10.1016/j.trpro.2016.05.346

[4] Ayeridis, G. Creating the cleaning Energy Economy; Analysis of the Electric Vehicle Industy. International Economic development Council [Internet]. 2013 Available on: https://www.iedconline.org/clientuploads/Downloads/edrp/IEDC_Electric_Vehicle_Industry.pdf

[5] European Commision. White Paper. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. Brussels. 2011

[6] National Research Council. Overcoming Barriers to Deployment of Plug-in Electric Vehicles. The National Academies Press. 2015. doi: https://doi.org/10.17226/21725

[7] ChargeHub. 2020 Guide On How To Charge Your Electric Car With Charging Stations. Available from: https://chargehub.com/en/electric-car-charging-guide.html [Accessed 24th March 2020].

[8] Drive electric Vermont. Types Of Charging. Available from: https://www.driveelectricvt.com/charging-stations/types-of-charging [Accessed 24th March 2020].

[9] Nemry, F., Brons, M. Plug-in Hybrid and Battery Electric Vehicles. Market penetration scenarios of electric drive vehicles, JRC Tehnical Notes. 2010

[10] Banasl P. Charging of Electric Vehicles: Technology and Policy Implications. Jorunal of Science Policy & Governance. [Internet] 2015 Feb Available from: https://issuu.com/jofspg/docs/bansal_new_ta3_1.2.2015_lb [Accessed 24th March 2020]

[11] Pod Point. Cost of Charging an electric car. Available on: https://pod-point.com/guides/driver/cost-of-charging-electric-car [24th March 2020].

[12] Compare The Market. Globaly Charged. Available from: https://www.comparethemarket.com/car-insurance/content/cost-of-charging-an-electric-car-globally/ [20th March 2020]

[13] Zap-Map. Charging point statistics 2020. Available from: https://www.zap-map.com/statistics/#location [Accessed 24th March 2020].

[14] Tsakalidis, A., Thiel, C. Electric vehicles in Europe from 2010 to 2017: is full-scale commercialisation beginning?, An overview of the evolution of electric vehicles in Europe, JRC Science for Policy report. 2018

[15] Germany Trade & Invest. Electromobility in Germany: Vision 2020 and Beyond. 2015/16. Available on: http://v2city-expertgroup.eu/wp-content/uploads/2016/02/electromobility-in-germany-vision-2020-and-beyond-en.pdf [Accessed 26th March 2020]

[16] Swedis Electromobility Centre. Available on: http://emobilitycentre.se/en/forskning/ [Accessed 26th March 2020]

[17] European Environment Agency. Electric vehicles as a proportion of the total fleet. Available on: https://www.eea.europa.eu/data-and-maps/indicators/proportion-of-vehicle-fleet-meeting-4/assessment-4 [Accessed 27th March 2020]

[18] Wallbox. EV and EV Charger Incentives in Europe: A Complete Guide for Businesses and Individuals. Available on: https://wallbox.com/en_us/guide-to-ev-incentives-europe?fbclid=IwAR1AugUdBt8bsH5DQ6wvilDgxqdqVN27NGS1WcMFUhrLR6fkoRb87CR9S-s [Accessed 26th April 2020]
[19] NEXT-E. About. Available on: https://next-e.eu/ [Accessed 27th March 2020]
[20] Večernji list. Hrvatska ima 730, a Norveška čak 215.000 električnih automobila. Available on: https://www.vecernji.hr/auti/hrvatska-ima-730-a-norveska-cak-215-000-elektricnih-automobila-1384622 [28th June 2020]
[21] Croatian Vehicle Center, Available on: https://cvh.hr/tehnicki-pregled/statistika/ [Accessed 30th June 2020]
[22] Jutarnji list. Kraj jedne ere: Do kraja godine sve električne punionice naplaćivat će punjenje automobila. Available on: https://novac.jutarnji.hr/aktualno/kraj-jedne-ere-do-kraja-godine-sve-elektricne-punionice-naplacivat-ce-punjenje-automobila/8827031/ [Accessed 30th June 2020]
[23] Balkan Green Energy News. EU proposes € 12.9 million in support for a project in the e-mobility sector. Available on: https://balkangreenenergynews.com/rs/eu-predlozila-grant-od-129-miliona-evra-za-projekat-u-sektoru-e-mobilnosti/ [26th March 2020]
[24] Jedvaj D. Development of electromobility in Koprivnica. University North, University Center Koprivnica. 2019. Republic of Croatia.
[25] Jutarnji list. A real cycling oasis opened in Koprivnica. [image on the Internet]. 2014 Sept 18 [Cited 2020 Mar 24]. Available from: https://www.jutarnji.hr/incoming/otvorena-prava-biciklisticka-oaza-u-koprivnici/700255/
[26] EBP, VZO. Electric bus strategy for rural transportation (EBP). Lake Zurich and Oberland Transport Company (VZO). 2020

MIROSLAV DRLJAČA, Ph.D.[1]
IAQ-Associate Academician
(Corresponding author)
E-mail: mdrljaca@zagreb-airport.hr
PATRICIA REPNJAK[2]
E-mail: parepnjak@unin.hr
[1] Zagreb Airport, Ltd., Zagreb, Croatia &
University North, Varaždin-Koprivnica, Croatia
[2] University North, Varaždin-Koprivnica, Croatia

SUPPLY CHAINS IN THE CONTEXT OF THE COVID-19

ABSTRACT

Crown virus pandemic (COVID-19) in 2019/2020 is a new respiratory disease. More than one pandemic in recent history has affected the global economy. In addition to the fight for human health, all countries are taking action to mitigate the negative economic consequences. Within this framework, a number of measures have been taken to reduce disruption to commodity flows and Supply Chains (SC), as well as to the provision of services. The SC represents the flow of goods, services and information from raw material suppliers, manufacturers, distributors, retailers to the end-customers. There is a main problem in how the end-customer comes to the consumable product, since the SC is unable to provide its complete flow. All emergent shapes of the SCs: complete, short or reversible, undergo some transformation and adjustment to new conditions. In this paper, the authors research the changing context in which SCs take place, the limitations of particular emergent SCs shapes, and the measures and ways to adapt them in complex pandemic context. In the paper, authors, by applying scientific methods, research the SCs adjustment in the context of a pandemic as a main output of this research.

KEY WORDS

supply chain; pandemic; COVID-19; limitation; adaptation;

1. INTRODUCTION

SC has the focus on the flow of goods. In addition to commodity flow SC also includes the flow of services and information. SC is a dynamic phenomenon. While traditional logistics is primarily based on warehousing and transportation activities, the SC also implies the flow of information between the many SC participants. Therefore, there is a need to talk about the flow of goods and information among SC participants, namely suppliers of raw materials, transport organizations, producers or service providers, product distributors, retailers that enable the product to reach the end-customer and become a consumer. The same principles apply to services. [1]

The SC can be defined as a type of a dynamic system in which information, money and products are constantly exchanged among the chain participants. [2]

SC defined also as set of entities involved directly in the upstream and downstream of products, services, finances and information from source to customer. [3]

The SC can be considered a network of structures, distribution, transforming of procured materials into semi-products or final products for end-customer. [4]

The SC can also be described as "... a series of activities and organizations through which materials pass during their journey from initial suppliers to end-customer". [5]

In order to respond to rapidly changing manufacturing environment and market, SC must be flexible, adaptable and reconfigurable. The potentials of changes in organization structure caused by changes in businesses must be taken into consideration during structural modelling of the SC. [6]

Consequently, Supply Chain Management (SCM) ‘‘is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders’’. [7]

SCM has also inspired a new Council of Logistics Management (CLM) definition of logistics as ‘‘that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers’ requirements”. [8]

Can be concluded that the SC is a complex system of integration of many participants, such as suppliers, producers, distributors and retailers for the purpose of production and distribution of goods/services as a results of the process, in the right quantities, in the right place and at the right time, all with the aim to balance supply and demand, as one of the fundamental economic laws.

2. METHODS

The research question in this paper is in how the end-customer comes to the consumable product/service, since the SC is unable to provide its complete flow. All emergent shapes of the SC: complete, short or reversible, undergo some transformation and adjustment to new conditions. In this paper, the authors research the changing context in which SCs take place, the limitations of particular emergent SC shapes, and the measures and ways to adapt them in complex pandemic context. The success of adaptation depends to a large extent on the stability of the supply of goods and services globally. In researching this phenomenon, the authors approach the research of the COVID-19 context that caused the limitations of the normal unfolding of SCs, and also adjustment to new conditions.

The basic hypothesis of this research is: Even in a pandemic, SCs must not be completely interrupted because their interruption would cause unprecedented economic, social and political consequences. Despite the limitations, measures are being taken at national and global level to allow SCs to take place. The SCs show a high degree of flexibility and elasticity.

In the paper, the authors have applied general and special scientific methods of cognition. From the general scientific methods of cognition, the system theory method is applied to understanding the context and its impact on the SCs and its very complex structure.

The statistical method was applied to statistical data presentation and their interpretation.

The comparative method was applied in the research and comparison of limitations and adaptation to new conditions of different emergent shapes of the SC: complete, short or reversible.

Of the special scientific methods of cognition an analysis was used to research the limitations of the SCs and the ways and / or measures to adapt to new circumstances.

The deduction method was applied when deciding on the impact of the context that represents the economic environment in which emergent shapes of the SCs take place.

3. COVID-19 CONTEXT

Crown virus pandemic (COVID-19) in 2019/2020 is a new respiratory disease. The disease first appeared in late December 2019 in Wuhan, China's Hubei province. In January 2020, it developed into an epidemic in the People's Republic of China and spread worldwide. It was triggered by the hitherto unknown SARS-CoV-2 virus. To prevent worldwide spread, the World Health Organization (WHO) declared an international emergency on January 30, 2020, but as early as March 11, 2020, the WHO

officially declared a pandemic due to the rapid spread of the virus worldwide and high risk. Twenty days after the global pandemic is officially declared, all EU / EEA countries and more than 150 countries worldwide are affected. [9]

Countries around the world are increasingly accepting increasing security measures: including closing borders, closing airports, imposing travel restrictions, restricting movement, self-isolation or quarantine of the diseased. [10] The outbreak of COVID-19 affects all segments of society and is especially harmful to members of the most vulnerable social groups such as the elderly, chronically ill from other diseases, etc. [11] The pandemic has also raised the great dilemma of opting for a strategy to protect the lives of citizens or protect the economy from the severe economic crisis that will occur to halt production, disrupt SCs, and absent tourism trips globally. Due to the new economic situation, the COVID Global Action Platform was created to bring together the business community for collective action, protect people's lives and facilitate business continuity, and mobilize support to respond to COVID-19. [12]

At the time of writing there are 11,500,302 patients worldwide in 216 countries, 535,759 people have died. [13] The number of patients is still increasing, as is the number of deaths and it is difficult to predict the final consequences.

Based on the World Bank analysis the significant potential impact of COVID-19 is assessed on Gross Domestic Product (GDP) and trade the shock as underutilization of labour and capital, an increase in international trade costs, a drop in travel services, and a redirection of demand away from activities that require proximity between people. Global GDP is expected to decline by 2.09%, while developing countries' GDP is expected to decline by 2.49% and high-income countries by 1.84%, as presented in Table 1. The declines are 3,86% below the benchmark for the world, in an amplified pandemic scenario in which containment is assumed to take longer and which now seems more likely. [14]

Table 1 – GDP implications of various scenarios - cumulative impacts (% deviations from the benchmark)

Country/Region	Global pandemic	Amplified global pandemic
China	-3.69	-4.31
Hong Kong SAR, China	-2.31	-4.82
Canada	-1.57	-3.18
European Union	-1.85	-3.85
Japan	-2.23	-4.57
United States	-1.67	-3.40
Middle East & North Africa	-1.38	-2.95
Russian Federation	-1.94	-3.99
Developing countries	-2.49	-4.00
High-income countries	-1.84	-3.77
World Total	-2.09	-3.86

Source: [14]

The biggest GDP losses under the global pandemic scenario are expected in East Asia and Pacific (EAP) countries due to their relatively deep integration through trade and direct impact on tourism. The biggest negative shock is recorded in the output of domestic services affected by the pandemic, as well as in traded tourist services. High-income countries could see significant losses of GDP, with the estimated loss in the European Union -3.85%, Japan -4.57%, the United States -3.40% and Canada -3.18%. [15]

GDP decline in Croatia will be larger in 2020 than in 2009. According to the projections of the Government of the Republic of Croatia, GDP will fall by 9.5% in 2020, instead of the planned real growth of 2.5%. The latest EU estimates predict a 10.8% drop in Croatia's GDP in 2020, the third largest drop among EU member states. Such a significant decline is a consequence of the structure of the Croatian economy, with tourism contributing almost 20% to GDP, and this sector of the economy, due to restrictions, suffers the greatest damage on a global scale. The impact is big and there is no world economy that can handle it without consequences.

A big negative impact of amplified global pandemic expected in agriculture, natural resources, trade, manufacturing, transport and services, as presented in Table 2.

As presented in Table 2, the highest decline is expected in Traded tourist services, which is -9.26% globally. An even greater decline is expected in the United States -11.27%, Middle East & North Africa -10.03%, Russian Federation -9.62%, High-income countries -9.60%, etc. Significant decline is realized in all countries and regions and with Domestic services, too.

Table 2 – Output implications of amplified global pandemic – cumulative impacts (% deviations from the benchmark)

Country/Region	Agri-culture	Natural resources	Manufac-turing	Service	Domestic services	Traded tourist services	Total
China	-3.12	-1.08	-3.61	-3.67	-4.85	-4.64	-3.54
Hong Kong SAR, China	-1.29	-3.24	-1.33	-6.06	-8.46	-9.23	-5.35
Canada	-4.30	-1.10	-3.25	-3.02	-8.95	-9.16	-2.96
European Union	-3.00	-1.02	-2.89	-4.02	-9.04	-9.06	-3.65
Japan	-4.71	-2.85	-2.77	-4.62	-8.75	-8.35	-3.98
United States	-3.60	-0.21	-2.45	-3.80	-9.99	-11.27	-3.38
Middle East & North Africa	-2.76	-1.65	-2.67	-3.02	-9.11	-10.03	-2.65
Russian Federation	-3.00	-2.19	-3.73	-3.86	-8.72	-9.62	-3.58
Developing countries	-2.90	-1.42	-3.47	-3.87	-7.98	-8.63	-3.51
High-income countries	-3.49	-0.95	-2.78	-4.00	-9.20	-9.60	-3.59
World Total	-3.04	-1.29	-3.13	-3.95	-8.77	-9.26	-3.56

Source: [14]

After a decade of uninterrupted growth, the global economy came to a sudden halt because of the COVID-19 pandemic. The question now is not whether there will be a global recession but how deep it will be and how quickly countries can overcome the health crisis and pave the way for economic recovery.

The answers to these questions will be particularly important for developing economies, which are likely to be hit hardest by the crisis. These economies would have been hard pressed, in short, to mount an effective response even to a moderate global downturn. What they got instead was a simultaneous health and economic calamity without parallel in modern times.

In a nutshell, it assumes that everything goes right. Even under these assumptions, the global economy would fall into a deep recession in 2020 and output of developing economies would shrink by roughly 2%. This would not just mark the first contraction in these economies since 1960 but would also imply an astonishingly weak growth outcome relative to their average growth of 4.6% over the past sixty years.

Growth outcomes could be considerably worse if just one assumption fails to materialize. Even if three months of mitigation measures prove effective in halting the pandemic, investors and households could remain skittish or local or global SCs may not be restored. [16] The world recognized the need to close ranks across the world, not just governments and international institutions but also private creditors and businesses.

4. SUPPLY CHAIN LIMITATIONS AND ADJUSTMENTS

One of the most important measures for the functioning of the economy in the context of the COVID-19 pandemic was, despite the necessary constraints, to ensure that SCs take place at the national, regional and global levels. The European Commission has issued guidelines for Member States with border migration management measures in the context of the COVID-19 epidemic. Their goal is to protect the health of citizens, ensure that they have to be treated appropriately, and ensure that basic goods and services are accessible through the running of SCs. [17]

Food supply chains are the lifeline for human existence on the planet. Whether these chains are local or international, the availability of food at the right time, right quality and right quantity is paramount. [18]

In this way, it was possible to ensure the distribution of the necessary medical equipment and materials, energy, food and other necessities of life. This prevented the shortage of essential items, inflation, the rise of crime and created the preconditions for focusing on solving the health part of the problem, as well as the assumptions for faster and easier recovery of the economy after the pandemic.

4.1 Complete Supply Chain

Complete Supply Chain (CSC) is a SC that has all the components, from raw materials and raw material suppliers, through production, storage, distribution, retail, to the end-customer. The modern approach of SC does not finish there, but implies feedback and material flow (waste) through selective collection, recycling, and return of recycled waste as raw material to a new production cycle, as presented on Fig. 1. "Waste is no more disposed of uncontrolled in the environment but is recycled. Part of waste that can no longer be recycled is disposed of permanently in a non-hazardous manner, in accordance with the regulations." [19]

In the context of COVID-19, CSC is under difficult conditions due to a number of limitations that have taken effect in almost all countries of the world. Limitations covered all stages of the CSC and manifested themselves in various forms through: difficult raw material procurement, difficult production, stockpiling and lack of storage space, difficult distribution, difficult retail, difficult waste management.

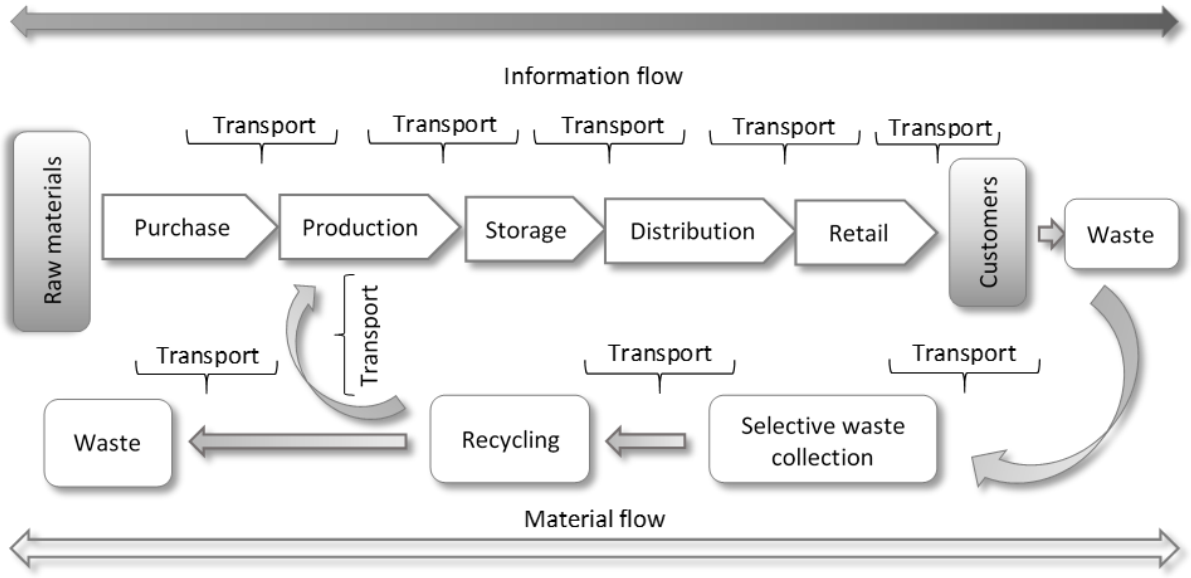


Figure 1 – Complete Supply Chain as a modern approach
Source: [1]

CSC can be discontinued at any time, at any stage of its development, and most often in retail, as one of the first measures in many countries was the closure of shopping malls. No matter what stage of the CSC unfolds, the CSC does not work. The limitations of CSC developments that have occurred globally as a result of COVID-19, as well as the response to these limitations through adjustments, are shown in Table 3.

Table 3 – Limitations and adjustments of CSC in context of COVID-19

Limitations	Adjustments
Difficult procurement of raw materials	
reduced demand	new distribution channels (web sales, delivery, dedicated production)
reduced number of workers	worker protection measures
Difficult production	
difficult procurement of raw materials	decrease in production
reduced number of workers	worker protection measures
production ban	gradual liberalization
conversion of production	dedicated production
reduced number of workers	worker protection measures
Large inventory and lack of storage space	
difficult distribution	agreed procedures
lack of storage space	production reduction, alternative warehouses
rising storage costs	reduced deliveries
Difficult distribution	
closed state borders	interstate agreement
strict sanitary controls at the border	unified simplified procedure
ban on traffic of trucks, aircraft, etc.	convoys of trucks across the country with escorts
self-isolation for drivers	simplification of self-isolation or abolition
reduced number of drivers due to illness	new drivers, higher pay, lower fuel costs
Difficult retail	
retail does not work, no buyers are coming	new distribution channels (e-sales)
limited number of customers	adjustment of working hours, customer protection measures
increased quantity and value of purchase	stock insurance, customer information
limited working hours	better organization, gradual liberalization
Waste management	
difficult selective collection of waste	better organization
difficult transportation	reduction of transport frequency
difficult recycling	better organization
difficult manipulation	better organization
difficult care	better organization
reduced number of workers due to illness	worker protection measures

Source: Authors.

The adjustments are a response to the necessary limitations that had to be introduced to reduce the risk of uncontrolled spread of the infection. The adjustments aim to allow the CSC to unfold as much as possible under the circumstances so that life can also take place in the context of COVID-19.

4.2 Short Supply Chain

Short Supply Chain (SHSC) is a product of the efforts of small businesses, especially family farms, to remain competitive in the market. SHSC is actually an innovation of CSC.There is no clear and simple definition of "local food products" or "short supply chains" that could be applied to a variety of production, processing, distribution and distribution systems associated with local food production systems in the EU Member States. More important than a single definition is that these terms are interpreted in accordance with the area and context in which they are developed.

The definition of SHSC can also be derived from SC definitions. Accepting this approach may be defined as a flow of goods, services and information from the supplier, through the transporter, the manufacturer, the distributor, the retailer to the end-customer, whereby the manufacturer independently carries out the transport and distribution, very often storage, too, of the product to the end-customer and at the distribution and delivery stage sales realizes immediate contact with the customer (Fig. 2). In the EU, SHSC is mainly used in the production of agricultural food products on small and medium-sized farms. The main goal is logistic costs optimization. [1]

Today, it is essential that organizations move towards sustainability. Manufacturing organizations, willingly or not, must be committed to sustainable thinking of the environment because there are drivers in the environment which forces them to adhere to sustainability standards. [20]

This concept is applied in many EU countries, very successfully. About 46,000 or a third of the total number of Austrian small agriculture companies deals with direct sales. Their 11,000 direct sales outstrip more than half of their annual income. Fruit, wine, pork meat and eggs are the most commonly used for SHSCs. They are less used for placement and distribution of milk and meat products from dairy and livestock farms. 5% of the money spent in Spain for food was spent on products from the SHSCs. There are more and more SHSCs in Italy. In 2009, 63,000 producers were included, an increase of 4.7% over 2008, with a total value of EUR 3 billion, an increase of 11%. Of this, 40% refers to the wine sector and 20% to fruits and vegetables. [21]

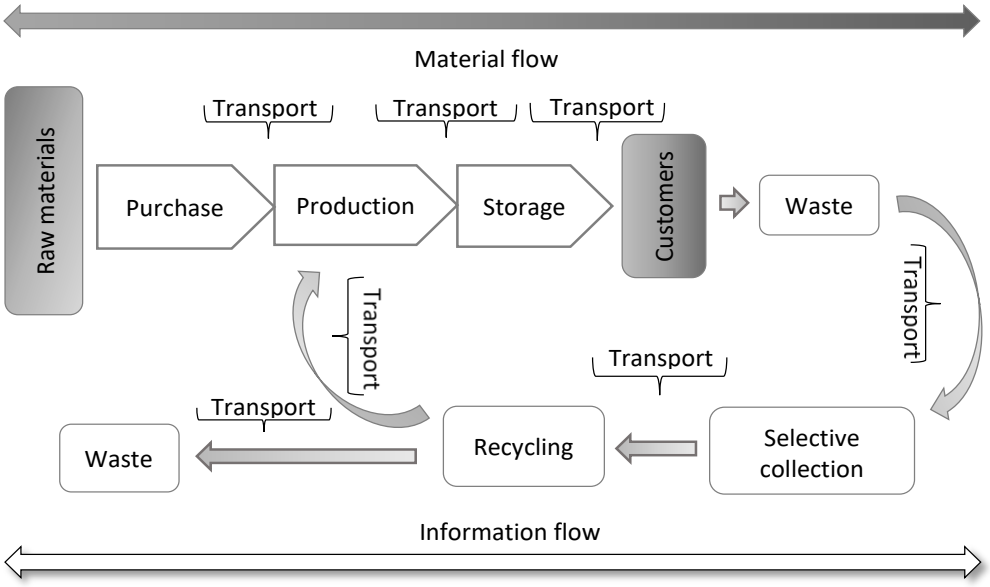


Figure 2 – Short Supply Chain as a modern approach
Source: [1]

Micro, small and medium-sized enterprises and private sector production can play a significant role in the work and development of Clusters and can accelerate economic activities and contribute to the development of the local economy.

In the case of SHSC, there were a number of limitations in the context of COVID-19, as shown in Table 4. They are characteristic of all stages of the SHSC. SHSC is most often interrupted in the distribution stage due to closure, such as green markets, or shopping malls. The problem with small farmers is that agricultural products mature in a very short period of time when they need to be marketed or fail.

In the case of SHSC, it can be talked about in the service sector as well, not just in the producing sector. This example also covers services provided by providers to users such as construction services, postal delivery services, various artisanal maintenance services performed in households by users, etc.

Table 4 – Limitations and adjustments of SHSC in context of COVID-19

Limitations	Adjustments
Difficult procurement of raw materials	
reduced demand	new distribution channels (web sales, delivery, dedicated production)
reduced number of workers	worker protection measures
Difficult production	
difficult procurement of raw materials	decrease in production
shortage of workers	worker protection measures, additional stimulation
production ban	gradual liberalization
conversion of production	dedicated production
reduced number of workers	worker protection measures
Large inventory and lack of storage space	
difficult distribution	agreed procedures
lack of storage space	production reduction, alternative warehouses
limited durability of the product	new distribution channels (web sales, delivery)
rising storage costs	reduced deliveries
Difficult distribution	
restriction of movement in a certain area	movement passes
strict sanitary controls	unified procedure
the manufacturer also distributes	better organization
limit number of customers	new distribution channels (e-sales, delivery, individual customer approach)
Waste management	
difficult selective collection of waste	better organization
difficult transportation	reduction of transport frequency
difficult recycling	better organization
difficult manipulation	better organization
difficult care	better organization
reduced number of workers due to illness	worker protection measures
Difficult to provide services	
reduced demand	diversification of services (emergency services)
reduced number of workers	worker protection measures
services ban	gradual liberalization
restriction of movement in a certain area	movement passes
strict sanitary controls	unified procedure

Source: Authors.

However, flexibility and focus on the end-customer as fundamental features of SHSC resulted in adjustments as shown in Table 4. Some of the innovations are: reorientation to dedicated production to combat COVID-19, new distribution channels such as web sales, changed procedures in coordination with government bodies, etc. The basic task of the adjustments measure is to ensure that the SHSC unfolds in the context of COVID-19 and continue the unfolding of the SHSC to meet the needs of end-customer, to continue its economic activities, and to ensure the survival of producers and service providers in the market.

4.3 Reversible Supply Chain

The Reversible Supply Chain (RVSC) stems from the later shortening of the SHSC. This is due to the fact that there is insufficient labour force to harvest fruits and vegetables that matures in the short term and needs to be put to the end-customer in a time that guarantees high quality. In these circumstances, producers do not deliver the products themselves to customers as with the SHSC but the customers come to the producer and on the spot pick up the products (Fig. 3). In this way the products are of high quality to the customer, and the producer optimizes their logistics costs and remains competitive. [1]

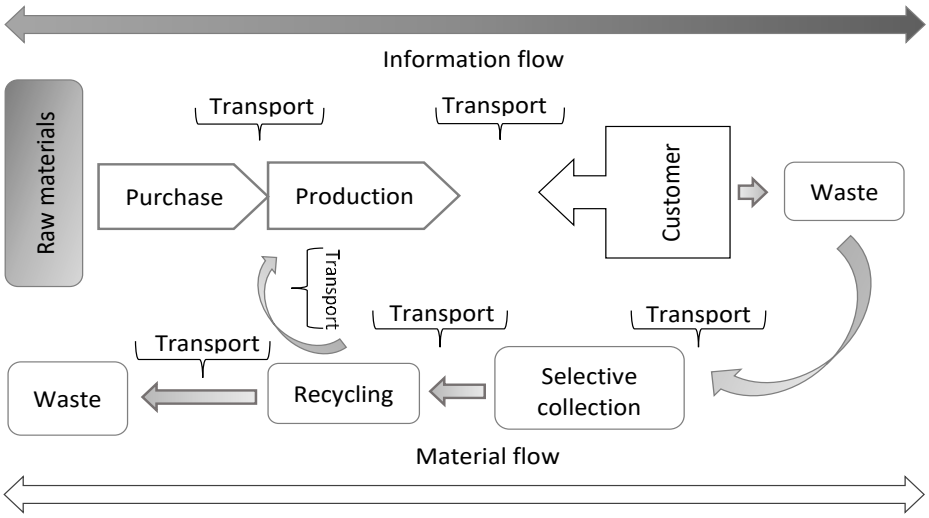


Figure 3 – Reversible Supply Chain as a modern approach
Source: [1]

As with the previous two emergent SC shapes, in the context of COVID-19, constraints also occurred in the unfolding of RVSCs, as shown in Table 5. The limitations are of such a nature that they prevent the RVSC from proceeding as it was before COVID-19. Due to limitations on movement and prohibition of gathering people, it is not possible for customers to come to the producer and harvest or pick up agricultural products or take another product, pay for it and leave it, and subsequently consume it.

Table 5 – Limitations and adjustments of RVSC in context of COVID-19

Limitations	**Adjustments**
Difficult procurement of raw materials	
reduced demand	new distribution channels
reduced number of workers	worker protection measures
Difficult production	
difficult procurement of raw materials	decrease in production
shortage of workers	worker protection measures, additional stimulation
production ban	gradual liberalization
conversion of production	dedicated production
reduced number of workers	worker protection measures
Difficult distribution	
restriction of movement in a certain area	movement passes
difficult distribution	agreed procedures
greater quantity of products in a short time	temporary convenient warehouses
limited durability of the product	new distribution, customer arrival to producer, drive-in,
demand reduction, limited number of customers	reduced deliveries, individual approach to the customer
strict sanitary control	a unified procedure
Waste management	
difficult selective collection of waste	better organization
difficult transportation	reduction of transport frequency
difficult recycling	better organization
difficult manipulation	better organization
difficult care	better organization
reduced number of workers due to illness	worker protection measures
Difficult to provide services	
reduced demand	diversification of services (necessary services)
reduced number of workers	worker protection measures
services ban	new distribution channels (e-school, e-lectures, tv school, e-animation of children, e-citizens), gradual liberalization
restriction of movement in a certain area	movement passes
strict sanitary controls	unified procedure

Source: Authors.

When it comes to manufacturers, many forms of adjustments have been developed, which has enabled end-customers to consume their products. Designing adjustments has also led to certain innovations through the establishment of uniform procedures and individual approach to the customer in order to understand his needs and product requirements as much as possible.

The experiences of some countries, such as Canada, United States, Europe and UK are useful. „An element of food distribution that is undergoing significant change during the COVID-19 pandemic is the expansion of online grocery deliveries. Prior to the pandemic, the Canadian grocery sector had been slower than its counterparts in Europe and the United States to offer online grocery delivery services. Click and collect services, wherein a customer places an online food order for collection at a retail store, have been on the increase, particularly in major urban centers, but home delivery services are considerably less common. Online grocery delivery models encompass two main categories: dedicated online-only services, for example, Ocado in the UK as well as Amazon, and existing grocery retailers with an online delivery option“. [22]

This also applies to services such as services which require close contact (hairdressers, pedicurers, masseurs, etc.). It is the same with the consumption of hotel and other tourist services where customers come to the service provider to consume the service.

„The modern supply chain network has complex structure and dynamic environment. It is very important to evaluate the network robustness, which represents its ability to maintain function and connectedness once some nodes or edges are lost. A resilient supply chain network is able to maintain the delivery of supplies in response to demands under unexpected disruptions.“ [23]

Numerous innovations have also been noted in this area. One of the very pronounced phenomena is „The phenomenon of supply chain elasticity (SCE)“, that is, the transformation of RVSP into SHSC, such as in education, sport training and kindergartens. Prior to the advent of COVID-19, services of all levels of education and childcare were provided in the form of RVSP, as trainees and children (users) came to educational institutions and kindergartens, ie to providers, to consume the service. Due to limitations on movement and the ban on gathering more people, providers (schools, colleges, educational institutions) continued to provide services, but as SHSCs, they also provided distance education services as e-education or education through nationally concessioned TV channels. In the case of kindergarten children, it was about animating children through e-playrooms and the like. In the same way, athletes in many branches of sports have trained. In these examples, it is significant that delivery took place through communication infrastructure such as the Internet, transmitters, receivers, etc. Thus, in the cases of education, sports and animation of kindergarten children, the RVSC experienced a transformation into the SHSC due to limitations and only as such continued to take place.

The results of this research confirm the basic hypothesis that even in a pandemic, SCs must not be completely interrupted because their interruption would cause unprecedented economic, social and political consequences. Despite the limitations, measures are being taken at national and global level to allow SCs to take place. The SCs show a high degree of flexibility and elasticity.

The producer and the end-customer are involved, because the environmental problem is not an individual problem, but every individual (the producer, the end-customer) has the responsibility for environmental protection and should make a contribution within the system that operates in a particular area. [20]

5. CONCLUSION

SC is one of the foundations of any economy and its contribution to economy is crucial. SHSC is the result of the need and effort of small producers, primarily agricultural food products and others, to be competitive on the market with large sales chains. In order to improve their competitiveness, they have to fill several conditions, including the association and implementation of the SHSC strategy. The

RVSC stems from the later shortening of the SHSC. This is due to the fact that there is insufficient labour force to harvest fruits and vegetables that matures in the short term and needs to be put to the end-customer in a time that guarantees high quality. In the context of COVID-19, all three emergent shapes of the SC have been confronted with a number of limitations aimed at stopping the COVID-19 pandemic and preserving human lives. At some point, these limitations completely halted the development of SCs, which diminished the effectiveness of the fight against pandemics, and at the same time threatened the powerful collapse of economies both nationally and globally. Completely stopping SCs was unacceptable to all market participants and threatened shortages, panic, rising crime, inflation and other side effects. Various adjustments have therefore been made to enable SCs to take place, to combat the pandemic and to ensure that the economy operates at a reduced intensity. Designing customizations has also resulted in innovative solutions such as designing new distribution channels and a stronger focus on end-customers. One of the results of these innovations is the phenomenon of transformation of RVSC in to the SHSC in the provision of services at all levels of education, sport training as well as in the animation of kindergarten children. This transformation showed the elasticity and adjustment of the SCs to a particular complex situation, and therefore the authors called „The phenomenon of supply chain elasticity (SCE)".

The problem researched in this paper is the changing context in which SCs take place, the limitations of particular emergent SC shapes, and the measures and ways to adapt them in complex pandemic context. The success of adaptation depends to a large extent on the stability of the supply of goods and services globally.

The result of the research presented in this paper is the SCs adjustment ability to the context such as COVID-19, based on the principles of quality, sustainable development, process and costs optimization, life cycle approach, social responsibility, circular economy, for the benefit of mankind.

Further research will be directed toward new models of adjustment of SCs as context changes. The development of such models is essential for risks management, that is, managing future crises, both nationally and globally.

REFERENCES

[1] Drljača, M. Reversible Supply Chain in function of competitiveness. Production Engineering Archives. Poland. 2019; 22:30-35.
[2] Pupavac D. Cross-docking in Supply Chain. Proceedings of the international scientific conference The Prospect of Trade; 2013 Nov 20-21; Zagreb, Croatia: 2013.
[3] Mentzer JT., DeWitt V, Keebler KS., Min S., Nix NW., Smith, CD., Zacharia, ZG. Defining Supply Chain Management. Journal of Business Logistics. 2001; 22(2):1-25.
[4] Sharma KS., Bhat A. Supply chain risk management dimensions in Indian automobile industry: A cluster analysis approach. Benchmarking: An International Journal. 2014;21(6):1023-1040.
[5] Monczka RM, Handfield RB, Giunipero LC, Patterson JL, Waters D. Purchasing & Supply Chain Management. Twente; 2010.
[6] Liu SW., Dong H., Zhao WL. Optimization Model Based on the Fractal Theory in Supply Chain Management. Advanced Materials Research 2013;694–697:3545-3548.
[7] Stock JR., Lambert DM. Strategic Logistics Management. 4th Edition, McGraw Hill. New York; 2001.
[8] Larson P., Halldorsson A. Logistics Versus Supply Chain Management: An International Survey. International Journal of Logistics. 2004; 7(1):17-31.
[9] European Centre for Disease Prevention and Control; Event background COVID-19, (Accessed 19th April 2020).
[10] World Economic Forum, url:https://www.weforum.org/agenda/2020/03/why-lockdowns-work-epidemics-coronavirus-covid19/, (Accessed 19th April 2020).
[11] United Nations: Department of Economic and Social Affairs Social Inclusion; Everyone Included: Social Impact of COVID-19, url: https://www.un.org/development/desa/dspd/everyone-included-covid-19.html, (Accessed 19th April 2020).

[12] OECD, url: https://www.oecd.org/coronavirus/en/, (Accessed 19th April 2020).
[13] https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (Accessed 7th July 2020).
[14] Maliszewska M., Mattoo A., Van der Mensbrugghe, D., The Potential Impact of COVID-19 on GDP and Trade, A Preliminary Assessment, World Bank Group, East Asia and the Pacific Region Office of the Chief Economist & Macroeconomics, Trade and Investment Global Practice, April 2020.
[15] http://documents.worldbank.org/curated/en/295991586526445673/The-Potential-Impact-of-COVID-19-on-GDP-and-Trade-A-Preliminary-Assessment (Accessed 26th April 2020).
[16] World Bank, https://blogs.worldbank.org/voices/scaling-covid-19-crisis-response-now-will-avoid-higher-costs-later (Accessed 30th April 2020).
[17] https://ec.europa.eu/croatia/News/covid_19_komisija_predstavila_smjernice_za_upravljanje_granicama_radi_zastite_zdravlja_i_dostupnost_osnovnih_dobara_i_usluga_hr (Accessed 3rd May 2020).
[18] Dani S. Food Supply Chain Management and Logistics: From Farm to Fork. Kogan Page. London, Philadelphia & New Delhi: 2015.
[19] Drljača M., Grgurević D. Supply Chain in the Context of Circular Economy. International Scientific Conference ZIRP 2018, Science and Traffic Development, Transport and Logistics Industry in Digital Age; 2018 May 10-11; Opatija, Croatia: 2018.
[20] Drljača M., Effective Waste Management as a Part of the Concept of Circular Economy. Congress Proceedings 61st EOQ Congress 2017, Success in the digital era, Quality as a key driver. European Organization for Quality and Slovenian Association for Quality and Excellence; 2017, Oct 11-12; Bled, Slovenia: 2017.
[21] EU; 2012.
[22] Hobbs J. E. Food supply chains during the COVID-19 pandemic. Canadian Journal of Agricultural Economics. Special Issue Article. Wiley. 2020: 1-6.
[23] Xia H. Improve the Resilience of Multilayer Supply Chain Networks. Complexity Journal. Hindawi Wiley. 2020: 9 p.

BRANIMIR DUVNJAK, Ph.D. Candidate[1]
E-mail: branimir.duvnjak@hzinfra.hr
TOMISALV JOSIP MLINARIĆ, Ph.D.[2]
E-mail: mlinaric@fpz.hr
HRVOJE HARAMINA, Ph.D.[2]
E-mail: Hrvoje.haramina@fpz.hr
[1] Hž Infrastruktura d.o.o.
Mihanovićeva 12, Zagreb
[2] Faculty of Transport and Traffic Sciences
Vukelićeva 4, Zagreb

IMPROVEMENT OF PASSENGER SERVICE QUALITY BY APPLICATION OF THE NEW MODEL OF RAILWAY SYSTEM (ON THE RAILWAY LINE ZAGREB MAIN STATION – DUGO SELO)

ABSTRACT

In the framework of this research an analysis of the current state of railway operations on the line from Zagreb Main station to Dugo Selo was conducted. Measures, based on the affirmed shortcomings, were proposed to improve the passenger transport service on this relation. On the observed railway line a new model of the railway system was developed, which includes modification of the existing railway infrastructure topology and signalling system and introduction of a new corresponding timetable solution based on the new cyclic timetable of suburban trains. Simulation analysis of rail operations on the proposed model of railway system showed that the suggested modifications can enable application of the proposed cyclic timetable of suburban trains while separating regional trains from the suburban transport system. Quality of infrastructure determines division points for each areas of new proposal categorization of passenger traffic.

KEY WORDS:

simulation modelling; railway re-signalling; passenger transport; cyclic timetable; suburban traffic

1. INTRODUCTION

Passenger transport in Europe in this century is trying to maintain its position in the transport system in two areas:

- at distances up to 500 km competitiveness of air traffic by introducing high-speed trains
- in urban areas by participating in integrated transport with other modes of public rail and road transport

In the territory of the Republic of Croatia, international passenger transport has lost its former importance, and with each new timetable there are fewer and fewer international passenger trains. In national traffic, the division and categorization of trains has remained unchanged and as such makes it impossible to adjust to traffic demand. Due to this situation in the period from year 2012 to 2017, the number of transported passengers stagnated with a slight growth trend in 2017. The reason is partly an increase in the quality of transport by introducing new low-floor electric multiple units in urban and suburban transport (Figure 1), however, a reliable and regular timetable is lacking.

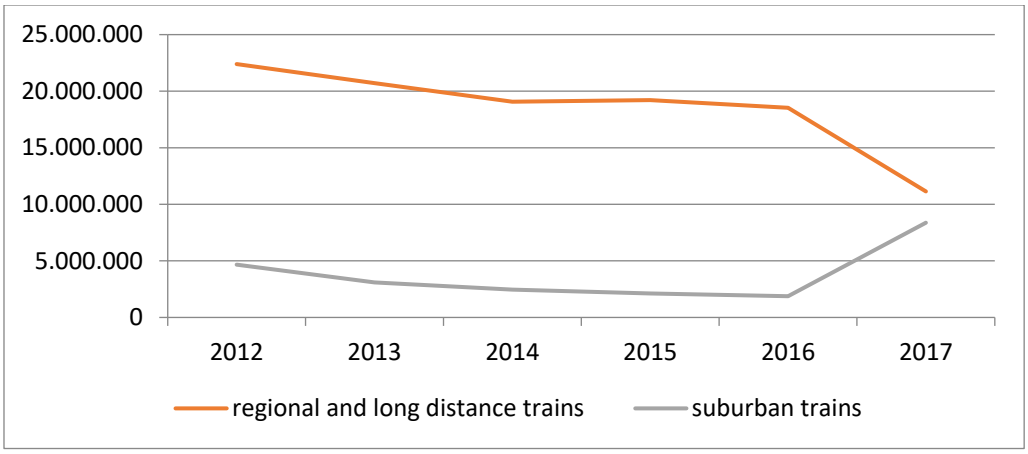


Figure 1 – Number of transported passengers in the period from year 2012 to 2017 [Source: HŽ PP]

The inherited railway network does not meet the growing transport needs, and investments in construction and modernization are not taking place at an acceptable speed. With the occurrence of higher level of daily migrations of the population in urban areas, there is a need to improve transport technology and change the categorization of trains. According to the required transport needs, the largest capacities are required by commuter transport in suburban area, and in this paper the technical and technological features in relation to other regional and national transport will be explained.

2. ORGANIZATION OF RAILWAY PASSENGER TRANSPORT IN THE ZAGREB RAILWAY NODE

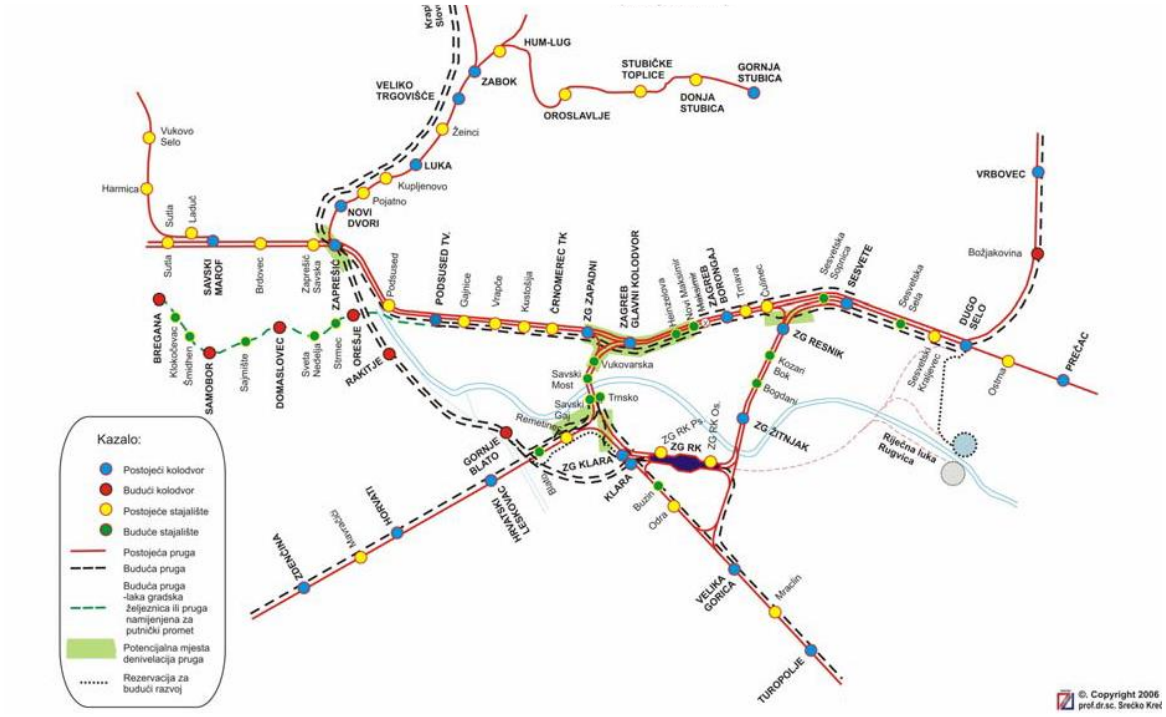


Figure 2 – Future solution of the Zagreb railway node, Source: [1]

Given the transport capacity that can be achieved, it is necessary to make the most of it. Concerning a rail infrastructure, it starts with the inclusion of all existing railway lines in public transport and the construction of new ones as in the proposal for the construction of railway lines to Samobor and the

airport (Figure 2). In the technological sense, it means the introduction of a cyclic timetable with the introduction of a new categorization of trains.

The existing organization of passenger transport is based on the mode of transport according to the existing capacities and the long-term unchanged categorization of trains. According to the experience of large European cities, there is a need to change such attitudes and adapt it to the requirements of transport demand. results of the analysis of the transport capacity of railway lines in the node of Zagreb and the mutual influence of trains of all ranks in passenger traffic, showed that any deviation in the timetable of higher-ranking trains has a great impact on lower-ranked trains. Thus, it is necessary to determine a new categorization (ranking) of trains with reference to their main characteristics.

According to the valid timetable for the period 2018/19, one rapid train (970 - Koprivnica - Zagreb Main station) and 22 passenger trains of regional traffic (14 trains of regional traffic Novska - Zagreb Mainstation, 8 trains of regional traffic Koprivnica - Zagreb Main station) are included in suburban traffic. The inclusion of long-distance and regional passenger trains in the suburban traffic is not acceptable due to the composition of their wagon series that are not adapted for short dwell time. In conditions when there is no passenger information system at the stops, the visual appearance of the electric multiple units helps passengers to prepare for boarding the train on the platform, while a shorter dwell time on the electric multiple units for suburban traffic allows faster exchange of passengers. Such characteristics are not present in the composition of trains with conventional wagons or electric multiple units intended for regional traffic.

3. A NEW CONCEPT PROPOSITION FOR THE ORGANIZATION OF PASSENGER TRANSPORT IN THE ZAGREB NODE

Given the necessary reorganization of passenger traffic in order to achieve its technologically optimization, it is necessary to determine the criteria for changing of existing rules. The first criterion is new categorization of passenger traffic. The proposed categorization of passenger traffic depends on the length of the passenger transport route and it includes:

1. long-distance traffic (LT) - internal and international long-distance traffic - the characteristics are comfort, speed and quality of additional services

2. regional traffic (RT) - internal local and possibly border traffic - the characteristics are sufficient number of trains connecting the regional centres, larger number of seats and a timetable which is adjusted to the needs of passengers

3. suburban traffic (ST) - which takes place in suburban areas of the largest gravity zones - the characteristics are relatively short traveling time, short dwell time at stations or stops, cyclic timetable and regularity.

The second criterion is train traveling time between division points, which in no case should be longer than 60 minutes for ST trains and 120 minutes for RT trains. All trains with traveling time longer than 120 minutes are LT trains.

The third criterion is introduction of a cyclic timetable of suburban trains. By this a maximum capacity of passenger transport during rush hours is achieved. Depending on the daily migrations, there are two crucial intervals during the day. The cyclic timetable does not interfere with the timetables of RT and LD trains and it does not affect ST trains in case of their delay because they are dispatched in free intervals between two ST train departures.

The route on which the largest number of passengers in the ST is transported stretches from Savski Marof to Dugo Selo railway station. In this case Zagreb Main station is only a transit station.

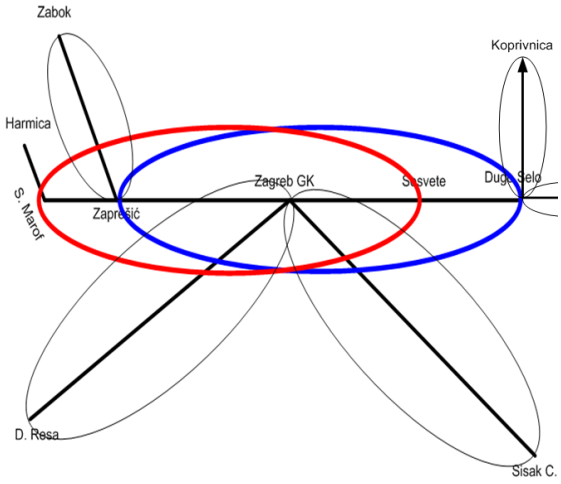


Figure 3 – Graphical review of relations (Source: [2])

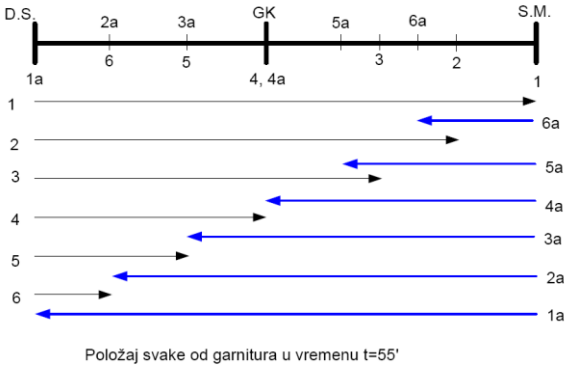


Figure 4 – Position of trains within 60 minutes of travel between turn around stations (Source: [3])

The graphic review (Figure 4) refers to the route Savski Marof - Dugo Selo with the indication that the headway between suburban trains of 10 minutes was achieved on the section Zaprešić - Sesvete, considering that the number of users increases by approaching the urban center [4].

The characteristics of passenger trains in regional and long-distance traffic remain unchanged, i.e. they exchange passengers according to the valid timetable to ST revolving stations, while in the ST area they exchange passengers only at stations, they are not part of ST and tickets for ST trains are valid. Such trains are not used for ST due to the electric multiple units or classic wagons composition that are not intended for short dwell time and a higher probability of delay, and thus interference with the planned headway between ST trains. This unreliability is primarily related to the distance over which these trains run and the greater possibility of unpredictable disturbances that may affect their regularity. The complete separation of RT trains from ST trains with an indication of train categorization reduces the impact of such trains on the punctuality of ST to a minimum.

According to the new categorization proposal, ST trains have priority over other trains in the ST area.

The higher quality of ST can be influenced by technical and/or technological measures. Technically, it can be influenced by building of new or improving the quality of existing infrastructure. By building of new infrastructure with tracks dedicated only to ST, the operational impact of other trains on ST would be completely avoided. Investment in new tracks is shown on the example of Zagreb Borongaj station, where the construction of tracks for receiving and dispatching ST trains, and side platforms for dwell of ST, allows other trains to pass (Figure 5), e.g. in case when the route of an international passenger train according to its train path violates the path of ST, i.e. ST train slows down such a train due to possible high number of passengers in that part of the network, and therefor longer dwell time at stops Čulinec, Trnava and Maksimir, international passenger train will be able to pass ST which would use a new proposed tracks dedicated exclusively for ST trains. From a passenger safety point of view this is also an advantage because they are moved away from the main to the loop track.

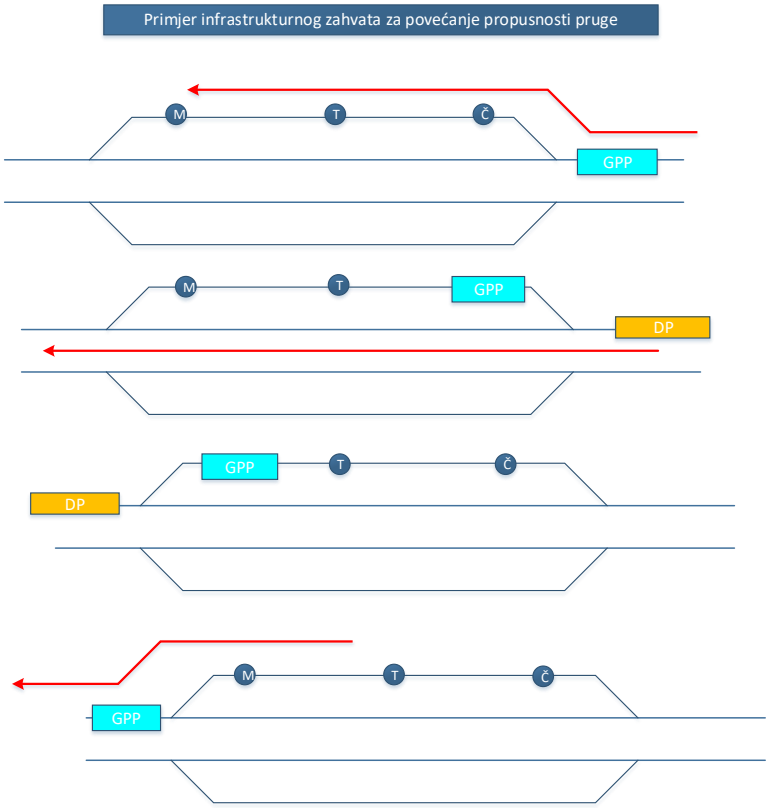


Figure 5: Graphical review of LT train pass ST train (Source: Authors)

4. SIMULATION MODEL OF CYCLIC OPERATION OF SUBURBAN TRAINS - VERIFICATION OF THE PROPOSED CONCEPT

For cyclic timetable operation with headways of suburban train paths in interval of 10 minutes, a simulation model in the micro-simulation program Open Track was performed. The time interval of 180 minutes in the morning peak is load from 06:00 AM to 09:00 AM. In the simulation 34 ST trains, five LT trains and 11 RT trains were included (Figure 7). The line capacity of the critical section on the line Dugo Selo – Sesvete is 196 trains/day. If this model is used for the whole day and for the maximum distance of all trains between division points, the maximum number of ST trains would be 145. However, the model predicts train routes according to Figure 5, Dugo Selo - Zaprešić and Sesvete - Savski Marof, due to which the number of ST on the section Dugo Selo - Sesvete is 78. This set of traffic requires 9 train compositions [4].

The number of free routes when using tact traffic can be calculated by the equation (1):

$$N_{st} = N_{max} - \sum_{i=1}^{n} \frac{T_{int}}{t_i} \quad (1)$$

Content of equation:

- N_{max} - maximum number of trains on the tracks
- $\sum_{i=1}^{n} \frac{T_{int}}{t_i}$ - sum of all trains of all tact intervals during the day

In the timetable for the period 2015/16. in the observed time interval of 180 minutes operated 4 LT, 5 RT and 16 ST. RT involved in suburban traffic come to the ST area with a capacity of 50%, consisting

of five classic wagons with a capacity of 500 passengers. The available capacity of all involved in the ST is 9,100 passengers [5]. Described and simulated cyclic operation of ST trains provides capacity in the specified interval of 15,640 passengers. The main characteristics of new Končar's EMU are low floor construction, less seats, capacity 500 passengers, four units and two enters per unit, max speed 160 kmph (Figure 6).



Figure 6 – New EMU for suburban traffic

The new categorization of trains with a change in regulations related to such categorization allows the use of line throughput that can be increased or decreased by changing the time interval of cyclic train operation without the impact of RT and LT trains on the regularity of ST trains and vice versa.

In the morning and afternoon peak period, which are time periods of 6/24, train operations take place in cycles of 10 minutes, and the rest of the day the transport capacities are optimized by increasing the headway of cyclic train paths. The technological impact by determining the time interval of the cycle enables optimal management of user requirements for capacities in different parts of the day. Maximum capacities are used in peak time periods in daily migrations.

With the construction of two new additional station tracks at the Zagreb Borongaj station, which due to the specific length of the station area currently includes three train stops, the Maksimir stop should be dislocated for 250m to the west. In this way, it is possible to connect the corresponding platform and underpasses of the nearby Borongaj tram rounding station. For this purpose, according to the simulation model, a fourth stop is being introduced that would connect the University Campus with Zagreb Main station. The model determines that all trains running on the route Zagreb Main station - Sesvete - Dugo Selo have to deal with stops Maksimir, Borongaj, Trnava and Čulinec. Trains involved in the transport of the Zagreb Ring, which means that they have a circular route Zagreb Main station - Zagreb Resnik - Zagreb RK - Zagreb Main station, are engaged at the stops Maksimir, Zagreb Borongaj and Čulinec (Figure 8).

The presented and simulated technical and technological changes of existing model of railway system on the observed railway line include its integration into the public transport system with the maximum use of railway infrastructure capacities in city of Zagreb area.

The new criterion for ST is important for all users on all lines and should not be singled out because they are not in the direction of city of Zagreb development and expansion.

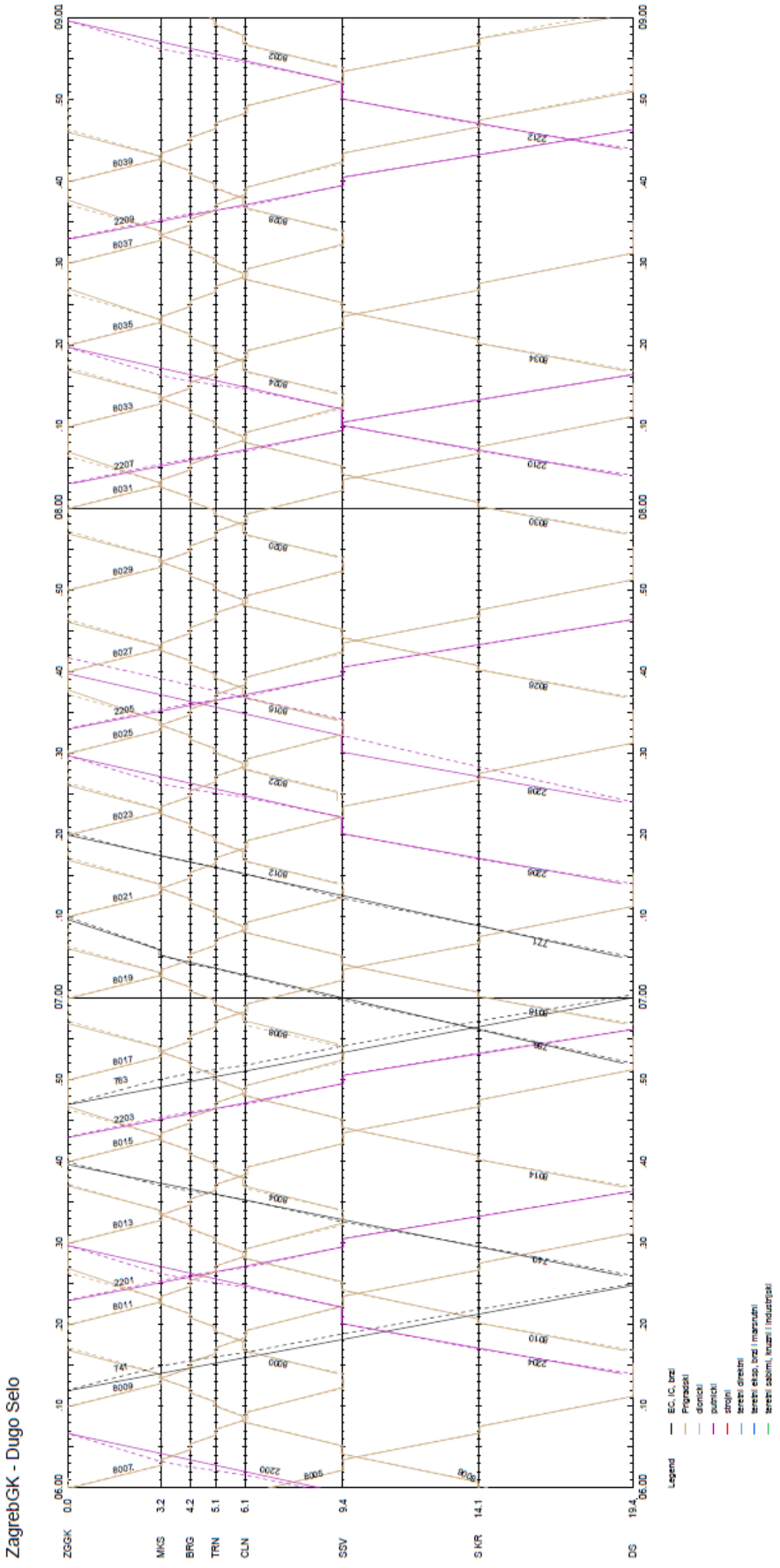


Figure 7 – Timetable graph according to the simulation model - Opentrack

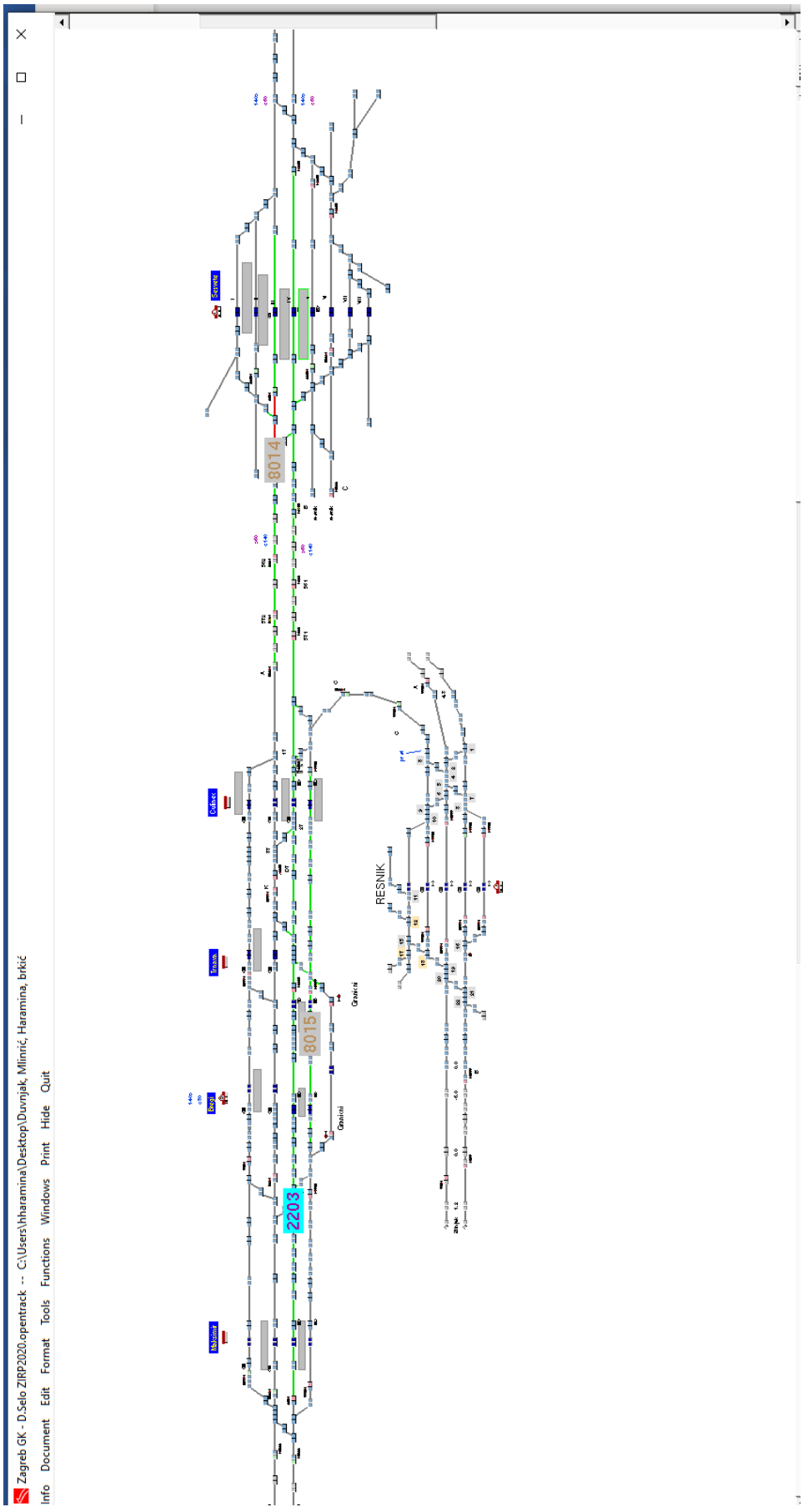


Figure 8 – Simulation model of Zagreb Borongaj station

5. CONCLUSION

The existing ST service quality in the Zagreb node was not improved only by the replace of old EMUs with new low-floor EMUs and the number of train paths in the timetable remained unchanged. Technological improvement of the proposed cyclic timetable contributes to the quality of the offer, but for successfully implement of such cyclic timetable the proposed new categorization of trains should be implemented. Areas of each type of traffic should be define with time interval of traveling because division points of new categorization of passenger traffic depends of quality of infrastructure. In the proposed new train categorization, ST trains have priority over all trains so that regularity would be their main feature, which would have a big impact on the service quality in passenger transport.

The analysis of the existing timetable, transport and infrastructure capacities identified weaknesses and shortcomings that were influenced by the research of the proposed concept. The proposed concept of ST optimization enables the regulation and increase of slightly more than 40% of transport capacities and higher utilization of maximum line throughput with minimum financial costs. There are three possible phases for introduction of the proposed timetable solution. In the first phase, a cyclic timetable with new low-floor EMUs would be introduced on the existing rail infrastructure. In the second phase, as it is proposed in this paper, the introduction of the proposed timetable solution can be achieved with minimal investment in infrastructure. Interventions on the infrastructure of the specific station Zagreb Borongaj should increase the utilization of all railway lines in the Zagreb node and the utilization and optimization of their existing capacity.

The application of the proposed cyclic timetable solution should have a positive impact on increasing the number of railway transport users in integrated public passenger transport.

In case of a high demand in such way of transport, further research would be focused on the modernization and construction of infrastructure subordinated to the timetable as the third phase in the introduction of the quality timetable solution.

REFERENCES

[1] S. Kreč, J. Božičević i S. Amanović, »Hrvatska znanstvena bibliografija« [Mrežno]. Available: https://bib.irb.hr/datoteka/260258.bozicevic_paper.pdf. [Pokušaj pristupa 05. Travanj 2020.].
[2] M. Mlinarević, K. Bačić, T. J. Mlinarić, M. Nikšić, D. Dedović, M. Bilić, I. Perić, B. Duvnjak, M. Jukić, D. Nikić, K. Đurašević, J. Hercigonja i F. Palić, Studija razvoja i unapređenja kvalitete usluga gradsko-prigradskog željezničkog prijevoza putnika, Zagreb: Convena - inženjerski biro, 2010.
[3] T. J. Mlinarić, M. Nikšić, Z. Schauperl, B. Duvnjak i T. Pleša, Studija opravdanosti investicije u nove prijevozne kapacitete - motorne vlakove, Zagreb: Fakultet prometnih znanosti, Sveučilište u Zagrebu, 2012.
[4] M. Čičak, Modeliranje u željezničkom prometu, Zagreb: Institut prometa i veza, 2005..
[5] HŽPP d.o.o., »Godišnje izvješće o stanju društva,« Zagreb, 2016.
[6] HŽPP d.o.o., »Godišnje izvješće o stanju društva,« Zagreb, 2019.

MARKO EMANOVIĆ, mag. ing. traff. [1]
E-mail: Marko.Emanovic@gmail.com
MARIO ĆOSIĆ, Ph.D. [2]
E- mail: mcosic@fpz.hr
EDUARD MISSONI, Ph.D. [2]
E-mail: eduard.missoni@fpz.hr
JULIJAN JURAK, mag. ing. traff. [2]
E-mail: jjurak@fpz.hr
MATIJA SIKIRIĆ, mag. ing. traff. [2]
E-mail: msikiric@fpz.hr
[1] Center for vehicles of Croatia
Capraška 6, 10 000 Zagreb
[2] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10 000 Zagreb

ANALYSIS OF TRAFFIC POLICY MEASURES IN THE RESTRICTION OF THE USE OF OLDER FOSSIL - POWERED MOTOR VEHICLES CONSIDERING EUROPEAN UNION AND THE REPUBLIC OF CROATIA

ABSTRACT:

Pollution of the atmosphere caused by various pollutants such as industry, households, agriculture, energy, and traffic like many others has become a major problem in the world. The world is facing a big problem, and it is necessary to react opportunely to avoid a complete disaster. Taking care of the environment and preserving a healthy preserving a healthy ambience is the task of every person but also of the society as an organized whole. Vehicles as well are not exempt from this problem. This paper considers the traffic factor with an accent on vehicles as one of the atmospheric pollutants. Countries around the world strive to bring quality measures to save the atmosphere and the environment from pollution. The aim of this paper is to approach the problem of atmospheric pollution in the form of pollution caused by motor vehicles. Furthermore, the plan of this paper is to present traffic policy measures that would reduce the number of older fossil-powered motor vehicles in the Republic of Croatia, as well as to turn to some new technologies that can be made available to all users with appropriate traffic policy measures.

KEY WORDS:

Pollutants; atmosphere; traffic; vehicles; environment; traffic policy

1. INTRODUCTION

There are many sources of air pollution, but the main ones are industry, traffic, energy production and agriculture. The production and sale of new motor vehicles is increasing every day and it is constantly growing worldwide. Technologies are advancing every day and new and safer vehicles are being produced. They guarantee safety and quality. But there is also a group of motor vehicles that are having a major growth, contributing to atmospheric pollution, and are called used vehicles. According to different Euro standards, used vehicles can contribute to creation of positive image and the roads conditions when it comes to the age of vehicles. But they can also have a negative impact when it comes to exhaust and vehicle pollutants.

A group of used vehicles which are being criticised in both the European Union and the Republic of Croatia are motor vehicles of smaller Euro standards. For example: Euro 2, 3, 4 which are atmospheric pollutants, and changes are needed in that area. Decarbonisation and exhaust emissions

have become commonplace worldwide, and proper traffic policies are being sought. As fare as traffic is considered, the use, subventions and purchases of electric vehicles and vehicles using other forms of alternative fuels are encouraged in the battle against atmospheric pollution. Some more developed countries of the European Union have gone even further, prohibiting the use of motor vehicles of certain Euro standards, as well as the introduction of Low Emission Zones (LEZ) zones to prohibit the movement of older vehicles. The Republic of Croatia as a member of the European Union must have an elaborated traffic policy for the import of vehicles of smaller Euro standards from other countries. That type of vehicles is acceptable for inhabitants of Republic of Croatia considering the price and many other characteristics, but they are unfortunate in struggle to reduce atmospheric pollution by motor vehicles exhaust emissions.

Main goal of this paper is to see current situation in area of traffic policy measures in the restriction of the use of older fossil - powered motor vehicles. Traffic policy measures represent by numerous papers from various authors who is traying to detect best measures for achieving decarbonization of traffic. Decarbonization is not achievable only by using vehicle with electric or hybrid engine. Set of policy measures can help to achieve best results for reduction green emissions gases. Chapters in this paper are introduction, literate overview about decarbonization and the effect of CO_2 emission on climate change, proposal for traffic policy measures in the republic of Croatia for the prevention of atmosphere pollution by exhaust gases of older motor vehicles on fossil fuel and conclusion.

2. LITERATE OVERVIEW ABOUT DECARBONIZATION AND THE EFFECT OF CO2 EMISSION ON CLIMATE CHANGE

Numerous authors try to detect best approach for determining the influence of traffic policies on energy on greenhouse gas emissions. Driving behaviour has an undeniable impact on vehicle greenhouse gas emissions. Paper [21] propose a probabilistic approach to reaffirm and evaluate the influence of traffic management conditioning factors on driving behaviour, energy consumption, and greenhouse gas emissions of a battery electric vehicle in a city. This probabilistic approach suggests an alternative view for understanding and evaluating the environmental impacts of traffic control decisions or urban planning regulations in terms of their effects on routes and their characteristics [21]. Technological deployment of electric vehicles will constitute only a partial solution for the problem regarding the availability of automotive fuel and its impact on air quality [22]. Global Zero-Emissions (ZE) transport solution goes through supplying electricity using renewable energy sources (such as wind, solar and geothermal), together with a change in social habits [22]. Paper [22] calculation of the GHG emissions associated to the use of BEVs is put under research, and a new approach for assessing realistic GHG emissions at power plant level.

Electric vehicles are an efficient mean to mitigate carbon dioxide emissions in the transport sector [23]. Paper [23] demonstrates results from measuring time-dependent electricity consumption of electric vehicles during driving and charging. In paper there is also detect4ed potential reduction of GHG. Specific smart charging services are a convincing strategy to reduce electric vehicle specific carbon dioxide emissions [23]. Electric vehicles with low-carbon electricity sources offer the potential for reducing greenhouse gas emissions and exposure to tailpipe emissions from personal transportation [24]. Paper [24] develop and provide a transparent life cycle inventory of conventional and electric vehicles and apply inventory to assess conventional and EVs over a range of impact categories. Improving the environmental profile of EVs requires engagement around reducing vehicle production supply chain impacts and promoting clean electricity sources in decision making regarding electricity infrastructure [24].

Paper [25] address the current European Union's support policy for battery electric vehicles manufacturing under the Super-credit modality, and its actual relationship with the reduction of carbon emissions derived from the use of battery electric vehicles. Paper [25] also employed a measure

of driving aggressiveness by modifying the standard benchmarking driving cycle fostered by the European Union and of necessary application by vehicle manufacturers to show that battery electric vehicles emissions are not negligible when compared with internal combustion vehicles, mainly in urban environments.

Paper [26] consider the implications of highway expansion and travel demand management policies for road traffic emissions. By using a simplified partial equilibrium simulation model over a twenty five year period, authors contrast the situations in developed and developing countries where the emission profiles may take very distinct forms. Paper [26] show that demand management policies which internalise the costs of congestion can be effective in containing or reducing emissions over the simulation period.

The life-cycle cost of electric vehicles has been widely studied to evaluate their competitiveness compared to conventional vehicles [27]. In China, electric vehicles are exempted from purchase restrictions (license plate control policy) and driving restrictions [27]. Paper [27], from the consumers' perspective, the intangible cost of purchase and driving restrictions is modelled and expressed in monetary terms. With the increasingly worse traffic and environmental problems China facing, it is suggested that the promotion of electric vehicles in mega-cities be prioritized and that electric vehicle promotion policies based on taxes, subsidies and traffic control be balanced [27]. Paper [28] assesses the impact of different spacing policies for Adaptive Cruise Control (ACC) systems on traffic and environment. It is found that ACC with quadratic spacing policy has significantly positive effects on string stability and energy consumption [28].

The papers mentioned above show the necessity of joint implantation of the electric vehicles together with restriction measures for internal combustion vehicles in the urban and rural areas. However, there is only limited data about real situation with implementation phase of restriction. Further research in that field can help to better understand how situation will develop in various countries.

The European Commission has defined the EU energy development strategy for 2020 in an official document titled "Energy 2020 — A strategy for competitive, sustainable and secure energy" (European Commission, 2010). In 2011, the European Commission issued another official document under the title "Energy roadmap 2050" (European Commission, 2011) which defines the strategic objectives of the energy sector of the EU for the period until 2050. The European Union's 2050 strategy for that time frame rests on ten fundamental structural changes that must encompass the energy system in its entirety at the EU level [1].

The EU, as one of the largest producers of climate change-related CO2 emissions, had conscientiously responded to the situation. Therefore, in January 2014, proposals for climate change goals, outlined in the White Book, were substantially debated, setting significantly stricter measures to reach the goals by 2030. At the end of 2014, after a contentious debate, the EU adopted a new climate and energy policy framework, which implies reducing greenhouse gas emissions by at least 40% by 2030 and increasing the share of renewable energy sources to 27% compared to 1990. At a summit in Paris, the EU came forward with a proposal to change the obligatory level of CO2 reduction compared to 1990 [2]:

- by 2020 – a 30% reduction in greenhouse gas emissions compared to 1990,
- by 2030 - a 40% reduction in greenhouse gas emissions compared to 1990.

This goal reflects Europe's ambitions to encourage most of the world's countries to face the global climate challenge. The EU has expressed a political will for changes; thus, the problem of setting goals shifts to the choice of necessary measures for implementing a new climate policy [1].

The main sources of exhaust gasses pollution are traffic and industry. Although the development of traffic significantly contributes to the progress of the economy and society, it nevertheless has a negative impact on the environment. Fossil fuels are responsible for as much as 25% of global CO2

emissions. Large amounts of emitted CO2 have negative effects on the environment; global warming occurs, causing further problems such as glacier melting and climate change. It is crucial to bring about changes in traffic policy and to be aware of environmental protection and hence of human health [3].

Of all types of traffic, road traffic has the greatest impact on the environment and human health. With the development of the automotive industry, there has been a rapid increase in the number of vehicles and, consequently, greater problems related to environmental pollution since exhaust gases are generated by combustion of fuel in internal combustion engines.

However, today's modern vehicles are more economical and safer. Reducing fuel consumption, reducing pollutant emissions, and removing hydrochloride from vehicle air conditioners have led to a significant reduction in the greenhouse effect [5]. The existing Euro 5 and Euro 6 emission standards for cars and light vans set emission limit values for a range of pollutants in the air, especially for nitrogen oxides and particulate matter [4].



Figure 1 – Air pollution from exhaust emissions of vehicles

The energy consumption structure of the EU countries also shows a noticeable tendency to increase the share of energy consumption in the traffic sector. The traffic or transport sector is a growing energy consumer in Europe. The largest share of consumption in 2017 was recorded by the household sector, with a share of 42.1% of energy. The traffic sector with 30.8% of energy consumption comes next, the industry sector which consumed 24.6% of energy holds the third place, and on the fourth place is the agriculture sector with 2.4% of energy consumption. It can be concluded that the observed traffic sector is a large energy consumer. The total share of energy consumed by sectors for EU countries in 2017 is presented in Figure 2 [5].

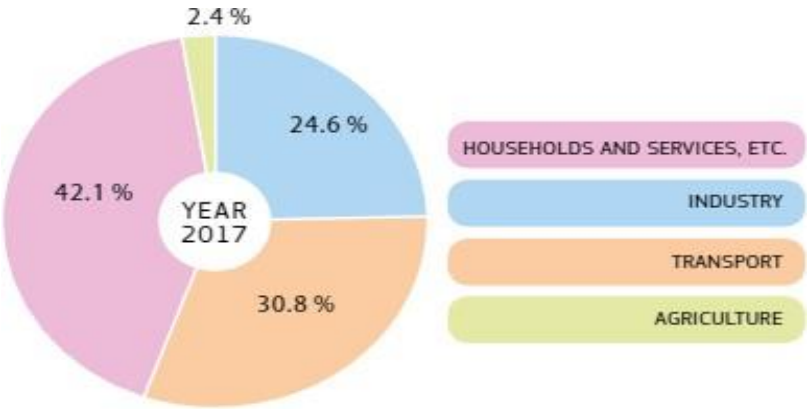


Figure 2 – Energy consumption per sector in EU countries for 2017

Common ways to reduce emissions are to use natural gas instead of coal, improve machinery and fabrication processes, maintain machinery, use electric motors of higher efficiency, and monitor air quality in the plant [5]. The Industrial Emissions Directive covers highly polluting industrial activities that cause a significant proportion of pollution in Europe. The Directive sets out the obligations to be met by all industrial plants and sets out a series of measures to prevent water, air and soil pollution and provides the basis for the issue of licenses and permits for industrial plants. The concept of "best available techniques" plays a central role in it, as well as flexibility, environmental inspections, and public participation [4].

Also, an additional problem is the dependence of European traffic on oil (about 94%), of which the bulk comes from imports (about 84.3%). Since imported oil is mainly coming from increasingly unstable areas of the world, this further increase supply insecurity and thus threatens the regular functioning of traffic [6]. Therefore, there is a clear need for diversification of energy sources in traffic. In this regard, a solution arises in the form of establishing and strengthening the infrastructure for alternative fuels, which are, among others, considered more environmentally friendly than conventional fuels (gasoline and diesel). Such a possibility has been recognized at European Union level and Directive 2014/94 / EU of the European Parliament and the European Council of 22 October 2014 establishing an alternative fuel infrastructure was adopted [6].

In order to reduce motor vehicle exhaust emissions, the Leipzig Administrative Court issued a decision banning the operation of diesel vehicles, specifically in the cities of Stuttgart, Düsseldorf, but also in other 70 cities, where the values of exhaustion exceed the permitted limits [8], [9]. Germany has a national Umwelt zone framework, which came into force in March 2007. To enter such zones, vehicles must have an appropriate sticker affixed to the windshield of the vehicle or, in the absence thereof, the driver faces a financial penalty by the police [10]. The main objective in 55 environmental areas in Germany is to protect the inhabitants of municipalities and cities from the presence of fine and dangerous particles in the air [11]. Three cases from Germany will be explained below in the following paragraphs.

The first low emission zones in Germany were established in Berlin. They cover 88 square kilometres of the city centre and about 10% of the whole Berlin area. There are about one million people in Berlin's low-emission zones. The first zone requires a red, yellow, or green sticker and was introduced in January 2008. The second zone requires a green sticker, which was introduced two years after the first zone, namely on 01.01.2010. During the planning phase, it was projected that Zone 1 would result in a reduction (PM) of emissions by 15%, which would make an annual decrease in concentration (PM10) of 3%. In Zone 2, exhaust emissions will be reduced by 50%, with an average annual reduction (PM10) of 5 to 10% and a concentration reduction of about 4% (NO_2) [10], [12]. Attempts to identify the direct effects of concentrations in low emission zones on ambient air (PM10)

have failed because there are too many oscillations due to weather conditions and other unknown factors.

In Munich, low emission zones were introduced in October 2008 as a part of the national framework (Sadler LTD, 2015). In terms of European standards, a vehicle classification system is being used. Red codes refer to Euro emission vehicles: Euro 2, yellow codes for Euro 3 standards and green labels for Euro 4 standards. Munich's low-emission zones cover an area of 44 square kilometres (14% of the city's size), affecting 700,000 vehicles. For vehicles operating in these zones, the required emission standards are prescribed, and if the vehicle does not have valid markings on it, fines of € 80 are awarded. The zones are overseen by the police [10], [12], [13]. Figure 4 shows an example of low emission zone area for the city of Munich.

Low emission zones in the city of Stuttgart were introduced in 2008 and is a credible example of zones that have limited use of vehicle movement to reduce the harmful effects of motor vehicle exhaust and to improve the quality of life of citizens. Low emission zones in Stuttgart have been introduced in accordance with the German National Framework, first published in 2007 and now valid in several cities across the country In German cities with low emission zones, which only allow vehicles with green codes in the zone, there was an average particle reduction of 10 - 12% (Umwelt Bundesmant, 2016). This has significantly improved the air quality in cities and is ultimately assumed to have positive impacts on residents 'health [14], [15].

For most of the countries the total number of vehicles is increasing. Such data also suggest an increasement of environmental pollution caused by the emissions of internal combustion engines [16]. Figure 3 shows according to the available data, the annual CO_2 emissions in the EU Member States during the period of 1990 to 2017. The figure shows a decrease in CO_2 emissions compared to 1990 and 2017, however, comparing 2015 and 2017, we can see that the total number of CO_2 emissions in the EU countries has increased, indicating an increasement in atmospheric pollution [16].

	1990	1995	2000	2005	2010	2015	2016	2017
EU-28	4541.8	4304.9	4298.1	4438.9	4073.9	3656.3	3646.0	3674.1
BE	123.6	129.0	131.5	129.1	118.0	104.1	102.8	102.4
BG	77.3	58.5	45.5	51.2	48.3	48.6	45.9	48.1
CZ	166.6	133.6	128.8	127.7	119.4	106.5	108.3	107.4
DK	56.5	64.5	57.4	54.7	52.0	38.1	40.1	38.0
DE	1064.6	954.5	919.7	889.6	856.6	820.4	828.0	827.1
EE	37.2	18.3	15.4	17.3	19.1	16.0	17.6	18.8
IE	34.0	37.0	47.0	50.6	44.0	40.9	42.5	41.8
EL	85.9	89.6	105.5	116.5	99.9	77.8	74.4	78.3
ES	235.8	273.8	320.4	379.5	295.4	285.2	276.0	291.4
FR	409.2	408.1	430.3	442.7	405.7	358.3	359.9	363.7
HR	23.8	17.2	19.9	23.6	21.4	18.2	18.5	19.2
IT	443.9	457.2	478.2	502.9	435.2	365.4	363.8	360.2
CY	5.4	6.7	8.0	8.9	8.9	7.7	8.2	8.5
LV	19.8	9.2	7.2	8.0	8.9	7.6	7.6	7.7
LT	36.2	15.1	11.9	14.2	13.9	13.4	13.4	13.7
LU	12.2	9.7	9.7	13.4	12.5	10.7	10.6	10.9
HU	73.9	62.2	59.3	61.3	52.8	47.2	48.0	50.3
MT	2.1	2.8	2.9	2.9	2.8	2.1	1.8	2.0
NL	167.9	181.3	182.4	188.9	192.9	178.3	178.5	176.9
AT	63.2	65.6	68.0	81.4	74.3	68.9	69.6	72.2
PL	377.6	363.2	319.0	323.4	334.9	314.2	325.0	339.1
PT	47.3	56.7	68.4	72.0	55.8	55.5	53.9	58.7
RO	170.2	127.6	95.9	103.0	84.5	78.5	76.7	76.0
SI	15.1	15.3	15.5	17.0	16.4	13.7	14.5	14.3
SK	61.6	44.3	41.3	43.0	38.6	34.6	35.0	36.2
FI	58.1	59.2	58.2	58.4	65.8	46.1	49.3	46.9
SE	58.8	60.6	56.6	55.7	55.0	45.2	45.1	44.8
UK	613.9	584.2	594.5	601.9	540.9	453.0	430.8	419.5
MK								
TR	152.1	181.7	231.4	267.5	320.2	392.4	411.9	436.3
IS	2.5	2.7	3.3	3.4	4.0	4.2	4.4	4.8
NO	36.0	39.3	43.4	44.9	47.5	47.0	46.0	45.4
CH	47.6	47.3	48.5	49.4	49.4	43.7	44.4	43.6

Figure 3 – Total CO_2 emissions (millions of tons) by EU countries from 1990. to 2017 year

3. PROPOSAL FOR TRAFFIC POLICY MEASURES IN THE REPUBLIC OF CROATIA FOR THE PREVENTION OF ATMOSPHERE POLLUTION BY EXHAUST GASES OF OLDER MOTOR VEHICLES ON FOSSIL FUEL

Literature overview with addition examples show needs for implementing set of measures whit who can be achieved decarbonization of transport systems. To prevent the pollution of the atmosphere by those vehicles, it is necessary to implement a set of measures that would circumvent or at least mitigate such a scenario. All these proposed measures need to be implemented to achieve desired goals. Implementation only few of them will not be enough to achieve goals. We present an example of such a set of measures in the following paragraphs.

1. **Co-financing the procurement of energy efficient vehicles** – one of the key measures to promote energy efficiency in traffic is to encourage the use of hybrid and electric vehicles. According to data from the Hrvoje Požar Energy Institute, CO2 emissions in the total domestic traffic amount to around 5.6 million tons, of which almost 3 million tons are road traffic. More than 2 million road vehicles are registered in Croatia today, of which almost 1.5 million are passenger cars. From 2014 to 2017, the Environmental and Energy Efficiency Fund co-financed the purchase of 1,425 electric, hybrid and plug-in hybrid vehicles with HRK 50 million. In 2012, there were only 13 electric cars in Croatia, 74 in 2014 and 730 in 2019 what indicating a large increase [17], [18].
2. **Environmental Measure** – eco-driving has been recognized as one of the most effective measures to promote energy efficiency in traffic at EU level.
3. **Investment set of measures** – also a very important measure in the overall set, which would also cover investments in the field of infrastructure and vehicles:
   - construction of charging stations for electric vehicles in cities, construction of charging stations for electric vehicles on motorways and expressways,
   - purchase of N2 hybrid vehicles,
   - introduction of public city bicycle systems,
   - software solutions containing a road database, which can be used to increase energy efficiency in cities,
   - equipping existing or incorporating traffic lights with a visual indicator of the red-light phase duration,
   - the purchase of electric bicycles with a maximum continuous power not exceeding 0.25 kW and progressively decreasing to zero when the speed reaches 25 km/h, or sooner if the driver stops pedalling,
   - remodelling of existing electric and compressed natural gas (LPG) vehicles of all categories through the vehicle test process,
   - use of photo voltage systems when charging electric vehicles.
4. **Fiscal measures when importing and bringing vehicles**– these types of measures would cover the tax system when importing or bringing vehicles.
5. Prohibition of the circulation of vehicles of lower Euro standards in the city centre.
6. **Co-financing and incentives for upgrading – modification of motor vehicles of lower Euro standards to meet higher Euro standards.**
7. **Road use tax for vehicles of lower Euro standards** – this measure would encompass vehicles of Euro standard 3 and below and could be completely abolished or reduced for electric vehicles [19].
8. **Innovation Financing** – for example, Croatia is the home of Rimac Automobili and Dok-Ing, which develop and manufacture high-performance electric vehicles, power transmission systems and battery systems [20].

4. CONCLUSION

A set of measures that encourage people to buy or rent vehicles of very low or zero greenhouse gas emissions while adapting infrastructure is a key part of traffic policies in creating a sustainable energy future for the European Union, and thus for the Republic of Croatia. Relevant scientific research has shown the high impact of road traffic on the amount of greenhouse gas emissions, and therefore traffic policies have been adapted to focus primarily on the need to use alternative energy sources for motor vehicles. The data collected show an increasement in the number of registered motor vehicles, leading to an increased atmospheric emission. Traffic policies consist of series of measures aimed at stimulating greater procurement of vehicles with alternative drive modes to reduce atmospheric emissions. The implementation of such measures has shown an increase in the procurement of this type of motor vehicles, however the measures taken so far have shown a very small impact on the overall picture so the set of measures needs to be expanded along with the area of their implementation.

REFERENCES:

[1] D. Sabolić: HEP: Ekonomska pitanja u vezi dekarbonizacije elektroenergetskog sustava, [ožujak 2020],
[2] Hrvatski Ogranak Međunarodne elektrodistribucijske konferencije – Ho Cired 5.(11). savjetovanje, Osijek 15 – 18. svibnja. 2016, [ožujak 2020],
[3] J. Golubić, Promet i okoliš, Fakultet prometnih znanosti, Zagreb, 1999,
[4] Preuzeto sa: Europski parlament: https://www.europarl.europa.eu/factsheets/hr/sheet/75/oneciscenje-zraka-i-oneciscenje-bukom, [Pristupljeno: ožujak 2020.],
[5] Perfect Pollution Services, How to reduce air pollution from industries https://www.ppsthane.com/blog/reduce-air-pollution-industries, [Pristupljeno: ožujak 2020.],
[6] Tianhong Medical: Preuzeto sa: http://ba.absorbentgauze.com/non-woven-fabric/medical-mask.html, [Pristupljeno: ožujak, 2020],
[7] Nacionalni portal energetske učinkovitosti, Preuzeto sa: https://www.enu.hr/, [Pristupljeno: ožujak 2020.],
[8] https://www.theguardian.com/world/2018/may/23/hamburg-first-german-city-ban-older-diesel-cars-air-quality-pollution, [Pristupljeno: ožujak 2020.],
[9] http://hr.urbanaccessregulations.eu/countries-mainmenu-147/germany-mainmenu-61/hamburg, [Pristupljeno: ožujak 2020.],
[10] Airues, Low Emissions Zones in Northern and Central Europe, Report 16, (12/2016),
[11] https://www.eko-vinjeta.com/hr.html,[Pristupljeno: ožujak 2020.],
[12] C.: Holman; R.:Harrison; X.:Querol: Review of the efficacy of low emission zones to improve urban air quality in European cities,
[13] Claire Cornes: Effectiveness of Urban Mobility Management Strategies to Improve Air Quality: Department of Civil and Environmental Engineering, 17. May 2016,
[14] The University of Manchester: The implementation of Low Emission Zones to improve urban air quality and public health,
[15] Ministry of Transport and Infrastructure, Baden-Württemberg. (2011). Low emission zones in Baden-Württemberg.,
[16] Preuzeto sa: European Comission: EU Transport in figures, Statistical Poocketbook 2019,: https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2019_en, [Pristupljeno: ožujak 2020.],
[17] Preuzeto sa: Fond za zaštitu okoliša i energetsku učinkovitost: http://www.fzoeu.hr/ , [Pristupljeno: ožujak 2020.],
[18] Preuzeto sa: Centar za vozila Hrvatske: https://www.cvh.hr/tehnicki-pregled/sve-o-tehnickom-pregledu/ [Pristupljeno: ožujak 2020.],

[19] Preuzeto sa: DW: https://www.dw.com/hr/industrija-politika-i-zabrana-za-dizela%C5%A1e/a-42740028, [Pristupljeno: ožujak 2020.],
[20] Nacionalni Okvir Politika za provedbu Direktive 2014/94 EU: Modeliranje parametara infrastrukture za punjenje električnih vozila, Pregled mjera poticanja prihvaćanja električnih vozila,2015.
[21] Fernandez R A, Caraballo S C, Lopez F C. A probabilistic approach for determining the influence of urban traffic management policies on energy consumption and greenhouse gas emissions from a battery electric vehicle. *Journal of Cleaner Production.* 2019;236(1).
[22] Fernandez R A. A more realistic approach to electric vehicle contribution to greenhouse gas emissions in the city. *Journal of Cleaner Production.* 2018;172(1): 949-959.
[23] Ensslen A, Schucking M, Jochem P, Steffens H, Ficthner W, Wollersheim O, Stella K. Empirical carbon dioxide emissions of electric vehicles in a French-German commuter fleet test. *Journal of Cleaner Production.* 2017;142(1): 263-278.
[24] Picirelli de Souza L, Silva Lora E E, Escobar Palacio J C, Rocha M H, Reno M L G, Venturini O J. Comparative environmental life cycle assessment of conventional vehicles with different fuel options, plug-in hybrid and electric vehicles for a sustainable transportation system in Brazil. *Journal of Cleaner Production.* 2018;203(1): 444-468.
[25] Alvarez R, Zubelzu S, Diaz G, Lopez A. Analysis of low carbon super credit policy efficiency in European Union greenhouse gas emissions. *Energy.* 2015;82(1): 996-1010.
[26] Lee S. Transport policies, induced traffic and their influence on vehicle emissions in developed and developing countries. *Energy Policy.* 2018;121(1): 264-274.
[27] Diao Q, Sun W, Yuan X, Zheng Z. Life-cycle private-cost-based competitiveness analysis of electric vehicles in China considering the intangible cost of traffic policies. Applied *Energy.* 2016;178(1): 567- 578.
[28] Bayar B, Sajadi-Alamdari S A, Viti F, Voos H. Impact of Different Spacing Policies for Adaptive Cruise Control on Traffic and Energy Consumption of Electric Vehicles. *24th Mediterranean Conference on Control and Automation (MED).* 21-24 June 2016, Atena Greece.

MARKO EMANOVIĆ, mag. ing. traff.[1]
E-mail: marko.emanovic@gmail.com
JULIJAN JURAK, mag. ing. traff.[2]
E-mail: jjurak@unizg.fpz.hr
IGOR JELIĆ, mag. ing. traff.[3]
E-mail: igor.jelic@scp.hr
[1] Centre of Vehicle of Croatia
Capraška 6, City of Zagreb
[2] Faculty of Transport and Traffic Sciences
Vukelićeva 4, City of Zagreb
[3] School for Road Transport
J.F. Kennedy square 8, City of Zagreb

SAFETY OF PEDESTRIAN CHILDREN IN PRIMARY SCHOOL ZONES

ABSTRACT

Mobility is a fundamental right of every human that allows children to explore the world around them, but on the other hand exposing them to risks. However, it would be wrong to restrict the mobility of children in order to increase traffic safety. On the contrary, measures should be taken to promote independent, autonomous mobility of children by adapting the transport environment to a child's age. The perception of most parents is that their children are threatened in traffic. So today, more than ever before, they bring them with cars to schools. With their participation in traffic, they create additional crowds that usually coincide with the peak periods and so they endanger their own but also other children. School children face serious hazards in all places where motor vehicles are moving, either as they get out from the vehicle near the school or walk to the school. The transport participant is the most important link in the road safety chain, irrespective of the technical measures applied or effectiveness of the policy. Road safety depends primarily on the behaviour of traffic participants. Therefore education, application and harmonisation of laws are the basis for achieving the objective.

KEY WORDS

Pedestrian safety; children pedestrian; education of children

1. INTRODUCTION

In traffic accidents the most vulnerable are children of school age, especially when they are in the role of pedestrians. Unlike adults, children are of lower growth and drivers are more difficult to spot them. This problem is particularly pronounced in school environments, near parked vehicles that impede children visibility. Children do not have well-developed cognitive and perceptual abilities. Their behaviour is unpredictable. Although traffic accidents are complex and random events, they are predictable and can be prevented. This proves the highly developed countries with their extensive strategies, which include the implementation of the law on controlling the speed and consummation of alcohol, the promotion of the use of belts and helmets, and the safer design and use of roads and vehicles, which have proved effective in preventing traffic accidents. The strategies and experiences of developed countries can be transferred to countries that do not have such experience. Developed countries, which have much more success in implementation the National Traffic Safety Programme than Croatia, long a go realised that traffic safety is not only an individual but also a collective problem of the entire society. According to the World Health Organisation, unless appropriate measures are taken, traffic accidents are predicted to become the third cause of mortality by the end of 2020. and the number of traffic fatalities increased to 1.9 million, with a tendency for traffic accidents to become the leading cause of mortality among the human population. Aim of this paper is to examine level of knowledge of schoolchildren in primary school zones with possible solution to increase their safety. Paper consists of literature review, education in the field of road safety, data preparation and analysis, discussion and conclusion.

2. LITERATURE REVIEW

The authors of the paper "Road safety education for schoolchildren" deal with the issue of child safety in primary school areas in Singapore. By analysing the databases, it was concluded that traffic accidents are the cause of death of children under 15 in 6% of cases. The author's state that the frequent approach to reducing the number of traffic accidents, in terms of motor traffic restrictions, although sometimes effective, needs to be supplemented by educating children about safe movement in the traffic environment. They also state that it was previously the case that traffic accidents were difficult to predict, while the development of technology and knowledge has resulted in models that can predict such situations with significant certainty and thus enable timely response of decision makers and facilitate their elimination.

The author of the paper "Traffic education for young pedestrians: an introduction", analyses approach to the education of children at an early age from four to eight years. The following elements have proven to be crucial: focus on situations that often result in pedestrian or driver error; it is necessary to shift the focus to skill acquisition, rather than to knowledge acquisition, because according to research the two mentioned skills become complementary only at the age of nine or ten; education needs to be conducted in realistic conditions, rather than indoors, such as classrooms; children need to be taught what are the important factors, i.e. what is important to pay attention to; there is a high importance of parental participation in education.

The authors of the paper "Effect of railway safety education on the safety knowledge and behaviour intention of school children" analysed the impact of railway safety lessons on increasing safety knowledge and behaviour intention. The study was conducted among children aged eight to eleven in Finland. The focus was on the study of three variables that are considered to have a large impact on their behaviour, namely: behaviour intention, estimated danger of the behaviour, and level of knowledge on the legality of the behaviour. Research has shown that this method of education has a certain impact on the safe movement of children near railway crossings, although it is not necessarily large. The authors conclude that education can result in fewer unsafe crossings in the future, and thus a reduction in the frequency of traffic accidents.

Authors of the paper "How Well Can Child Pedestrians Estimate Potential Traffic Hazards?" conducted a research on the perception skills and visual cues of schoolchildren in Sweden. Research has found that the current level of training to cross streets may not be enough for the prevalent traffic environments. When performing exercises, where children are given the situation of moving in an intersection, almost 90% of children forgot the basic recommendations about which directions they should look. The study confirmed earlier findings that children may be overwhelmed by traffic complexity. It was concluded that an individual and practical approach is crucial to help children respond to the various hazards they are exposed to daily.

In "The meaning of liveable streets to schoolchildren: An image mapping study of the effects of traffic on children's cognitive development of spatial knowledge", the author studies the impact of innovative cognitive mapping methods in children aged nine to ten in San Francisco, with the aim of obtaining insights into children's spatial knowledge. Cognitive exercises reveal multi-dimensional effects, including exposure to traffic, as determined by volume, speed, and the adequacy of walking and bicycling infrastructure. The research showed that children without adequate pedestrian and bicycle infrastructure that would protect them from motor traffic, show a negative attitude towards traffic, and do not feel safe. Also, the study showed how children develop spatial knowledge using independent, active travel modes, and interaction with the environment.

Literatures show that research who was conducted in several countries which is consider most developed (USA, Sweden, Finland) proved that current state of infrastructure and level of knowledge and experience of schoolchildren have impact on number of traffic accident.

3. EDUCATION IN THE FIELD OF ROAD SAFETY

Traffic education is essential from the earliest age to have traffic participants who will behave in accordance with the regulations and to recognize traffic hazards. Education should also include parents in order to properly direct children for safe participation in traffic. Education in traffic means providing opportunities for children in traffic to improve their knowledge and skills for safe movement in traffic and to form awareness of various aspects related to traffic. A good example of the application of education and media campaign of the "National Road Traffic Safety Programme" aimed at parents is a statistical data from 2010. in which 10 children were killed and 1327 injured, which was compared to 2009. it achieves 50% lower rate of child injuries in traffic with death consequences.

According to survey research from the Faculty of Traffic Sciences in Zagreb, 14% of parents do not educate their children on the importance of traffic participation and in general road traffic safety. This is the reason for introducing education of children about traffic regulations from their earliest age.3 In order to further protection children pedestrians, as the most vulnerable participants in the traffic, they must be continuously educated on the proper and safe road movements, and at the same time, increase awareness of other traffic participants of the presence and exposure of those most vulnerable groups in traffic. Education is a strategy accepted by developed countries whose impact has been valued and confirmed as unquestionable for reducing traffic accidents.

4. DATA PREPARATION AND ANALYSIS

In traffic accidents during 2017. in Croatia, four people under the age of 13 died, and 645 children were injured. When children under 17 years of age are considered, the number of children died is five, while 611 children are injured. If compared to the previous year, according to the data of the Ministry of Internal Affairs of Croatia in 2016. one person under the age of 13 died and 626 people were injured. In the group above (up to 17 years of age), which also encompasses one part of elementary school children, the number of children died is six, while 590 children were injured. Also, comparing the previous 2015. statistical data do not support road safety, which is also an indicator of the necessary for changes.

Conducted survey was about determining level of knowledge and behaviour of children pedestrian and their parents about traffic regulations near elementary schools. This survey was part of project “Pedestrian Children Safety in Elementary School Areas”. The children and parents of five elementary schools in Zagreb participated in the survey: elementary school Janko Drašković, elementary school Kustošija, elementary school Savski Gaj, elementary school Izidor Kršnjavoi and elementary school Retkovec. Representative sample of 541 children has been selected from 55.000 children in all elementary school in City of Zagreb. Sample size is chosen by determing confidence level about 95 % with 5 % margin of error. Need sample size was 392 and representative sample is 541 so it can be used as representative data for schoolchildren. Survey was conducted at random chosen three grades in every of five elementary school that participated in survey.

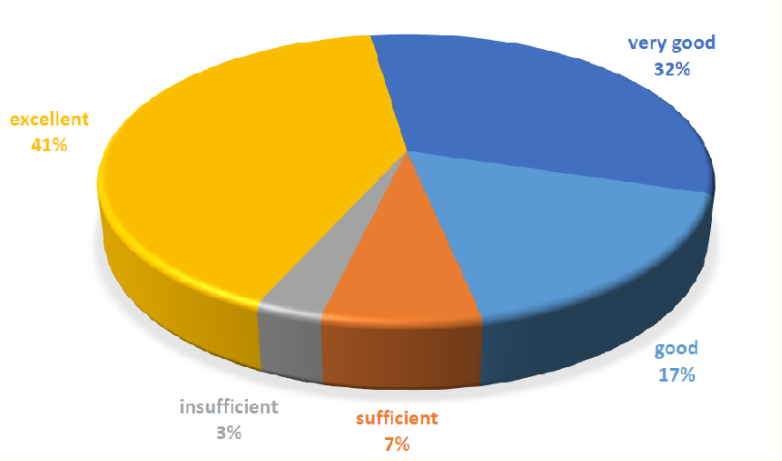


Figure 1 – Level of knowledge about traffic rules of children from grades 5 to 8.

Chart 1. show that only 3% of children stated they insufficiently know traffic regulation and 7% sufficiently (total 10%). Regarding to survey, most parents often or always warn children about risk of traffic (86%) and 73% of children think that they know the traffic rules exquisitely or very well. Analysis of traffic accidents in zones of five elementary school show that children caused 37% of traffic accidents between 2012 and 2014. From this data, conclusion is that parents and children do not have the correct perception of traffic regulations and dangerous in road traffic.

Worryingly fact is that 12.3% of children in elementary school admit they often or always cross the road when there is a red light, and 49.3% do it sometimes. This number is considerably lower among younger children (1st to 4th grade). About 1.5% of them often or always cross the road when there is a red light, and 4.6% do it only occasionally. The reasons for such behaviour are understandable: younger children are often drive to parents by the school, while elderly is free to choose the way of crossing the road, which is usually wrong.

Some of the potentially dangerous situation for pedestrians are crossing the road, especially in urban areas where traffic is dense and has more visual information in the driver's field of vision and thus more attention. In addition, careless of pedestrians have a great impact. Examples of such situations are locations where pedestrians try to cross the road outside the marked crossing. Such situations are especially dangerous at night, under reduced visibility conditions, glare from the wet roadway, etc.

The following chart shows carelessly behaviour of children when crossing the road. To accomplish this task, observers recorded the children who use distractors (mobiles, headphones) when crossing the road, not looking left and right before stepping on pedestrian crossing, running or overcoming the road to slow, passing between stopping cars, etc. The most common mistakes of children are not stopping before stepping on the pedestrian crossing and not looking left and right before crossing the road.

Figure 2. shows that careless crossing (42%) of children almost equalized with the correct crossing (58%), which represents a huge risk for children and safe traffic. When comparing observations conducted by experts from the Faculty of Traffic Sciences with survey results (41% of children think that they know the traffic regulations very well), it can be concluded that children have the wrong perception of their knowledge of traffic and safety regulations and that they need additional education about traffic safety, by parents, as well as by teachers and traffic experts.

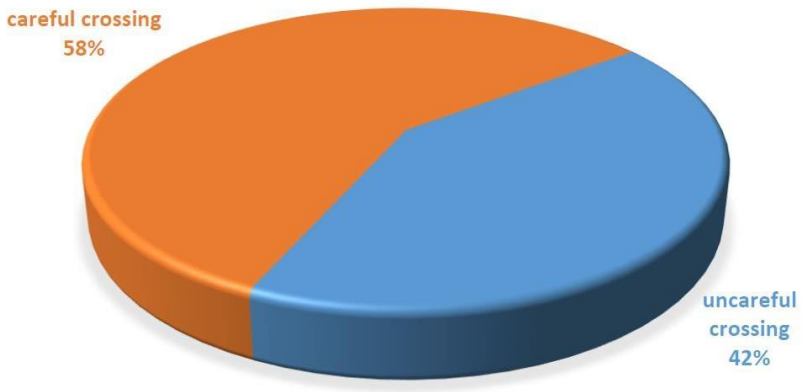


Figure 2 – Children careless crossing of road

Determining the objective behaviour of the driver was made by a similar method as well as determining the objective behaviour of children. Data from figure 3. shows that almost 35% of motor vehicle drivers do not stop pedestrians at pedestrian crossing, which can seriously endanger children when crossing the road. Reasons for such driver behaviour are roadside conditions that prevent drivers from good visibility of children on pedestrian crossing and intense traffic flow. When is high traffic flow and the speed of the traffic flow is small, the vehicles often stop ("stop and go") and get stopped at the pedestrian crossing and the children are pushing between them. This mutual mistakes of children and drivers can be very dangerous for children due to their low height, which prevents timely attention of children.

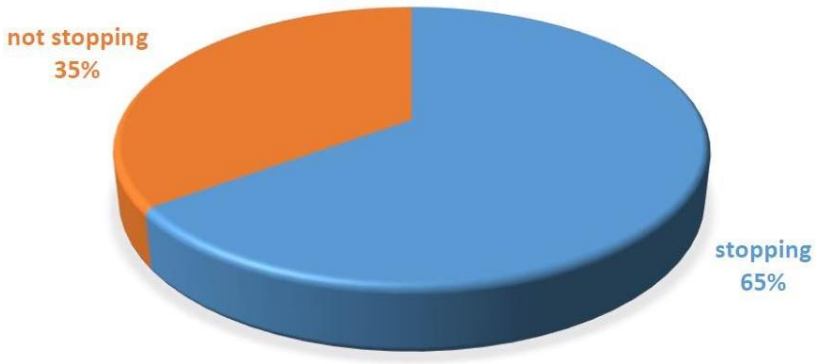


Figure 3 – Not stopping of drivers on marked pedestrian crossing

Chart 4. shows the use of distractors during driving. Distractors are means or devices that interfere with driver concentration when driving a motor vehicle. These can be mobile devices, music listening, eating food and drinks while driving, talking to passengers, makeup, etc.

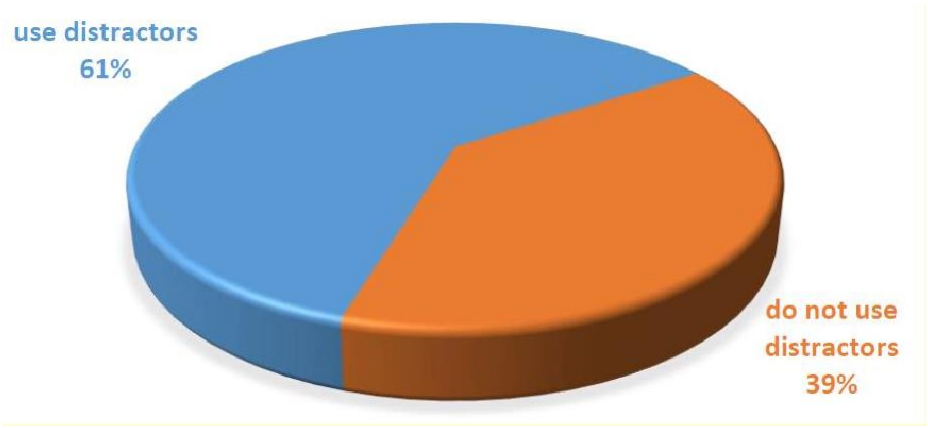


Figure 4 – Using the distractors during driving

Dismantling the driver's attention by using a distractor is a common problem and one of the frequent causes of traffic accidents. In addition to fines, activities like prevention, awareness raising of the negative impact of the use of distractors on driver behaviour and the safety of road traffic in the Republic of Croatia are not sufficiently expressed. Conclusion from figure 4. is that more than 60% of all observed drivers use some kind form of distractor that prevents them from fully concentrating on the drive.

Conducted survey and analyses of the collected data show needs to improve knowledge and experience of schoolchildren in primary school zones. Improving knowledge and experience can achieve with organizing educations and different workshops about protentional dangers in primary school zones, improving road, cyclist and pedestrian infrastructure and by promoting sustainable modes of travel (walking, cycling and using public transport). This can be achieved by implementing “5E“ concept of traffic safety. “5E” concept represent the acknowledgement that safer walking and biking routes can best be accomplished through a combination of infrastructure and non- infrastructure projects and programs. These are known collectively as the "5 Es": Education, Encouragement, Engineering, Enforcement, and Evaluation.

5. DISCUSSION

Analysing data of conducted survey shows that parents and children between 1th and 4th Grade with children from 5th to 8th grade have insufficient perception about their knowledge traffic condition and right behaviour. Insufficient perception is caused by too much confidence with their skills and knowledge about right behaviour and traffic regulations. Data showing very large percentage of children and parents that breaks and they do not respect traffic regulations at least in one of three cases. Reasons that also

affect on data is using distractors during walking or driving near the school facilities. By implementing "5E" concept of traffic safety, it is possible to reduce number of traffic accidents in the primary school zones.

6. CONCLUSION

Based on the research and the obtained results, with the goal of improving the mobility of pedestrian children, it is necessary to raise the level of traffic culture, knowledge and skills necessary for the safe participation of children in traffic. Children as the most vulnerable traffic participants are our future, but also our responsibility. Therefore, it is necessary to point out to them about the potential danger in road traffic already in elementary and in high school education. The conducted survey of children in elementary school gives us a worrying picture of their knowledge when traveling where almost every second children uses a distractor. It is also necessary to educate and change the thinking of drivers on driving procedures and to increase the traffic culture in the driver-pedestrian relationship. Through continuous education and awareness-raising, children learn to recognize the dangers and to behave properly when travelling. Conducting various research about current state of infrastructure and behaviour of schoolchildren can help to implementing right set of measures to reduce number of traffic accidents. "5E" concept show best results in this filed, and it is necessary to implement that concept in primary school zones.

REFERENCES

[1] Cloutier MS., Desrosiers-Gaudette L. Child pedestrian safety: individual and environmental correlates of interactions with vehicles at street crossings around schools and parks. *Injury prevention*. 2018; 24(2): 135-135.

[2] Diaz-Insense N., McEwan L., Hilland J. The six E's of active school travel: how active and safe routes to school (ASRTS) programs across Canada increase the number of children walking to school every day. 2017; *Journal of transport & health*; 7: 50-51

[3] Ferenchak NN., Marshall WE. Redefining the child pedestrian safety paradigm: identifying high fatality concentrations in urban areas. 2017; *Injury prevention*; 23: 364-369.

[4] Rothman L., Cloutier MS., Manaugh K., Howard A., Macpherson A., Macarthur C. Child pedestrian risk and social equity: spatial distribution of roadway safety features in Toronto, Canada. 2018; *Injury prevention*; 24(2): 49-50

[5] Sullivan SO., O'Connor S. Safe roads parallel to safe kids: public private partnerships to increase global road safety for children. 2016; *Injury prevention*; 22(2): 31-32

[6] Ministry of Interior Affairs of the Republic of Croatia. *National Road Traffic Safety Programme 2010. – 2020.* Narodne novine; 2011.

[7] Ministry of Interior Affairs of the Republic of Croatia. *Road Traffic Safety bulletin for 2017.* Narodne novine; 2016.

[8] Faculty of Traffic and Transport Sciences. *Safety of pedestrian children in primary school zones.* Faculty of Traffic and Transport Sciences; 2018.

MARKO EMANOVIĆ, mag. ing. traff.[1]
E-mail: marko.emanovic@gmail.com
LJUPKO ŠIMUNOVIĆ, Ph.D.[2]
E-mail: ljsimunovic@fpz.unizg.hr
JULIJAN JURAK, mag. ing. traff.[2]
E-mail: jjurak@fpz.unizg.hr
MATIJA SIKIRIĆ, mag. ing. traff.[2]
E-mail: msikiric@fpz.unizg.hr
[1] Centre of Vehicle of Croatia
Capraška 6, City of Zagreb
[2] Faculty of Transport and Traffic Sciences
Vukelićeva 4, City of Zagreb

ANALYSIS OF PEDESTRIAN TRAFFIC ACCIDENTS USING THE MULTIPLE-CRITERIA DECISION-MAKING METHOD - CASE STUDY OF THE CITY OF ZAGREB

ABSTRACT

Multi-criteria decision-making (MCDM) or multiple-criteria decision analysis (MCDA) is a methodological approach to assessing the selection of the optimal variant by following certain set criteria. Traffic accidents involving pedestrians are increasingly a problem of urban areas. By increasing the level of motorization and financial capacity of the population, the number of pedestrian and motor vehicle trips is increasing, and thus their conflict points and areas. Defining the key factors that affect pedestrian safety is the first step in solving the problems that arise. However, defining a factor is not a problem, but rather defining an optimal variant for improving pedestrian safety in urban areas. Defining the optimal variant is the basis of this paper. Optimal variant selection was created using multicriteria selection analysis. The multicriteria selection analysis was chosen because of the possibility of defining key factors and examining several different variants and how the weight of a factor influences the selection of the optimal variant.

KEY WORDS

Multi-criteria decision analysis; pedestrian safety; traffic accident; AHP method; pedestrian accident criteria

1. INTRODUCTION

Walking is a traditional way of moving people and carries a high risk of possible casualties. Pedestrians are the least protected group in traffic and require the necessary safety treatment and measures to reduce casualties. Every day, the number of motor vehicles in cities is increasing and they are living an accelerated lifestyle. The tendency is to reach the destination as soon as possible, which can leave behind many consequences due to improper movements, uncontrolled speeds of movement, and other negative factors.

Walking does not yet have a proper place in traffic, while passenger cars are symbols of modern times and the higher social status of people. The issue of non-motorized traffic is neglected and does not have the same representation as other forms of traffic. Many financial resources are being invested in motor traffic every day, which is a very attractive method for end users, while non-motorized traffic is put aside and is, for the most part, seen as a problem of traffic disruption. No form of traffic is so good that it would be the only one, as neither is it bad for users to give it up. The optimal traffic solution can only be found if all available traffic patterns are matched.

The main aim of the paper is to present the possibility of evaluating the improvement of pedestrian safety by applying multicriteria analysis. The paper consists of an introductory section, analysis of existing literature, processing of available data, determining and defining parameters for evaluating solution variants using the multicriteria AHP method, evaluating variant solutions by multicriteria analysis, and conclusion.

2. LITERATURE OVERVIEW

Avcl and Durduran in paper “Analysis of pedestrian accidents using a geographical information system GIS in Konya city, Turkey” analyse pedestrian accidents that occurred in the period 2005-2006 and 2011-2012. Using GIS technology, spatial analysis with an emphasis on the aspect of environment was carried out. The authors of the paper state that traditional methods fail to prevent and reduce road accidents and that some new methods are needed. Emphasis is placed on new technologies, which can produce accurate results that are of great importance for future traffic planning. Furthermore, the authors state that they view the solution as a geographic information system (GIS) as a technology that can produce effective solutions related to processing, storing and analysing data and presenting their results to users. [1]

The evaluation thoroughly considered road traffic accidents involving pedestrians. The concluding considerations of the paper present the obtained solutions on pedestrian traffic accidents by region in the observed period. According to the results obtained, the main reasons for the occurrence of traffic accidents are lack of traffic inspections, errors of pedestrians and drivers, deficiencies in transport infrastructures, insufficient fines, malfunctioning of first aid and insufficient information. This study identified an increase in pedestrian accidents in the Yazir, Sančak, Isiklar and Karaaslan Dede regions, which have a dense population rate and a high number of road accidents. The authors state that it is necessary to carry out research in specific regions and to take precautionary measures. [1]

Kuşkapan et al. in paper “Traffic accidents caused by pedestrians in Turkey” studied shortcomings and traffic offences caused by pedestrians that occur during a road accident in Turkey. Furthermore, the authors state that when it comes to pedestrian traffic accidents, the biggest cause is non-compliance with the traffic rules in places where there are no crossings or intersections, which is often the case in urban areas. Pedestrians do not adhere to the rules, so that they do not "waste time", they use simpler options, thereby causing traffic violations. [2]

In concluding considerations, the authors state that road users must abide by the rules in order to reduce the number of traffic accidents. Participants' education levels also play a major role in reducing accidents, and it is emphasized that traffic in schools as a topic should be more pronounced and more frequent in order to develop awareness and traffic culture, especially among younger populations. [2]

Youn-Soo et al. in paper “Analysis of pedestrian – vehicle crashes in Korea: Focused on developing probabilistic pedestrian fatality model” analyse pedestrian-vehicle traffic accident data. Microscopic analysis of pedestrian-vehicle accident data is the backbone for designing various intelligent vehicle functionalities to reduce the number of fatalities and the severity of pedestrian injuries in the event of a collision. The authors state that an overview of the characteristics of pedestrian accidents in Korea is first needed. [3]

The second major focus of the study is to develop a probabilistic model of pedestrian traffic accidents. A logistic regression approach, that is, one of the multivariate statistical modelling techniques, is applied in the development of the model. The model developed is expected to support different traffic safety policies to increase pedestrian safety. The results of this study would be an invaluable link between pedestrian accident data and the development of different measures to protect them in traffic. [3]

Zhen and Wei in paper "A multinomial logit model of pedestrian – vehicle crash severity in North Carolina" discusses the development of a multinomial logit model to investigate and identify significant factors contributing to the determination of the consequences of pedestrian-vehicle collisions in North Carolina. The study used pedestrian-vehicle collision data from the Road Safety Information System database from 2005 to 2012. The severity of collision injuries is classified into five categories. The desired multinomial logit model was developed using the SAS PROC MDC procedure, where boundary effects are calculated. [4]

The results obtained show that the factors that significantly increase the likelihood of fatalities include: driver's physical condition (poor condition), vehicle type (motorcycle and heavy vehicles), pedestrian age (26-65 and over 65), weekend, light conditions (dawn, dusk, dark), pavement characteristics (curve), pavement surface (water), road class (NC route) and speed limit (35 - 50 mph and more than 50 mph). The model developed and the results obtained from the analysis provide insights for the development of effective countermeasures to reduce the severity of collisions involving pedestrians and to improve the safety of the transport system. [4]

Lee and Abdel-Aty in paper "Comprehensive analysis of vehicle – pedestrian crashes at intersection in Florida" analyse pedestrian-vehicle collisions at intersections in Florida in the period 1999-2002. The study looks at a group of drivers and pedestrians, as well as the traffic characteristics associated with pedestrian collisions, all using linear models. The study also estimates the severity of pedestrian injuries when involved in a collision using a probit model. [5]

As a result of the analysis, demographic factors, pedestrian and driver factors, road geometry, traffic and the environment were found to be closely related to the frequency and severity of pedestrian injuries. Furthermore, the authors point out that greater traffic volume at intersections increases the number of pedestrian accidents. It is concluded that, based on the analysis, the paper recommends countermeasures to improve pedestrian safety in traffic. [5]

Lord in paper "Analysis of Pedestrian Conflicts with Left-Turning Traffic" studied the interaction of pedestrians and vehicles turning left at signalized intersections. For the purposes of the research, the author used the technique of traffic conflicts. The study compared the safety of left turns at intersections of two types: T- intersections and X-intersections (cross-intersections). [6]

Statistical tests on the correlation between traffic conflicts and the expected number of accidents were performed. The test results showed that there is a positive correlation between traffic conflicts and the expected number of accidents. Research also suggests that T- intersections have a higher rate of traffic conflict than X- intersections. [6]

Kong and Yang in paper "Logistic regression analysis of pedestrian casualty risk in passenger vehicle collisions in China" investigated the relationship between impact speed and the risk of pedestrian casualties in car crashes using data from the China Accident Database. The sampling criteria were defined as (1) the accident was a frontal impact that occurred between 2003 and 2009; (2) the pedestrian age was above 14; (3) the injury according to the Abbreviated Injury Scale (AIS) was 1+; (4) the accident involved passenger cars, SUVs, or MPVs; and (5) the vehicle impact speed can be determined. [7]

The study found that the risk of a fatal pedestrian accident was 26% at a vehicle speed of 50 km/h, 50% at 58 km/h, and 82% at 70 km/h. At an impact speed of 80 km/h, a pedestrian rarely survives an accident. Weighted risk curves have shown that in China the risks of deaths and injuries to pedestrians are higher than those in other high-income countries. [7]

3. STATISTICAL ANALYSIS OF PEDESTRIAN TRAFFIC ACCIDENTS

According to the data available from the Ministry of the Interior, statistics related to pedestrian traffic accidents in the Republic of Croatia will be presented for 2018. Data on the types of traffic

accidents, as well as data and the percentage of injuries and fatalities in traffic in 2018 have been analysed. The data show that in the observed year, 1,405 (4.2%) traffic accidents were recorded in the type of traffic accident in the form of pedestrian accidents, where 64 (21.5%) were fatalities, while 1,300 (12). 8%) were injured. Also, the data on casualties by types of traffic accidents that occurred in 2018 were analysed. The data shows that for the observed and target group "pedestrian", 65 deaths were recorded (20.5%), 409 were seriously injured (15.0%) and 973 were slightly injured (8.6%). [8]

Data on traffic accidents are analysed according to the characteristics of roads in the Republic of Croatia. For the observed pedestrian group, the following data were recorded. There was a total of 195 traffic accidents at pedestrian crossings (0.6%), where 4 people were killed (1.3%), while 143 were injured (1.4%). In addition, there were a total of 23 traffic accidents (0.1%) in the pedestrian zone, while 9 injured persons (0.1%) were reported. Two other types of pedestrian-related road features are also presented, namely the sidewalk and the calm traffic zone. In the case of the "sidewalks" group, the total number of traffic accidents was recorded, amounting to 111 (0.3%), while the number of injured persons was 65 (0.6%). In addition, 17 traffic accidents (0.1%) were recorded in the calm traffic zone and 2 people were injured. [8]

Table 1 shows statistics on the number of pedestrian traffic deaths in EU countries for the period 2006-2015 The figure shows that the highest number of pedestrian deaths was recorded in Poland, where only in 2015 a small decrease in the number of deaths was seen, while at the same time 915 deaths were recorded. The lowest number of pedestrian deaths was recorded in Luxembourg where 7 pedestrian deaths were recorded in 2015. Looking at the Republic of Croatia, it can be seen that there are oscillations in the number of deaths, and in the observed period, the lowest number of deaths was recorded in 2015, where there were 61 deaths. [9]

Table 1 – Number of pedestrian death injuries in EU countries from 2006 to 2015.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BE	122	104	99	101	106	113	104	99	106	92
BG	-	-	278	198	-	-	-	-	-	-
CZ	202	232	238	176	168	176	163	162	130	150
DK	60	68	58	52	44	33	31	34	22	27
DE	711	695	653	591	476	614	527	561	527	545
EE	64	38	41	23	14	26	29	23	26	24
IE	72	81	49	40	44	47	29	31	-	-
EL	267	255	248	202	179	223	170	151	125	128
ES	614	591	502	470	471	380	370	371	336	367
FR	535	561	548	496	485	519	489	465	499	466
HR	-	124	136	103	105	71	72	69	73	61
IT	758	627	646	667	621	589	576	551	578	602
CY	19	17	16	9	13	13	10	8	10	16
LV	153	158	105	82	79	60	62	70	71	63
LT	-	-	-	-	-	-	-	96	109	81
LU	10	7	6	12	1	6	6	5	3	7
HU	296	288	251	186	192	124	156	147	152	149
MT	4	3	1	0	0	-	-	-	-	-
NL	66	86	56	63	62	65	64	51	50	60
AT	110	108	102	101	98	87	81	82	71	84
PL	1.802	1.951	1.882	1.467	1.236	1.408	1.157	1.140	1.116	915
PT	156	156	155	148	195	199	159	144	145	146
RO	1.034	1.113	1.067	1.015	868	747	728	726	697	649
SI	36	32	39	24	26	21	19	20	14	16
SK	214	217	204	113	126	-	-	-	-	-
FI	49	48	53	30	35	41	29	34	36	32
SE	55	58	45	44	31	53	50	42	52	-
UK	697	663	591	524	415	466	429	405	464	427
EU	**8.604**	**8.655**	**8.165**	**7.034**	**6.385**	**6.502**	**5.931**	**5.812**	**5.768**	**5.515**

Source: [9]

4. METHODOLOGY

Multi-criteria analysis, i.e. multi-criteria decision-making, is a model used in the decision-making process. The first step that precedes the process of evaluating variants is to identify the problem itself, define goals and criteria. The multi-criteria analysis model is appropriate for complex problems where the objectives are very complex and vaguely formulated, and it is difficult to find a single solution when looking at the proposed variants. The poor structure of the problem results in the criteria for evaluating the solution while the model includes a select number of variants. The problem is solved by finding the best variant from the set of offered variants in relation to setting the criteria and the relationships between them. [10][11]

The mathematical model of multi-criteria analysis is written in the form [10]:

$$\max \{f1(x), f2(x), \dots fk(x)\}, k \geq 2$$

with restrictions:

$$x \in A = [a1, a2, \dots am]$$

where:

fj – criteria, j = 1,2, …, n

k – number of criteria, j = 1,2, …, k

m – number of alternatives, i = 1,2, …, m

ai – alternatives to consider, i= 1,2, …, m

A – set of all alternative.

In multi-criteria analysis, depending on the nature of each particular problem being solved, there are three basic approaches to solving it [10][11]:

- ranking the defined alternatives from best to worst;
- selecting one, the best variant or;
- choice of multiple alternatives, where multiple alternatives are selected in two ways:
  - starting with the highest rank, a predefined number of alternatives or;
  - choose those alternatives for which other conditions are fulfilled which are not incorporated in the initial model of multi-criteria analysis.

The most commonly used methods of multi-criteria analysis are the dominance method, PROMETHEE IIV, ELECTRICAL I-IV, analytical hierarchical process (AHP) method, multi-criteria compromise ranking method (VIKOR) and others. [10][11]

4.1. Analytical Hierarchical Process (APH)

The main advantage of the APH method is the ability to adapt the decision maker in terms of the number of criteria and variants to be decided simultaneously, which can be described both quantitatively and qualitatively. Therefore, the AHP method allows for the flexibility of the decision-making process and helps decision makers prioritize and make the best decision taking into account both qualitative and quantitative aspects of the decision.

The problem-solving process using the AHP method consists of four parts [10][11]:

- structuring the problem;
- data collection;
- assessment of relative weights and;
- determining the solution to the problem.

The AHP method uses the ratio scales, the most famous of which is the so-called Saaty scale, which has five degrees of intensity and four inter-degrees. Each of them is judged by the value judgment of how many times one preference is given to one variant over the other, and when comparing criteria how many times one criterion is more important than another. The criteria are compared in pairs in relation to how many times one of them is more important for measuring goal achievement than the other, while the variants are compared in pairs for each of the criteria, assessing to what extent one of them favours the relationship to another. [10][11]

4.2. Determining and Defining Parameters for Evaluating Variants Using the Multi-Criteria AHP Method

The analysis that will be conducted in this paper using the AHP method is related to pedestrian traffic accidents in the City of Zagreb. Traffic accident questionnaire (UPN) data, which contains selected criteria and sub-criteria, will be used to analyse pedestrian traffic accidents. In order to use the AHP method to choose the optimal variant solution for pedestrian protection in traffic, which overall represents the highest quality option, it is necessary to define the relevant parameters. The parameters include criteria, sub-criteria and alternatives.

4.2.1. Selected criteria

5 main criteria were selected in the paper, which include: pedestrian mistakes/errors, driver influence, traffic regulation, and weather and visibility conditions, as shown in Figure 1.

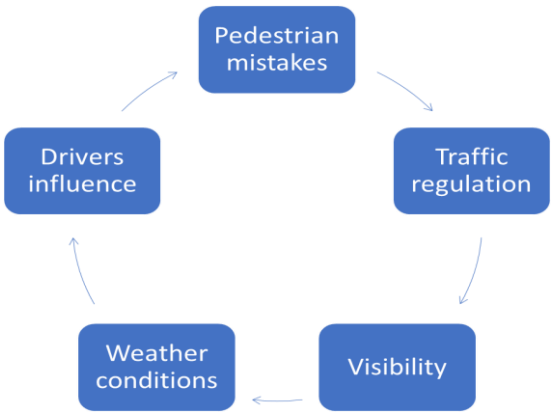


Figure 1 – Selected criteria
Source: authors

4.2.2. Selected sub-criteria

U In the paper, four types of sub-criteria were selected for each type of criteria. The following sub criteria were selected:

- Criterion: Pedestrian mistakes
  - Sub-criterion: use of unmarked pedestrian crossings, disregard of traffic signs and signalling, non-use of underpasses and overpasses, and other errors.
- Criterion: Driver influence
  - Sub-criterion: Improper speed, improper overtaking, disregard for passing advantage, and non-compliance to the light signal.
- Criterion: Traffic regulation
  - Sub criterion: Traffic signs, traffic rules, traffic lights off and flashing yellow light.
- Criterion: Weather conditions
  - Sub-criterion: Rain, fog, snow and cloudy.
- Criterion: Visibility
  - Sub-criterion: Night, day, dawn and dusk.

4.2.3. Selected alternatives

The alternatives chosen in the paper are: Better transport infrastructure, more frequent (stricter) traffic control and efficient education of traffic participants. A schematic of the selected alternatives is shown in Figure 2.

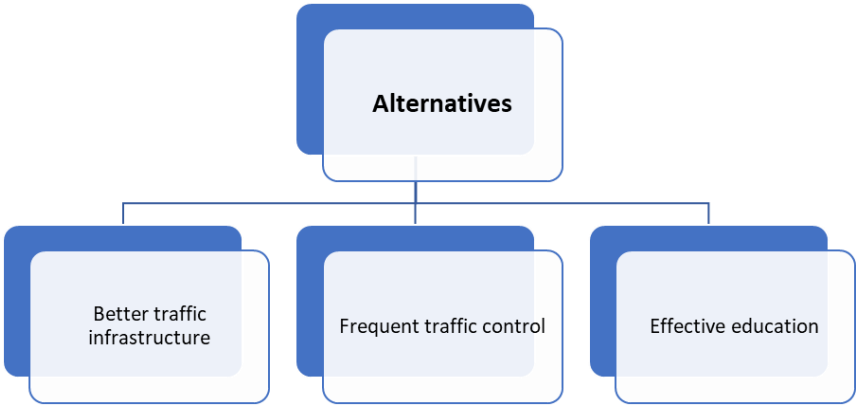


Figure 2 – Selected alternative
Source: authors

5. EVALUATION OF ALTERNATIVES BY MULTICRITERIA ANALYSIS (AHP METHOD)

This chapter presents the evaluation of the proposed variants by the AHP method, based on the relevant criteria and sub criteria previously defined. The AHP method is one of the most well-known and commonly used decision-making methods, that is, the multi-criteria analysis method, and is used to solve complex decision problems when there are a number of criteria.

The Expert Choice program was used to create the AHP method. The method of data collection was carried out using a survey of a sample of 31 respondents, by assigning values to the selected criteria and sub criteria. The aim of implementing the AHP method is to increase pedestrian safety in the City of Zagreb. Furthermore, the criteria selected in the paper are: Pedestrian mistakes, driver influence, traffic regulation, weather conditions and visibility conditions. The alternatives that have been selected and compared to the criteria and sub-criteria are the following: Better transport infrastructure, more frequent traffic control and efficient education of traffic participants.

5.2. Ranking of Criteria, Sub Criteria and Alternatives

The following figures show the selected criteria, sub-criteria and alternatives that were used in implementing the AHP method with the resulting statistics. Figure 3 shows that the highest numerical value obtained relates to the criterion (K1) of pedestrian mistakes (0,518), while the smallest value recorded under the criterion (K5) is the visibility and it amounts to (0,056). Furthermore, data for each selected sub-criterion, as well as for alternatives in operation, are also visible from the attached figure.

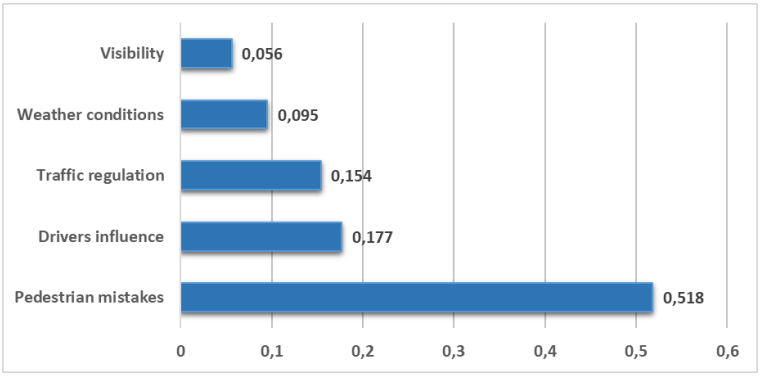


Figure 3 – Obtained values of selected criteria
Source: authors

Figure 4 shows the obtained values for the selected alternatives in operation. According to the presented alternative, effective traffic education has the highest recorded value of (0.375), followed by stricter traffic control (0.334). The lowest value refers to the alternative of better transport infrastructure and it amounts to (0.29).

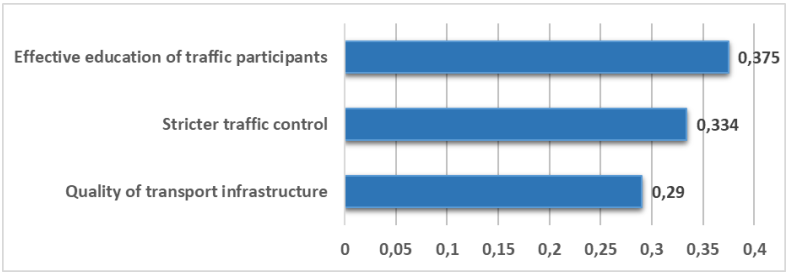


Figure 4 – Obtained values of selected alternatives
Source: authors

Figure 5 shows the obtained values for the selected sub-criteria in the paper. It can be seen from the attached that the highest value was recorded in the sub-criterion snow (0.577), which is also the highest value in the group of sub-criteria. This is followed by the sub-criterion night, which has a value of (0.529), followed by the sub-criterion of non-use of a marked pedestrian crossing with values of (0.525). For the traffic sign sub-criterion, the value was (0.487). When it comes to the lowest recorded values for sub-criteria, they refer to: cloudy (0.05), which is also the lowest value in the group of sub-criteria, and non-use of underpasses and overpasses (0.08).

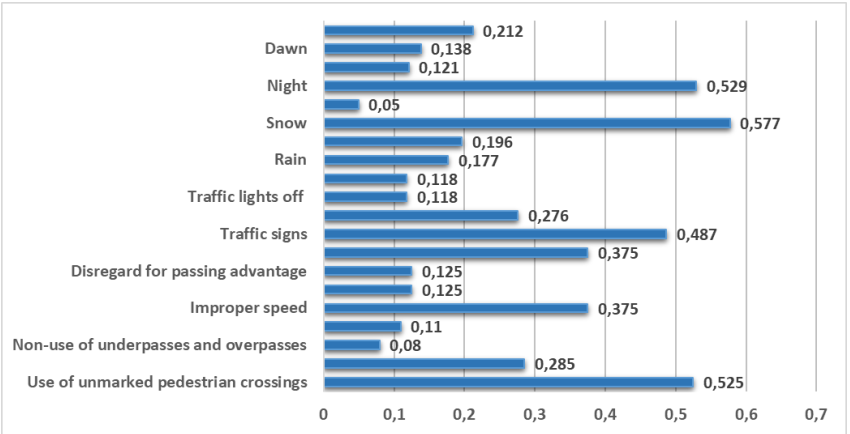


Figure 5 – Obtained values of selected sub-criteria
Source: authors

5.3. Results of Sensitivity Chart

Figure 6 presents a graph of sensitivity, which shows how the criterion (K1) - pedestrian error (which also has the highest values), affects the selected alternatives. Selected alternatives in the paper are: (A1) - better transport infrastructure, (A2) - stricter traffic control, and (A3) - effective education of traffic participants.

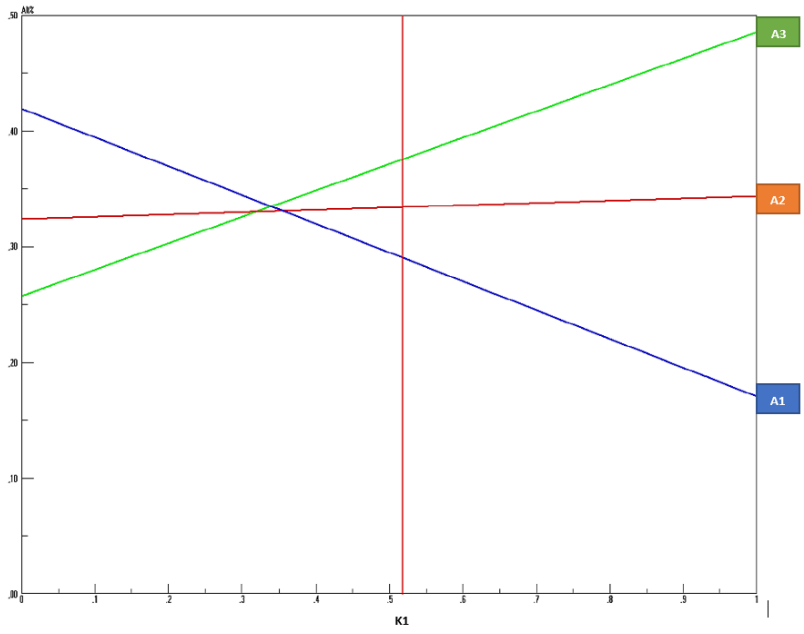


Figure 6 – Influence of criterion K1 on the choice of alternative
Source: authors

Figure 7 presents a sensitivity graph showing how the selected criteria (five analysed criteria) affect the selected alternatives (three alternatives). The picture shows that the alternative (A1) - better transport infrastructure, leads, while it is followed by the alternative (A2) - effective education of traffic participants, and the alternative (A3) - stricter traffic control.

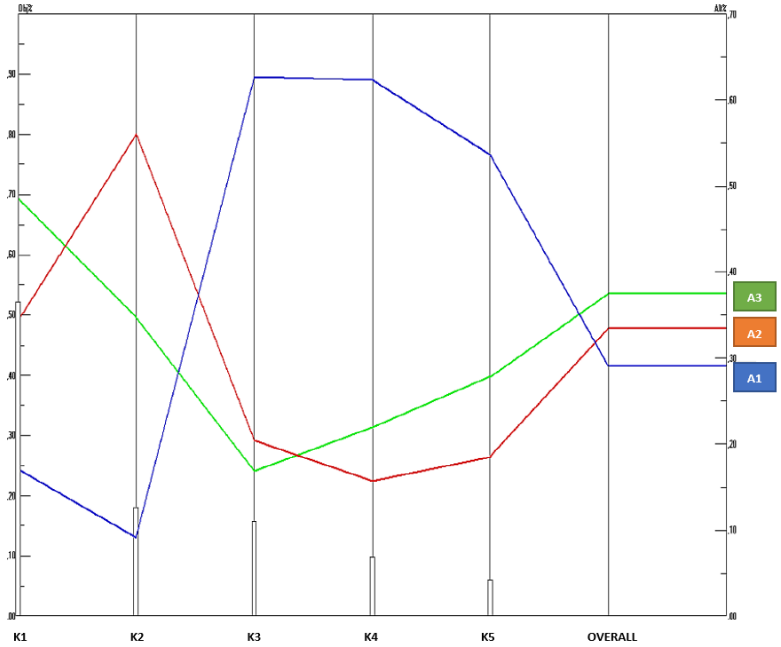


Figure 7 – Influence of criteria on alternative selection
Source: authors

The last step of the analysis was to establish a correlation between criteria and alternatives. The values obtained for the selected criteria are as follows: (K1) - pedestrian mistakes (51.8%), (K2) - driver influence (17.4), (K3) - traffic regulation (15.4%), (K4) - weather conditions (9.5%), and (K5) – visibility (5.6%). The values obtained for the selected alternatives are as follows: (A1) - better transport infrastructure (29.0%), (A2) – more frequent (stricter) traffic control (33.4%), and (A3) - efficient education of traffic participants (37.5%).

6. CONCLUSION

According to the conducted survey and according to the data obtained in the paper, the best rated alternative is (A3) called efficient education of traffic participants with a total score of 0.375, while the worse rated alternative (A1) is better quality transport infrastructure with value of 0.29 and alternative (A2) more frequent (stricter) traffic control with 0.334. Considering the criteria in the paper, the highest rating is the criterion (K1) of pedestrian mistakes 0.518, while the lowest grade refers to the criterion (K5) of visibility conditions 0.056. If the impact (K1) of pedestrian mistakes is reduced, then alternative (A1) quality of transport infrastructure will be increased. When the influence of the (K1) pedestrian mistakes criterion increases, then the need for more effective education of traffic participants will be increased, referring to alternative (A3). If the criterion (K2) is increased, the impact of the driver will require stricter traffic control as regards alternatives (A2). In the case of increasing traffic regulation criteria (K3), traffic safety is increased from the aspect of transport infrastructure quality, which refers to alternative (A1). If the criterion (K4) of the impact of meteorological conditions in traffic increases, as well as the criterion (K5) of visibility conditions depending on the time of day (night, day, dawn or dusk), alternative (A1) quality of transport infrastructure comes to the fore.

REFERENCES

[1] Avcl C, Savas Durduran S. Analysis of pedestrian accidents using a geographical information system (GIS) in Konya city, Turkey. *WIT Transactions on The Built Environment*. 2014; 134: 495-501.

[2] Kuşkapan E, Diler Alemdar K, Kaya Ö, Yasin Çodur M. Traffic accidents caused by pedestrians in Turkey. *International Journal for Traffic and Transport Engineering*. 2019; 9(I): 118-126.

[3] Youn-Soo K, Beomil K, Wonkyu K. ANALYSIS OF PEDESTRIAN-VEHICLE CRASHES IN KOREA: Focused on developing probabilistic pedestrian fatality model. *Proceedings of the 19th International Conference on the Enhanced Safety of Vehicles (ESV), 06-09 June 2005, Washington DC, United States*.

[4] Zhen C, Wei (David) F. A multinomial logit model of pedestrian-vehicle crash severity in North Carolina. *International Journal of Transportation Science and Technology*. 2019; 8(1): 43-52.

[5] Lee C, Abdel-Aty M. Comprehensive analysis of vehicle-pedestrian crashes at intersections in Florida. *Accident Analysis and Prevention*. 2005; 37(4): 775-786.

[6] Lord, D. *Analysis of Pedestrian Conflicts with Left-Turning Traffic*. Transportation Research Record: Journal of the Transportation Research Board, 1996; 1538(1), 61–67.

[7] Kong, C., Yang, J. *Logistic regression analysis of pedestrian casualty risk in passenger vehicle collisions in China*. Accident Analysis & Prevention, 2010; 42(4), 987–993.

[8] Ministry of the Interior of the Republic of Croatia. *Data about traffic accidents involving pedestrian in the Republic of Croatia.* 2016-2018.

[9] European Road Safety Observatory: *Annual Accident Report 2017*. Available from: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/asr2017.pdf [Accessed 04th March 2020].

[10] Brunelli M. *Introduction to the Analytic Hierarchy Process*. Springer. 2015.

[11] Saaty TL, Vargas LG. *Decision Making with the Analytic Network Process*. Springer. 2013.

KARLO EVDJENIĆ[1]
E-mail: karloevdjenic1@gmail.com
LUCIJA BUKVIĆ, MSc. Eng.[1]
E-mail: lbukvic@fpz.unizg.hr
JASMINA PAŠAGIĆ ŠKRINJAR, Ph.D.[1]
E-mail: jpasagic@fpz.unizg.hr
[1]University of Zagreb
Faculty of Transport and Traffic Science
Vukelićeva 4, 10000 Zagreb, Croatia

INTERMODAL ROUTES ANALYSIS OF TRANSPORT ORGANIZATION FROM GOTHENBURG TO ZAGREB

ABSTRACT

This paper presents the transport of Volvo parts from the factory, using different modes of transport and their combinations, to the capital of Croatia. Europe's transport network is diverse. From various inland waterways, a dense network of roads as well as railways, there is a plentiful number of ways the cargo can be transported. In this article, a few routes will be analysed also as transportation costs and travel time. By taking into account new technologies and opportunities presented by them, a more time-saving and efficient way of transporting goods will be presented. The calculations were made using various programs that allow us an in-depth view of individual branches of transportation.

KEY WORDS

road transport; intermodal; transportation cost; railway; route

1. INTRODUCTION

The point of transportation of goods is to find the most favourable, environmentally conscious, and fastest way to transport goods. Today, more than ever, there are diverse opportunities to transport these goods with the help of integrated and intermodal modes of transport. By combining modes of transport, the aim is to achieve cheaper, faster and overall better transport than via traditional road transportation. The demand for transportation has never been higher but the offer is increasing day by day. Webshops and door-to-door services guarantee deliveries within one day. Some companies are already developing drone deliveries. As a manufacturer or shipper of goods, we have many options today to bring our product to the consumer's doorstep.

In this work, the headquarters of Volvo are connected with the Croatian capital. In this example that is an analysis of the transportation of goods of Volvo parts from Gothenburg to Zagreb. The subject of transport are 345,000 gas valves packed in packages (20.5 cm x 25.5 cm x 5.1 cm). Twenty 40-foot containers were used, in every container there were 25 pallets with 690 packages on it. The weight of the 25 pallets combined with the container is 25,113.75 kg. The total value of the shipment at retail is around 774,650,000 HRK.

1.1. Literature Review

Resor, R. et al. [1] showed that rail transport is not cost effective on shorter distances compared to road transport. The reason for this is the high density of roads (especially in Europe). Another study by Winebrake, J. et al. [2] shows how using intermodal transportation can get the best results by combining different modes of transportation to transport goods. However, this study is based on the territory of the United States of America, while this work is based on the transport of goods within Europe, ie. the European Union. It is the aim of this paper to present the current situation and the

possibilities of improvement in order to improve short-distance freight transport. Southworth , F. et al. [3] also concluded that keys to realistic freight routing are the identification of intermodal transfer locations and associated terminal functions, a proper handling of carrier-owned and operated sub-networks within each of the primary modes of transport, and the ability to model the types of carrier services being offered. Another study [4] analysed the multimodal freight assignment component determines the network flow pattern from a mode–path alternative set calculated by the multiple product intermodal shortest path procedure, based on the link travel costs and node transfer delays from the multimodal freight network simulation component. This model can represent individual shipment mode–path choice behaviour, consolidation policy, conveyance link moving, and individual shipment terminal transfer in an iterative solution framework. Another study [5] declares road transport vital for economic development but clarifies its negative effects on the environment and society. The study addressed energy consumption, greenhouse gases, and the number of road casualties. This study helps our scientific work by highlighting the need to improve road transport conditions. Autonomous vehicles will replace the human factor and reduce the number of accidents and electric vehicles that will improve the utilization of invested energy and reduce greenhouse gases. In another study [6] to improve intermodal freight transport between Western, Central, and Eastern Europe, a survey of shippers, terminal operators, and link operators was conducted. The study identified problems of intermodal freight transport that impede competitiveness to road freight transport. The study identified 35 groups of delays, which were then sorted by importance according to the given criteria.

1.2. Methodology

Research methodology for this paper will be based on comparative analysis, interpretative and descriptive method. The comparative analysis, the use of which in traffic science has been well established, is the most important method used. Different scenarios will be analysed in comparison with each other, as well as assumptions of future developments. In addition, the paper relies on the interpretative method, particularly with matters of cost-efficiency and time savings as outlined in presented scenarios. Descriptive method is used to highlight how transport of goods changes with different parameters.

Calculations used in this paper are based on available information of real-life prices which are subject to change over time. Prices used are from January 2020. Tolls for road transport are calculated for each country using open source available data [8]. Price of the fuel is 9.84 HRK/l and fuel consumption is based on fuel consumption of Volvo FH16 which equals to 24.6 l/km. Loading and unloading cost is considered equal for all transport modes for an unbiased and equal representation (40 € / UTL). Train fare is calculated using given taxes from HŽ-Cargo [9].

Water transport is calculated by using fixed price of 5.75 €/km for a single transport unit. For a new scenario cost of charging stations is calculated using “A Better Routeplanner” for a Volvo FE. Some data used in the paper is extrapolated from publicly available sources due to a lack of reliable company-issued information.

2. DIFFERENT ROUTES

For the transportation of freight, parameters that were available at the time were used taking multiple routes into consideration as well as combinations of intermodal transport. In this way, the price and duration of the trip were available for analysis to make the data as realistic as possible.

2.1. Scenario One

First is the easiest route, from Gothenburg to Zagreb by road transport is shown in Figure 1. The total length of travel is 1,773.3 km. Multiple drivers taking turns so that there isn't an unnecessary loss of time over stops to get rest. A vehicle used in this transport is Volvo FH16 (2019) because of his

characteristics (EURO 6 norm, the towing capability of 325 tones, combined fuel consumption: 24.6 l/100 km). Estimated time of transport is 23 hours and 33 minutes (without stopping: 19 hours). [8]

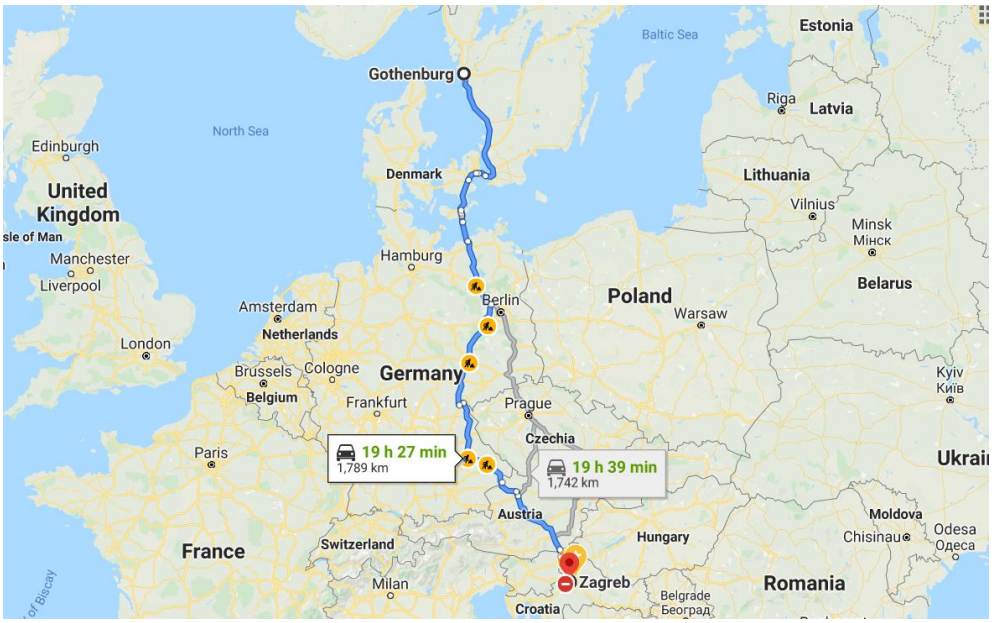


Figure 1 – Road route for scenario one
Source: https://www.google.com/maps [Accessed: 18.01.2020]

Key cities and points on this route are Gothenburg - Malmo - Copenhagen - Rostock-Gedser (by ferry) – Berlin - Regensburg - following River Inn crossing into Austria - Slovenia – Zagreb. The total toll cost on this route can be seen from Figure 2.

COUNTRY	FREE	CHARGED	TOLL
Sweden	0 km	292.3 km	98.44 €
Denmark	53.8 km	131.6 km	12.00 €
Germany	31.8 km	826.2 km	151.74 €
Austria	0 km	305.9 km	133.54 €
Slovenia	8.3 km	51.9 km	16.33 €
Croatia	17.0 km	51.7 km	29.05 €
	110.9 km	**1659.8 km**	**441.10 €**

Figure 2 – Toll cost for scenario one
Source: https://apps.impargo.de [Accessed: 18.01.2020]

Toll cost: 441.10 € 441.1 € x 20 = 8,822€ = 65,282.8 HRK	Fuel cost (Volvo FH16): 24.6 l/100km 9.84 HRK/l x 443.7 l = 4,366 HRK = 87,320 HRK	Bridge toll cost: 153 € 153 € x 20 = 3,060 € = 22,644 HRK
Loading and unloading costs: 40 € / UTL Shipping: 5,920 HRK Unloading: 5,920 HRK	**Total = 187,086.8 HRK**	

Figure 3 – Total cost for scenario one
Source: authors

Total cost for transporting 345,000 packages of gas valves by road results in 187,086.8 HRK including toll, fuel, bridge toll, handling, and shipping cost.

2.2. Scenario Two

In this case, only rail transport is used for financial analysis opposite to the use of the unimodal road transport. The length of the route is 2,185.64 km and the estimated time of transport is 27 hours 19 minutes as shown in Figure 4.

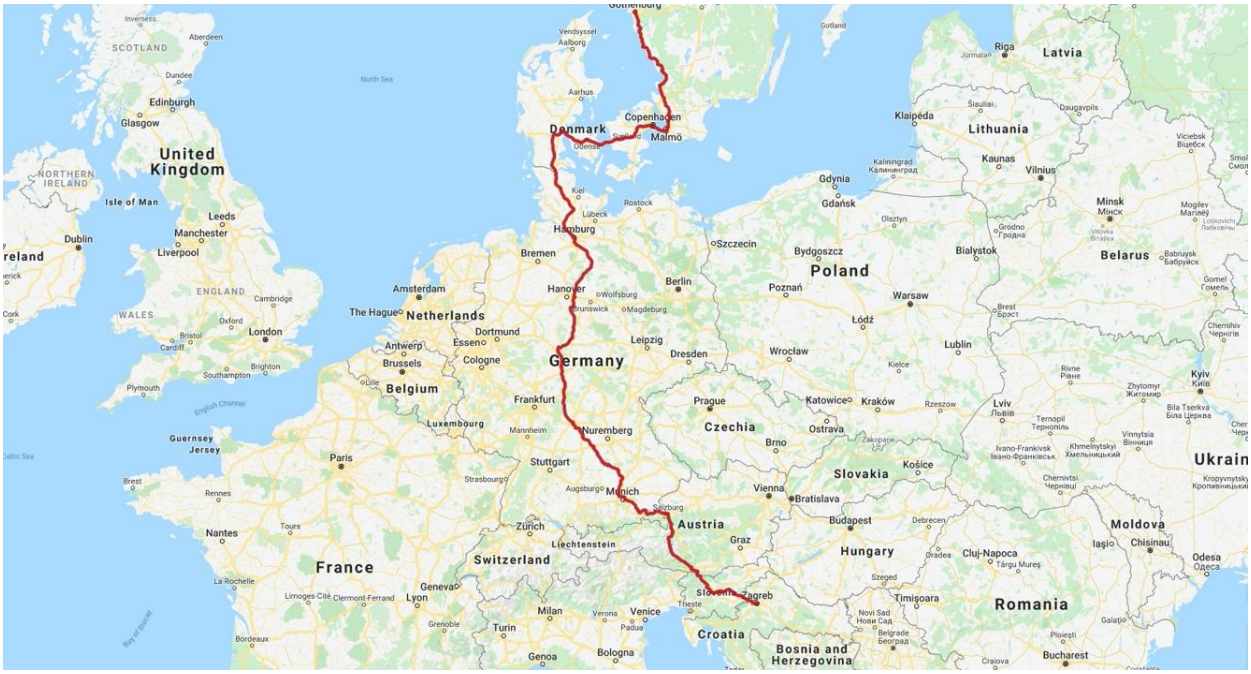


Figure 4 – Rail route for scenario two
Source: https://www.google.com/maps [Accessed: 18.01.2020]

Key cities on this route are Gothenburg - Malmo - Copenhagen - Flensburg - Salzburg - Jesenice - Savski Marof – Zagreb (Figure 4).

Train fare: 2,053 € / wagon = 18,522.2 HRK 18522.2x 20 wagons = = 370,444 HRK	Loading and unloading costs: 11,840 HRK	**Total: 382,284 HRK**

Figure 5 – Total cost for scenario two
Source: authors

The total cost for transporting 345,000 packages of gas valves by railway results in 382,284 HRK including train fare and handling. Also, it is worth mentioning that train stations (industrial tracks) are usually not near the warehouse, so they will also have to be transported by road.

2.3. Scenario Three

With the help of intermodal transport to save money and time, the railway is combined with road transport. The length of railway route is 1,447.81 km and it will take 18 hours 5 minutes to complete. Key cities are Gothenburg - Malmo - Copenhagen - Flensburg - Hamburg – Hanover – Nurnberg (Figure 6). The length of the road transport route is 673.3 km and the estimated time of transport is 11 hours 12 minutes. Key cities on this route are Nurnberg - Regensburg - Wels - Graz – Zagreb (Figure 7).

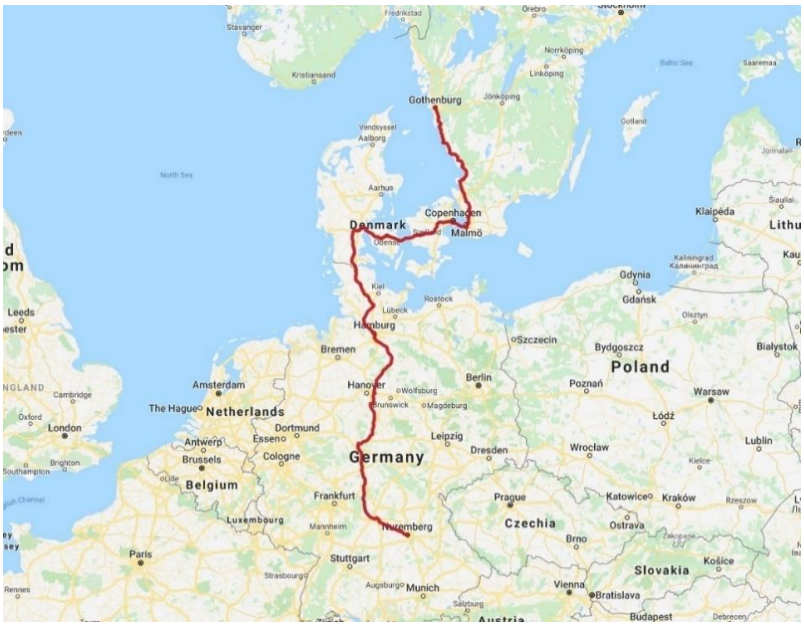


Figure 6 – Rail route for scenario three
Source: https://www.google.com/maps [Accessed: 18.01.2020]

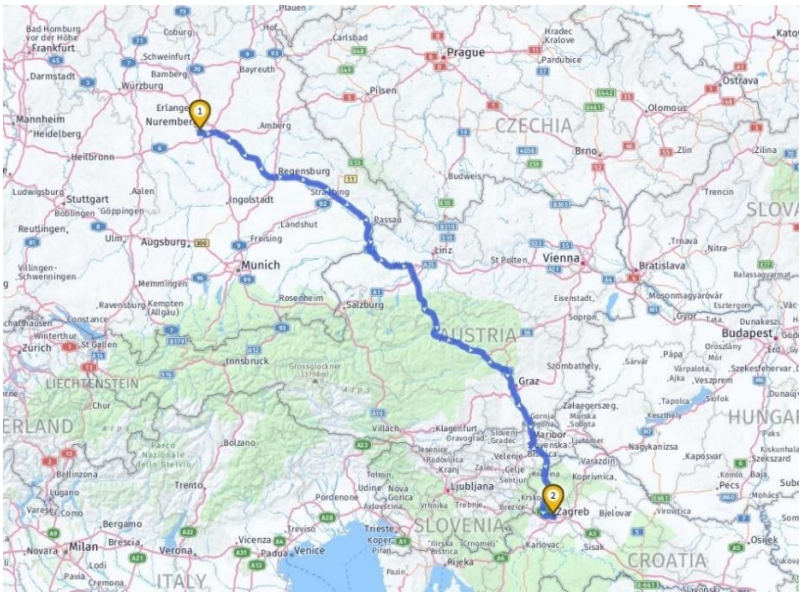


Figure 7 – Road route for scenario three [8]
Source: https://apps.impargo.de [Accessed: 18.01.2020]

Railway cost: 1,738 €/UTL = 1,738 € x 20 = 34,760 € = 257,224 HRK	Toll cost: 235.55 € = 1,752.21 HRK x 20 = 35,044.2 HRK	Fuel cost (Volvo FH16): 24.6 l/100 km = 32,436.58 HRK
Loading and unloading costs: = 23,680 HRK	**Total: 348,384.78 HRK**	

Figure 8 – Total cost for scenario three
Source: authors

The cost for transporting 345,000 packages of gas valves by railway to Nurnberg results is 269,064 HRK including train fare and handling. The cost for transporting from Nurnberg to Zagreb by road results in 79,320.78 HRK including toll, fuel, handling, and shipping cost. The total combined cost for railway and road transport is 348,384.78 HRK.

2.4. Scenario Four

Route length is 1,300 km for sea and inland waterways, 309 km for road transport and 330 km for railway transport. Key cities on route for water transport are Gothenburg - Lübeck – Prague (Figure 9) for road transport are Prague and Vienna (Figure 10), and for the railway transport from Vienna to Zagreb (Figure 11).

Total estimated travel time is 1 day 17 hours 8 minutes. 1 day and 6 hours will be spent on water transport, 6 hours 8 minutes on road transport then 5 hours on railways transport.



Figure 9 – Sea and inland waterways map for scenario four
Source: https://www.boatbookings.com/ [Accessed: 19.01.2020]

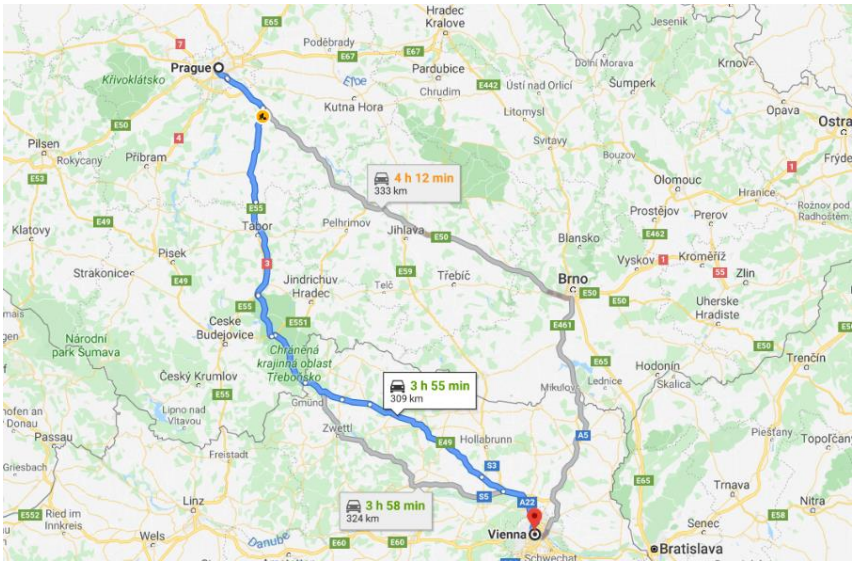


Figure 10 – Road transport map for scenario four
Source: https://www.google.com/maps [Accessed: 19.01.2020]



Figure 11 – Rail freight corridors for scenario four
Source: http://rne.eu/rail-freight-corridors/rail-freight-corridors-general-information/ [Accessed: 19.01.2020]

Water transport cost: 5.75 €/km = 7,475 € = 55,315 HRK	Road transport toll cost: 62.14 €/UTL = 62.14 € x20 = 1242.8 € = 9,196.72 HRK	Fuel cost (Volvo FH16): 24.6 lit/100 km x 20 9.84 HRK/l x 76.7 l =754.5 HRK/truck 754.5 x 20 trucks = 15,090.3 HRK
Railway fee cost: 553 €/UTL = 553 € x 20 = 11,060 € = 82,260 HRK	Loading and unloading cost: = 35,520 HRK	**Total: 197,382 HRK**

Figure 12 – Total cost for scenario four
Source: authors

The cost for transporting 345,000 packages of gas valves by water to Prague results in 67,155 HRK including sea and inland waterway transport cost and handling. The cost for transporting from Prague to Vienna by road results is 24,287.02 HRK including toll, fuel and handling. From Prague to Zagreb railway transport includes handling and railway fee, and it costs 94,100 HRK. The total shipping cost is 197,382 HRK.

2.5. Scenario Five

According to previous calculations, railway transport on this route is simply too expensive and therefore inadequate. To surpass that obstacle final route will consist only of road and water transport in the last calculation.

Route length for water transport is 2,400 km (Figure 13) and 361.7 km for road transport (Figure 14).

The total estimated time is 2 days 10 hours 31 minutes. From the total time, 2 days 4 hours 19 minutes goes on water transport and 6 hours 12 minutes on road transport.

The main cities on this route are Gothenburg and Amsterdam. Ship transports goods from Gothenburg to Amsterdam where the cargo is unloaded and loaded onto a ship suitable for inland waterways. That ship goes to Vienna where it is unloaded and loaded and transported further by trucks. Last step, trucks go on the highway towards Zagreb where goods are unloaded on its final destination.

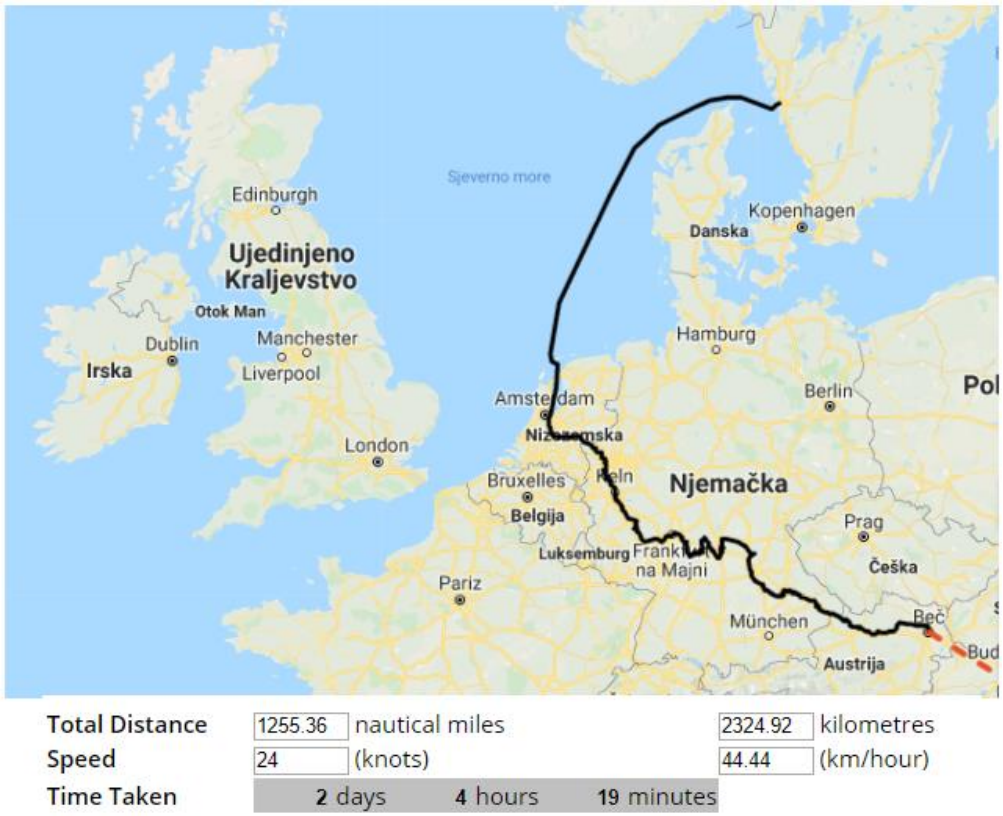


Figure 13 – Water transport map for scenario five
Source: https://www.boatbookings.com/ [Accessed: 21.01.2020]

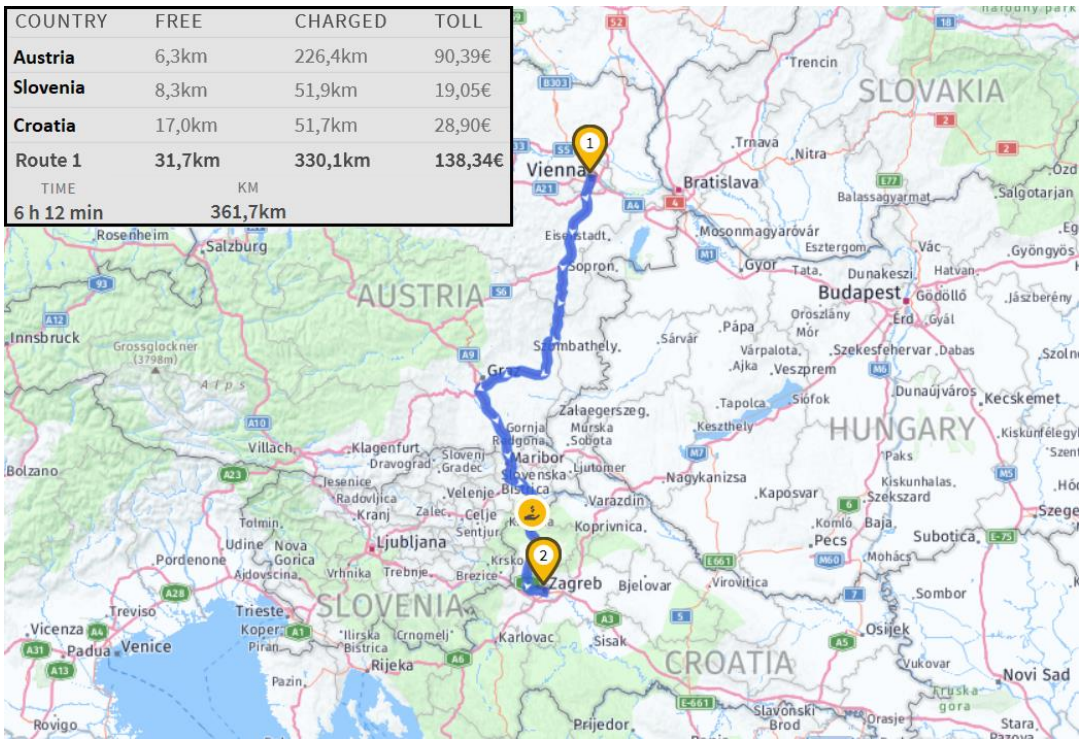


Figure 14 – Road transport map for scenario five [8]
Source: https://apps.impargo.de [Accessed: 21.01.2020]

Water transport cost: 5.75 €/km = 13,800 € =102,120 HRK	Toll cost: 138.34 € /UTL = 138.34 € x 20 = 2,766.8 € = 20,474.32 HRK	Fuel cost: (Volvo FH16): 9.84 HRK/l x 88.9 l = 875.5 HRK/ truck 875.5 x 20 trucks = 17,510.9 HRK
Loading and unloading cost: 23,680 HRK	**Total: 163,785.3 HRK**	

Figure 15 – Total cost for scenario five
Source: authors

The cost for transporting 345,000 packages of gas valves by water to Vienna results in 113,960 HRK including sea and inland waterway transport cost and handling. The cost of transporting from Vienna to Zagreb by road results is 49,825.22 HRK including toll, fuel, and handling. The total shipping cost is 165,785.3 HRK.

3. THE RESULTS

The results from carried-out scenarios are compared in two ways: by cost and by the estimated time of travel. All costs were previously transferred to the Croatian national currency, the Croatian kuna, and are shown as such (Figure 16). The time required to execute the transport of an individual scenario is displayed in hours in order to maintain the clarity of the displayed content (Figure 17).

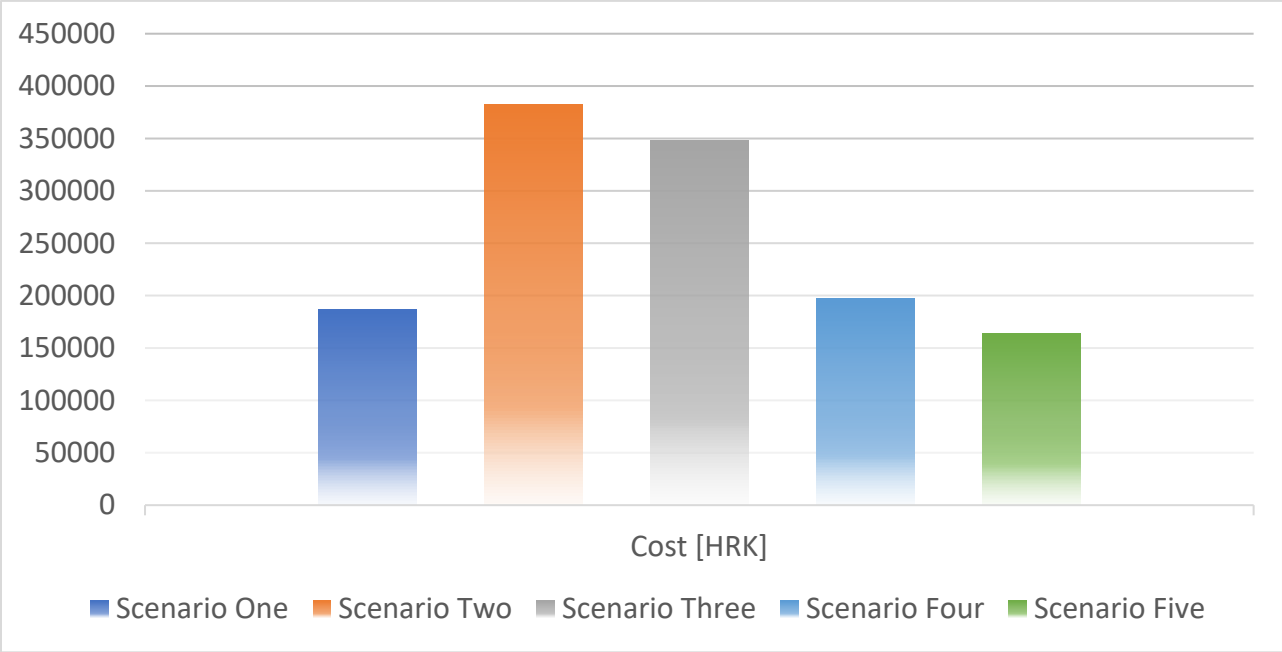


Figure 16 – Comparison of all total costs
Source: authors

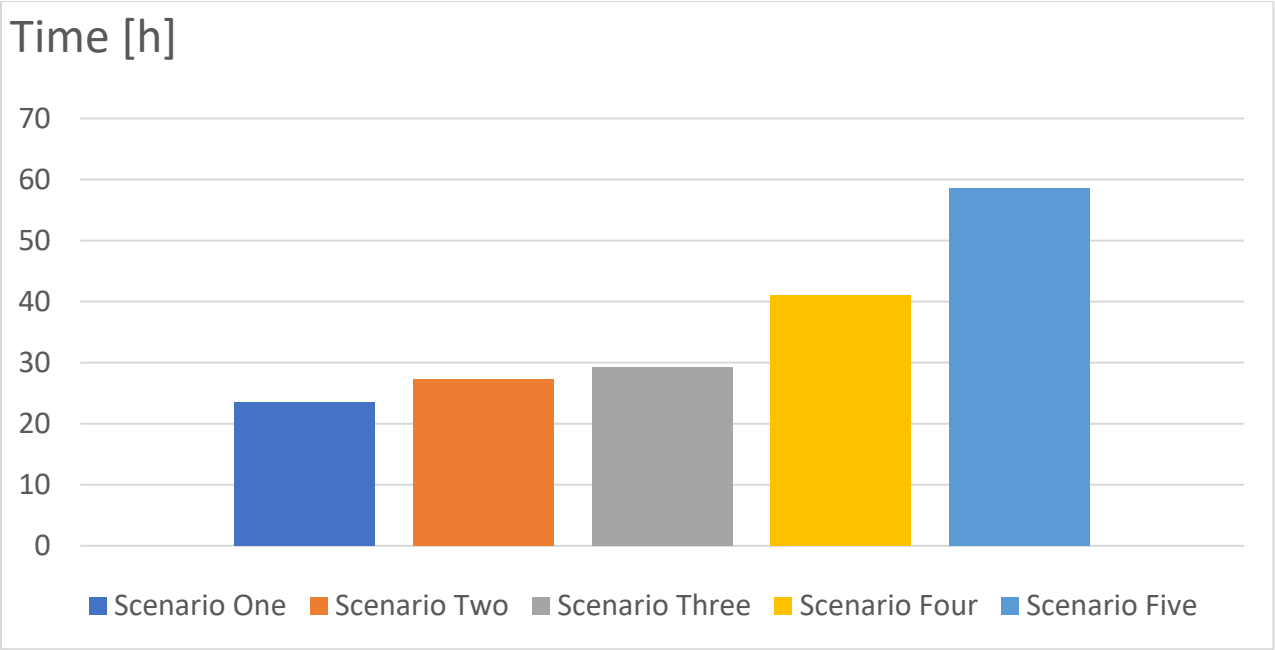


Figure 17 – Comparison of total estimated times
Source: authors

The scenario of transport number 5 is the most cost-efficient as it can be seen from Figure 16, while scenario two is the most expensive. It suggests that transport only by rail is expensive and slow, which is not compatible with this type of freight transported.

On the other hand, looking into the travel time (Figure 17), scenario one is also optimal while the scenario five is taking too much time even if it is the cheapest option.

The goal of the analysis was to combine different modes of transport as well as different routes to get the optimal one. Though, some buyers/companies will decide for scenario five for the sake of savings. The conclusion is that for goods with a retail value of 774,650,000 HRK, the difference in the cost of transportation between scenario one and five is insignificant, while time is not. But there is also a possibility to further improve the road transport and to find future solutions.

4. FUTURE: SELF-DRIVING TRUCKS

Autonomous trucks are vehicles that do not require a driver. There are currently multiple companies investing in this dream (Google, UPS, Mercedes-Benz, Volvo, ZF…). In December 2019, Plus.ai had hauled a refrigerator trailer full of butter 2,800 miles (4,500 km) from California to Pennsylvania in less than three days. For example, usual transport via train for this route is about 7-8 days from Pennsylvania to Phoenix and then an additional 1-2 days with a truck from Phoenix to San Francisco. In urgent cases, it takes 5 days. The technology relies on sensors, cameras, radar, and Lidar (light detection and ranging) technology, also as computer vision software supported by artificial intelligence. [14]

Today's technology is not yet on the door-to-door level of delivery, but it is not difficult to see that it is moving in that direction. The autonomous level of Plus.ai is at level 4, which currently means that the vehicle must be under the control of the driver and is adapted to the traffic of certain roads, such as in this case the highway. When technology reaches level 5, regulations will still require a person to oversee all systems working properly, but vehicles will also be able to navigate city roads. Then delivery will be possible from any and to any point. Benefits other than faster travel is safer travel, lower fuel consumption, lower insurance premiums, and meeting the ever-demanding global demand for drivers.



Figure 18 – VERA from Volvo trucks
Source: https://www.volvotrucks.com/en-en/about-us/automation/vera.html [Accessed: 20.07.2020]

The assumption is that autonomous driving should be combined with new, and lighter materials in vehicle construction, driving more autonomous vehicles in the column and new sources of energy. Figure 18 shows the new autonomous electric freight vehicle from Volvo trucks called VERA. VERA is designed to be a part of a larger system with the potential to optimize transport in highly repetitive short-distance transport flows with large volumes of goods, such as ports, factory areas, and logistic megacentres. The autonomous electric vehicles operate together in a network and are connected through a cloud-based service and management center. [7]

Volvo VERA has the same specifications as the FL model. A driving range of 300km and the battery can be charged in just two hours with a 150kW fast charger. But it takes more than ten hours to charge the battery with a standard charger. The Vera autonomous truck can pull a load of up to 32 tonnes and it can tag to any standard trailer. For now, it is not a substitute for a driver-operated truck driven on public roads, it is used only as a solution to automatization, but it gives us an insight to what is possible in the future.

5. ELECTRIFICATION

One easy way to improve the road transport process is to replace fossil-fuel-powered vehicles with electric ones. The biggest obstacle in the process is the range that the vehicle can cross. Currently, the most advanced commercial electric trucks come from Volvo. The Volvo FL model has a load capacity of up to 16 tonnes, a maximum output of 185 kW, and a range of up to 300 km. Charging time is 2 hours on fast chargers and 13 hours on regular chargers. The FE model has a capacity of 27 tonnes, maximum power of 300 kW but therefore a range of up to 200 km.

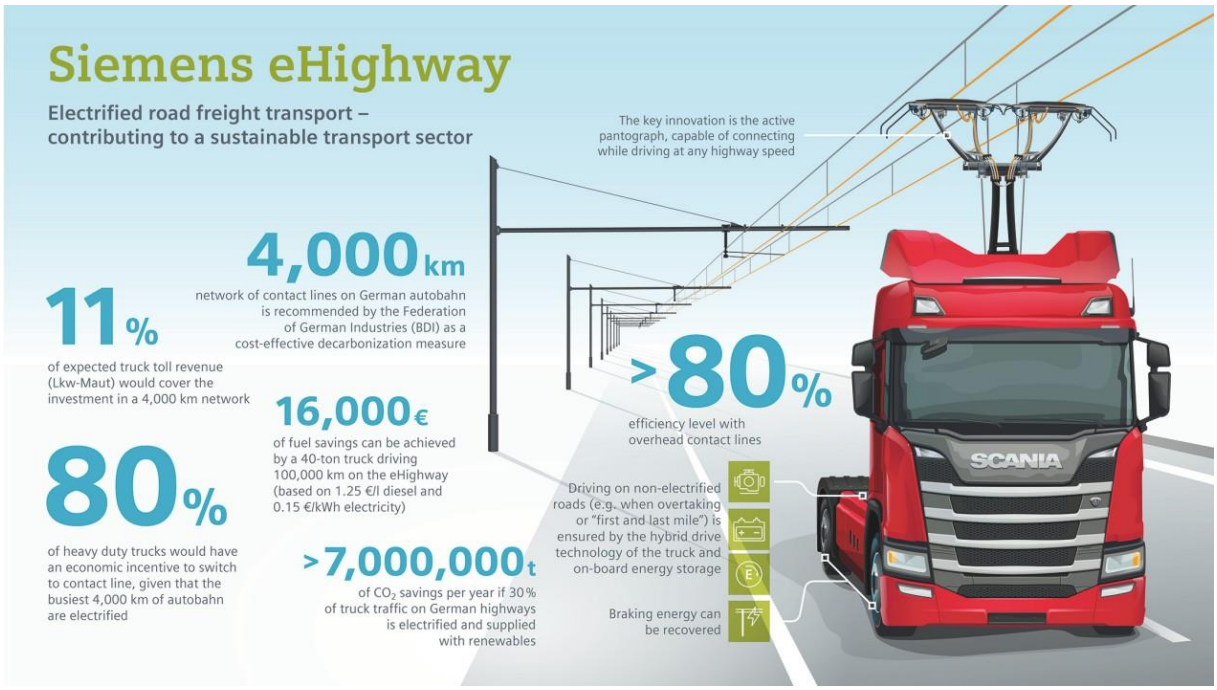


Figure 19 – Rail freight corridors
Source: https://www.mobility.siemens.com/global/en/portfolio/road/ehighway.html [Accessed: 21.01.2020]

So future technology should allow for greater range but also adapt infrastructure to enable more charging stations. But there is also an easier solution that will work on the trolleybus principle. Such is already in operation on the 5 km highway in Germany between the cities of Darmstadt and Frankfurt. Currently, this is adapted for hybrid (diesel-electric) vehicles. If we manage to increase the capacity of our batteries and expand this highway power grid, the costs will be significantly reduced but also the global gas emissions.

6. A NEW SCENARIO

Road transport was the most successful way of transport considering the price and time it took for delivery. A new scenario includes using an electric truck (Volvo FE) instead of that one powered by fossil fuels (Volvo FH16). We will use *"A Better Roadplanner"* website for the calculation. With the battery capacity entered for this model, the results are that it will take a total of 26 hours and 57 minutes for transport, 6 hours and 48 minutes of that goes to charging time. This time can also be used for the driver's rest. This is the situation on 25.04.2020. and it is possible to predict that the development of the electric highway network will continue to improve in a way that there is no need for stopping and charging the vehicle. This is the currently fastest route on which unfortunately some charging stations charge a certain fee.

Waypoint	Arival SoC	Depart SoC	Cost	Charge duration	Distance	Drive duration	Arrival	Departure
Gothenburg, Sweden		100%			216 km	2 h 12 min		1:33
Ionity Helsingborg [Ionity]	10%	59%	338 SEK	17 min	122 km	1 h 16 min	3:46	4:02
Rasteplads Karlslunde Vest E20/E47 [E.ON]	10%	59%		17 min	102 km	59 min	5:19	5:36
Nyborg [Ionity]	10%	83%	355 DKK	32 min	151 km	1 h 24 min	6:35	7:07
Aalbenraa [Ionity]	10%	82%	355 DKK	32 min	122 km	1 h 16 min	8:31	9:03
Aalbek West [Ionity]	33%	79%	29 €	21 min	121 km	1 h 3 min	10:19	10:40
Lüneberger Heide West [Ionity]	10%	81%	44 €	30 min	121 km	60 min	11:44	12:14
Hildesheim [Fastened]	10%	73%	17 €	27 min	120 km	1 h 17 min	13:12	13:39
Lutterberg [Ionity]	10%	80%	44 €	29 min	120 km	1 h 2 min	14:57	15:26
Eichenzell [Ionity]	10%	76%	41 €	26 min	111 km	56 min	16:29	16:54
Haidt Süd [Ionity]	10%	80%	44 €	30 min	116 km	58 min	17:50	18:20
Neumarkt [Ionity]	10%	76%	41 €	26 min	113 km	58 min	19:18	19:44
Bayerischer Wald Süd [Ionity]	10%	81%	44 €	30 min	121 km	60 min	20:42	21:12
Praml [be.energised]	10%	59%		18 min	100 km	1 h 1 min	22:12	22:29
Wiesenstraße [Wels Strom]	10%	74%		28 min	134 km	1 h 19 min	23:31	23:59
Raststation Kammern [Kelag]	10%	61%		20 min	104 km	1 h 1 min	1:19	1:38
Kreisler GmbH [MOON]	15%	74%		26 min	142 km	1 h 23 min	2:42	3:08
Zagreb, Grad Zagreb, Croatia	10%						4:32	
26 h 57 min				6 h 48 min	2138 km	20 h 8 min		

Figure 20 – Route plan for a new scenario
Source: https://abetterrouteplanner.com [Accessed: 21.01.2020]

Toll cost: 441.10 € 441.2 € x 20 = 8,822€ = 65,282.8 HRK	Charging station cost (Volvo FE): 488,4 € x 20 = 9,760 € = 72,283 HRK	Bridge toll cost: 153 € 153 € x 20 = 3,060 € = 22,644 HRK
Loading and unloading costs: 11,840 HRK	**Total = 172,050.8 HRK**	

Figure 21 – Total cost for a new scenario
Source: authors

Using an internet program "A Better Routeplanner" (Figure 20), the new route was calculated. The route is optimal for Volvo FE electric truck because it shows exactly how long the vehicle has to be charged to spend the least amount of time and money.

Total cost for transporting 345,000 packages of gas valves by road, using Volvo FE electric truck results in 172,050.8 HRK including toll, charging station fees, bridge toll, handling, and shipping cost (Figure 21). As a result of using fast charges (which cost extra compared to regular but slower), only a saving of only 15,036 HRK was realized. For greater savings, of a total of 87 320 HRK, the route should be optimized for using only free charging stations (which will inevitably extend travel time).

7. CONCLUSION

At this point, transportation in all branches is changing daily. Transportation modes are getting some new tasks and possibilities every day as global freight transport rapidly increases, some of them were unthinkable to this day. With today's technology growing exponentially, it is almost impossible to imagine modes of transportation without this kind of development.

Looking at the Volvo Group it is sure to say that not only are they following the development of technology, but with their policies and investments in development they are new pioneers in today's transportation. And because of them there are emerged new players in the market of autonomous and electric vehicles from which rivalry society benefits.

Intermodal transport is undoubtedly the future of transport. Using intermodal transport, we use all branches of transport, more people are involved at the same time, which opens new workplaces and gives opportunity to everyone while reducing the cost of transport itself. Neither branch should take precedence over the other, but in some cases 'infrastructure has its favourites'. In this corporate analysis that favourite is road transport. By combining water and road transport we can get a more cost-effective route (scenario four) but if we take time into consideration then road transport is the fastest and for this type of transport the best alternative (first scenario).

Therefore, to further improve the scenario four, we can improve the infrastructure or the transport vehicle. In today's world by using Volvo electric truck and prolonging transport time by only 3 and half hours (in regard to the scenario one with fossil driven Volvo truck) costs saving of around 15 000 HRK can be made. Furthermore, if we wanted to sacrifice more time and find only free charging stations the total cost of this transport could cost just under 100,000 HRK. With electrification of our road networks, electric vehicles would get a longer range with virtually no pollution. With autonomous vehicles we would get safer roads, faster time travel, and reduced transport costs. While such developments would require large investments and education efforts, they would open cost-cutting and time-saving possibilities which would enable further development of international trade and stronger economic integration within a wider European market.

REFERENCES

COPYRIGHTED MATERIAL IS USED FOR RESEARCH PURPOSES; AS SUCH ITS USE IS LEGAL WITHIN THE FAIR USE/FAIR DEALING DOCTRINE. ALL SOURCES AND AUTHORS ARE ACKNOWLEDGED.

[1] "Short-Haul Rail Intermodal: Can It Compete with Trucks", Available from: https://journals.sagepub.com/doi/abs/10.3141/1873-06 [Accessed: 14.07.2020.]
[2] "Assessing Energy, Environmental, and Economic Tradeoffs in Intermodal Freight Transportation", Available from: https://www.tandfonline.com/doi/abs/10.3155/1047-3289.58.8.1004 [Accessed: 14.07.2020.]
[3] Mahmassani, H. S., Zhang, K., Dong, J., Lu, C.-C., Arcot, V. C., & Miller-Hooks, E. (2007). Dynamic Network Simulation–Assignment Platform for Multiproduct Intermodal Freight Transportation Analysis. Transportation Research Record, 2032(1), 9–16. https://doi.org/10.3141/2032-02
[4] Southworth, F, Xiong, D, and Middendorf, D. Development of analytic intermodal freight networks for use within a GIS. United States: N. p., 1997. Web.
[5] "Sustainable Road Transport in the European Union: Changes in Undesirable Impacts", Available from: https://journals.sagepub.com/doi/pdf/10.3141/2242-05 [Accessed: 29.07.2020.]
[6] "Improving the Intermodal Freight Transport System Linking Western Europe with Central and Eastern Europe: Identifying and Prioritizing Policies", Available from: https://journals.sagepub.com/doi/pdf/10.3141/1873-13 [Accessed: 29.07.2020.]
[7] Volvo Trucks, Available from: https://www.volvotrucks.com [Accessed: 21.1.2020.]

[8] Impargo, CargoApps, Available from: https://apps.impargo.de/dashboard [Accessed: 21.1.2020.]
[9] HŽ Cargo – Cjenik usluga (HRT 156), Available from: http://www.hzcargo.hr/upload/156%20-%20Cjenik%20usluga%20(HRT%20156),%20(stanje%20od%2029.3.2019.).pdf [Accessed: 21. 1.2020.]
[10] iContainers, Available from: https://www.icontainers.com/ship-container/gothenburg/ [Accessed: 21.1. 2020.]
[11] Boat booking, Available from: https://www.boatbookings.com/yachting_content/map_distances.php [Accessed: 21.1. 2020.]
[12] RailNetEurope, Available from: http://rne.eu/ [Accessed: 21.1. 2020.]
[13] Siemens, Available from: https://www.mobility.siemens.com/global/en/portfolio/road/ehighway.html [Accessed: 21.1. 2020.]
[14] Plus.ai, Available from: https://plus.ai/index.html [Accessed: 21.1. 2020.]
[15] A Better Routeplanner, Available from: https://abetterrouteplanner.com/?plan_uuid=96d40638-ddd3-40e2-ac4e-c0133215564c [Accessed: 25.04.2020]

MARTIN GOLUBAN, M.Sc.[1]
E-mail: goluban.m@gmail.com
MARJANA PETROVIĆ, Ph.D.[2]
E-mail: marjana.petrovic@fpz.hr
JASNA BLAŠKOVIĆ ZAVADA, Ph.D.[2]
E-mail: jasna.blaskovic@fpz.hr
TOMISLAV JOSIP MLINARIĆ, Ph.D.[2]
E-mail: tomislav.mlinaric@fpz.hr
[1] University of Zagreb
Trg Republike Hrvatske 14, 10000 Zagreb
[2] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb

SIMULATION OF PASSENGER TRANSPORT ON RAILWAY SECTION ZAGREB MAIN STATION - ZABOK

ABSTRACT

With the system of integrated transport, the urban and suburban railway in a wider Zagreb area should become the carrier of the transport load in passenger transport. This area sees the most intensive railway passenger transport in the entire Republic of Croatia. The railway section between Zagreb Main Station and Zabok with the number of trains and the carried passengers has a significant share in the total railway traffic. The traffic and technical characteristics of the railway line are very unfavourable which results in low speeds. The reconstruction and electrification of a part of the railway section R201 between stations Zaprešić and Zabok would shorten the travel times of passenger trains, thus improving the quality of the provided service.

This paper shows how after the track modernization, the organization of passenger transport can significantly improve the quality of the transport service. This refers primarily to the reduction of the travel time, which has been proven by the carried out simulations in the OpenTrack software for three variants of transport organization.

KEY WORDS:

integrated passenger transport; travel time; improvement measures in transport organization; OpenTrack simulation software

1. INTRODUCTION

By cohesion policy, the European Union promotes cooperation and networking of the cities and the long-term smart development of urban regions that go beyond administrative borders. From this perspective the emphasis is placed on the needs of the local population in their daily migration so that through the projects of integrated traffic, the transport would become more accessible, faster and less expensive for them. Integrated urban-suburban transport with the emphasis on sustainable mobility is highlighted as a key factor in the harmonization of the development of the cities and their surroundings.

The traffic systems of the City of Zagreb, Zagreb and Krapina-Zagorje Counties in previous development plans were not considered as a whole, especially in the area of public urban and suburban transport. This has resulted in traffic congestions, reduced traffic safety, higher emission of exhaust gases and noise.

The area around the City of Zagreb has the most intense railway passenger traffic. The north-western part of Croatia i.e. the Croatian Zagorje also gravitates into this "Zagreb ring". The inhabitants of the Croatian Zagorje travel traditionally to Zagreb by train. Travelling by train is in a way an integral part of their lives. The

most important role in this is the railway line of regional importance R201 Zaprešić – Zabok – Varaždin – Čakovec, which diverges in the station Zaprešić from the railway line of international significance M101 DG - Savski Marof - Zagreb Main station. The station Zabok with its connecting lines from Đurmanec (R106) and Gornja Stubica (L202) together with the trains from the direction of Varaždin generate most passengers.

The integrated transport system, modernization and electrification of the Zaprešić - Čakovec (R201) railway line section and connection of Zabok into the suburban traffic of the city of Zagreb should raise the quality of the railway passenger transport and reduce the travel time between Zagreb and Zabok. An important role in all this belongs to the organization of passenger transport since good organization can raise the quality of transport and reduce the travel time. The paper analyses the obtained results of the proposed variants and measures to improve the organization of passenger transport between the City of Zagreb MS (Main Station) and Zabok using the OpenTrack software package.

2. SYSTEM OF INTEGRATED PASSENGER TRANSPORT AND TARIFF-TRANSPORT UNION ON THE TERRITORY OF THE CITY OF ZAGREB, ZAGREB COUNTY AND KRAPINA-ZAGORJE COUNTY

The strategy of traffic development of the Republic of Croatia (2017-2030) through general and specific goals stimulates the distribution of passenger transport in favour of public transport, with focus on urban rail system and rail transport, higher quality usage of the Croatian railway system in major Croatian agglomerations and within and between the functional regions (sub-regions), better integration of the railway system in the local traffic systems [1].

The integrated transport of passengers is a system of public transport that is supported and recognized as an optimal system of the public transport organization in all the basic strategic European documents. The backbone of the system consists of the rail systems (trains and trams) due to their ecological and energy benefits. Other vehicles in the system (buses) serve as feeders of the rail systems [2].

It is proposed that, by means of integrated transport system, the urban and suburban railway in a wider Zagreb area takes the role of the carrier of public passenger transport, and in the Zagreb centre this should be done by the existing tram system until the new faster urban rail system. These connections should be connected to suburban and urban bus lines.

The Master plan of the traffic system of the City of Zagreb, Zagreb County and Krapina-Zagorje County and its realization through the project of integrated transport system will contribute to the improvement of the accessibility in passenger transport, i.e. inclusion of the neighbouring cities and regions into the integrated transport system with the City of Zagreb [3].

The most important aspect of railway passenger transport is the quality of service. Public railway passenger transport is one of the most important modes of mass passenger transport and therefore its quality is of great importance since the quality affects the satisfaction or dissatisfaction of the passengers. The passengers' satisfaction with a certain service can contribute to a larger number of passengers, and dissatisfaction can reduce this number [4].

One of the capital railway projects whose realization will be part of Integrated transport system of the City of Zagreb, Zagreb County and Krapina-Zagorje County is also the project "Modernization and electrification of the Zaprešić – Čakovec railway line (R201) on the Zaprešić (excl.) – Zabok (incl.) section". The project has been co-funded in the share of 85% from the European Union funds via Operative program of competitiveness and cohesions 2014-2020, and the rest of 15% from the national funds. The acceptable project expenses are estimated at an amount of 614.4 million kuna [5]. The time period of carrying out the project is set from 1 January 2014 to 31 December 2021.

3. TRAFFIC AND TECHNICAL CHARACTERISTICS OF THE RAILWAY SECTION R201 ZAPREŠIĆ – ZABOK AFTER MODERNIZATION

The Zaprešić – Zabok railway line section stretches through the Zagreb and Krapina-Zagorje Counties. The section length is 23.85 km (Figure 1).



Figure 1 – Railway line section R201 Zaprešić - Zabok
Source: [5]

The reconstruction of the rail section through improvement of the railway line construction parameters will enable the design construction speed of 120 km/h. This would mean a reduction of the travel times of passenger trains by 30%, and of fast trains by about 50% [5].

The rail section will be electrified, new signalling-safety and telecommunication devices of remote traffic management will be installed. The rail-road crossings will be modernized in order to raise the safety. The stations, station buildings will be reconstructed, underpasses, parking lots and new platforms of the usable length of at least 160 m will be built. At stations and stops safe access to persons with disabilities and reduced mobility will be provided, as well as a system of video surveillance and visual and audio information of passengers [5].

4. PASSENGER TRANSPORT SIMULATIONS FOLLOWING RAILWAY SECTION MODERNIZATION

4.1. OpenTrack Software

OpenTrack simulation software has been developed at the Swiss federal institute for technology as part of the project whose aim is to develop such a software that will be able to satisfy the criteria of all the users, regardless of the technical and technological differences of single national railway systems. OpenTrack is a software for the development of microscopic software models of all types of railway systems. As such it enables the simulation of operation of all elements related to railway infrastructure, vehicles and schedules, as well as their mutual influence. The input data are processed in three different modules (module for rolling stock management, infrastructure module and module for scheduling) [6]. The user's input is stored in special databases. Apart from this, there is also an option for automatic generation of databases which requires that all the data are prepared in advance.

To create the model, OpenTrack uses input data that are defined by the user, and that refer to the data about the longitudinal track profile, security system of single railway station areas and open railway line, trains and schedule, including the data from the technological process of the rail station so that along with the transport of trains also the manoeuvring operations at stations could be simulated [6].

For the development of infrastructural part of the railway section Zagreb MS – Zabok the longitudinal profiles of the railway line M101 DG - Savski Marof - Zaprešić - Zagreb Main station and railway line R201 Zaprešić - Zabok - Varaždin - Čakovec have been used, and these are necessary to input and develop the railway line model in the OpenTrack software package [7].

4.2. Simulation Variants

Variant 1

The simulation of Variant 1 of passenger transport between Zagreb MS and Zabok plans that all trains to be driven by series 6111electromotor sets. All trains are planned to stop at all stations and stops. The speed between Zagreb MS and Zaprešić is the current one and it amounts to 60 km/h, and between Zaprešić and Zabok 120 km/h. Regarding type all trains are urban-suburban ones [7].

In the schedule graph presented in Figure 2 one can see that the travel time on the Zagreb MS - Zabok section is 48 minutes. For such organization four electromotor sets are required which can be easily seen by the analysis of the schedule graph. Figure 3 shows the graph of speed dependence on the travelled path. The graph shows that the train cannot always reach 120 km/h as predicted on the Zaprešić – Zabok section. Therefore, it can be concluded that the travel time between Zagreb MS and Zabok after introducing the optimal speed will be even longer than 48 minutes [7].

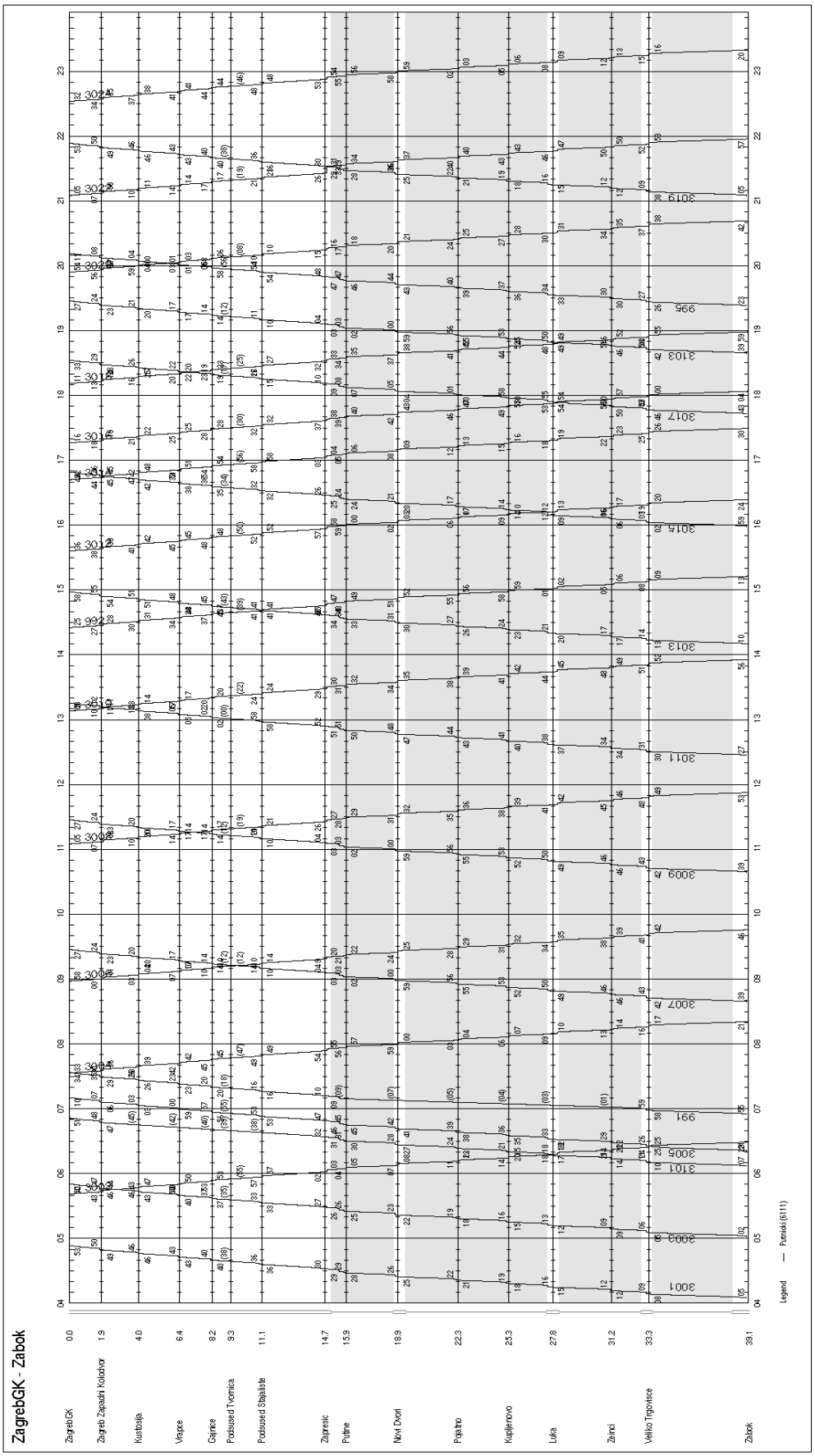


Figure 2 – Schedule graph between Zagreb MS and Zabok for Variant 1
Source: [7]

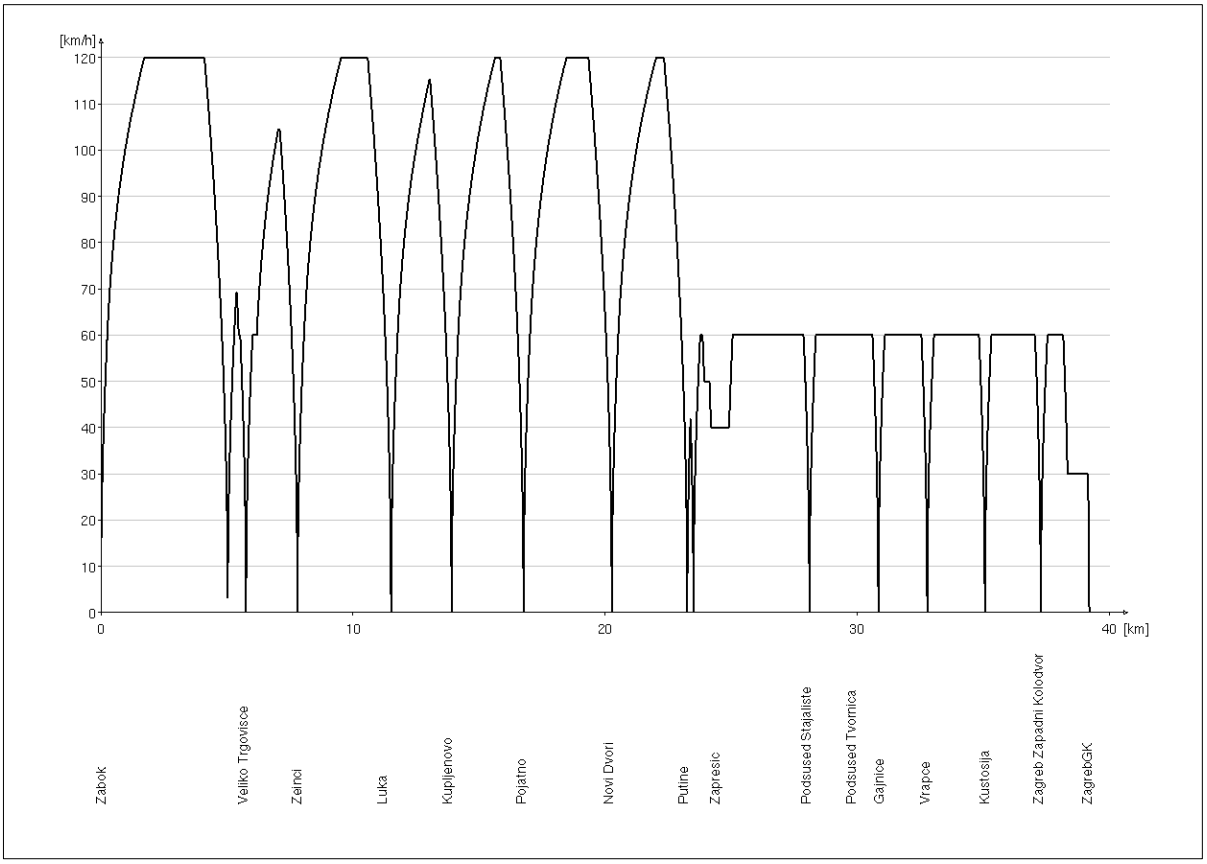


Figure 3 – Graph of speed dependence on the travelled path for Variant 1
Source: [7]

Variant 2

In this simulation all trains are operated by 6112 series electromotor sets. Here, the novelty is the speed on the section of the international railway track M101 between Zagreb Main Station and Zaprešić of 120 km/h, which means the same as on the section of the regional R201 Zaprešić – Zabok railway line. The speed between Zagreb MS (Zagreb WS) and Zaprešić has been defined according to the project of the reconstruction of the international railway line M101 Zagreb MS - Zaprešić - Savski Marof [8]. In order to achieve the minimum possible travel time and thus improve the quality of the transport service, a measure has been planned for the trains that arrive from the direction of R201 not to stop on the section Zaprešić - Zagreb MS. This measure has been found by the analysis of the existing urban – suburban schedule between Savski Marof and Zagreb MS (M101). It can be observed that along with the trains from the direction of R201 in a very short time also the trains from the direction M101 operate. By non-stopping of the trains between Zagreb WS and Zaprešić and by increasing the speed the travel time of approximately 36 minutes has been achieved, which can be seen in Figure 4. This travel time significantly contributes to the competitiveness of the railway in relation to road traffic. If one takes into consideration the competitiveness of the travel time, and other advantages of railway transport in relation to passenger cars (arrival to the city centre, no need to park the car) it may be assumed that the number of railway transport users would increase [7]. The graph of speed dependence on the travelled path of the series 6112 electromotor set in the above described conditions is presented in Figure 5.

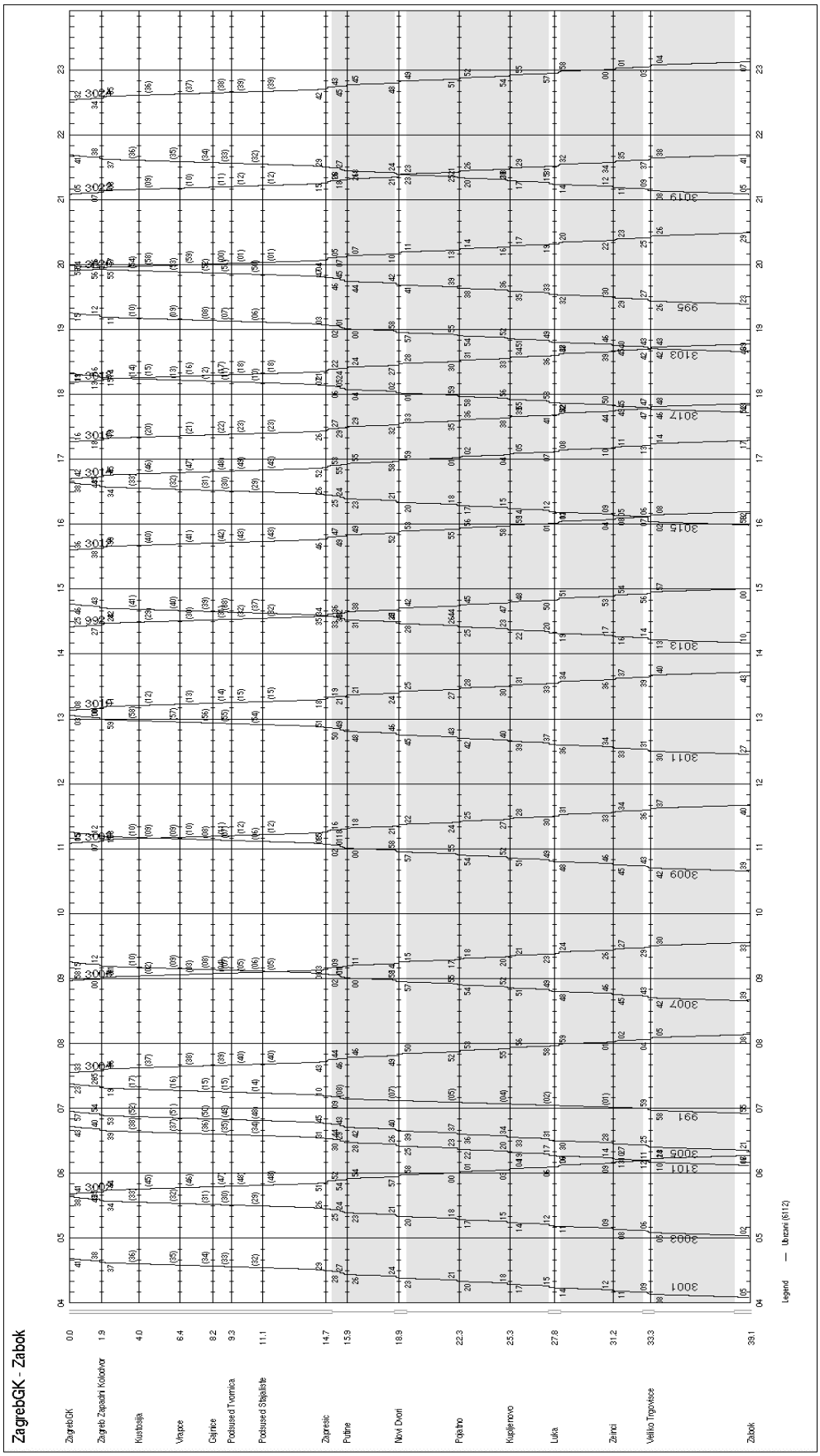


Figure 4 – Schedule graph for Variant 2
Source: [7]

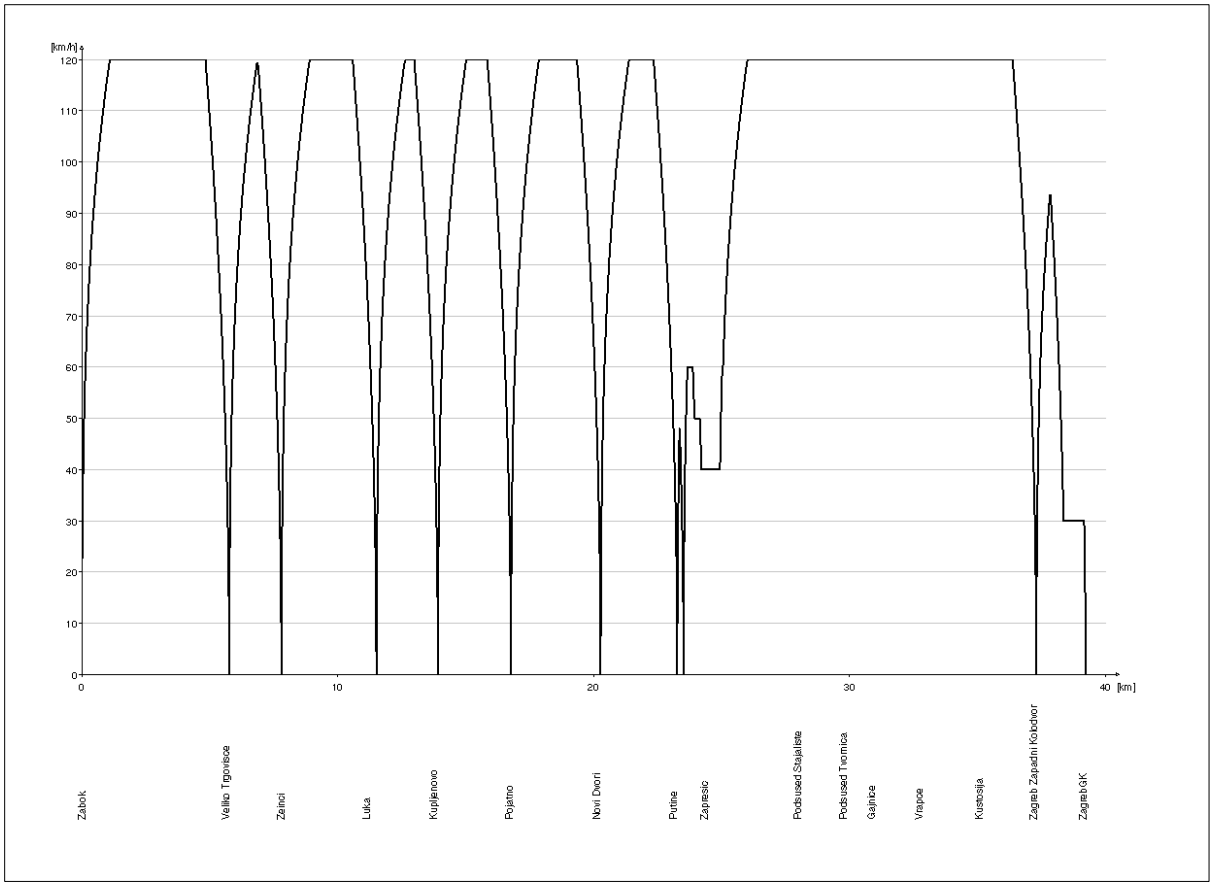


Figure 5 – Graph of speed dependence on the travelled path for Variant 2
Source: [7]

Variant 3

The third variant plans for the morning and afternoon peak hours to be operated by diesel-motor sets or compositions hauled by locomotive in order to allow travelling without changing in Zabok (transport should operate in classical train sets for greater comfort of travelling and more seating places since the new series 7023 diesel-motor sets provide insufficient capacity for the needs of the railway line (R201). The speed between Zagreb MS (Zagreb west station - WS) and Zaprešić amounts to 120 km/h and the trains do not stop on the Zagreb WS – Zaprešić section. One should always keep in mind that a negligible number of passengers from the direction R201 travel to the stop of the mentioned section. In the morning and in the afternoon five diesel trains operate, whereas in between the operation is done by series 6112 electromotor sets. Three electromotor sets are necessary for the turnover that would operate outside peak loads, and the travel duration is on average 36 minutes. The travel time of diesel trains is on average 40 minutes as shown in Figure 6, depending on whether the train is run by a diesel-motor set and the time is slightly shorter or the train is hauled by a 2044 series locomotive. This variant would give the best results in terms of travel time. The justification of this type of transport organization is reflected in the fact that out of the total number of passengers who travel daily to Zagreb, Zabok generates only one third. The remaining two thirds of passengers come from the direction of Krapina (R106), Stubica (L202) and Varaždin (extension R201) [7]. There is currently no sense in introducing new trains as long as there is no major reduction in the travel time to Zagreb, which would attract a larger number of new passengers [6]. The graph of speed dependence on the travelled path for the series 2044 locomotive is shown in Figure 7.

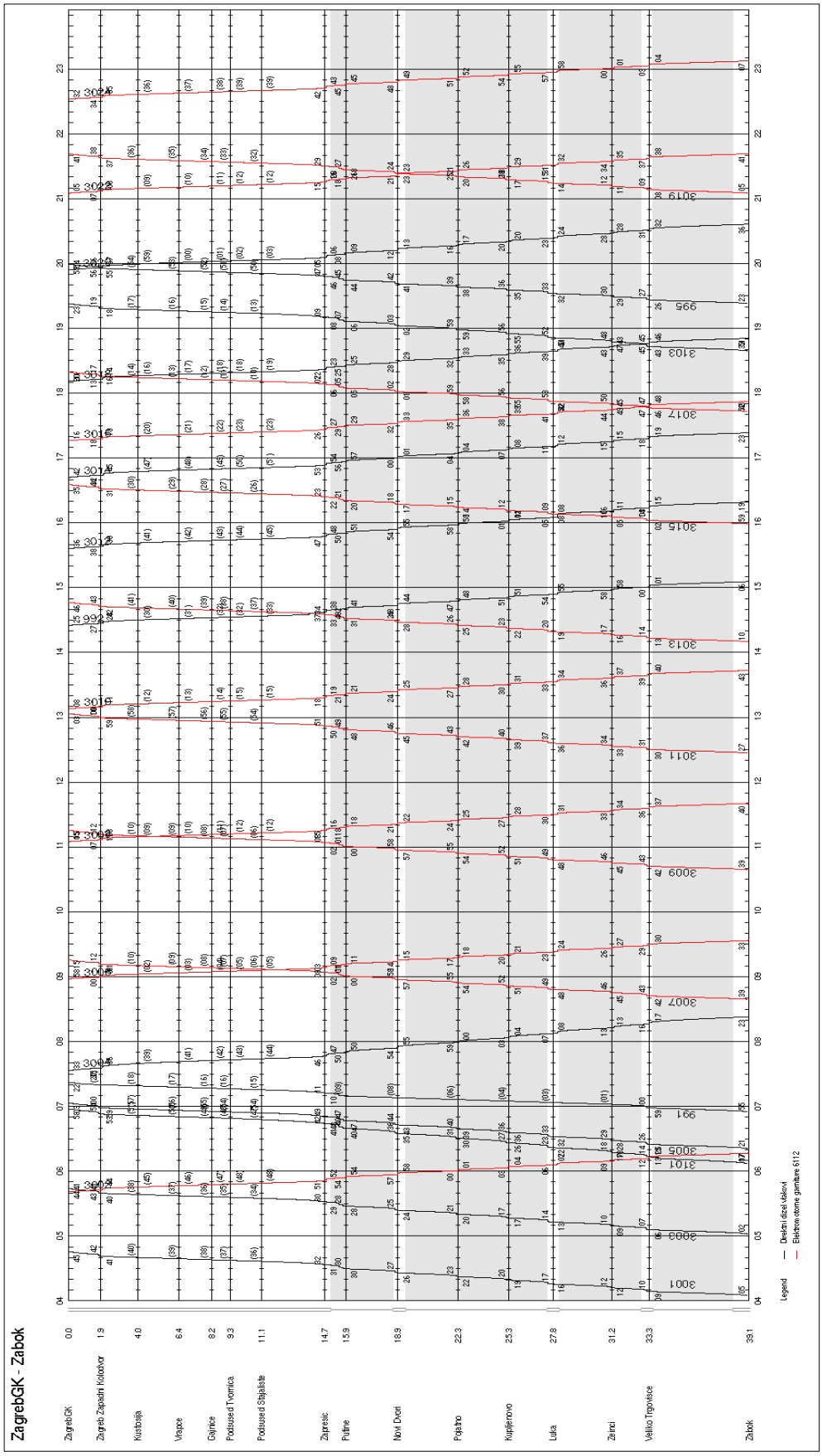


Figure 6 – Schedule graph for Variant 3
Source: [7]

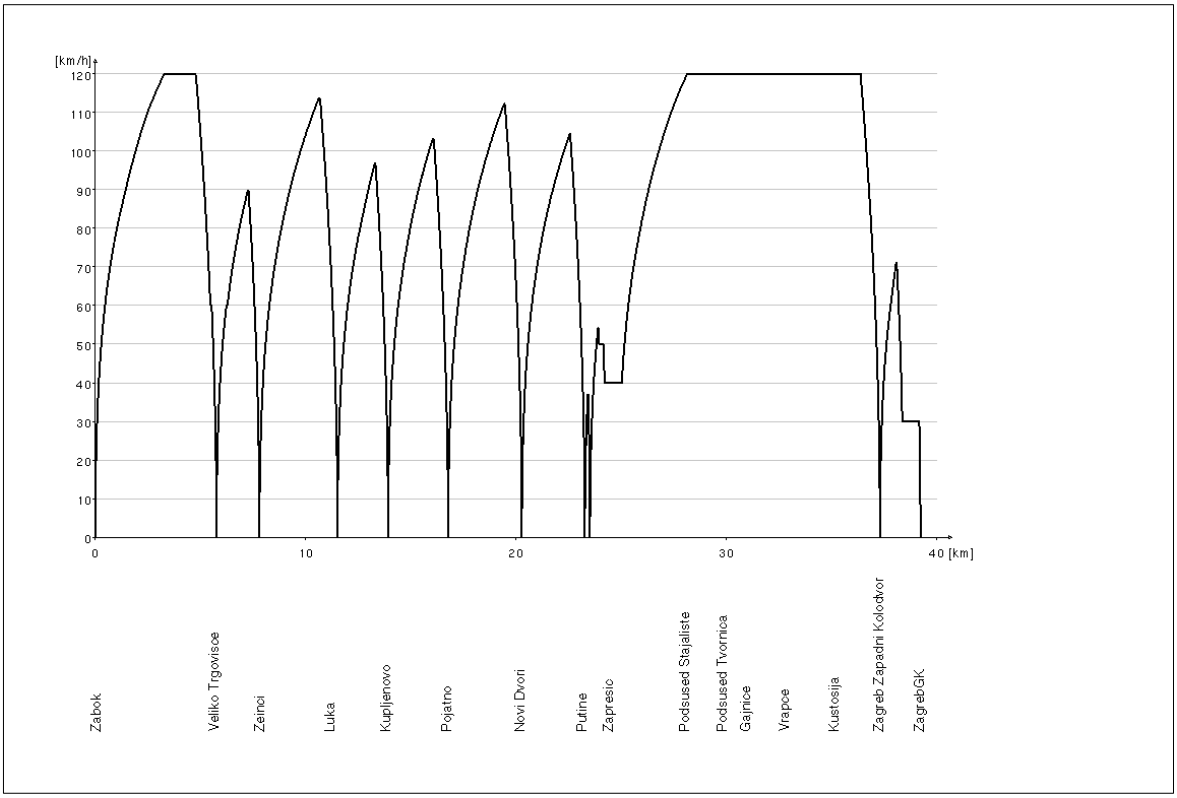


Figure 7 – Graph of speed dependence on the travelled path of the locomotive 2044 for Variant 3
Source: [7]

5. Discussion and Results

Prior to construction of the railway line R201 Zaprešić – Zabok, the travel time from Zagreb MS to Zabok was between 59 and 68 minutes. After the reconstruction, the travel time is reduced to 48 minutes (Variant I). Considering that this investment is worth more than 80 million euros reduction of travel time for the average 11 minutes could be insufficient to attract new passengers. Due to that it is important to emphasize the importance of the organizational aspect of passenger transport that could increase the level of transport service. Apart from that it is important to enable direct passenger trains for passengers that are traveling further than Zabok. Direct trains should be introduced during morning and afternoon peak hours. Since the planned reconstruction of the line M101 (Zagreb Ms – Zaprešić) would enable speed up to 120 km/h, the results from variant 2 and 3 looks promising in comparison to the variant 1 (Table 1). Significant reduction of the travel time is obtained in variant 2 and 3 (36 minutes) that could increase level of service and attract new passengers.

Table 1 – Comparison of the results obtained by simulation

Variants	Speed Zagreb MS - Zaprešić	Speed Zaprešić - Zabok	Stops and stations	Travel time Zagreb MS – Zabok (after reconstruction)	Train type	Difference in travel time prior reconstruction (≈ 59 min)
Variant 1	**60**	**120**	**Stop at each stop/station**	**48 min**	**6111**	**11 min**
Variant 2	**120**	**120**	**Stop only Zaprešić - Zabok**	**36 min**	**6112**	**23 min**
Variant 3	**120**	**120**	**Stop only Zaprešić - Zabok**	**36 min / 40 min**	**6112 / 2044**	**23 / 19 min**

6. CONCLUSION

Reconstruction, modernization and electrification of the railway line R201 section Zaprešić - Zabok results in a completely new aspect of the railway line. There is large potential that needs to be used in the best possible way. Reconstruction and modernization will significantly change the state of the stations and stops on the observed section. The travel time, as an aspect of service quality would be reduced by 11 minutes in relation to the time before reconstruction, that according to the schedule (2018/2019) was from 59 to 68 minutes.

The organization of railway passenger transport is very important since it can achieve high level of the quality of provided service regarding the travel time. It should be noted that the travel time needs to be reduced as much as possible by the traffic reorganization in order to stop the trend of losing passengers. The introduction of new trains means nothing unless the travel time is significantly reduced.

The paper shows three different variants of organizing passenger transport between Zagreb MS and Zabok. Each variant features certain advantages and drawbacks. The first variant maintains the speeds as currently achieved on the considered section of the network, and the trains stop at all stations and stops. Since the travel time in the first variant is 49 minutes, the question is whether the stopping of trains on all stations and stops is justifiable.

This was used as a sufficient argument to eliminate stopping of trains between Zaprešić and Zagreb West Railway Station and other variants have been based on this concept.

Variant 3 has proven to be the best, since it features the best travel time according to the provided conditions and the state of the railway line. It gives the solution for the passengers who continue their travel further from Zabok, i.e. according to this variant they would not need to change in Zabok. It offers the best travel time from 36 to 40 minutes to Zagreb, depending on whether a diesel train or an electromotor set is used, and it offers the speed of 120 km/h on relation Zagreb MS - Zaprešić.

REFERENCES

[1] Ministarstvo mora, prometa i infrastrukture Republike Hrvatske. Strategija prometnog razvoja Republike Hrvatske (2017 - 2030). Downloaded from: http://www.mppi.hr/UserDocsImages/MMPI%20Strategija%20prometnog%20razvoja%20RH%202017.-2030.-final.pdf; 2017 [Accessed: February 2020]

[2] Integrirani promet zagrebačkog područja (IPZP). Downloaded from: http://www.ipzp.hr/integrirani-prijevoz-putnika-ipp/ [Accessed: February 2020.]

[3] Blašković Zavada, J., Abramović, B., Šipuš, D.: A Strategic Model of Sustainable Mobility in the city of Zagreb and its Surrounding Area *// International Journal for Traffic and Transport Engineering (IJTTE),* (2017); 4(7); 430-442. doi:10.7708/ijtte; 2017.03

[4] Petrović, M., Kamenščak S.: Analiza kvalitete usluge željezničkog gradsko – prigradskog putničkog prijevoza. Željeznice 21, 2018; ISSN 1333-7971; UDK 625.1-6; 629.4; 656.2-4; p. 23 – 32 Downloaded from: http://www.hdzi.hr/images/casopis/2018_1.pdf [Accessed: March 2020.]

[5] HŽ infrastruktura. Modernizacija EU sredstvima. Downloaded from: https://www.hzinfra.hr/?page_id=321 [Accessed: March 2020.]

[6] OpenTrack Railway Technology. Downloaded from: http://www.opentrack.ch/opentrack/opentrack_e/opentrack_e.html, [Accessed: March 2020.]

[7] Goluban, M.: Organizacijska unapređenja putničkog prijevoza na dionici pruge Zagreb Glavni Kolodvor – Zabok [Diploma thesis]. University of Zagreb. Faculty of Transport and Traffic Sciences, 2019. Downloaded from:https://repozitorij.fpz.unizg.hr/islandora/object/fpz%3A1728 [Accessed: March 2020.]

[8] Obnova dionice pruge Zagreb ZK – Savski Marof: https://www.hzinfra.hr/?p=22563, [Accessed: April 2020]

HRVOJE HARAMINA, Ph.D.[1]
Corresponding author
E-mail: hharamina@fpz.unizg.hr
ADRIAN WAGNER, Dipl.-Ing.[1]
E-mail: adrian.wagner@fhstp.ac.at
IVAN BELOBRAJDIĆ, B.Sc. [1]
E-mail: ibelobrajdic91@gmail.com
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Department of Railway Transport,
Vukelićeva 4, Zagreb

A MODEL OF AN EXPERT SYSTEM FOR TRAIN PRIORITY ASSIGNING IN RAILWAY TRAFFIC CONTROL PROCESS

ABSTRACT

The paper is dealing with the problem of trains priority assignment in railway traffic control process. For this purpose, a new model of expert system for decision support railway traffic control process is developed. The proposed model of expert system considers different factors influencing decision making process for train priority selection to ensure a maximal operation quality and it is based on a specific set of train priority rules in railway operations. After its creation, the model is tested with traffic scenarios related to railway traffic in Zagreb Klara railway station which has an important role in Zagreb railway node. For simulation of these traffic scenarios infrastructure and trains data from simulation model of observed part of the railway network created in specialized program OpenTrack and official timetable for the network of Infrastructure Manager HŽ Infrastruktura d.o.o. for the period of 2019/20 were used. This kind of expert system is aimed to help dispatcher to cope with train priority assigning problems especially in more complex traffic situations and solution offered by the system are not obligatory but only should help train dispatcher to make his final decisions in the process of traffic control.

KEY WORDS

railway traffic control; train priority assignment; expert system

1. INTRODUCTION

Due to safety principles which prevents train collision in the railway station area, train routes are not allowed to cross or touch each other. Even more, train routes must not cross or touch with an additional safety zone behind the end of movement authority (e.g. exit signal) of train entry route called overlap (*Figure 1*) [1]. Usually, certain disturbances in railway traffic leading to a situation where a decision about priority of one train over another should be made. For instance, in the situation when two trains are approaching the same railway station sometimes they are not able to enter the station at the same time but one of them gets the advantage of entering the station (train 1 in the figure 1), while the other one must begin to slow down after the distant signal and stop in front of the home signal (train 2 in the figure 1).

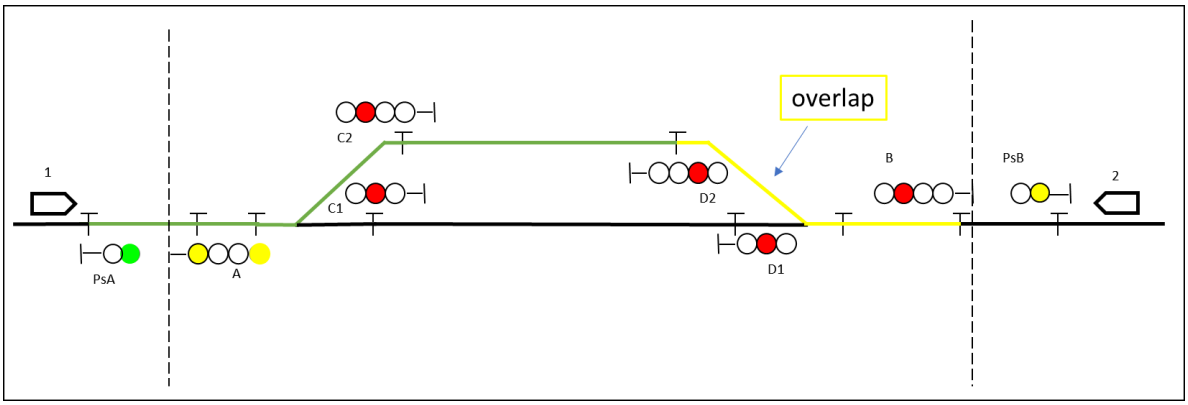


Figure 1 – Trains approaching station conflict

The decision about which of two or more competitive trains will get priority should be given by dispatcher and it is based on his skills and experience in traffic control as well as valid operational rules. Because the quality of such decision-making which is based on optimization process depends on dispatcher's cognitive workload it can be improved by introduction of an expert system for decision support in railway traffic control [2]. Such kind of expert system could help dispatcher to cope with train priority assigning problems, especially in more complex traffic situations and it is aimed only to give support to dispatcher in traffic control process where solutions offered by the system are not obligatory but only should help him to make his final decision which can be made by his wider perspective. Furthermore, infrastructure managers and operators around Europe are starting to explicitly request the use of optimization modules aimed for this purpose because of fair and transparent way of traffic control [3]. Previous research was focused on different tools for real-time traffic control based on mathematical algorithms for timetable rescheduling with the purpose to recover train delays caused by timetable disturbances and prevent occurrence of secondary delays [4, 5, 6, 7, 8]. Thereby, the very common strategy is to recover delays in shortest period of time by minimal modification of other planned train paths and in this purpose anticipation for train conflict detection and resolution can be applied. The railway traffic rescheduling is a complex task from both, practical and computational perspective, and despite many proposed tools for real-time traffic control their effect on traffic efficiency had not been studied in the real environment [9, 10]. Complexity of optimisation process of such a NP-hard problem leads to approaches for faster solving of this task which also consider application of artificial intelligence methods [11, 12]. The real-time train dispatching problem can be decomposed where this decomposition can be the basis for a master-slave solution algorithm, in which the master problem can be associated with the area of centralized dispatching (e.g. line or node) and the slave problem with the smaller parts of this area (e.g. one or more adjacent stations) [13]. Accordingly, the aim of this research is to develop a model of an expert system for transparent train priority assigning in case of traffic disturbances for the observed smaller part of railway network equipped with Croatian national train control system which do not imply use continuous influence on trains by track or radio communication equipment which could be used for network orientated driver advisory systems for train speed management. Beside this, in the observed part of railway network is no possibility for energy recovery by means of supercapacitor batteries.

2. TRAIN PRIORITY RULES IN RAILWAY OPERATIONS

The main goal of dispatching is to ensure a maximal operation quality in order to achieve a high punctuality level on the observed network. There are significant differences in priority rules in operations applied by various Infrastructure Managers in Europe [14]. These rules are not adjusted to available possibilities of modern train control systems such as continuous influence on train speed profile which can improve user cost-based goals e.g. better energy efficiency of train driving, less maintenance costs, less pollution, better comfort of travel for passengers etc. Additionally, this allows

a better prediction of train movements in some shorter time period and thus can positively affect the quality of traffic control results [15]. Regarding to this, proposed model of expert system considers different factors influencing decision making process for train priority selection represented by a specific set of train priority rules in rail operations. This set of rules implies as follows:

a) The difference between train ranks

Infrastructure managers also defining train priorities based on certain number of train ranks e.g. according to regulations in Croatia there are 21 ranks of trains. Because trains of the same rank from international traffic have an advantage over domestic trains, there are in total 24 different levels of train priority. In this research certain number of train ranks for priority assignment is selected in the way it is shown in table 1.

b) Occupancy rate and actual delay of passenger train

The occupancy rate and amount of train delay can affect the priority of that train. A train that already has a big delay should try as far as possible to reduce or at least not increase existing delay. This is in rail transport primarily referred to passenger trains, especially to higher-rank trains which, because of their rank can have higher negative impact on delays of other trains. In this model a train is considered as being late if the gap between real-time and timetable plan assigned differs by more than 1 minute.

c) Actual freight train delay

In this model freight trains running on time are to keep their allocated pat in the planned timetable. A train is considered as being late if the gap between real-time and timetable plan assigned differs by more than 5 minutes.

d) Losses of time and energy if route preference is not given to train

In case of massive freight train which is running at full speed, it is more efficient to give the priority to this train than much less massive freight train with the higher rank or even certain passenger train that would not be too late in that case, because the massive freight train would significantly saved its time (avoiding its own and possible secondary delays) and energy [5]. This relates to the fact that long massive trains using indirect brakes cannot start their run again immediately after stopping, but after the pressure in braking pipes is achieved again.

e) Predicted route occupation time

The priority given to a train which will release its route later then its competitive train can affect the railway line capacity and the delay of the competitive train.

Route release time for some train can be predicted by using data of route setting time and train running time from the train position when the route is set (in some ideal case it should be the sight distance of distant signal) till the end of the train realises the last track occupation element what refers to a condition for releasing the train route (in the case of home route it is usually a last switch occupation element). This time depends on infrastructure data related to line resistance and permitted speed, trains dynamics and the time needed for interlocking to release train route. In this research for calculation of trains running times microsimulation model of the real railway network in the Republic of Croatia is created by application of OpenTrack program for modelling and simulation of railway systems.

f) Train approach to a big station

If a train is next to arrive at a big hub station this means it can have bigger influence on other trains in the network. If such a train has certain delay it can cause negative impact on other trains arriving or departing the hub, because of possible train connections or disruptions regarding possibilities of simultaneous train runs in the station area caused by safety interlocking principles.

g) Role of trains in an integrated passenger transport

In this research a role of trains in an integrated passenger transport is considered. If some passenger train is playing a role in an integrated passenger transport its priority is increased.

h) Process of train priority assignment

After the inference process system gives priority rank for competitive trains. The output variable is designed in way that some train can be compared with its competitive train by certain number of points reached by validation of train priority rules in operations in the first place by a rank of trains in the way it is shown in table 1. By possible application of this proposed concept a certain infrastructure manager can define its own pointing system adjusted to its operational praxis and in general consensus with all interested railway operators, but generally the number of points for priority rules should mainly depend on the importance of trains and their influence on the traffic quality during disturbances. Previous research shown that the best selection of prioritisation rules depends on which perspective are being used [3]. In that view traffic quality can be influenced by various parameters of specific railway system such as infrastructural parameters (e.g. use of different interlocking principles related to setting and release of train routes can affect duration of station intervals), timetable parameters (e.g. amount and distribution of time reserves in planned running times during the trip for recovery of train delays and train headways, number of trains with specific rank or role in the network like suburban trains with cyclic timetable which can get higher priority to keep their headways), characteristic of power supply system (e.g. number of points for heavy freight trains which need a passing route through the station can be assessed differently for the case when energy recuperated by train braking actions can be immediately used by other trains running in the same power supply section or can be stored by usage of supercapacitors compared the case when this is not an option) etc. For the purpose of this research authors defined a certain number of points for each priority rule based on traffic control experience in the railway system selected for testing of the new expert system model which is based on Croatian national train control system.

Table 1 – Validation of train priority rules

PASSENGER TRAINS	EuroCity (EC)	155	**FREIGHT TRAINS**	Express freight train	75
	InterCity (IC)	145		Fast freight train	70
	Express train	120		Military train	65
	Fast train	110		Block freight train	63
	Rapid train	100		Direct freight train	62
	Passenger train	90		Local freight train	55
	Local train	85		Special service train	50
	Border train	80		Feeder train	45
	Suburban train	80		Circuit working train	40
	Special train for railway staff	67		Train for industrial purposes	30

In table 1 it is shown a certain number of points regarding train rank. Additionally, every train can reach even more points based on the next rules:

- If some passenger train is playing role in an integrated passenger transport it is awarded with 30 additional points.
- If some long-distance passenger train has connection with some other long-distance passenger train it is awarded with 30 additional points

- If some long-distance passenger train is late for:
  - 1-2 minutes it will be awarded with 6 points,
  - 2-5 minutes it will be awarded with 11 points,
  - more than 5 but less than 10 minutes it will be awarded with 16 points,
  - between 10 and 15 minutes it will lose 6 and
  - for more than 15 minutes it will lose 11 points.

Thus, the term long-distance passenger train refers to following train categories:
- EuroCity (EC)
- InterCity (IC)
- Express train
- Fast train
- Rapid train
- Passenger train

- If the passenger train reach passenger occupancy rate, it will be awarded with additional points as follows:
  - from 35 to 50 % with 5 points,
  - from 51 to 70 % with 8 points,
  - from 71 to 85 % with 12 points,
  - from 85 to 100 % with 20 point.
- If some freight train which needs a passing route through the station has a higher mass, it will be awarded with additional points as follows:
  - between 1500 and 2000 tons it will be awarded with 20 points,
  - between 2000 and 2500 tons it will be awarded with 30 points,
  - more than 2500 tons it will be awarded with 50 points.
- Train which should release its route before then its competitive train will be awarded with 2 additional points
- International trains will be awarded with 15 additional points.
- If a train is next to arrive at a big hub station it will be awarded with 25 additional points.

Train which reaches more points will get advantage over its competitive train. In the case when both trains score the same number of points, priority will be given to the train with higher rank. Additionally, trains for remedy of operational defects always have priority (e.g. breakdown trains running to the accidents).

3. TESTING OF THE EXPERT SYSTEM MODEL

For testing of the new model of an expert system, railway station Zagreb Klara is selected. This station plays very important role in the Zagreb railway node. Namely, this station is connected with five adjacent stations Velika Gorica, Hrvatski Leskovac, Zagreb Zapadni, Zagreb Ranžirni (marshalling yard) and Zagreb Main station which is a main hub in the railway network in Republic of Croatia (*Figure 1)*. For the purpose of this research simulation model of the railway station Zagreb Zapadni and adjacent railway lines is created. This simulation model is used for calculation of release times of train routes.

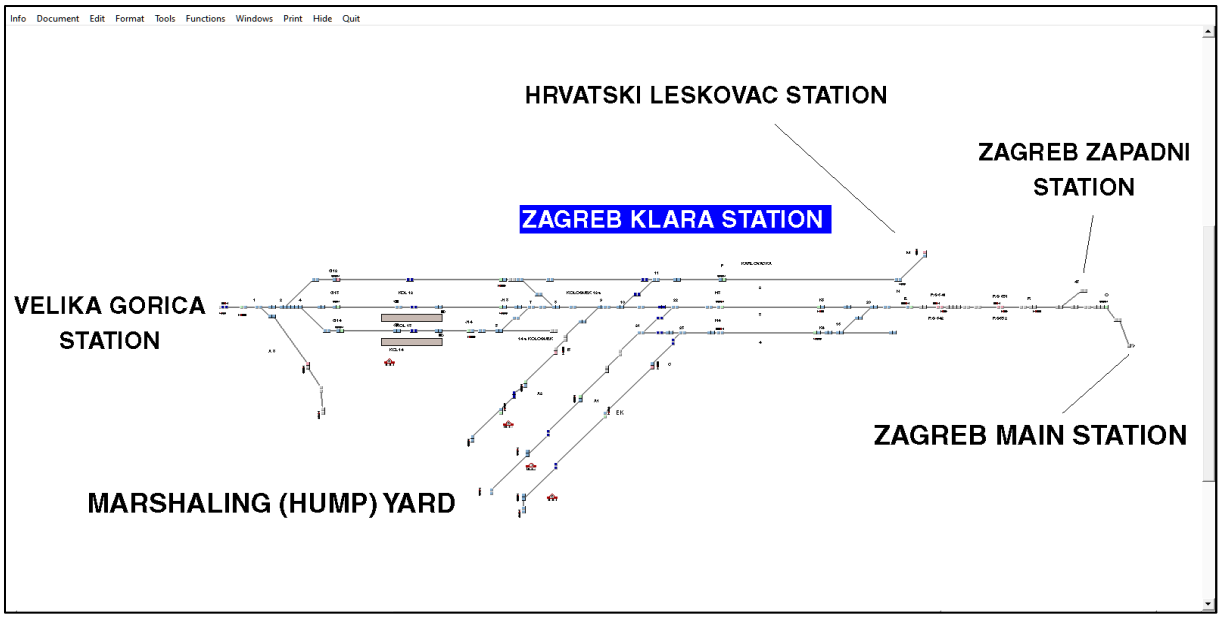


Figure 2 – Scheme of Zagreb Klara railway station created in simulation program OpenTrack

For testing of the created expert system model two different scenarios were prepared. Train data was taken from HŽ Infrastructure d.o.o. official timetable for 2019/20. This company is main infrastructure manager in the Republic of Croatia. In the first scenario two competitive trains were compared. The first one is domestic passenger train number 5119 which is arriving from Zagreb Main station and continue its ride in direction of Velika Gorica station and Its passenger occupation rate is 80%. Its competitive train is international freight train number 47701 which is arriving from marshalling yard Zagreb Ranžirni station and continue its ride in direction of Zagreb Zapadni railway station. This freight train is very heavy with the mass of 2178 tons. Domestic passenger train 5119 should depart from Zagreb Main station at 19:08:00 and to arrive in Zagreb Klara with planned time for entrance route setting at 19:12:51 (Figure 3).

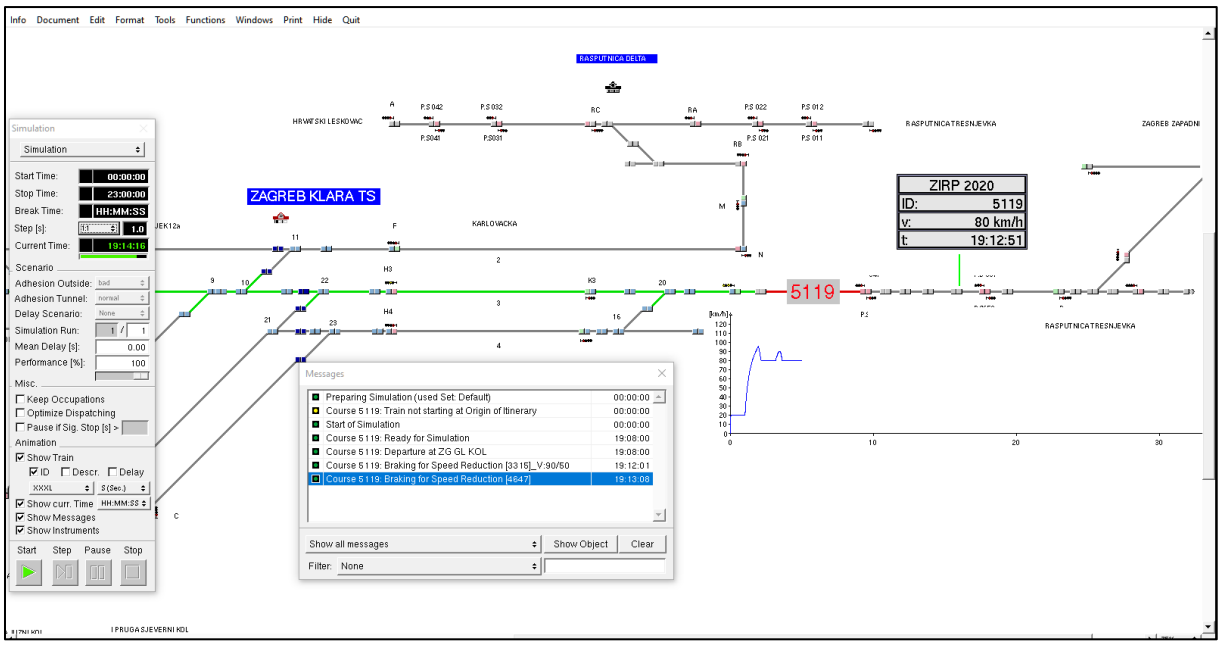


Figure 3 – Simulation of route occupation times in OpenTrack

Planned route occupation time for this train is 3 minutes and 3 seconds so the route release time is planned for 19:15:54. In this scenario this train has delay of 6 min, so the new planned time for entrance route setting should be at 19:19:03 and according to this its planned route release time at 19:25:03. International fast freight train 47701 starts from Zagreb RK at 19:16:00 and should pass Zagreb Klara station with planned time for entrance route setting at 19:17:34. Planned route occupation time for this train is 6 minutes and 17 seconds and time of route release at 19:23:51.

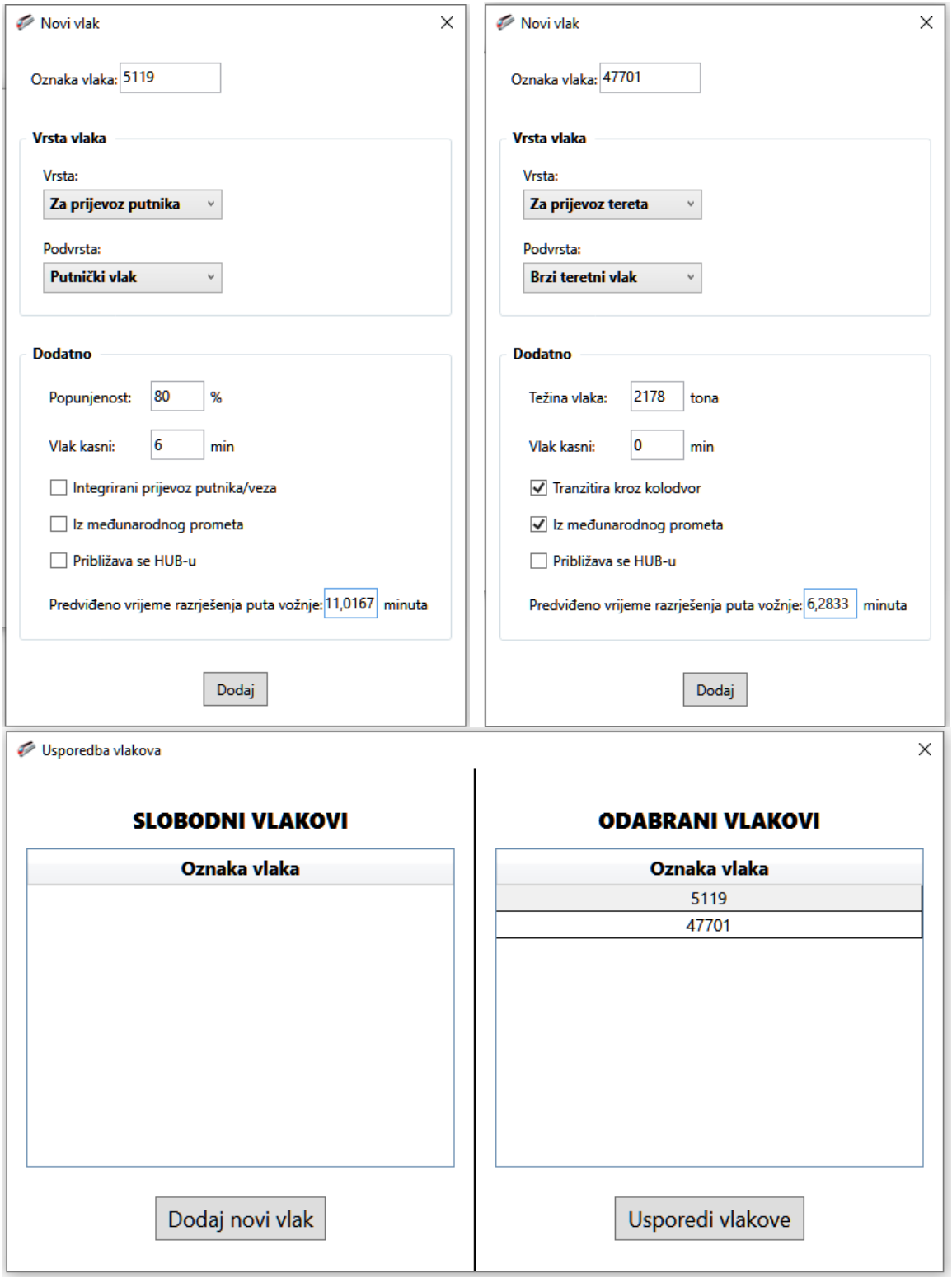


Figure 4 – Interface of the Train Comparer system for adding and selection of trains priority

In the second scenario the same trains were compared but in this case passenger train 5119 had 5 minutes of delay and passenger occupancy rate of only 40 % and second data was not changed. In that case priority would be given to the international freight train 47701.

5. CONCLUSION

In this research a solution for the problem of train priority assignment in railway traffic control process was considered. For this purpose, a new model of expert system for railway traffic dispatcher decision support is created. Its purpose it to help dispatcher to make decisions in order to improve overall traffic situation but taking care about fair praxis and transparency in the traffic control process. The proposed model of expert system considers different factors influencing decision making process for train priority selection to ensure a maximal operation quality and it is based on a specific set of train priority rules in railway operations. After its creation, the model is tested with two traffic scenarios related to traffic in Zagreb Klara railway station. In these scenarios infrastructure and trains data from simulation model of observed part of the railway network created in OpenTrack program and official timetable from Infrastructure Manager HŽ Infrastruktura d.o.o. for the period of 2019/20 were used. Further research will be focused on development of this model for the case of better communication possibilities between trains and control center and influence on trains movements by implementation of train driver support systems and semi-automated train driving.

REFERENCES

[1] Toš Z. Signalizacija u željezničkom prometu [Railway Signalling], University of Zagreb, Zagreb, 2013.

[2] Haramina H, Sumpor D, Širol M. Modelling of Fuzzy Logic Based Dispatcher Support System for Railway Traffic Control*. Book of Proceedings of the 7th International Ergonomics Conference ERGONOMICS 2018 – Emphasis on Wellbeing, 13-16 June 2018.* Zadar, Croatia, p. 125-132.

[3] Andersson E.*,* An Economic Evaluation of the Swedish Prioritisation Rule for Conflict Resolution in Train Traffic Management, Procedia - Social and Behavioral Sciences, 2014; Vol. 111, 634-644.

[4] Larsen R, Pranzo M, D'Ariano A, Corman F, Pacciarelli D. Susceptibility of optimal train schedules to stochastic disturbances of process times, Flexible Serv. Manuf. J., 2014; 26 (4): 466-489.

[5] Corman F, D'Ariano A, Hansen IA. Disruption handling in large railway networks, *Computers in Railways XII,* WIT Transactions on The Built Environment, Vol. 114, WIT Press, 2010.

[6] Lamorgese L, Mannino C, Pacciarelli D, Törnquist Krasemann, J. *Train Dispatching (268ed.)*. In: Borndörfer, R. (et al.) (Ed.), *Handbook of Optimization in the Railway Industry*: (p. 265-283). Springer New York LLC; 2018.

[7] Yan F, Goverde R. Railway Timetable Optimization Considering Robustness and Overtakings, 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), Naples, 2017.

[8] Jaekel B, Albrecht, T. Comparative analysis of algorithms and models for train running simulation, Journal of Rail Transport Planning & Management, 2014; 4, (1–2): 14-27.

[9] Prashanth Josyula S, Törnquist Krasemann J, Lundberg L. A parallel algorithm for train rescheduling, Transportation Research Part C: Emerging Technologies, 2018; Vol. 95: 545-569.

[10] Quaglietta E, et all. The ON-TIME real-time railway traffic management framework: A proof-of-concept using a scalable standardised data communication architecture, Transportation Research Part C Emerging Technologies 63, 2016: 23-50.

[11] Sama M, et all. Ant Colony Optimization for train routing selection: operational vs tactical application, 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), Naples, 2017.

[12] Garrisi G, Cervelló-Pastor C. Train-Scheduling Optimization Model for Railway Networks with Multiplatform Stations, Sustainability, 12, 257; MDPI AG, 2020.

[13] Lamorgese L, Mannino C. An exact decomposition approach for the real-time Train Dispatching problem, Operations Research 2015; 63(1): 48-64.
[14] RailNetEurope, Overview of priority rules in operation, RNE Operation & After-sales WG, 4th December 2019.
[15] Erdem D. Short-term Traffic Flow Prediction Using Artificial Intelligence with Periodic Clustering and Elected Set. *Promet - Traffic&Transportation.* 2020; 32 (1): 65-78.

TIHOMIR LUKANIĆ, Ph.D. student[1]
Corresponding author
E-mail: tihomirlukanic@hotmail.com
DENIS ŠIPUŠ, Ph.D. student[1]
E-mail: denis.sipus@fpz.unizg.hr
BORNA ABRAMOVIĆ, Ph.D.[1]
E-mail: borna.abramovic@fpz.unizg.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

CROATIAN TRANSPORT DEVELOPMENT STRATEGY: A REVIEW ON RAILWAY SECTOR

ABSTRACT

This paper analyses the part of the Transport Development Strategy of the Republic of Croatia 2017–2030 that concerns the railway sector. The document defines the vision and position of the railway in the said period, providing a clear outline of the railway system for the time the strategy is implemented, by 2030. Transport infrastructure is a substantial instrument of development that facilitates the exchange of goods and ensures higher accessibility to all economic, health, tourist, and other contents.

KEY WORDS

strategy; transport development; railway transport; transport policy

1. INTRODUCTION

Transport infrastructure development in the Republic of Croatia is regarded as highly relevant to economic and social growth, as well as to international connectivity. Transport infrastructure is the instrument of regional development that facilitates the exchange of goods and better accessibility to economic, health, tourist, and other contents. The competent state administration body for drawing up the transport development strategy is the Ministry of Sea, Transport and Infrastructure.

Transport development strategies are based on the analysis of the current state of affairs which identifies issues and opportunities and provides the best solutions for meeting existing needs. The document establishes midterm and long-term development in Croatia and is seen as a decisive step forward compared to the existing situation. In other words, it aims to improve the existing transport system and infrastructure. That said, defining clear objectives is the most fundamental and vital stage of the strategic planning process. Based on the policies and strategies of the European Union and Croatia, a list of general objectives was drawn up, followed by specific objectives resulting from the analysis of the Croatian transport system. Specific objectives are then devised in detail according to sectors.

The Transport Development Strategy of the Republic of Croatia 2017–2030 aims to evaluate and define measures in the transportation sector related to international and domestic transport for all transport segments regardless of the source of finance. The strategy also establishes the framework for developing interventions and develops interfaces with other strategies and evaluations (the concept of functional regions, central plans, sector strategies, etc.). The strategy must take into consideration European strategies and demands (TEN-T, ERTMS, TSI, environmental protection, climate protection, etc.; general objectives) and be based on a comprehensive analysis of the situation in Croatia (specific objectives for the Republic of Croatia).

2. COMPREHENSIVE ANALYSIS OF THE EXISTING SITUATION

In both passenger and cargo transport, the overall state of the operators' public transport vehicle fleet does not meet modern transport demands. Investments in the railway infrastructure have not been met with the modernization of the fleet. Operational characteristics of the outdated vehicles negatively impact the infrastructure in terms of a faster deterioration of track superstructure. Low-quality and inadequate track maintenance has a negative effect on the substructure of tractive and hauled units. Before modernizing the vehicle fleet, a study must be carried out that will highlight the shortcomings of the fleet and the technical demands that the new vehicles must meet [1].

A comprehensive analysis of the existing situation entails the analysis of the vehicle fleet, the railway infrastructure, the organization, and business.

2.1 Vehicle Fleet

There are around 700 passenger and 110 cargo trains operating on Croatian railway tracks every day. The passenger transport fleet is largely fitted with outdated and inefficient communication and information technologies and facilities for transporting people with reduced mobility. A great number of tractive units must be replaced based on the estimate that 70 percent of them are within the next 10 years going to reach the end of their shelf life. The unsatisfactory infrastructure maintenance brings with itself the limitations of operation which combined with the low-level station security in rural areas diverts passengers away from the railway.

The worn-out condition of the vehicle fleet and its equipment and devices has a negative impact on the infrastructure, which results in a high level of noise. The noise level, in turn, is affected by the construction of the track with many inclines, declines, and curves. Furthermore, the vehicle fleet and the railway equipment are on average older than 30 years, which means that they wear the reconstructed infrastructure more so than normal. To overcome these issues, a series of procedures is required – procuring new vehicles, installing noise barriers, and others. [1].

2.2 Track Superstructure

The integral parts of the railway network have not been well-maintained due to the lack of funding [2,3]. Some tracks were either destroyed during the war or have since not been well-maintained. Most terminals and stations in rural areas do not meet modern safety and accessibility standards [4]. Given the outdatedness and the technical and safety condition of the superstructure, the next five to eight years can ensure the normal or increased maintenance for only 45.6 percent of the entire track length. The remaining 54.4 percent of tracks must in the same period undergo infrastructural investments and larger maintenance procedures.

2.3 Signal Safety and Telecommunications Equipment

A major part of tracks at terminals and tracks between stations along the main railway tracks for international transport is fitted with outdated relay signal safety equipment. A smaller part is not because the equipment was destroyed in the war (in the 1990s) and has since not been reconstructed. Only a part of the stations on the regional and local transport tracks is fitted with relay systems, while inter-station distances on the tracks are not fitted with any signal safety devices. The existing equipment is technologically outdated and cannot meet the demands according to the specifications of the interoperability of the Trans-European Railway network. Due to the poor equipment, the telecommunication system along the railway network in Croatia will not be able to adhere to the demands of the modern railway transport.

2.4 Safety at Level Crossings

The railway infrastructure of the Republic of Croatia comprises 1520 level crossings, 70 of which are pedestrian. Level crossing signs (Saint Andrew's Cross and stop signs) and visibility triangles are the only warning methods used at 63 percent of level crossings. These places are critical (so-called black spots) on the railway network as most railway accidents, often involving human causalities, occur there. On average, 60 percent of all accidents at level crossings take place at crossings where the only safety is a road sign [1].

2.5 System Organization and Coordination

The railway system is characterized by a lack of coordination in how the system works (know-how). The reconstructed sections of the network have remained underutilized with regard to available capacity. The sector does not have a coordinated direction of the business. There exists a need for more quality coordination between the railway undertaking and infrastructure manager. Generally speaking, road transport dominates over the railway despite the existing availability of parallel railway corridors and market liberalization. For instance, the share of road cargo transport to and from the Port of Rijeka is substantially higher compared to other ports nearby. The source of problems is the non-alignment of project maintenance, track reconstruction, and transport organization with the existing and/or planned transport of cargo and passengers.

2.6 Financial Business

The railway system of Croatia is financially unsustainable. The existing business in all three trading companies within the railway system, owned by the state, cannot be sustained without the financial support of the state. Public service agreements in the railway sector are in line with the Regulation (EC) No 1370/2007. Financial sustainability is one of the key factors of railway system development in Croatia. The European Commission has completed the restructuring program of Passenger transport Ltd (HŽPP) and HŽ Cargo Ltd.

The railway system of the Republic of Croatia comprises three great trading companies: HŽ Infrastructure Ltd. (hereinafter HŽI), HŽ Passenger Transport Ltd. (HŽPP), HŽ Cargo Ltd. (HŽC) and other railway undertakings registered in Croatia. HŽI provides access services to the railway network according to the demands of the other two companies (HŽPP and HŽC) and other users that depend on the demands of passengers and cargo. The number of train kilometers on the infrastructure network dropped from 24,1 million in 2012 to 20,3 million in 2014. In 2015, the number remained steady at 20,4 million. The funds allocated for the infrastructure from the state budget in 2015 amounted to HRK 985 million in 2015, of which 516 million was intended for the railway infrastructure and traffic regulation and the remaining 440 million was gathered from expenses (20 Croatian lipas per sold liter of fuel) [1].

In 2014, HŽPP achieved 52 percent of its overall revenue form the funds allocated from the state budget (pursuant to Public Service Agreement), which amounted to HRK 498,3 million [5].

2.7 Recapitulation of the Existing Situation

The comprehensive analysis of the existing situation reveals the following challenges:

- The vehicle fleet of HŽPP and HŽC is on average more than 30 years old,
- 70 percent of tractive units will reach the end of their use date within the next 10 years,
- Due to its outdatedness, the vehicle fleet is wearing out the railway infrastructure,
- Most stations in rural areas do not meet the minimum safety and access requirements,
- Only 18 percent of the total track length allows the maximum train speed,
- The train speed of up to 160 km/h is permitted on 7.14% on inter-station tracks, while 100 km/h is allowed on only 12.2%,

- System reconstruction, stipulated to take place every 8–10 years, has not been carried out in the last 35 years,
- A greater number of tracks are fitted with outdated signalling and safety equipment,
- The existing signalling and safety equipment are 25–40 years old, i.e., technically outdated,
- Cables are 25–70 years old and lines more than 70,
- Portable analog and track communication devices are 18–40 years old,
- Automated phone systems are as much as 60 years old,
- Level crossing signs (St. Andrew's Cross) and the visibility triangle are the only warnings at 63% of all level crossings,
- The railway system is marked by the lack of coordination in the organization of system operation,
- The existing business of HŽI is unsustainable,
- In 2014, HŽPP generated 52% of its revenue from the state budget.

3. STRATEGY OBJECTIVES

The 2017–2030 transport strategy defines general strategic objectives concerning the railway sector. For the objectives to be achievable, they were divided for some tracks into junctions [6]:

- *Zagreb–State Border with Slovenia towards Ljubljana*. One of the main international connections to Zagreb. The track must meet the following minimum technical requirements: 22-ton axle load, 750 m of the usable length of reception-dispatch tracks, ERTMS.
- *Zagreb–Rijeka*. The initial significance of this corridor is cargo and partly passenger transport (Zagreb–Karlovac). The route must meet the following criteria: 22.5-ton axle load, ERTMS, usable length of reception-dispatch tracks depending on the logistics concept. Based on feasibility studies, the best track variant was the low-land railway track, having in mind the potential construction of the Krk terminal and the adjoining Dalmatian tracks, the speed and need for capacity, and the economic and ecological aspects.
- *The railway network of the Rijeka railway junction*. Additional analyses should look into railway capacity, having in mind the logistical concept and capacities of the Port of Rijeka.
- *Zagreb–Križevci–State Border with Hungary towards Budapest*. The corridor that connects Zagreb and Rijeka to Eastern Europe via Hungary. Apart from a capacity increase, the section must meet the following minimum technical demands: 22.5-ton axle load, 750 m of the usable length of reception-dispatch tracks, ERTMS.
- *State Border with Hungary–Osijek–State Border with Bosnia and Herzegovina*. The potential of this international corridor will increase once the current EU Schengen Area is expanded.
- *Vinkovci–Vukovar regional railway line*. To be used as the railway line connecting RH1 and a Croatian inland waters' port in the TEN-T network on the Danube in Vukovar. The track will have to meet the minimum technical criteria in terms of axle load and length of usable track used for reception and dispatch.
- *Zagreb Central Station*. It is likely the station will require an adaptation of the existing accesses and platforms and a reorganization of passenger mobility within and beyond the station.
- *European Train Control System (ETCS)*, L1, L2 fitted into other tracks, and GSM-R. Specific studies will be used to define the specific demands and technical parameters that must be met in each case.
- *Electrification of other tracks*. This would ensure an increase in the efficiency of the existing infrastructure. Further studies will define specific needs and technical parameters.
- *Reconstruction of remaining tracks, terminals, stops, and construction of new ones*. Individual case studies (Lika railway line, Una railway line, Lepoglava Railway Connection, etc) will determine the need for the reconstruction and construction of new tracks, stops apart from the ones already included in other measures. This takes into consideration the operational concept of economic and ecological aspects.

- *Regional transport, apart from Zagreb and Rijeka (Split, Varaždin, Osijek, etc.).* Railway transport can play an important role in regional transport and regional centers that are not part of the TEN-T railway network.
- *Improvements and new shunting stations and logistics centers*. The need to develop new shunting stations and logistics centers or improve the existing ones will be analysed to increase railway capacity.
- *Improvements to the passenger transport vehicle fleet*. Railway vehicles must be modernized. Future demands, operational and maintenance plans will be analysed. Once demands are determined, further studies will define specific technical demands for the railway vehicle fleet.
- *Improvements to the cargo transport vehicle fleet*. A great number of tractive units must be replaced. According to the estimates, 70 percent of locomotives will reach the end of their shelf life within the next decade. A detailed analysis of the current organization and operational structures as well as railway undertaking maintenance structure.
- *Passenger transport liberalization*. Gradual liberalization of the transport market and ensuring equal opportunities to all potential undertakings. Managing and administrative bodies, such as regulatory and safety agencies, must be ready for the situation to come.
- *Cargo transport liberalization*. The liberalization of the railway sector of Croatia has already begun. Managing and administrative bodies, such as regulatory and safety agencies, must improve in technical and organizational aspects.
- *Reorganization of business/timetables*. To increase the share of railway transport, existing timetables must be reorganized (e.g., clock-face timetables).

4. DISCUSSION

The Government of the Republic of Croatia adopted the Transport Development Strategy of the Republic of Croatia 2017–2030 on its assembly of 24 August 2017 [7]. The strategy aims to respond to numerous challenges and issues that have been accumulated by the lack of professional and political will, the systematic negligence of the railway infrastructure, and a complete disregard for the regulation concerning the super- and substructure of railway tracks. What is important to consider, however, is whether the conditions that have generated the existing situation can overhaul the rundown infrastructure. To catch up with investment and maintenance cycles, radical steps need to be made. This research does not aim to determine those steps but it will argue that substantial changes are needed in the strategic and political action to return the railway to its former glory.

Even though all companies have taken over the maintenance and construction of the railway infrastructure on behalf of the country, initially under the same market conditions, substantial differences arise in the success rate and the organizational, technical, and technological development among the companies.

Every responsible country takes special care of developing its strategic documents, using them to define its vision of the future, and setting the direction based on which the strategies will develop and how projects and plans will be realized.

4.1 Poor Transport Policy Being Carried out in Croatia?

A relevant scientific hypothesis in the research of the transport strategy of Croatia postulates that the transport policy that is being implemented is inadequate.

The sentence in question, taken from the analysis of the existing transport development strategy, adopted by the Government of the Republic of Croatia, is the following: “System reconstruction, stipulated to take place every 8–10 years, has not been carried out in the last 35 years” [1]. Given that Croatia has been independent for 28 years – and the fact that there has not been a system reconstruction in the last 35 years – it can be concluded that the country has not made efforts to overhaul the system. The question remains: Who is responsible?

If there have always been ordinances stipulating infrastructure management that have been ignored, clearly the responsibility lies with the management board(s) of companies in charge of the infrastructure [2,3]. If such companies are state-owned, then the state is aware of the declining infrastructure (seen in the increase in journey time, reduction of speed, fewer trains on tracks, etc.). Clearly, the executive branch of the state did not act and has not made the necessary changes in personnel in charge of infrastructure management. If the state failed to respond, it is the duty of the executive branch to make changes. If the state failed to recognize infrastructural changes, it is responsible for not doing so. Should both the state and infrastructure management do everything they can to stop the downward trend, we could state that there is a will, but there is not a way. However, given the almost three decades of unconscientious management, the only conclusions that can be drawn up are the following:

a) A cadre of incapable people are managing the state and railway sector and

b) The railway system is purposefully neglected to achieve the personal gain of third parties.

With time and if there is interest, the existing cadre will be replaced by people who desire to manage conscientiously. It is likely that the current documentation will be used to reconstruct the period and responsibility with greater precision. However, there is still a common denominator to the said statement. The responsibility clearly lies with the persons managing the state and railway sector, on all levels. This is a conclusion that is easily drawn. On the other hand, every dispersion of responsibility would only lead to guilt being attributed to the consequences of long-term negligence of the property being managed.

4.2 EU Funding

After three decades, a model for co-financing large reconstruction and construction railway projects was developed. Given that 55 percent of the railway network of Croatia comprises tracks important for international transport, in the modernization of the railway, HŽI places great emphasis on projects which were co-funded mostly by the EU. In other words, these are projects whose funds have already been ensured [8]. All the projects being carried out are partly funded by the EU. What is questionable is whether the entire railway system could be reconstructed if there was not for EU funding. Based on the model used prior to EU funds, investments would be on the level they were before EU funding – insignificant.

The railway system of Croatia depends on the funds provided by the EU, whereby terms and conditions apply. This means that projects are implemented based on the dynamics that are subject to verification of the European Commission, which is not an integral part of the structure of the Republic of Croatia. Therefore, the priorities of the EU are not necessarily aligned with Croatian national interest. In theory, those who represent national interest would strive to achieve a greater effort that those who do not. However, the practice has proved this is not the case. The factors of the system, which should represent and implement national interests of the Republic of Croatia are not doing so in an orderly and timely fashion, thus bringing into question the set deadlines and subjecting the project to penalties in accordance with the agreements signed with the EU. The interest and capabilities of the factors involved in the railways of Croatia, evaluated based on realization, are on an extremely low level. Reasons for implementing poor transport policies are manifested in the lack of clear transport policy and strategy of the country.

For the Transport Development Strategy of the Republic of Croatia 2017–2030 to be implemented into the system, the cadre must perform on a higher level than it has so far.

4.3 Political Responsibility

In principle, the state (Republic of Croatia) owns the railway infrastructure. Since its independence (25 June 1991), the country has not carried out a reconstruction of the railway. Political decisions that

have been made have appointed incompetent heads of companies in charge of infrastructure maintenance and management. In countries with positive trends of management and development, the railway is managed by competent and capable cadre. The countries whose infrastructure is in decline are managed indirectly by incompetent politicians who through the personnel they have appointed do not have national interests in mind [9]. The situation is clear – poor transport policy is being implemented in the Croatian railway sector.

The ever-poorer condition of the railway sector is confirmed by Figure 1 which illustrates the number of trains operating on the Ljubljana–Zagreb–Belgrade railway line in the time period from 1985 to 2015 [10]. The section on the key route that connects the capital cities of two neighbouring states is part of the European east-west corridor. Since 1985 and the start of the changes in social orders in the former Yugoslavia, the number of trains has reduced six-fold. From to 2015 there is only one regular train per day and from 2019 there is one additional train during summer. Given the ecological and economic features of railway transport and the international politics stand towards the railway sector, the result is absolutely disappointing.

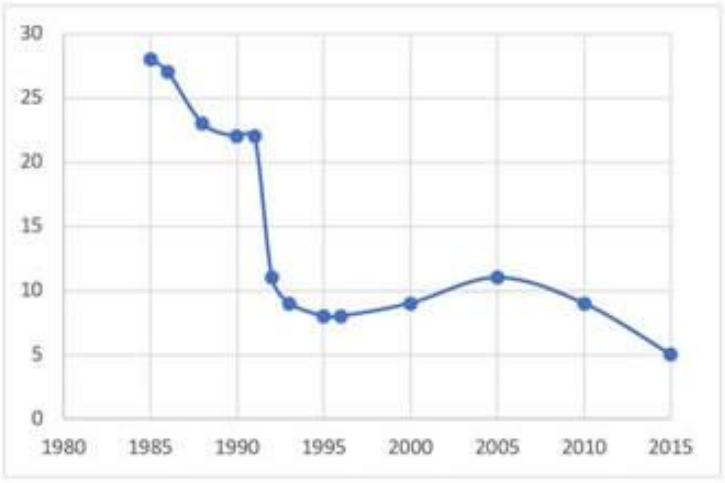


Figure 1 – Number of trains operating on the Ljubljana–Zagreb–Belgrade railway line
Source: [10]

5. CONCLUSION

This paper has analysed the Transport Development Strategy of the Republic of Croatia 2017–2030, particularly the part of which concerns the railway. The document is supposed to define the vision and position of the railway in the forthcoming period and provide a clear overview of what the railway system should look like by 2030. However, on the whole, it can be stated that it fails to meet the expectations of what such a complex and significant document has set out to do.

Although valorisation of the existing situation has been carried out in an adequate manner, visions of the future and the context of the railway have not been clearly defined. There is a lot of space for future analyses and studies of issues that are current and should become the priority. What the strategy does offer are responses to making up for deficiencies. It, however, does not respond to the situation in which the system is concerned with the trends in development in Europe and the world. In other words, this fundamental document, upon which the future of the railway transport of Croatia should be based, lacks ambition and at the same time remains realistic because it is reluctant to address, purposefully or unintentionally, the degree to which projects have been carried out thus far.

However, there are too few concretely analysed projects and feasibility studies. A great number of questions remain unanswered. It is not clear whether projects should start being implemented or not. Based on that, the strategy remains incomplete. Such an approach will result in additional time

needed, in which the non-realized reconstruction or railway element construction will not be undertaken.

The railway system of Croatia depends on the funds provided by the EU under certain terms and conditions. This means that projects are being implemented in stages that must be verified by the European Commission, which is not an integral part of the structure of the Republic of Croatia. Therefore, the chief interests do not necessarily align with the interest of the country. That said, national interest must be clear when the strategy is being implemented, particularly in the railway sector.

It is essential to invest in additional cadre and potentially reorganize human resources. Certain areas must receive additional personnel to catch up with planned and spatial documentation and facilitate concrete infrastructural and organization projects. Implementing the strategy in the railway sector of the Republic of Croatia will require exceptional political will. Alternative project financing models must be developed and capacities must be fully utilized to realize the projects. Given the existing results and the human factors that have managed processes so far, one cannot be overly ambitious nor optimistic.

REFERENCES

[1] Hrvatska. Ministarstvo mora, prometa i infrastrukture. *Strategija prometnog razvoja Republike* Hrvatske *(2017. - 2030.)*. Republika Hrvatska; 2017.

[2] Jugoslavija. Zajednica Jugoslavenskih željeznica. 314 *Pravilnik o održavanju gornjeg stroja pruga Jugoslavenskih željeznica*. Beograd; 1989.

[3] Jugoslavija. Zajednica Jugoslavenskih željeznica. 315 *Pravilnik o održavanju donjeg stroja pruga* Jugoslovenskih *željeznica*. Beograd; 1989.

[4] Hrvatska. Ministarstvo mora, turizma, prometa i razvitka. *Pravilnik o željezničkoj infrastrukturi* . Republika Hrvatska. NN 127/2005; 2005.

[5] Schreyer C, Schneider C, Maibach M, Rothengatter W, Doll C, Schmedding D. External Cost of Transport. Update study. Iww, Universitet Karlsruhe. Zurich/Karlsruhe; 2004.

[6] Hrvatska. Vlada Republike Hrvatske. *Odluka o razvrstavanju željezničkih pruga*. Republika Hrvatska. NN 03/2014; 2014.

[7] Hrvatska. Vlada Republike Hrvatske. *Odluka o donošenju strategije prometnog razvoja Republike Hrvatske za razdoblje od 2017. do 2030. godine*. Republika Hrvatska. Narodne novine 84/2017; 2017.

[8] HZ Infrastructure Ltd. Available from: https://www.hzinfra.hr/?page_id=321&page_id=321. [Accessed 18th May 2020].

[9] Hrvatska. Ministarstvo mora, prometa i infrastrukture *Nacionalni program željezničke* infrastrukture *za razdoblje od 2016. do 2020.,* Available from: https://mmpi.gov.hr/UserDocs Images/arhiva/Nacionalni%20program%20HZI%2024-9_15.pdf [Accessed 18th January 2020]

[10] Brezina T, Abramović B, Shibayama T, Jelisić S, Šipuš D, Zlokapa B. Barriers to trans-national passenger rail services in the Western Balkans - The quantitative background. In: Proceedings of the Fourth International Conference on Traffic and Transport Engineering. City Net Scientific Research Center Ltd. Belgrade; 2018. p. 717–24.

MARKO MATULIN, Ph.D.[1]
E-mail: mmatulin@fpz.unizg.hr
ŠTEFICA MRVELJ, Ph.D.[1]
E-mail: smrvelj@fpz.unizg.hr
SERGO MARTIROSOV, Ph.D. Student[2]
E-mail: martiros@rti.zcu.cz
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[2] University of West Bohemia
Univerzitni 2732/8, 30100 Pilsen, Czech Republic

QUALITY OF OMNIDIRECTIONAL VIDEO STREAMING SERVICE: A STUDY OF USER QUALITY OF EXPERIENCE

ABSTRACT

As a part of the QoE4VR project, a study of user Quality of Experience (QoE) for omnidirectional video streaming service was conducted on a sample of 20 test subjects. The subjects rated the quality of pre-prepared video sequences whose quality was degraded by introducing different frame drop patterns and by changing the video resolution. The continuous rating method was used to collect the subjects' opinions about the video quality, i.e., the subjects were asked to rate the quality whenever they notice the change during screening. Hence, multiple ratings were collected per test subject, which enabled us to evaluate user QoE level per specific segment of a video, i.e., per specific type of video degradation, which was introduced. This paper presents the obtained results and discusses the possible paths for future research.

KEYWORDS

omnidirectional video; 360-video; streaming; quality; user experience

1. INTRODUCTION AND RELATED WORK

The focus of this paper is on subjective evaluation of user Quality of Experience (QoE) when a user watches omnidirectional videos (ODVs), which are transferred via a communication network using streaming technology. Nowadays, the ODVs are more frequently consumed by users due to increasing market penetration of devices capable of presenting different VR (Virtual Reality) content such as videos, games, or learning applications. For instance, there is a growing number of supporters of using the VR environment for training truck and lorry drivers [1]. In this particular use case, the costs and the traffic impact produced is considerably lower compared to using actual vehicles for drivers training. We can also observe a wide range of VR applications in the automotive industry, e.g., as described in [2], that will genuinely fast-forward the industry into the future. Cisco in [3] forecasts that by 2022 the usage of VR applications, including ODV streaming, will increase 12-fold, reaching 4.02 Exabytes per month of data traffic. Hence, we were motivated to disclose different parameters which may produce an impact on user QoE for this new type of service.

In the recent research endeavors aimed at ODV quality analysis, different authors are describing and developing ODV coding techniques and projection methods, investing time into network capacity planning as well as defining the new objective and subjective methods for the evaluation of user QoE. The latter is the focus of the review, which follows. The objective assessment of ODV quality is usually based on the well-known video quality metrics (VQM) that can be used to evaluate the difference between the original and processed video (Full Reference methods) or by analyzing only the processed

video (No Reference methods) when the task is to detect different video artifacts such as blurring or blocking. The most widely used VQM is Peak Signal to Noise Ratio (PSNR) metrics. It is used and upgraded to suit the needs of ODV evaluation by many authors, e.g., [4-9]. Some of those PSNR modifications include weighted PSNR, Weighted to Spherically uniform PSNR, Spherical PSNR Nearest Neighbor, Spherical PSNR Interpolation, Craster's Parabolic Projection PSNR, and Resized-PSNR. Many of these upgraded PSNR VQMs are also suitable for comparing the two images of different resolutions and/or projections. In addition to the PSNR metrics, SSIM (Structural Similarity) index is often being redeveloped to make it applicable in the process of evaluation of ODV quality. For instance, in [10], the authors introduce a link between a 2D stereoscopic image and a spherical representation of that image. In [11], the performance results of the MS-SSIM (Multi-Scale SSIM) index are presented. It is shown how MS-SSIM can be used for the evaluation of the two images of different resolutions.

Subjective evaluation of ODV quality focusses on the analysis of user viewing angles [12], the impact of video projection types on user experience [13-15], and the development of computer and mobile applications that can be used for subjective testing of the quality [16-17]. Furthermore, in [18] and [19], the authors investigate the impact of various video degradation types on user QoE levels. The importance of virtual walls and slowdown impairments is highlighted in [18], while in [19], frame freeze effect was in the focus of the authors. This is similar to our research, which was also aimed at discovering how different quality impairments (frame drop and resolution degradation) impact user QoE. The contribution of the paper can be outlined as follows: 1) a methodology for conducting the subjective evaluation of ODV streaming quality is proposed; 2) the impact of two objective parameters (ODV resolution and frame drop) on user perception is investigated, and the obtained results are presented and discussed; 3) the importance of ODV pace and camera dynamics, as well as the impact of its content on user QoE, is identified.

The remainder of this paper is structured as follows. Section 2 elaborates on our test environment, targeted population, and test materials used in the experiments. Section 3 brings the results while concluding remarks and outlook of our future research are given in Section 4.

2. TEST SETUP

2.1 Test Environment and Materials

The objective of our tests was to investigate how changing video resolution and different frame drop patterns impact user perception of ODV quality. To this end, we downloaded two short ODV from YouTube (≤ 3 minutes long, 1080p resolution, 8 Mbps bitrate, 30 fps) and used them for the preparation of the two test sequences. Specifically, in Adobe Premiere Pro video editing software we: 1) created the first sequence by inserting several short lower resolution clips (720p, 480p, and 360p) into the original 1080p video (we also introduced one rebuffering event which lasted for two seconds) and 2) introduced different frame drop patterns into the video, thus creating the second test sequence. We tried to emulate changing network conditions, in which video resolution can be downgraded and upgraded during the streaming, and frames can be dropped during ODV transmission due to, e.g., packet loss. How the sequences were created is illustrated in Figures 1, 2, and 3.

Apart from the two test sequences, the subjects were also watching a training sequence. This sequence was free of any quality degradations, it was shown to each test subject before the actual test sequences, and its primary purpose was to accustom the subjects to the 360-degree perspective in VR and the Head Mounted Display (HMD) system used to render the ODVs. Note that training and actual test sequences were shown to the subjects using HTC Vive HMD in a well-isolated room with no outside sources of noise. The computer used for video playback had Intel Core i7 6800K processor, 16 GB of RAM, and EVGA GeForce GTX 1080 Ti FTW3 GAMING video graphic card. Test subjects were viewing the videos in a seated position on a chair that enabled them to rotate freely.

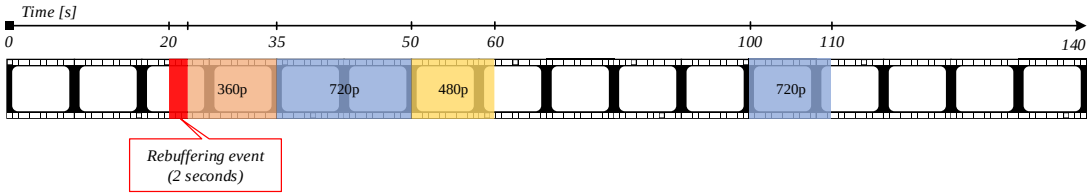


Figure 1 – Locations of the inserted clips of lower resolution videos in the first test sequence

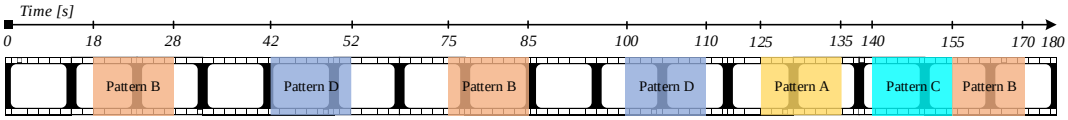


Figure 2 – Locations of different frame drop patterns in the second test sequence

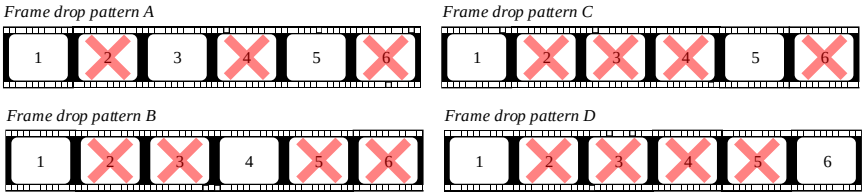


Figure 3 – The frame drop patterns inserted in the second test sequence (X indicates the deleted frames)

To demonstrate the extent of the degradations which were inserted into the first test sequence, Figure 4 shows two snapshots of the same scene (only a second apart in the timeline), but in different resolutions (1080p and 360p).

a)



b)

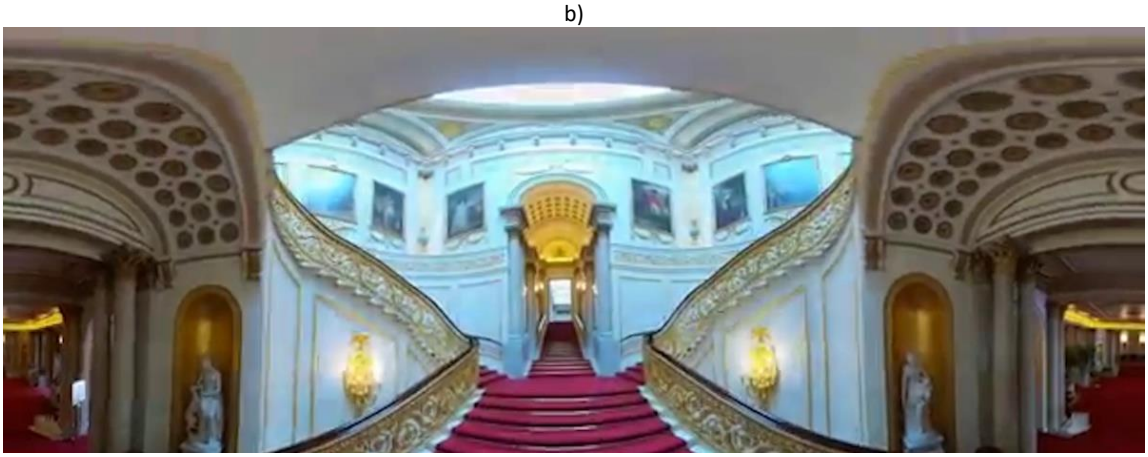


Figure 4 – The comparison between the two images in different resolutions: a) 1080p and b) 360p

As seen in this comparison (Figure 4), the level of detail of the scene is considerably downgraded due to lower 360p resolution. Note that the change is even more pronounced when the sequence is viewed in the HMD system since its screens are close to the viewer's eyes.

2.2 Test Participants and Procedure

Due to the availability of the test population, test participants were students of the Faculty of Transport and Traffic Sciences, the University of Zagreb (i.e., the convenience sampling method was used). The test included 20 participants (75% of whom were males) between the ages of 18 and 24 who rated the two test sequences. A continuous rating method was used for rating. Specifically, the subjects were instructed to rate the ODV quality whenever they notice the change during screening (for instance, when they see a frame drop). During the testing, the subjects' ratings relative to the sequence timeline were recorded. Hence, multiple scores were collected per test subject and test sequence. This enabled us to evaluate user QoE level for a specific segment of a video, i.e., for a specific video degradation type which was introduced. In total, the ratings of 17 and 20 participants, who evaluated the first and second test sequence, respectively, were accepted for further analysis.

After watching each test sequence, the subjects responded to several questions in the form of an interview. Those questions included the self-evaluation of their: level of immersion into the video, level of entertaining and enjoyment with the video, level of stress, fear and nausea induced by the ODVs, and overall level of ODV quality (after taking into account the degradations which they have experienced as well as other factors which may have surfaced during the interview). The test procedure used in this part of the test is shown in Figure 5.

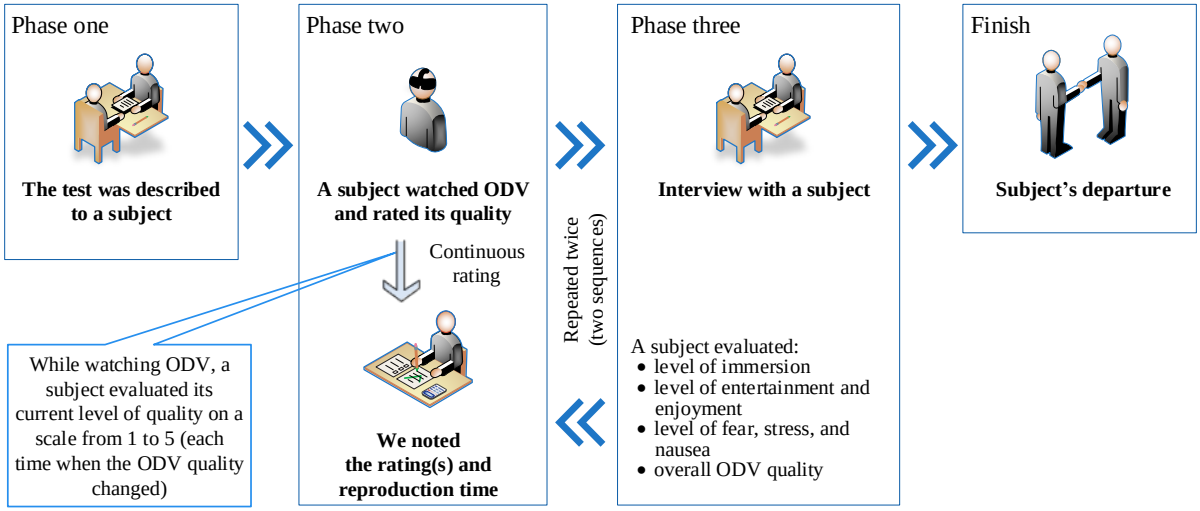


Figure 5 – Test flow of subjective testing

During the rating of the ODV quality (phase two) as well as while self-evaluating the level of immersion, entertainment, etc. (stage three), discrete 5-point rating scales were used. The scales contained linguistic meanings, so, for instance, rating 1 meant *bad quality,* while 5 meant *excellent quality.*

3. RESULTS AND DISCUSSION

The subjects evaluated each segment of the sequences separately, i.e., the ODV quality was continuously rated during screening (on a scale from 1 to 5). Hence, we were able to pair their responses to see if there is a statistically significant difference between the ratings of the two neighboring video segments which differ in the level of degradation (as shown in Figures 1 to 3). To this end, the Wilcoxon test for paired samples was used ($\alpha = 0.05$). The medians of the subjects' ratings for the first and second test sequences, per specific video segment, were calculated (depicted in

Figures 6 and 7, respectively). The *x*-axes of the figures show the type of degradation introduced (as explained while commenting Figures 1-3). Figures 6 and 7 also contain the p-values (indicated by the orange dots); p-values that imply the presence of statistically significant differences between the two neighboring medians of the ratings are located below the orange horizontal line.

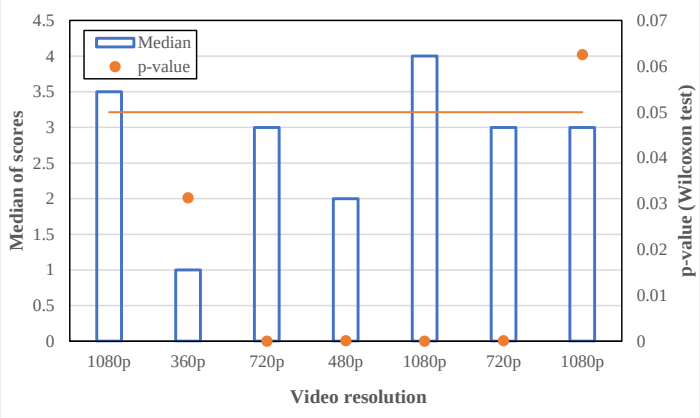


Figure 6 – The medians of scores for the first test sequence (level of significance equals 0.05 which is indicated by the orange horizontal line)

Figure 6 shows how the subjects negatively perceived the resolution drop from 1080p to 360p; the median of the ratings plunged from 3.5 to 1, indicating *bad* video quality. Note that this resolution shift was even more emphasized by the rebuffering event, which was introduced. The rating improved in the next segment of the video when the resolution was restored to 720p; however, the event adversely affected the user QoE level. It can be seen that users noticed all the changes in video quality, i.e., the changes in their ratings for a particular segment of a video are statistically significant ($p < 0.05$), except for the last segment. It is interesting to see how the median of the ratings for that last segment equals only 3 (*fair* quality) despite the fully restored video resolution. Moreover, the difference is insignificant ($p > 0.05$) compared to the median of the second to the last segment. The lack of significantly noticeable improvement can be explained by, as it seems, the negligible difference in the video quality between these two video resolutions, when the direction of the change is from lower to higher resolution.

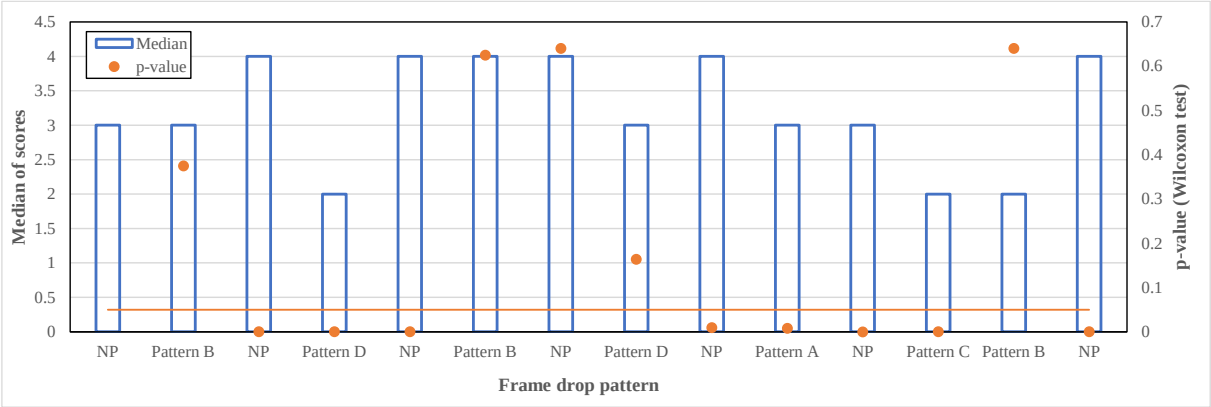


Figure 7 – The medians of scores for the second test sequence (level of significance equals 0.05 which is indicated by the orange horizontal line)

While analyzing the data depicted in Figure 7, one can see that some frame drop patterns did not evoke significant disturbances in the subjects' perception of video quality. Specifically, the medians of the ratings are mostly consistent with the changes in degradation in the video segments, yet some changes in ratings are not statistically significant ($p > 0.05$). There are multiple possible explanations for this behavior. First, the duration of the non-degraded periods (NP surrounding the patterns)

perhaps impacted the subjects' ability to perceive the patterns. Secondly, the changes in the quality between the two neighboring video segments were, in some cases, hard to notice. Interestingly, we can observe how the medians of the ratings remained relatively high in the middle section of the video, even when Pattern D occurred (its' features are shown in Figure 3). This can be explained if we consider the video content. The content of the second test sequence was a Hong Kong tour from the air. The video contained highly dynamic scenes with fast camera movements. This video was more entertaining to our subjects compared to the first video whose content was the tour through the Buckingham Palace. The average level of entertainment and enjoyment (LoEnt, LoEnj) for the first and second video equaled (3.55, 3.2) and (4.15, 3.9), respectively. Hence, we can argue that due to the fast pace of the second video, some quality degradations remained unnoticed by the subjects.

For each test participant, we calculated the median of all ratings given in phase two of the experiment (the phases are depicted in Figure 5). We compared it with the overall evaluation of video quality, which they gave us during an interview. The results of these analyses for the first and second test sequences are depicted in Figure 8.a and 9.a, respectively. Additionally, subplots 8.b and 8.c for the first test sequence, and subplots 9.b and 9.c for the second test sequence, show the subjects' level of entertainment, enjoyment, nausea, fear, and sense of losing a balance.

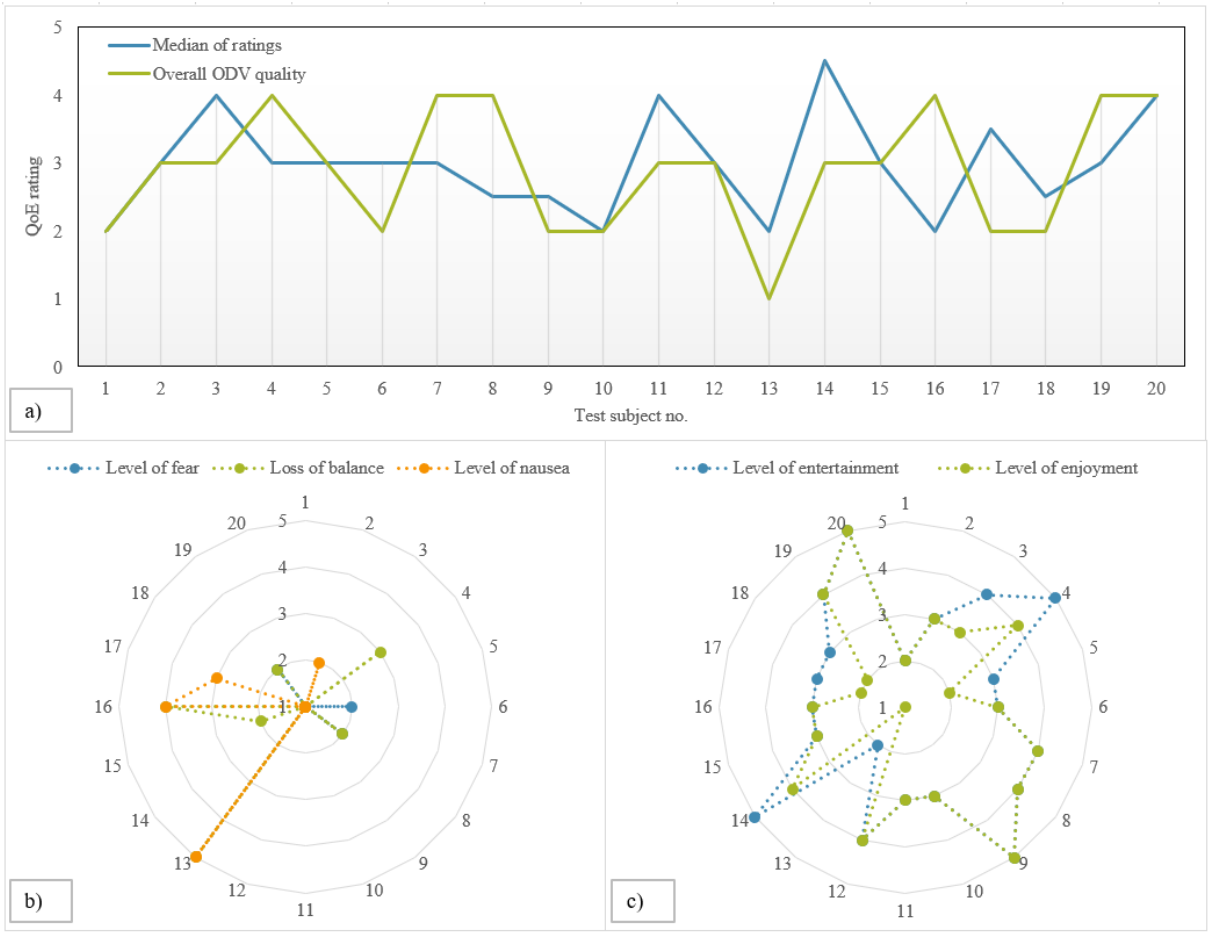


Figure 8 – Analysis of the first test sequence: a) The median of all ratings compared with the overall evaluation of video quality per test subject, b) Subjects' level of fear and nausea, and sense of losing a balance, c) Subjects' level of entertainment and enjoyment

From the data presented in Figure 8.a, we see that the median of ratings for 75% of our test subjects is greater or equal to their overall ODV quality rating given during the interviews. Eight participants indicated a lower overall rating compared to the median of their scores per specific video segment. Yet, only three of those eight participants evaluated the higher level of fear and/or nausea and/or sense of losing a balance. Hence, we cannot argue that the lower overall rating is impacted the

subjects' sense of discomfort, i.e., their sense(s) of fear, nausea or losing a balance (those three senses were investigated, although we are aware that *discomfort* may also include feelings such as anger or frustration). However, it interesting to note how test participants no. 4, 7, 8, and 19 increased their overall rating (green line in Figure 8.a) compared with their median of ratings (blue line on the same subplot), which may be impacted by the increased levels of entertainment and enjoyment (subplot 8.c) with almost no indication of discomfort (subplot 8.b) for those test subjects.

The same analyses of the test subjects' ratings were conducted for the second video (Figure 9). Here, 71% of test subjects have their median of the scores greater or equal to the overall ODV quality rating (subplot 9.a). Similar to the previous findings, the level of entertainment and enjoyment impacted the subjects' opinions. For instance, if the results for the subjects no. 1, 8, 12, 16, and 17 are observed, it can be seen how those subjects rated higher the overall ODV quality[1] compared to their median of the ratings (subplot 9.c). At the same time, those subjects did not experience any level of discomfort (subplot 9.b). As confirmed in both test sequences, the user level of QoE is closely linked to the level of discomfort, entertainment, and enjoyment.

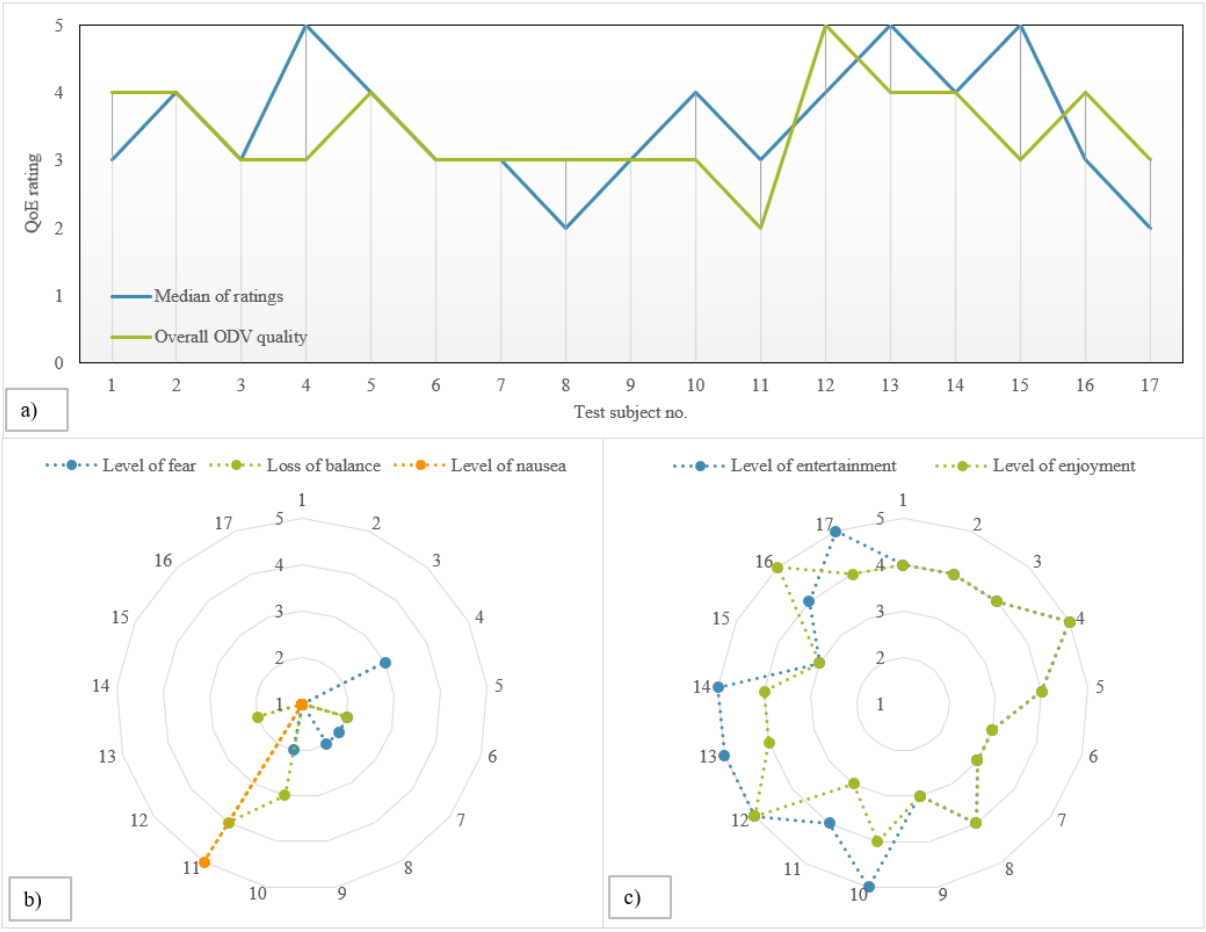


Figure 9 – Analysis of the second test sequence: a) The median of all ratings compared with the overall evaluation of video quality per test subject, b) Subjects' level of fear and nausea, and sense of losing a balance, c) Subjects' level of entertainment and enjoyment

While investigating the correlation between the level of entertaining and overall ODV quality, we witnessed that a moderate positive correlation exists in the first video (R = 0.556068), and a low positive correlation exists in the second video (R = 0.35678). This once again proves how other influential factors, such as video content and user level of fear, nausea, or sense of losing a balance, affect the results. Thus, we can argue that further research is needed to fully disclose and understand

[1] After contemplating about their level of entertainment and enjoyment during the interview.

which factors are in interplay with the user level of QoE and how those relationships affect user perception of the quality of VR applications.

4. CONCLUSION

In this paper, we reported the results of the evaluation of user QoE for the ODV streaming service. We pre-prepared test sequences to disclose the impact of changing ODV resolution and different frame drop patterns on user QoE level. Out of those two objective parameters, we reported how the changes in the video resolution (from 1080p to 360p, 480p, 720p, and backward) produced the most impact on the subjects' perception. The difference in the attitude was even more pronounced when the resolution shift was accompanied by a rebuffering event. Once degraded, the user perception was difficult to recover, especially if shorter test sequences are used for the experiment, like in our case. The importance of ODV pace and camera dynamics was also disclosed when evaluating the impact of different frame drop patterns since we noticed that even the choppiest video segments remained unnoticed by some of our test subjects. As we argued, one possible explanation of this result can be the ODV content, which was evaluated as highly entertaining by the subjects, i.e., we can argue that the content of the second video made test subjects more forgiving to the occasional advent of quality degradations.

In the horizon of our future research we see: a) repetition of this experiment on a larger group of test participants (for instance, with the more experienced and age-versatile VR users), b) expanding the scope of the experiment by introducing new types of degradation in the sequences and using different sequences (different content and ODV duration), c) experimenting with different methodologies for subjective tests (e.g., double-stimulus) and d) working on modeling the relationships between the objective (network dependent) QoE parameters and subjective perception of ODV streaming quality.

ACKNOWLEDGMENT

The results presented in this paper originate from the Quality of Experience for Virtual Reality Applications (QoE4VR) project activities. The project is funded by the University of Zagreb under *Short-term financial support for researchers* program in 2017.

REFERENCES

[1] Trucks. Virtual Reality Is the New Reality for Truck Driver Training. Available from: https://www.trucks.com/2017/08/24/virtual-reality-truck-driver-training/ [Accessed July 2020]

[2] Jasoren. 4 Virtual Reality Applications in the Automotive Industry. Available from: https://jasoren.com/4-virtual-reality-applications-in-the-automotive-industry/ [Accessed July 2020]

[3] Cisco. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017-2022 White_Paper._Cisco,_2019._Available_from:_https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-738429.html [Accessed June 2019]

[4] Yu M, Lakshman H, Girod B. A Framework to Evaluate Omnidirectional Video Coding Schemes, Mixed and Augmented Reality. Proceedings of the IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 29 September - 3 October 2015, Fukuoka, Japan. 2015, p. 31-36 (DOI:10.1109/ISMAR.2015.12).

[5] Sun Y, Lu A, Yu L. WS-PSNR for 360 Video Objective Quality Evaluation. MPEG Joint Video Exploration Team, vol. 116, Chengdu, 2016.

[6] Sun Y, Lu A, Yu L. AHG8: WS-PSNR for 360 Video Objective Quality Evaluation. Joint Video Exploration Team of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11, JVET-D0040, 4th Meeting. Chengdu, 2016.

[7] He Y, Vishwanath B, Xiu X, Ye Y. AHG8: InterDigital's Projection Format Conversion Tool. Joint Video Exploration Team of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11, JVET-D0021, 4th Meeting. Chengdu, 2016.

[8] Zakharchenko V, Alshina E, Singh A, Dsouza A. AHG8: Suggested Testing Procedure for 360-degree Video. Joint Video Exploration Team of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11, JVET-D0027, 4th Meeting. Chengdu, 2016.

[9] Wu S, Chen X, Fu J, Chen Z. Efficient VR Video Representation and Quality Assessment. Journal of Visual Communication and Image Representation. 2018;57: 107-117 (DOI:10.1016/j.jvcir.2018.10.018).

[10] Chen S, Zhang Y, Li Y, Chen Z, Wang Z. Spherical Structural Similarity Index for Objective Omnidirectional Video Quality Assessment. Proceedings of the IEEE International Conference on Multimedia and Expo (ICME), 23 - 27 July 2018, San Diego, United States. 2018, p. 1-6 (DOI:10.1109/ICME.2018.8486584).

[11] Wang Z, Simoncelli EP, Bovik AC. Multiscale Structural Similarity for Image Quality Assessment. Proceedings of the 37th Asilomar Conference on Signals, Systems & Computers, 9-12 November 2003, Pacific Grove, United States. 2003, p. 1398-1402 (DOI:10.1109/ACSSC.2003.1292216).

[12] Xu M, Li C, Chen Z, Wang Z, Guan Z. Assessing Visual Quality of Omnidirectional Videos, IEEE Transactions on Circuits and Systems for Video Technology. 2019 (DOI:10.1109/TCSVT.2018.2886277).

[13] Birkbeck N, Brown C, Suderman R. Quantitative Evaluation of Omnidirectional Video Quality. Proceedings of the 9th International Conference on Quality of Multimedia Experience (QoMEX), 31 May - 2 June 2017, Erfurt, Germany. 2017 (DOI:10.1109/QoMEX.2017.7965684).

[14] Zakharchenko V, Pyo Choi K, Alshina E, Hoon Park J. Omnidirectional Video Quality Metrics and Evaluation Process. Proceedings of the Data Compression Conference (DCC), 4-7 April 2017, Snowbird, United States. 2017, p. 472-472 (DOI:10.1109/DCC.2017.90).

[15] Chen Z, Li Y, Zhang Y. Recent Advances in Omnidirectional Video Coding for virtual Reality: Projection and Evaluation. Signal Processing. 2018;146: 66-78 (DOI:10.1016/j.sigpro.2018.01.004).

[16] Upenik E, Řeřábek M, Ebrahimi T. Testbed for Subjective Evaluation of Omnidirectional Visual Content. Picture Coding Symposium (PCS), 4-7 December 2016, Nuremberg, Germany. 2016, p. 1-5 (DOI:10.1109/PCS.2016.7906378).

[17] Pérez P, Escobar J. MIRO360: A Tool for Subjective Assessment of 360 Degree Video for ITU-T P.360-VR. Proceedings of the 11th International Conference on Quality of Multimedia Experience (QoMEX), 5-7 June 2019, Berlin, Germany. 2019 (DOI:10.1109/QoMEX.2019.8743216).

[18] Sassatelli L, Winckler M, Fisichella T, Dezarnaud A, Lemaire J, Aparicio-Pardo R, Trevisan D. New Interactive Strategies for Virtual Reality Streaming in Degraded Context of Use. Computers & Graphics. 2019 (DOI:10.1016/j.cag.2019.10.005).

[19] Schatz R, Sackl A, Timmerer C, Gardlo B. Towards Subjective Quality of Experience Assessment for Omnidirectional Video Streaming. Proceedings of the 9th International Conference on Quality of Multimedia Experience (QoMEX), 31 May - 2 June 2017, Erfurt, Germany. 2017 (DOI:10.1109/QoMEX.2017.7965657).

MATEA MIKULČIĆ, PhD student[1]
E-mail: mmikulcic@fpz.unizg.hr
IVICA LJUBAJ, PhD student[1]
E-mail: iljubaj@fpz.unizg.hr
TOMISLAV JOSIP MLINARIĆ, Ph.D.[1]
E-mail: tmlinaric@fpz.unizg.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb

PROGRESS IN THE ERTMS INTEGRATION OF CROATIAN RAILWAYS WITHIN EUROPE

ABSTRACT

At the beginning of the new decade, many radical changes await the railway infrastructure in Croatia with the aim of increasing the quality of the network and strengthening transport links with the rest of Europe. Synonymous with European interethnic integration and interoperability is the European Rail Traffic Management System (ERTMS), whose applicability has become far broader. In this article, the aim is to determine the current scale and future dynamics of Croatia's progress in the implementation of the ERTMS system and thus its integration into the European railway network. Progress in implementation is also observed in relation to other countries located on the common Mediterranean (MED) corridor and countries whose railway networks are similar in size to Croatia. In the national context, the results show a lag in the implementation and inconsistency in the realization of planned projects. This is confirmed by the convincingly low position among other countries along the Mediterranean corridor, but also in the context of railway networks of similar size as Croatia.

KEY WORDS

Railway integration; ERTMS progress; Croatian railway network; Mediterranean corridor;

1. INTRODUCTION

With the development of European rail traffic management system (ERTMS), related subsystems for European train control system (ETCS) and Global system of mobile communications for railway traffic (GSM-R), and the demonstration of its numerous capabilities, national railways in Europe have, among other things, been given the opportunity to better integrate with each other and strengthen their joint presence in the road-dominated transport market. With the first ERTMS European deployment plan (EDP) from 2009 [1], the basic dimensions of ERTMS development therefore included six international corridors with the highest freight traffic volumes, but also clear deadlines for 2015 and 2020 for its implementation. The planned scale was additionally expanded in 2017 to a total of nine core network corridors (CNC) of the Trans - European network - transport (TEN-T) corridors. The newly defined deadlines imply that 50% of TEN-T network should be equipped with ERTMS by 2022, and the rest until 2030. Since this 2020 was one of the initial deadlines for the introduction of ERTMS, this paper aims to determine the current scale of ERTMS deployment status on one of the TEN-T corridors, the Mediterranean (MED) corridor and investigate the extent to which it meets the requirements of the last EDP.

Achieving the set goals is also defined through national implementation plans (NIP) by which each individual member has defined the steps of its own progress towards the full implementation of ERTMS to comply with the Commission regulation (EU) 2016/919 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the

European Union [2]. By the time of defining its NIP plan [3], Croatia already had one double line section of the railway network equipped with ERTMS/ETCS level 1, from Vinkovci to Tovarnik, and it was the final part of the former X. Pan European corridor towards Serbia. Further ERTMS migration schedule has been adjusted according to the suggestions from the Study of implementing ERTMS in Croatia [4]. ETCS level 2 has been selected to equip all lines. However, the initial decision was modified with ETCS level 1 due to the lack of GSM-R equipment, which is a necessary prerequisite for the efficient functioning of ETCS level 2. To date, in addition to the section Vinkovci - Tovarnik of the M104 line, the Okučani - Novska double line section is also equipped with ERTMS/ETCS level 1.

The direct introduction of an ERTMS system makes sense if the status of the infrastructure meets safety and traffic requirements. Given the long-term non-investment in the maintenance and modernization of the network in Croatia, the real situation represents a significant problem for further implementation. The analysis of the state of the infrastructure or some of their subsystems in the context of the introduction of ERTMS has been the subject of several researches. In [5] obsolescence of different types of interlocking on the railway network in Croatia proved to be a major problem. After analyzing the railway infrastructure and possible strategies for the implementation and integration of the ERTMS system to the railway network in Croatia, authors in [6] pointed out the barriers to transfer to interoperability such as diversity in the level of equipment with signaling and safety devices, insufficient capacity on some railway sections, problem with the terrain, inadequate platforms and unsatisfactory access for passengers. In [7] comparison of the effects of ETCS level 1 and level 2 on railway capacity has been made for one regional railway line. The literature so far mainly deals with analyzes of the current state of the network and recommendations for the introduction of ERTMS, while there is no research on the current size of the equipped network in Croatia and the correlation of the achieved progress with the rest of Europe. More recently several activities have been started with the aim of modernizing the railway infrastructure in Croatia, and the last cycle of investments is considered as the largest so far [8]. Therefore, the second intention in this paper is to investigate whether started activities of modernization of railway infrastructure in Croatia follow the ERTMS equipping plan according to defined NIP, and how much progress Croatia has made so far and in relation to other countries with which there is a possibility of comparison. Furthermore, a similar analysis of current situation and expected deployment has been made in [9] for Czech Republic for period 2014 – 2020. This analysis was based on the expected installation projects according to the NIP of the Czech Republic and did not have a foothold with the actual projects, which requires sensitivity in the use of the obtained results. Another research [10] focused on the ERTMS deployment on all the new high speed lines in Spain. However, more attention was given to the problems with different suppliers and variability of the ERTMS specifications rather than monitoring overall national progress in deployment.

The presented content is divided into 5 chapters. First section presents a research motivation and literature review. Next section describes the process of data collection and processing. The third chapter brings the most important results in relation to the set research goals, while their synthesis in a broader sense is given in the fourth chapter. The last chapter contains the most important conclusions and guidelines for future research.

2. METHODOLOGY

The entire research process has been performed in several steps. After reviewing the current literature dealing with the evaluation of progress in the applicability of ERTMS/ETCS technology and reviewing research on its applicability in Croatia, the second step was to collect the necessary data. Since the European standard is being explored, the necessary data set comes from official statistical sources on its deployment, statistical databases and publicly available official documents of the European Commission. National data are taken from different documentation such as the Network Statements for 2020 and other different national transport strategies and studies.

In the first place, the projects realized so far and recently started are compared with the planned activities from the national implementation plan for Croatia adopted in 2017. The adopted ERTMS migration plan for railway infrastructure in Croatia implies two-phase equipping of lines that are part of the MED TEN-T corridor in the country. The first ten-year phase aims to equip international railways that are part of the core network by 2026. This applies to the following lines [4]:

- direction from Slovenia towards Hungary (Rijeka - Zagreb - Botovo): M203 (Rijeka – Šapjane – st. bor.), M202 (Zagreb Main Station – Rijeka), M102 (Zagreb Main Station – Dugo Selo), M201 (st. bor. - Botovo – Dugo Selo),
- direction from Slovenia towards Serbia (Dobova – Zagreb – Novska – Vinkovci - Vukovar/ - Tovarnik): M101 (st. bor. –Savski Marof –Zagreb Main Station), M102 (Zagreb Main Station – Dugo Selo), M103 (Dugo Selo – Novska), M104 (Novska – Tovarnik - st. bor.), M601 (Vinkovci – Vukovar).

After 2026, in the next 20 years, ERTMS implementation is planned for a part of the comprehensive TEN-T network, which includes [4]:

- direction Zagreb – Sisak – Novska: M502 (Zagreb Main Station – Sisak – Novska),
- direction Ogulin – Knin – Zadar/Šibenik/Split: M605 (Ogulin – Krpelj), M604 (Oštarije – Knin – Split), M606 (Knin – Zadar), M607 (Perković – Šibenik),
- direction from Bosnia and Herzegovina towards Hungary: M303 (Strizivojna Vrpolje – Slavonski Šamac - st. bor.), M302 (Osijek – Strizivojna – Vrpolje), M301 (st. bor.- Beli Manastir – Osijek),
- short direction from Slovenia towards Hungary (Središće – Čakovec – Kotoriba): M501 (st. bor.- Čakovec – Kotoriba - st. bor.),
- short direction towards Bosnia and Herzegovina: M304 (st. bor.- Metković – Ploče).

This was followed by the selection of criteria for comparing the collected quantitative data on the installation of ERTMS systems at the national level of Croatia and the European level. The following infrastructural criteria have been selected as important for assessment:

- the share of ERTMS infrastructural equipment of the principal lines of Mediterranean TEN-T corridor section per country until 2022,
- the share of ERTMS infrastructural equipment in relation to the size of the railway network (in the range of 2000 km to 3200 km) by 2022.

As might be expected, the most important shortcoming of this research is the uncertainty of some data on the latest level of equipment of the mentioned national infrastructures with the ERTMS system. There are no common guidelines that would unambiguously define the statuses of all involved projects in the considered countries, as well as the duration of the implementation phases. For this reason, deviations of the displayed quantities from the actual ones are possible. However, to determine whether there is progress in the equipment of Croatian infrastructure compared to networks in other European countries, the possible deviation of the data is acceptably negligible, assuming it is a small difference.

3. RESULTS

The poor condition of the railway infrastructure and the obsolescence of certain subsystems represent a significant obstacle to the normal course of national and international railway traffic. Therefore, the modernization of the railway is a basic precondition for the introduction of a new management and control system and its efficient functioning. Considering the current situation regarding the implementation of modernization works that include the improvement of the signaling system via ERTMS in individual countries, it provides insight into the extent of achieved and future interoperability on the European mainland. The following are independent and interstate assessments for the Croatian railway network.

3.1 National Scale of ERTMS Progress

Modernization projects on the railway network in Croatia are in various stages of development, from preparation of study documentation, design, public procurement procedures for the execution of works and implementation of works to completed projects. Table 1 shows the planned arrangement of equipping the railway lines or sections with the ERTMS system in Croatia, according to the scheduled year of implementation [3], and their current status if included in the present modernization plan [8]. The rating covers the ERTMS implementation projects from the first phase of deployment for the period from 2018 to 2023, since the next revision of the NIPs is set for 2022. From planned projects until 2020, only one of the eight projects in the NIP is not part of the modernization, and that is the line M203 Rijeka - Šapjane. Furthermore, four projects are in the implementation phase of infrastructure works. More specifically, works on the section M201 Križevci - Dugo Selo were supposed to be completed in 2020, but due to delays that deadline is questionable. Construction works on the other three sections are still at the beginning. Of that, works on the M101 line are planned on a shorter section of the state border - Savski Marof - Zagreb West Station. Study documentation is being prepared for the railway lines that are part of the Zagreb railway junction, while other projects that would enable the continuation towards Rijeka (M202) and the connection of the Zagreb railway junction with previously equipped ERTMS sections (M103 and M104) towards Serbia are still being designed.

Table 1 – Comparison of modernization projects with planned ERTMS installation

Planned in the NIP			**Current progress phase**
Start of work	Line	Section	
2018	M102	Sesvete – Dugo Selo	Study documentation
	M201	Križevci – Dugo Selo	Work in progress
	M601	Vinkovci - Vukovar	Work in progress
2019	M201	Križevci – Koprivnica – st. bor.	Work in progress
2020	M103	Dugo Selo - Novska	Design
	M202	Hrvatski Leskovac - Karlovac	Design
		Škrljevo - Rijeka	Design
	M203	Rijeka – Šapjane - st. bor.	/
2022	M104	Okučani - Vinkovci	Design
2023	M101	st. bor. – Savski Marof – Zagreb Main Station	Work in progress
	M102	Zagreb Main Station - Sesvete	Study documentation

Source: Authors according to [3,8]

Additionally, Figure 1 offers a more precise view of the distribution of progress phases of the mentioned sections on the entire national network and the connections with the railways in the area. For the sake of consistency in the consideration of implementation projects regarding the stage in which they are with the data of other countries and their later comparison, it is assumed that the railway sections with contracted works represent the relevant quantity of ERTMS equipped lines in Croatia in 2020. Additionally, given the phases in which are other modernization projects currently, as well as the duration of each phase, it can be assumed that the identical situation with the number of equipped railways will remain the same until 2022. With previously equipped 53.3 km of lines, new 38.2 km on the double line section Dugo Selo – Križevci, 42.6 km on the extension Križevci - Koprivnica – st.bor., 17.8 km on the section Savski Marof – Zagreb West Station and 18.7 km on the section Vinkovci - Vukovar, the total length of ERTMS equipped conventional lines in Croatia is 170.6 km or approximately 340 km of double line.

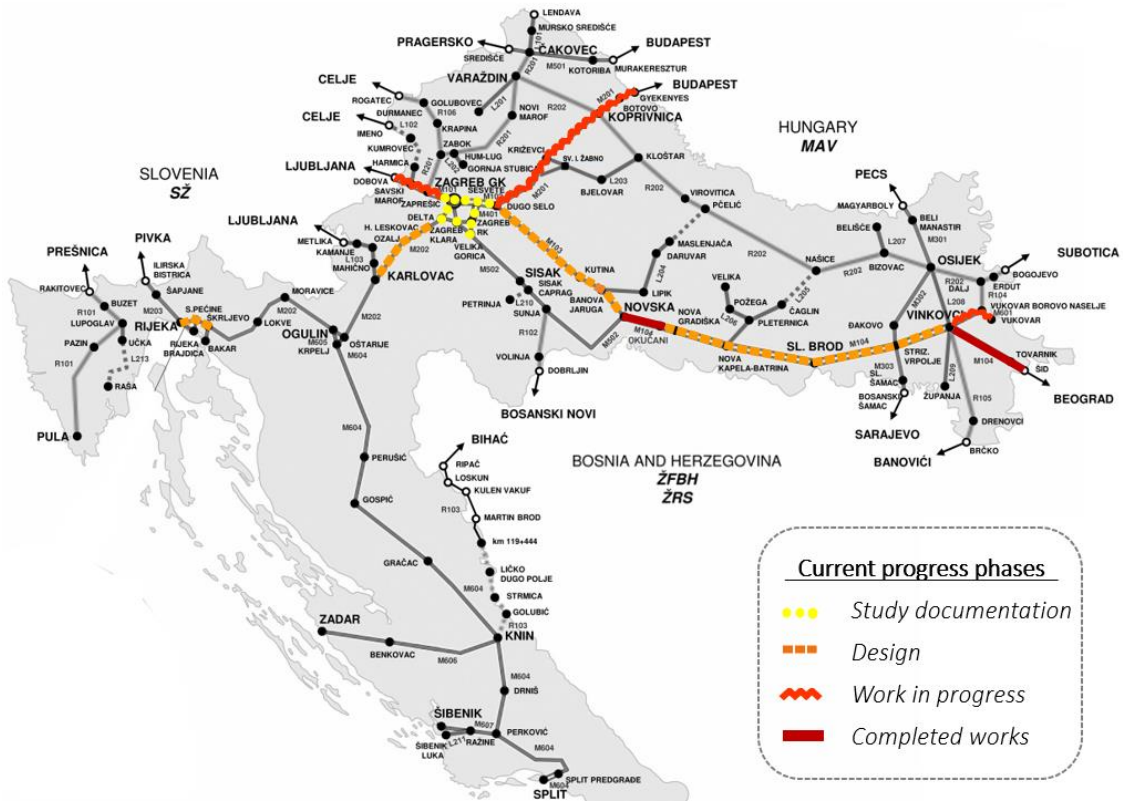


Figure 1 – Progress of works on planned ERTMS lines on the railway network in Croatia
Source: Authors according to [3,8]

3.2 Interstate Scale of ERTMS Progress Along the MED Corridor

Mediterranean corridor includes principal, diversionary and connecting railway lines of a total of six countries, all with different levels of infrastructural development. In general, the length of corridor section significantly depends on the geographical position of the country and the size of the railway network. Accordingly, lengths of individual MED corridor sections also vary [11,12]. Spain has the longest section of the corridor which extends to a total of 22% of its network. With twice the smaller section, France follows with 5.5% and Hungary with 18.5%. Furthermore, the corridor section in Italy is 5.1% of the network. The highest considering share has Slovenia with 37.8%, while the shortest MED section is in Croatia with 14.4% of total network.

Principal routes cover approximately 88.7% of the MED corridor [11], while other lines provide alternative routes in the presence of disturbances. Moreover, not all countries have them. Corridor sections in Croatia, Slovenia and France are only principal routes. Therefore, a further comparison of ERTMS implementation in the countries of the MED corridor is based only on this category of routes. The analysis uses the same principle of determining potentially realized ERTMS projects until 2022 as in the example of Croatia.

The share of the ERTMS equipped corridor section for a country can be obtained from the ratio of the lines already equipped or in the equipping phase (work in progress), and the total length of the corridor section in that country. The share of ERTMS equipment of the MED section for Croatia is 26.3%. Compared to other relevant countries according to Figure 2 [13–18], this is almost 3 times more than the lowest France with only 8% of ERTMS installation, but also 1.5 times less than the first following Spain. On the other side, Slovenia leads in the amount of ERTMS equipped railways that are part of the MED corridor and records 3.4 times better situation than Croatia.

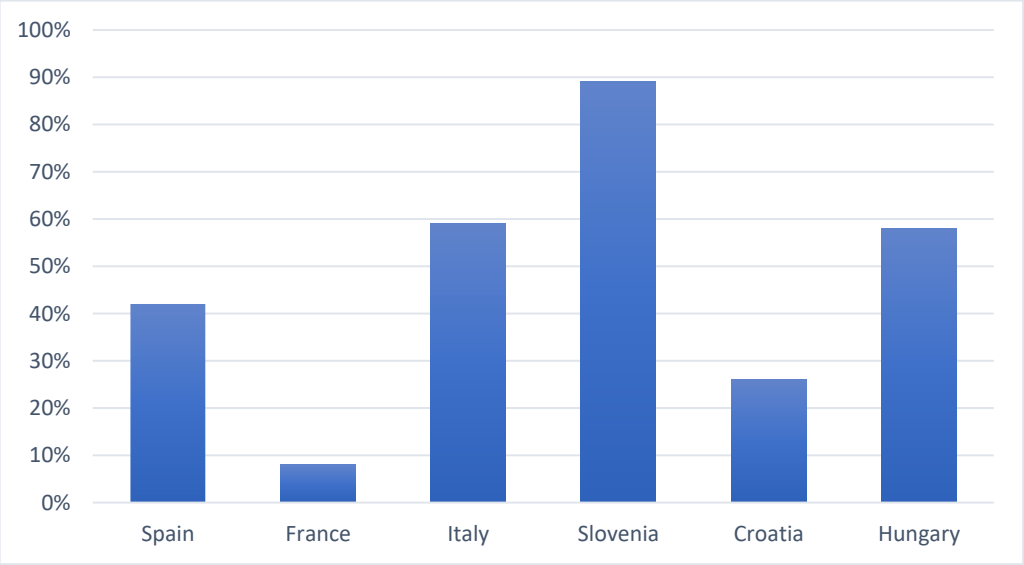


Figure 2 – Share of ERTMS equipped principal routes per country on the MED corridor
Source: Authors according to [11,13–18]

3.3 Scale of ERTMS progress in countries of similar network size

The next criterion for assessing progress is the amount of ERTMS lines in relation to the size of the railway network. The railway network in Croatia is 2604 km long [12]. Therefore, the optimal range of network size, which would allow a more adequate comparison, is between 2000 and 3200 km. Looking at the total length of railways of other European countries that meet this condition [12], Ireland, Portugal, Greece and the Netherlands stand out. Each of them has a section on at least one TEN-T corridor, and therefore a need to integrate into the European railways network with a single signaling and train management system [19]:

- Ireland: North Sea – Mediterranean corridor,
- Portugal: Atlantic corridor,
- Greece: Orient – East Mediterranean corridor,
- Netherlands: North Sea – Mediterranean, North Sea – Baltic and Rhine – Alpine corridor.

It should be emphasized that Ireland has no obligation to install ERTMS due to its isolated position, differences in track gauge and reduced scope of railway services due to small population [20]. Hence it is not included in the analysis of the ERTMS equipment of the network of the mentioned countries. Figure 3 shows the relationship between the equipped amount of lines until 2022 [21–23] and the total length of the railway network [12], assuming that the total length of the network of the countries concerned will remain the same. In conditions of similar sizes of the total network, the most equipped lines in 2022 will have Greece, which will be 67% of the network. The others are arranged as follows: Portugal with 27.3%, the Netherlands with 11.3% and Croatia with 6.6% of the total network.

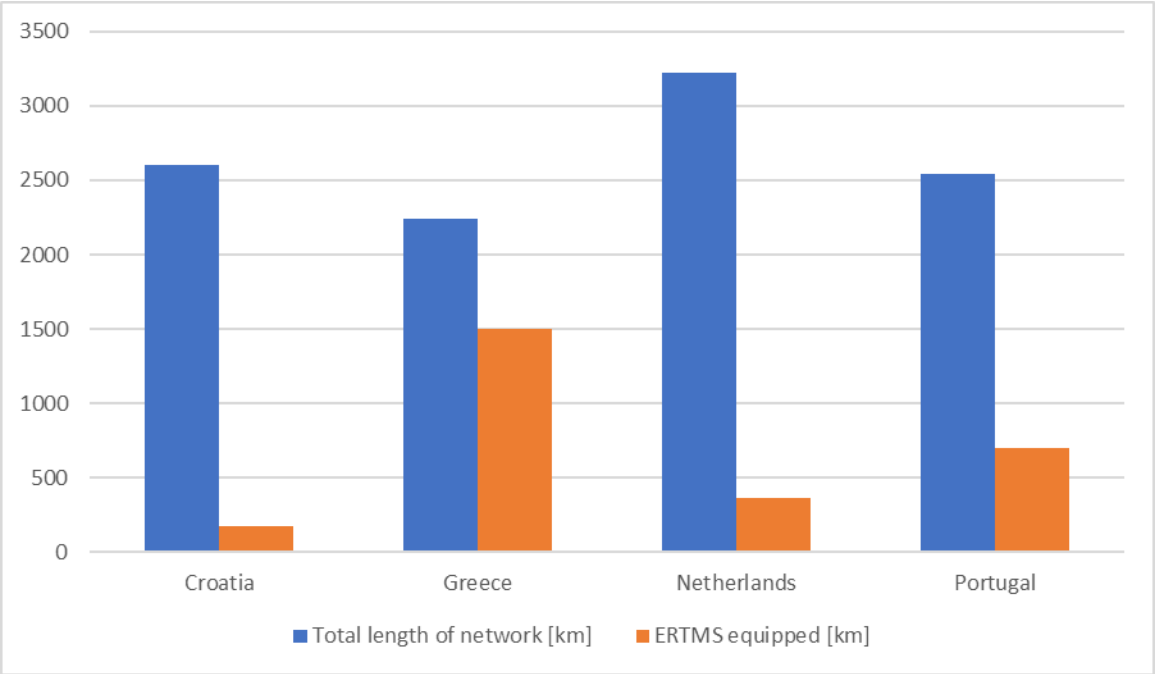


Figure 3 – The ratio of the total network length and ERTMS lines per country until 2022

Source: Authors according to [12,21–23]

4. DISCUSSION

Although ERTMS targets the integration of the different European national signalling systems, which hamper the interoperability of railway traffic, and its deployment is ongoing, the state of Europe's railway infrastructure remains quite heterogeneous. New investments imply removal of bottlenecks, improvement of rail transport services, attraction of more users and increase of competitiveness towards road transport. But their realization in practice is often subject to external factors that cannot always be influenced. In the case of Croatia, for many years there were no significant investments in railways, primarily due to the lack of recognition of the importance and role of railways in modern mobility. Greater awareness and a positive step in the modernization of railways has been achieved with the accession to the European Union (EU), the adoption of defined common strategic goals in transport and easier access to financial funds. Finally, with the liberalization of the freight transport market, ten operators in this segment of transport are currently participating in Croatia [24].

The performed compliance analysis of the realization of modernization projects in Croatia according to the defined guidelines for the implementation of ERTMS in the NIP, has shown an obvious lag in realization. The only project whose implementation is in the final phase of construction and whose commissioning is very likely by 2022 is the section Dugo Selo - Križevci. If there are similar complications with the remaining projects Križevci - Koprivnica - st. bor., Vinkovci - Vukovar and st. bor. - Savski Marof - Zagreb West Station, the future of their realization by 2022 is uncertain.

The possibility of deviations in the realization is not only specific to the Croatian network, but also in other considered countries. Compared to those countries along the MED corridor, there has been uneven progress towards completing the interoperability of this corridor. Observing the current level of implementation on the principal routes composed of conventional and high-speed lines on MED corridor, only 41% could be equipped by 2022. The most notable result in equipping is recorded by Slovenia with 37.8% of its network as part of the MED corridor and high 89% of ERTMS realization. Although this was not included in the analysis, it should be mentioned that among countries that have diversionary and connecting routes in addition to principal category, there are also differences

in the level of equipment. Moreover, in most countries there are several core freight corridors, which to some extent coincide with the MED corridor sections. With several important corridors within the country, it is difficult to expect the neglect or an uneven approach in equipping them. Furthermore, some countries are recording low equipment results due to a number of projects that modernize signaling independently in nodes, include works on several lanes in a section or involve upgrading ERTMS/ETCS versions on existing sections. Ultimately, better balancing of rail performance is needed for the whole corridor to achieve the desired level of interoperability from the latest EDP.

In comparison with other countries with a similar network size, Croatia records the weakest results. The preferred choice of ERTMS/ETCS level in these countries also varies. While some, such as Croatia, Slovenia and Greece, are opting for ERTMS level 1, others are equipping their networks with both levels 1 and 2. By correlating the results with the levels of specific individual economic development using gross domestic product (GDP) per capita for 2019 [25], the Netherlands is the only country with stronger economic development than the EU 28 average. Its position in relation to the other three countries in terms of completed ERTMS installation is a consequence of investments in the equipment and procurement of railway vehicles with built-in ERTMS technology, but also in the infrastructural upgrade of existing levels of ERTMS. Portugal records approximately 2 times lower economic development, Greece 2.5, and Croatia as much as 3.5 times. In light of the recent global slowdown and reduced economic activity due to the health crisis, GDP projections show a decline of 7.11% for this year [26]. This will have definitely an impact on the realization of many planned activities and those ongoing in the railway sector.

Until 2020, only the MED corridor section stretched in Croatia. With new extension of the rail freight corridor (RFC), the 10 RFC corridor Alpine - Western Balkans extends through Austria, Slovenia, Croatia, Serbia and Bulgaria. Its branch in Croatia coincides with the former X. Pan-European corridor from Slovenia - Savski Marof - Zagreb Main Station - Novska - Vinkovci - Tovarnik and continues towards Serbia. The equipping of certain parts of the new corridor section has already been carried out, and part of it is foreseen by the implementation plan discussed in this paper. It can be determined that in the first five-year period from the construction of the first section equipped with ETCS technology in Croatia until the adoption of the NIP 2017, 7.1% of the total length of the MED and Alpine - Western Balkan corridor sections in Croatia was equipped. In the next equivalent period, according to the analysis of the implementation of the started projects until 2022, a progress of a total of 17% is predicted. This surely positively affects railway planning and prioritization of interventions in the enhancement of railway infrastructure and its optimal use, but also opens up additional opportunities to improve the mobility service of passengers and goods and integrate better with other countries in different regions in Europe.

This review is based mainly on the infrastructural integration of Croatia. However, the basic task of ERTMS is not fulfilled and offers no real benefits of ERTMS integration as long as there is no adequate integration of vehicle subsystems and support for GSM-R technology. GSM-R equipment has not yet been installed on the railway network in Croatia. Likewise, new ERTMS vehicles have not been procured or retrofitting of existing vehicles is being performed. Unlike most other analyzed countries, the ERTMS fitted infrastructure equipment stands unused. Therefore, Croatia's real progress in ERTMS integration with the rest of Europe lies in better coordination of procurement activities by railway operators, with the support of the competent institutions and the infrastructure manager.

5. CONCLUSION

Thanks to joint coordination, support and development at European level, the fragmentation of European railways due to various incompatible train protection systems and operational barriers is slowly decreasing. With the introduction of a unified ERTMS solution on most major lines, the emphasis has been on better integration of national railways, increasing interoperability, safety,

quality of rail transport and other segments of progress in achieving better rail service. Determining the real scale of the current European ERTMS integration provides a clearer insight into the individual, but also the overall position of railway integration and the achieved level of interoperability. In doing so, it is possible to identify the most important indicators responsible for success in its implementation and take appropriate measures to bring them closer to the desired one. This certainly represents potential for future research in this area and especially in the case of Croatia.

This analysis pointed out an uncoordinated implementation of modernization activities in Croatia according to the expected stages of ERTMS implementation. A big problem is the uneven investment in all subsystems of ERTMS technology, which in the future could delay the realization of interoperable rail transport not only in a national context, rather than further disrupt performance in the wider region. All this has contributed to its insufficient ERTMS integration and low position in relation to countries of the same network size, as others along the Mediterranean corridor. Progress in the infrastructural implementation of ERTMS technology along the Mediterranean corridor, indicates the possibility of interoperable rail traffic at a minimum of 36% of its length by 2022. This situation may not be completely desirable, especially in this uncertain period. In addition, it is difficult to predict the realization of originally set scales in EDP since it also depends on the success of the ERTMS implementation results on the remaining corridors, the determination of which was not foreseen by this analysis. A more precise determination of the extent of ERTMS deployment on the entire core network will be known only after the scheduled review of ERTMS EDP for 2022. Until then, technology development, exchange of experiences, provision of financial support for both infrastructure managers and railway operators and comprehensive integration remain the main priorities not only for Croatia but all European countries.

REFERENCES

[1] European Commission. European Deployment Plan and National Implementation Plans, available from: https://ec.europa.eu/transport/modes/rail/ertms/ertms_deployment_en [Accessed 20th May 2020]

[2] European Commission. COMMISSION REGULATION (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union. 2016. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2016.158.01.0001.01.ENG

[3] Ministry of the Sea Transport and Infrastructure. National Implementation Plan for Commission Regulation (EU)2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union - Republic of Croatia. 2017. Available from: https://ec.europa.eu/transport/sites/transport/files/rail-nip/nip-ccs-tsi-croatia-en.pdf

[4] HŽ Infrastruktura, DB E&C HI. Studija uvođenja Europskog sustava upravljanja željezničkim prometom (ERTMS) [Study of implementing ERTMS in Croatia]. 2016. Croatian

[5] Matulić I, Musa M, Peraković D. ITS Solution in Railway Signalization, Control and Traffic Management. In: Katalinic B (editor). DAAAM International Scientific Book 2016. Vienna, Austria: DAAAM International Vienna and DAAAM scriptorium GmbH. 2016. p. 393–406.

[6] Mlinaric T, Rados B, Vajdic M. Proposal for the Implementation of the European Rail Traffic Management System (ERTMS) to the Railway Network in the Republic of Croatia. In: Katalinic B (editor). Proceedings of the 28th DAAAM International Symposium. Vienna, Austria: DAAAM International Vienna and DAAAM scriptorium GmbH; 2017. p. 109–0117.

[7] Ljubaj, Ivica; Mlinarić, Tomislav Josip; Ležaić, Tomislav; Starčević M. The Possibility of Capacity Increase on the Modernised and Electrified Railway Line R201 along the Zaprešić – Zabok Section. In: MATEC Web of Conferences, Horizons of Railway Transport. Žilina: University of Žilina; 2018. p. 1–4.

[8] HŽ Infrastruktura. Modernizacija EU sredstvima. [Modernization with EU founds] Available from: https://www.hzinfra.hr/?page_id=321 [Accessed 28th May 2020]
[9] Vopava J, Jánešová M, Kratochvíl R. Deployment of ERTMS in Czech Republic. In: Acta Polytechnica CTU Proceedings. Czech Technical University in Prague. 2016;5:69-73. Available from: doi: 10.14311/app.2016.5.0069
[10] Iglesias J, Arranz A, Cambronero M, Roza C De, Domingo B, Tamarit J, et al. ERTMS deployment in Spain as a real demonstration of interoperability: Near future challenges. 9th World Congress on Railway Research (WCRR). Lille, France. 2011;
[11] Rail Net Europe. Mediterranean RFC CID book 5 Implementation plan TT 2020/2021. 2020. Available from: https://www.railfreightcorridor6.eu/RFC6/Public/RFC6_CID_Book5_2020-21_05-02-2020.pdf [Accessed 6th Jun 2020]
[12] Eurostat. Total length of railway lines. 2020. Available from: https://ec.europa.eu/eurostat/databrowser/view/ttr00003/default/table?lang=en [Accessed 8th Jun 2020]
[13] Rete Ferroviaria Italiana. Network Statement. 2020. Available from: http://www.rfi.it/rfi-en/Railway-infrastructure-access/Network-Statement [Accessed 8th Jun 2020]
[14] MÁV Magyar Államvasutak Zrt. Network Statement. 2020. Available from: https://www2.vpe.hu/eng/network-statement [Accessed 8th Jun 2020]
[15] Slovenian Railways Ltd. Network Statement. 2020. Available from: https://www.slo-zeleznice.si/en/infrastructure/access-to-public-rail-infrastructure/network-statement [Accessed 8th Jun 2020]
[16] SNCF Réseau. National rail network statement. 2020. Available from: https://www.sncf-reseau.com/en/national-rail-network-statement [Accessed 10th Jun 2020]
[17] Administrador de Infraestructuras Ferroviarias. Network Statement. 2020. Available from: http://www.adif.es/en_US/conoceradif/declaracion_de_la_red.shtml [Accessed 10th Jun 2020]
[18] LÍNEA FIGUERAS PERPIGNAN S.A. Declaración de red. 2020. Available from: http://www.lfpperthus.com/declaracion-de-red.html [Accessed 12th Jun 2020]
[19] European Commission. The countries, Mobility and Transport. 2020. Available from: https://ec.europa.eu/transport/modes/rail/ertms-european-rail-traffic-management-system/countries_en [Accessed 14th Jun 2020]
[20] Ireland Member State. Account of the Planned Implementation - Command and Control Systems for the Irish Rail Network.2017. Available from: https://ec.europa.eu/transport/sites/transport/files/rail-nip/nip-ccs-tsi-ireland-en.pdf [Accessed 14th Jun 2020]
[21] OSE. Network Statements.2020 [cited 2020 Jun 8]. Available from: https://www.ose.gr/en/o-s-e/network [Accessed 12th Jun 2020]
[22] ProRail B.V. Network Statement.2020. Available from: https://www.prorail.nl/vervoerders/network-statement [Accessed 12th Jun 2020]
[23] Infraestruturas de Portugal S.A. Diretório da Rede I Network Statement.2020. Available from: https://www.infraestruturasdeportugal.pt/rede/ferroviaria/diretorio-da-rede [Accessed 12th Jun 2020]
[24] Croatian regulatory authority for network industries. Dionici na željezničkom tržištu. Available from: https://www.hakom.hr/default.aspx?id=7075 [Accessed 14th Jun 2020]
[25] Eurostat. Gross domestic product at market prices. 2019. Available from: https://ec.europa.eu/eurostat/databrowser/view/tec00001/default/table?lang=en [Accessed 14th Jun 2020]
[26] Statista. Growth of the real gross domestic product (GDP) in the European Union and the Euro area from 2009 to 2021.2020. Available from: https://www.statista.com/statistics/267898/gross-domestic-product-gdp-growth-in-eu-and-euro-area/ [Accessed 14th Jun 2020]

NATAŠA MUNITIĆ, Ph.D.[1]
E-mail: natasa.munitic@mmpi.hr
[1] Ministry of Sea, Transport and Infrastructure Republic of Croatia
Prisavlje 14, 10000 Zagreb, Republic of Croatia

COMPETITIVENESS AS A FACTOR OF SEAPORT MANAGEMENT EFFICIENCY

ABSTRACT

Seaports and related port systems have become the centers of modern transport systems. For each country, including the Republic of Croatia, the development of ports and port areas determines the development of economic activities with a multiplier effect on the whole economy development. Therefore, each country encourages the development of a sustainable and competitive port system. The establishment of state port authorities as seaport management bodies is one of such measures, needed for the development of the national port system and individual seaports within that system to increase competitiveness of seaports in the global market.

The aim of this paper is to discover how to increase the efficiency of managing seaports by increasing the competitiveness of the port. The analysis was performed on a sample of 155 questionnaires to generate information from memebers of seaport management and experts for seaport management. Based on the analysis of the obtained data, the described statistical data summarizes what determine the competitiveness of the port and thus increase the efficiency of seaport management.

KEY WORDS

Seaport; Port Authority; Competitiveness; Efficiency; Management

1. INTRODUCTION

One of the most important factors of the seaport managment efficiency is the competitiveness of the port. The impact of competition emphasizes the issue of adequate port policies and port management strategies. Therefore, changes may occur in operations that lead to a better quality of services at the same cost or same quality of services with the lower cost for users of the port.

The state investments in infrastructure increase the competitiveness of the port, but the investments alone are not enough to attract the users of port services. There is number of factors that having an impact on the competitiveness of seaports. One of them is presence of private concessionaires who manage port operations while the state retains a regulatory role and oversights a concession.

The purpose of this paper is to identify those factors that most strengthening the competitiveness of the seaport. The empirical research is done on the sample of 155 questionnaires to generate information from members of seaport management and experts for seaport management. The research is done in Croatia where the landlord is main port administration model, which is also a typical model of modern port authorities. The results of this research can be useful to the owners of port authorities (in this example are state-owned seaports) to learn about the determinants of the efficiency of port authorities.

The remainder of the paper is structured as follows: section 2 introduces theoretical background; section 3 presents empirical research and section 4 is the conclusion.

2. THEORETICAL BACKGROUND

2.1. Seaport as an Economic Entity

Seaports are part of the transport system in which the carriers of maritime and land transport are exchanged. Due to the crossroads where they are located, seaports are also the right place to perform various economic activities, such as shipbuilding, ship repair, maintenance, expert assessments, insurance, payment services, etc. All these activities create additional value for port services, and at the same time, effect on the realization of comparative advantages, not only of individual seaports but also on the whole port system of one country. However, competition in the maritime market is extremely high, so in port operations it is necessary to develop factors that affect the strengthening of competitive advantages.

Port authority, as the port management body, should choose the management model that best suits the needs of its customers and meets the expectations of all interested stakeholders while meeting the basic economic principles of business efficiency. The port management model and the organization structure of port authority depend on the geographical characteristics of the port system, the ownership structure and the importance of each port for the whole economy. Through port management model, the owner achieves strategic goals of maritime development, while the concessionaires from private sector targeting profit and greater efficiency of port operations. This creates a hybrid organization of the port authority, which is on the one hand a public institution, and on the other hand an economic entity that operates according to economic principles with the aim of providing appropriate services and generating profit.

2.2. Port Competitiveness

Competition in the port area can occur in four forms [9]. Verhoeff distinguishes between four levels of seaport competition: competition between port undertakings (intra-port competition); competition between ports; competition between port clusters (i.e. a group of ports in each other's vicinity with common geographical characteristics) and competition between ranges (i.e. ports located along the same coastline or with a largely identical hinterland).

Some groups of factors affect all of the mentioned forms of competition. Thus, the competition between ports, port clusters and/or port associations depending on geographical location, connections with the hinterland, economic development, port policy, costs of port services and similar. Intra-port competition is competition between different companies/concessionaires within one port area. Large shipping companies are specialized in "fighting" one port against another. Success in these competitions may depend on the ability to handle traffic and activities on land. Such competition can result in higher technical efficiency and integration of port functions. Competition within the port has the greatest impact on the management structure of the port and the relationship between the port authority and the operator or concessionaire. These relationships are often used as an important reason to change port management models and this research implies that the competitiveness is a factor of seaport management efficiency.

Market share is widely used for ports as a key indicator of competitiveness [2,6]. The competitive strength of seaports no longer depends solely on their own infrastructure and organization, but also on the efficiency of the maritime logistics chain consisting of three major units: maritime carriers, logistics operations in the seaport and inland transport services [3]. Recent literature insists on the role of "Supply Chain Management" (SCM) in creating a competitive advantage. The main features of SCM are integrated behavior of supply chain members, mutual exchange of information, sharing of risks and benefits, cooperation, coordination and joint control, existence of the same goal and the same focus on customer service, integration of all service and logistics processes and partnerships in construction and maintaining long-term business relationships [4]. All these activities aim to create the lasting competitive advantage of seaport.

2.3. Port Choice Factors

In line with this perspective the seaport competition essentially involves a competition for trades with terminals as the competing physical units, transport concerns and/or industrial enterprises as the chain managers and representatives of the respective trades and port authorities and port policy makers as representatives and defenders of the port sector at a higher level, engaged in offering good working conditions (e.g. infrastructure) to this sector [7].

The competitive environment in previous research has been determined by many of factors such as geographical location [9], preferred sea route, reliability and breadth of port services [8], infrastructure and investment in ports. On the basis of an extensive literature study and own surveys, Aronietis et al. [1] have drawn up the following list of factors directly or indirectly influencing the selection of a port: cost, location, port operations quality and reputation, speed/time, infrastructure and facilities availability, efficiency, frequency of sailings, port information system, hinterland and congestion.

Table 1 – Decision Variables in Choosing a Port

	Owner/Shipper of Goods	Forwarder	Shipping Company	Terminal operators
Cost	xx	x	xx	xx
Location	xx	x	xx	xx
Port operations quality and reputation	xx	xx	xx	xx
Speed/time	x	x	x	xx
Infrastructure and facilities availability	x		xx	xx
Efficiency	x	xx	x	xx
Frequency of sailings	x	x	x	xx
Port information system	x			
Hinterland	x	x	x	xx
Congestion	x	x	x	xx

xx: very important
x: important
Source: [1]

Table 1 assesses the importance of each variable to each of the port players. Which of them is decisive in choosing a particular port also depends on the own preferences of ship-owners and users of their services. Certainly, the location and infrastructural connection of the port with the hinterland is one of the most important factors influencing the competitiveness of the port on the international market.

3. EMPIRICAL RESEARCH - ANALYSIS OF PORT COMPETITIVENESS

The empirical research was conducted from July 6 to November 6, 2017, on the population of seaports in the Republic of Croatia, specifically six state-owned seaports open to public traffic in the cities of Rijeka, Zadar, Šibenik, Split, Ploče and Dubrovnik and six state port authorities as the managing bodies of these ports. To collect data, a survey was conducted for two groups of respondents:

1. Members of management structures (directors of port authorities, their assistants and management);
2. Experts from scientific and professional institutions dealing with the issue of management of seaports (faculties and institutes).

The questionnaire included two groups of questions. The first group of questions referred to a set of questions with a nominal scale and given information what makes the port competitive, what should be done in order to increase the competitiveness of the port on the market and what kind of role management and owner has in increasing "attractiveness" of the port. The second group of questions is consisted of a series of statements with an ordinal scale that investigated the respondents' attitudes

about the competitiveness of the port. The statements analyzed the attitudes of the respondents about the determinants that affect the competitiveness of the port. Respondents expressed the degree of agreement with seven statements by choosing the offered numerical values (1 - strongly disagree, 2 - disagree, 3 - neither agree nor disagree, 4 - agree, 5 - completely agree).

In the first group of questions was asked for answers to questions what all ports makes competitive and what can be done to increase the competitiveness of ports (*Figures 1-3 show the percentage of the answers for each question*):

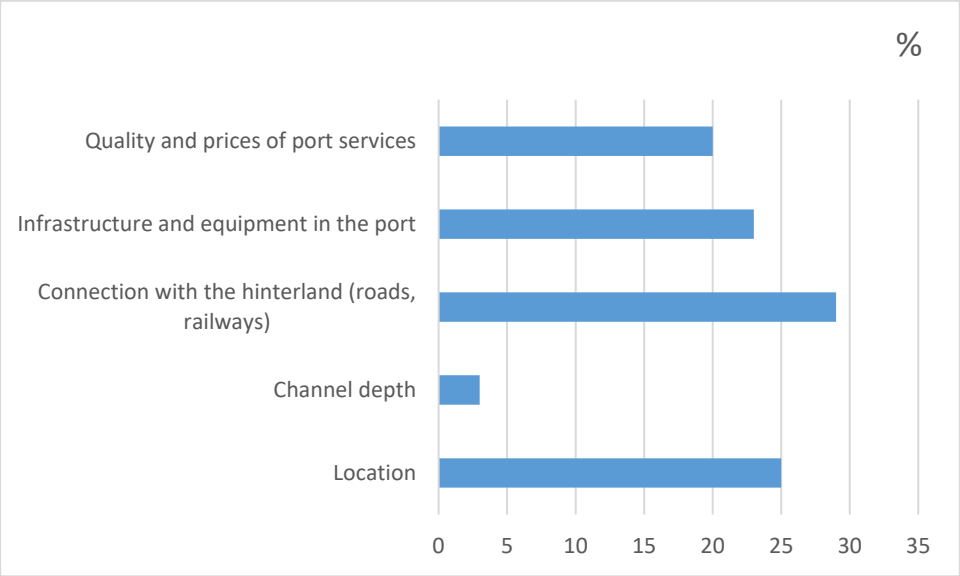


Figure 1 – Factors affecting the competitiveness of the port
Source: [5]

It is evident that the majority of respondents claimed that connections with the hinterland (29%) and location of the port (25%) are major for seaport competitiveness. What should be done to increase the port's competitiveness in the market shows *Figure 2*. Build infrastructure for better link port with the hinterland was the dominate answer (37%).

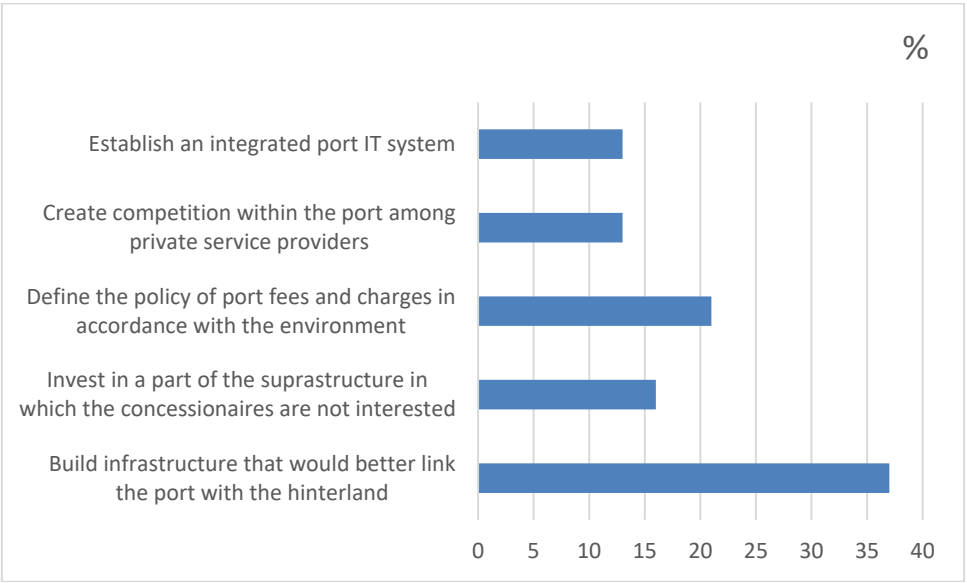


Figure 2 – Guidelines for increasing port competitiveness
Source: [5]

How does the management structure of the port authority (management board, the director, his assistants) contributes more "attractive" port shows *Figure 3*.

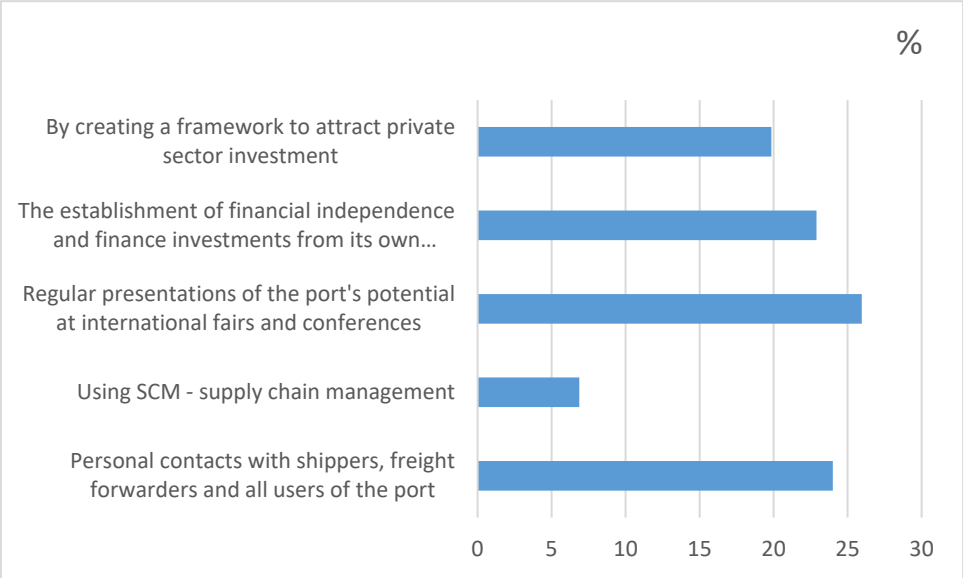


Figure 3 – Activities of the management structure for greater "attractiveness" of the port
Source: [5]

It is evident that the majority of respondents claimed that the presentations of the port at international fairs (26%) and personal contacts with users of the port (24%) are very important for attractiveness of seaport.

Table 2 analyses the attitudes of respondents about the determinants that affect the competitiveness of the seaport. Respondents expressed the degree of agreement with the following seven statements by choosing the offered numerical values (1 - strongly disagree, 2 - disagree, 3 - neither agree nor disagree, 4 - agree, 5 - completely agree):

From the answers of the respondents, it is possible to conclude that the majority agrees with the statement (42% agree and 21% of the respondents completely agree) that the ownership structure of the port authorities affects the competitiveness of the port. Furthermore, it can be concluded that a greater offer of port services affects the competitiveness of the port, which is claimed by 86% of respondents (44% agree, 42% of respondents fully agree). More than 2/3 of respondents agree with the statement that the preferred sea route (62% of respondents agree, 10% fully agree) as well as the port's reputation regarding cargo operations influence the choice of port (67% agree and 21% respondents fully agree). Almost all respondents agree (58%) or completely agree (42%) that the port's position on the traffic corridor makes it more competitive. Slightly less than a third of respondents (29% of respondents neither agree nor disagree) are undecided when claiming whether the seaport tradition affects its competitiveness, with 37% of respondents agreeing with this statement and 17% disagreeing. When it comes to whether state investments in the port area increase the competitiveness of the port, exactly a third of respondents neither agree nor disagree, a third of respondents agree, and there are 19% of them who disagree (15% disagree with the statement, 4% completely disagree).

Table 2 – Opinions of respondents regarding the determinants that affect the competitiveness of the seaport

	Strongly disagree	Total (%)	Disagree	Total (%)	Neither agree nor disagree	Total (%)	Agree	Total (%)	Completely agree	Total (%)
The ownership structure of the port authority affects the competitiveness of the port.	3	6	6	12	10	19	22	**42**	11	**21**
Tradition seaports affects its competitiveness	4	8	9	17	15	**29**	19	**37**	5	10
The larger government investment in the port area, the greater the competitiveness of the port.	2	4	8	15	17	**33**	17	**33**	8	15
The higher offer of port services affect the competitiveness of the port.	0	0	2	4	5	10	23	**44**	22	**42**
Preferred maritime route affects the choice of port.	2	4	3	6	10	19	32	**62**	5	10
The port's reputation for cargo operations influences port choice.	0	0	1	2	5	10	35	**67**	11	**21**
The position of the port in the corridor makes it competitive.	0	0	0	0	0	0	30	**58**	22	**42**

Source: [5]

With regard to the presented results, it is concluded that the majority of respondents agree with statements such determinants that influence the competitiveness of the seaport (the "no-agree-response" group does not exceed a quarter of respondents - indicated in the table in blue).

4. CONCLUSION

The seaport as an economic entity has crucial function in the development of a national economy because it is a hub of international trade. Therefore, each country needs to strengthen a competitiveness of seaport. Due to strong competition in the port services market, there are numerous structural changes in the port sector such as mergers and the creation of new strategic alliances, new seaport management models, the impact of technological innovation, higher service quality and intermodal transport development.

The research showed that the most important determinants that affect the competitiveness of the port are location, connection with the hinterland, infrastructure and quality of service in the port. The management of the port, as well as the owner, can also increase the competitiveness of the port through their actions. These activities should be an integral part of national maritime transport

development strategy and port policies. In this way, the owner, which is the state in the case of the Republic of Croatia, fulfils its role in strengthening the competitiveness of the port. The concessionaires as seaport service providers should apply best business practices in ports and should make efforts to improve the existing management model. In synergies with the owner, they have to decide which port management model to choose in a given competitive environment in order to increase the efficiency of the seaport business, which is their common goal. The landlord port, as dominate administrative model of port, has the most developed form of concession, which encourages competition within the port and strengthens the competitiveness of the port. On the other hand, the advantage of private port is that it reacts more quickly to changes in the environment, and thus becoming more competitive.

In this study, the sufficiently general approach is taken as a basic structure for the wider research, possibly on a different sample of ports, e.g. selection depending on ownership structure, port tradition or port area investments The results of this study are closely connected to the management of the seaport that are continuously dealing with how to boost port's competitive competitiveness.

REFERENCES

[1] Aronietis, Raimonds; Van De Voorde, Eddy; Vanelslander, Thierry. Port competitiveness determinants of selected European ports in the containerized cargo market. In: Proceedings of IAME 2010 Conference. (Lisbon). 2010. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.680.4083&rep=rep1&type=pdf [Accessed 21th Apr 2020].

[2] Haezendonck, Elvira; Verbeke, Alain; Coeck, Chris. Strategic positioning analysis for seaports. Research in Transportation Economics, 2006, 16: 141-169.

[3] Jančić, Vanja. 'Faktori konkurentskih prednosti morskih luka', Economics & Economy, 2015, vol. 3, no. 6, pp. 87-98.

[4] Mentzer, JT, DeWitt, W, Keebler, JS, Min, S, Nix, NW, Smith, CD & Zacharia, ZG, 'Defining supply chain management', Journal of Business logistics, 2001, vol. 22, no. 2, pp. 1-25.

[5] Munitić, Nataša. Model upravljanja morskim lukama u cilju povećanja njihove profitabilnosti. PhD Thesis. University of Rijeka. Faculty of Economics and Business, 2019.

[6] Notteboom, Theo. 'Concession agreements as port governance tools', Research in Transportation Economics, 2006, no. 17, pp. 437-455

[7] Notteboom, Theo; Yap, Wei Yim. Port competition and competitiveness. The Blackwell companion to maritime economics, 2012, p. 549-570.

[8] Tongzon, Jose l.; Sawant, Lavina. Port choice in a competitive environment: from the shipping lines' perspective. Applied Economics, 2007, 39(4): 477-492.

[9] Verhoeff, J. M. Seaport competition: some fundamental and political aspects. Maritime Policy & Management, 1981, 8(1): 49-60.

MLADEN NIKŠIĆ, Ph.D.[1]
E-mail: mladen.niksic@fpz.unizg.hr
JASNA BLAŠKOVIĆ ZAVADA, Ph.D.[1]
E-mail: jasna.blaskovic@fpz.unizg.hr
KREŠIMIR VIDOVIĆ, M.Sc.[3]
E-mail: kresimir.vidovic@zagreb.hr
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb
[3] City of Zagreb
Ulica grada Vukovara 56a

ANALYSIS OF INTRODUCING URBAN RAIL SYSTEMS IN LARGE CITIES – CASE STUDY SEOUL

ABSTRACT

Until late 1960s bus traffic played a leading role in the transportation system of the city of Seoul. The underdeveloped network of public transport prevented the city from expanding since all urban activities, even industry, were located within a small area. Traffic congestions caused by rapid population growth and traffic volumes could not be resolved by widening the road network and new high-occupancy transportation systems had to be introduced.

This paper presents the systemic approach to improving public urban transport in the city of Seoul based on contemporary traffic systems and theoretical and scientific knowledge. This has resulted in the Seoul public transport system being one of the most developed in the world today.

It also explains the method of functioning of the urban rail system in the city of Seoul, supported by examples and the charging system. It gives an overview of the safety and planning of the public transport system in the future.

KEY WORDS:

Seoul; urban rail system; metro; light rail

1. INTRODUCTION

Seoul is the capital of the Republic of Korea (South Korea), and because of its developed system of public urban transport it has become the subject of studies done by transport experts worldwide. A complex network of various modes of transport and different business entities managing individual segments of this system is interconnected and does not represent an obstacle for the use of average users. However, the number of passengers carried is constantly growing, while the usage of passenger cars for private purposes is significantly reduced. Passengers change the modes of transport with one transport document using transport means of various (competing) companies that are integrated into one organized system.

In its traffic development, Seoul had several milestones that significantly affected its overall development. Until the advent of metro, Seoul was limited in its growth, and the road network due to its congestion could not withstand the expansion of the city. Thus, from a local it became a national problem. With the construction of the metro, the population became more mobile, and the industry and other activities started to move beyond the city center.

In 2004 major reforms were made in the public urban transport system. This emphasized the reorganization of bus transport into a single unit, connecting it with the systems of metro, suburban and interurban rail and light urban rail, the construction of which is currently in the focus of the city authorities.

Currently, the city government is working on the traffic development plan until 2030. This would bring the public urban transport system to such a level that the use of passenger vehicles for an average citizen would be completely unnecessary. The emphasis is placed on the expansion of the urban rail systems and their access to all parts of the city.

The network and organization of public urban transport in the city of Seoul should be a good example for traffic experts in designing urban transport traffic strategies.

The purpose and goal of this paper is to analyze the public urban transport system in the city of Seoul, to define the advantages and drawbacks of such a system and to determine whether such a complex system could be mapped to other cities with a smaller population.

2. TRAFFIC IN THE CITY OF SEOUL

Seoul is the capital and the largest urban area of the Republic of Korea (South Korea), and it is located in the north-western part of the country on the river Han. It covers an area of 605.21 km^2, and the total population is declining and currently amounts to 10,025,927 citizens, out of which over 280,000 are foreigners (2019). The population density is 16,000 inhabitants/km^2, which is double that of New York. The wider city area has a population of 25,600,000 which accounts for approximately half of the population of South Korea. Regarding the GDP share, Seoul is the fourth urban economy in the world, following Tokyo, New York and Los Angeles [1]. It is divided into 25 districts (gu) covering an area of 10 – 47 km^2 and a population of 140,000 to 630,000 who have certain self-governing powers. Each district is divided into smaller units (dong) with a total of 423 of them [1].

It is a very busy hub. The banks of the Han river are connected by many bridges, it has a subway, good road and railway links with its surroundings (Incheon, etc.) and with other parts of the country (Daegu, Busan, Gwangju, etc.). Its port is on the Yellow Sea Incheon (about 32 km downstream of the Han river).

Seoul is connected with every major city by rail, with KTX (Korea Train eXpress) being particularly prominent, reaching speeds in excess of 300 km/h creating thus a fast and safe connection for the passengers.

Seoul has a developed bus network that is operated by the Seoul Metropolitan Government and private companies. As a result of reforms in 2004, the city government introduced a Hub-and-Spoke dual System of Trunk and Feeder lines. Some unreasonably long lines have been abolished and their efficiency has been improved and maximized. Special corridors (reserved lanes) have been introduced, intended exclusively for buses and of the planned 223.3 km, in 2012, twelve corridors in the total length of 115.3 km were opened, spanning the entire city [2].

2.1 Seoul Rail Network

Urban rail systems play the key role in the development of the cities and modern civilization since they can satisfy higher traffic demand than individual traffic. During the Japanese occupation, a rail network was built with the goal of exploiting natural resources and for the transport of the military, that was also used as an intercity connection system. When the Gyeongin line, in 1966 got the second gauge, it began to be used as urban rail which was of little importance [3].

In the early 20th century, tram played an important role in the Seoul traffic system. The tram network expanded parallel with the expansion of the city. Urban plans necessarily included the planned spaces for new tram lines on the newly constructed streets. After the tram network was discontinued (in 1968), bus transport took over the leading role in the public urban transport. Buses were adaptable to the expansion of the line network and they shared the road network with other traffic that was not yet sufficiently developed. With the increase in road traffic, congestion started to occur in the road networks and there was need to introduce a new type of public urban transport [3].

In the late 1960s the traffic grew faster than the population, which also grew rapidly. The underdeveloped public transport network prevented the city from expanding because all urban activities,

as well as industry, were located within a small area. The rapid growth of the population and the traffic volume within the small area could not be solved by constructing additional road networks or by introducing new bus lines, and it was necessary to introduce a new high-capacity transport system.

In 1970, President Chunghee Park ordered the city government to develop a plan to establish a new transportation system that would solve the problem of traffic congestion in Seoul. Thus, the construction of the metro system in Seoul became of national interest for the Republic of Korea. The city government devised a financing plan and started implementing the project [3].

The construction of line No. 1 started in 1971, and was launched in 1974, and was just the beginning of the first phase of the project of introducing four subway lines (*Figure 1*). Line No. 1 anticipated merging with lines that were to be established in the future. Line No. 2 was designed to link east – west direction, Gimpo Airport and the city center. However, it was modified due to the rapid population growth and new urban plans. At the time when Line No. 2 was built, the share of passenger transport in the metro system was only 4% [3].



Category	Origin and Destination	Extension [km]	Number of Stations
Line 1	Seoul Station-Cheongnyangni	7.8	10
Line 2	Loop line	54.2	57
Line 3	Gupabal-Yangjae	26.2	23
Line 4	Sanggye-Sadang	28.3	23
Sum	-	116.5	113

Figure 1 – First phase of metro network in Seoul
Source: [3]

By building lines No. 3 and 4 (in 1985) the first phase of the Seoul subway system was completed [3]. The number of passengers grew by 10-16% every year and the late 1980s saw congestion, i.e. maximal use of the capacity of the existing lines, but the large public debt prevented the construction of the new ones [4].

Korea Research Institute for Human Settlements proposed in 1989 a plan for the second phase of the subway construction that was different from the previous plan of the city government. The plan envisaged rapid transportation between the centers and maximization of the coverage area of the lines (*Figure 2*). The second phase of the project consisted of two steps: extending of lines 3 and 4 and construction of lines 5-8. The construction was done from the periphery towards the center in a tunnel design, and not in the open pit. Unlike the first phase, when the Han river was spanned by bridges, the first underwater tunnel under the river was constructed [3].



Category	Origin and Destination	Extension [km]	Number of Stations
Line 5	Bamghwa-Sangil Macheon	52.3	51
Line 6	Eungam-Bonghwasan	35.1	38
Line 7	Jangam-Bupyeong	57.1	51
Line 8	Amsa-Moran	17.7	17
Sum	-	162.2	157

Figure 2 – The second phase of the Seoul metro
Source: [3]

Line No. 9 route was defined in 1994 and launched in 2009 between Gaewha and Shin Nonhyeon station and represents the third phase of metro system expansion. The line was expanded twice, in 2015 and 2017. The line was constructed through private investments, which was the first such case of

public-private partnership in Korea. After 30 years of exploitation, the line will be given to the Seoul Metropolitan Government [5]. The current metro network in Seoul is presented in *Figure 3*.

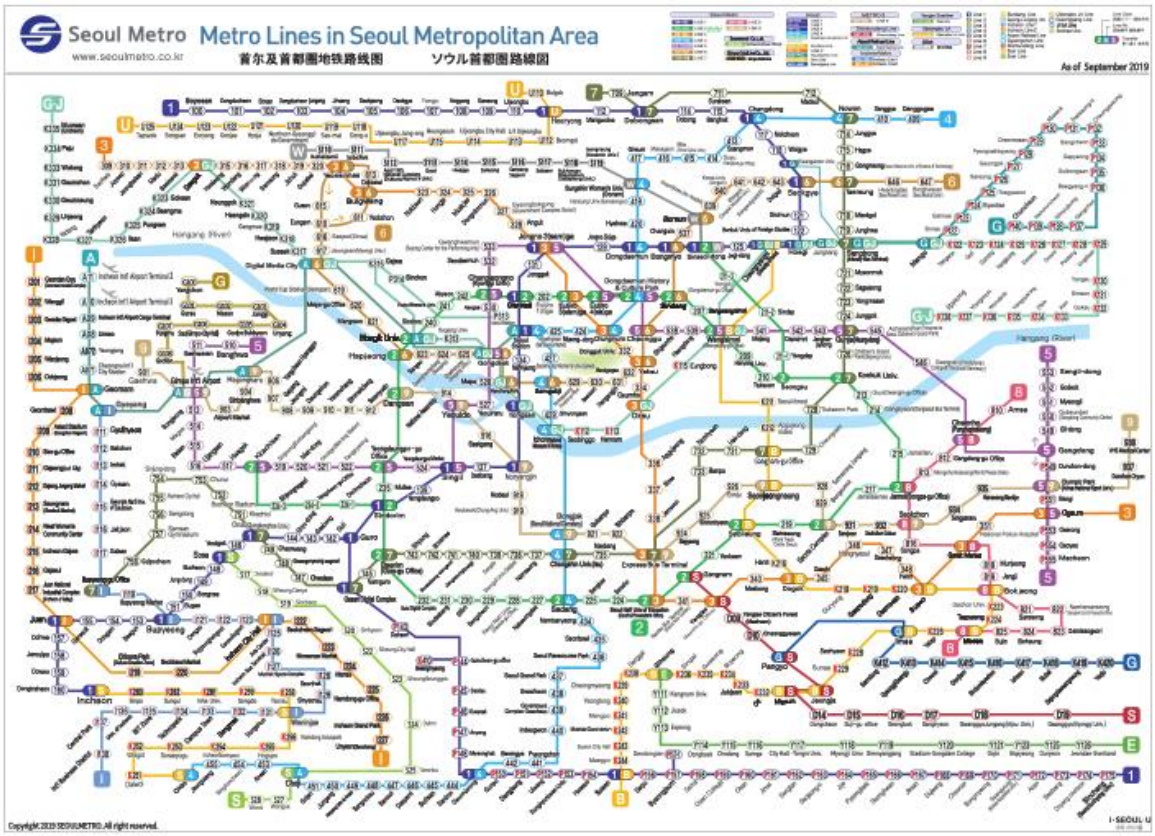


Figure 3 – Rail system line network (September 2019)
Source: [6]

Seoul urban rail system is a combination of urban rail systems (light urban rail and metro) and suburban and interurban rail that covers the city of Seoul and its wider surroundings.

Currently, the network of lines that covers the inner-city area consists of nine main metro lines serving the administrative area of the city with its surroundings. The metropolitan area of the city of Seoul comprises a system of over 20 lines of various types of rail systems, including Incheon and the satellite towns in the Gyeonggi province. Some regional lines extend to rural areas that are more than 100 km from the city of Seoul.

Line No. 2 (green line) is also known as a circular line in the total length of 60.2 km. The circular line consists of additional two branches, Seongsu and Sinjeong and it is one of the longest in the world. The departure headway is between 2.5 min at peak hours, and 6 min in off-peak hours [1]. Due to its length and position, there are many connections possible from Line No. 2 to many other public transport lines.

Line U is a light city rail, completely automated, driverless line. The system is very similar to Toulouse Metro, Lille Metro or Rennes Metro in France. The line has been built by a Korean consortium led by the GS Engineering & Construction Company and they will manage it for 30 years. The line is 11.2 km long and consists of 15 stops and runs on elevated rails. It is connected to the metro system at the Hoeryong station (transfer to Line No. 1). The trains run every 3 minutes and 30 s in peak hours and 6-10 minutes in off-peak hours. The U Line ride between the Balkog station and the Tapseok station takes about 19 minutes, unlike buses that take 40 minutes. [7 and 8].

The Shinbundang Line, literally meaning the new Bundang line, is a 31 km long line where also driverless trains operate, achieving an average velocity of 96 km/h. It consists currently of 13 stops and it was launched in 2011, operated by a private company NeoTrans Co. Ltd [9].

AREX (Airport Railroad Express) is a railway line that connects the airports Gimpo and Incheon with the city center, with the possibility of changing to other public transport rail lines [10].

The construction of this line started in 2001, after the completion of the Incheon Airport, and it was performed in several phases. Currently, more than 60% of the line operates the underground route [10].

2.2 Transfer System Between Lines

Spatial constraints in urban areas have led to the establishment of various transport systems, which were not built at the same time. They often did not have the same investor and were managed by various business entities.

With the introduction of Tmoney card, the users can transfer between different lines of rail systems and other modes of transport with a single transport document, regardless of the ownership structure of a particular company operating that particular line.

In some metro systems, as e.g. in Tokyo, the users changing from one line to another, need to exit one metro system, to the street level, enter another metro system through another entrance and make sure that they have the appropriate transport document. In the city of Seoul, the metro system is so built that all hub stops are interconnected, regardless of the ownership structure of the business entity operating the line or the mode of transport. The users of pedestrian passages transfer from line to line and the public urban transport system acts as a single unit.

In addition to making it easier for the users to transfer between lines, the stops are designed in such a way that it is possible to enter also the surrounding buildings from them, such as business and shopping centers without having to exit from the stop to the so-called “street level”.

At some stops such as: Konkuk University, Express Bus Terminal, Seoul National University of Education, Daerim, Dongdaemun and Dongdaemun History and Culture Park (4-5) over 100,000 passengers transfer daily from one line to another, whereas e.g. at stops Gunja, Chungmuro, Jogno 3-ga (Lines 1-5 and 1-3) this number amounts even to over 200,000 passenger/day. At the stop Jongno 3-ga the average time necessary for the transfer from Line 1 to Line 5 is only 5.48 min. [11].

2.3 Consideration of the Safety of Urban Rail Eystem Users

The expansion of the urban rail system in the city of Seoul and the surroundings has significantly increased the number of adverse events. Minor disturbances, such as engine failures or downtimes, have been reduced, but other types of accidents showed great increase, such as: falls from entry-exit platforms, passengers stuck in the wagon doors, passenger collisions, fires, and equipment breakdowns. Also, the noise level in the transport system coverage areas has increased significantly [12].

In 2005 the Seoul Metro and Metropolitan Rapid Transit Corporation started to introduce the PSD (Platform Screen Doors) system on the input-output platforms. The PSD system is a system of automatic doors mounted on the platforms, with the distance equal to the distance of doors on the trains (*Figure 4*). When the train stops at the station the train doors and the platform doors open at the same time thus preventing the passengers from falling on the rail. Since this system has proven useful, the city government decided to accelerate the installation of the PSD system on the passenger entry and exit platforms, and already in 2009 there were 120 Seoul metro stops (Lines 1-4), 148 Seoul Metropolitan Rapid Transit Corporation stops (Lines 5-8) and 25 stops of Seoul Metro 9 (Line 9) covered by such a system [12].



Figure 4 – PSD system, Hapjeong stop
Source: [13]

The introduction of the PSD system has significantly reduced the number of fatalities in the metro system. In 2003, on Lines 1-8 there were 147 incidents in which 77 persons were injured and 70 died and this number was reduced to 2 injured and 1 fatality in 2011, including also the newly opened Line No. 9. The number of suicides also decreased from 56 in 2007, to 2 in 2010 and 2012, i.e. zero in 2011 [12].

Apart from the PSD system, the city government brought also other measures in order to increase the passenger safety, as e.g.:

- Crime Prevention through Environmental Design (CPTED)
- Subway Sheriff System
- CBTC (Communication Bases Train Control) [12].

Seoul Metro, Seoul Metropolitan Rapid Transit Corporation and Seoul Metro 9 have introduced different pieces of safety equipment at their stations and trains. Thus, portable flashlights can be found at every 25 m, portable fire extinguishers at every 20 m on the platforms and station premises, at every station 334 gas masks are available and the automatic fire extinguishing system (sprinklers) at every 4.6 m [12].

2.4 Public Urban Transport Charging System

In 2003 the city government founded the Korea Smart Card Co. with the aim of providing reliable technology for single charging of transport services that currently covers the system of integral transport in Seoul, 15 other cities in Korea and several cities in the world [14].

T-money card is their most famous product. It is a card which works on a principle of a debit card that charges for transport services. In 2017 there were 81.3% of transport services in Seoul and the surroundings paid via their service [14]. Since 2019 the Korea Smart Card Co. changed its name to Tmoney [15].

Regardless of the mode of transport or business entity operating a certain line, the passenger uses one type of transport document with the possibility of changing through other lines or modes of transport in the entire area covered by Tmoney card.

3. SEOUL TRAFFIC IMPROVEMENT PLANS

The city of Seoul is continuously working on improving the quality of the urban transport, and in 2014 the Seoul Metropolitan Government brought a traffic development plan until 2030 which includes the vision of the city where advanced traffic networks completely replace the needs to own private passenger vehicles. This plan includes three main items:

1. 30% increase in "green mobility" (walking, cycling, and public urban transport);
2. 30% reduction of the use of passenger vehicles;
3. 30% acceleration in the total travelling time by public urban transport [16].

With the planned modal distribution of travelling, in 2030 there will be 66% of trips realized by public urban transport, whereas the number of trips by passenger cars will be reduced to 22.89% (Figure 5).

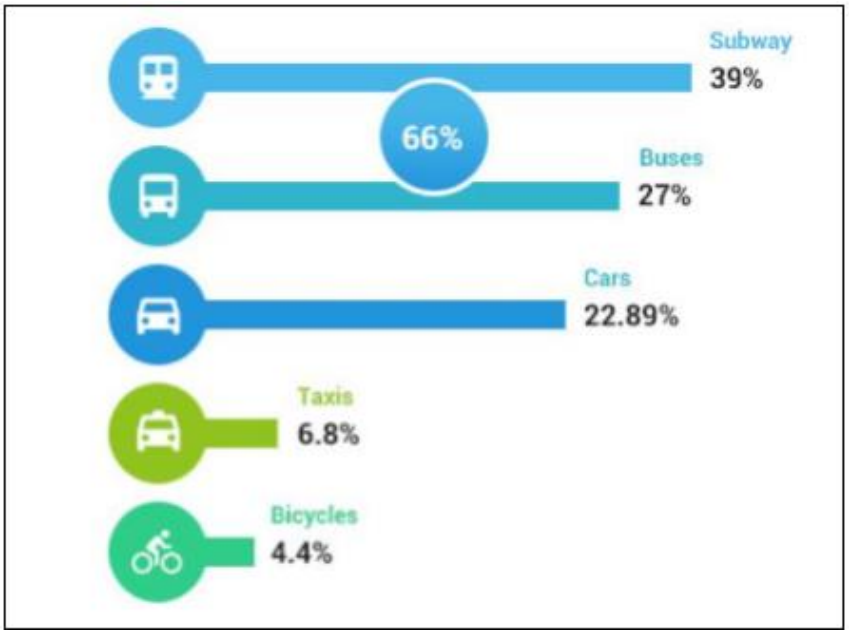


Figure 5 – Forecast modal distribution of travelling in 2030
Source: [16]

The citizen-oriented traffic increases the importance of the basic modes of transport in the city aiming to increase the pedestrian zones. The previously built infrastructure favored road transport whereas now the attention will be redirected to pedestrians. Cycling will also take over an important role in urban traffic. The city government promotes the use of bicycles and expands the cycling infrastructure and reduces the speed limit for road vehicles [16].

3.1 Introduction of Light Rail System in Qreas with Lower Network Coverage

The construction of an urban rail system in Seoul represents a great achievement. However, the loans needed for its construction are still being repaid. Currently, 75% of operating expenses are covered by the ticket sales, whereas the remaining 25% are subsidized through city government programs. Consequently, the traffic experts are looking for new ways to expand the traffic network at minimum expenses [17].

In order to accelerate the plans to increase the railway accessibility in the areas of poorer coverage, the establishment of the light urban rail has been planned. The branches of transport capacity of 10,000 pax/km per day will be constructed and it will be much cheaper than the construction of a metro (Figure 6).

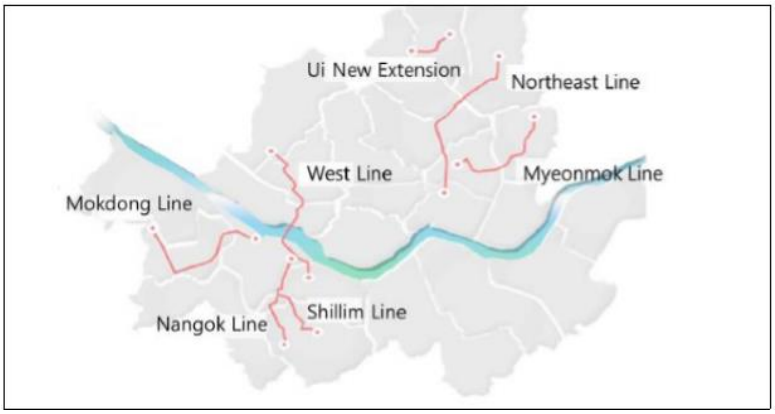


Figure 6 – Planned routes of light urban rail
Source: [18]

The construction of the urban light rail system will increase the modal distribution of trips in favor of public urban transport and every Seoul citizen will have access to the metro station at less than 10-minute walk. The users' travelling time by urban light rail will be reduced by 20% and a total of 9% for all the citizens of Seoul [18].

4. CONCLUSION

Although the Republic of Korea, due to its geographic location, is a traffic isolated country, internal traffic is very developed. The urban rail system of the city of Seoul is one of the most organized systems of this type in the world. The system has been fully adapted to the users and all modes of public urban transport have been integrated with one another. Regardless of the type of the transport means, the passenger transfers are facilitated, and a single transport document has been introduced that can be used in some other Korean cities with the tendency of expanding to the entire state. The information about the line network are available on every step, visually acceptable and written in several languages.

Through history, the city government of the city of Seoul has repeatedly, timely responded to the problems in urban traffic; by the construction of the metro system, integration of the metro system with the railway, 2004 reform in the transport system, the construction of the urban light rail system and their integration with the rest of the network, etc. Also, the long-term planned traffic policy it affected the development of the urban public transport of passengers and the development and expansion of the entire city. The administrative territorial divisions between the city of Seoul and other cities and its surroundings did not present a problem for the implementation of such traffic policy.

The method of integration of individual public transit systems in Seoul and its wider surroundings could be applied also, with certain adaptations, in the urban areas outside Korea, with a significantly smaller number of citizens than Seoul.

Regardless of the big difference in the economic development level and the number of citizens, the City of Zagreb is very similar to the city of Seoul, considering the geographic location, area, and administrative division. Therefore, some examples, such as e.g. the system of changing between different modes of transport, introduction of a single transport ticket or reform of the bus transport system, could be very easily implemented not only in the system of the City of Zagreb, but its surroundings as well.

The traffic policy of the city of Seoul is an example to many other cities in south-east Asia, and there is no obstacle for using this type of managing urban traffic in the European cities as well.

The introduction of a single transport document, which can be used between different modes of transport, makes it much easier for the passengers to use public urban transport.

REFERENCES

[1] Official pages of the city of Seoul, downloaded at: http://english.seoul.go.kr/ (Accessed: 20.02.2020.)
[2] Seoul Metropolitan Government: Seoul Public Transportation, Seoul, downloaded from: http://english.seoul.go.kr/wp-content/uploads/2014/06/Seoul-Public-Transportation-English.pdf
[3] Portal seoulsolution.com, downloaded from: https://www.seoulsolution.kr/en/node/1802 (Accessed: 14.02.2020.)
[4] Seong-Jun Kim: Construction of the Seoul Metro – the Driver behind Sustainable Urban Growth & Change, Seoul Institute, Seoul 2017., Downloaded from: https://www.seoulsolution.kr/en/content/metro-construction-seoul-metro-%E2%80%93-driver-behind-sustainable-urban-growth-change (5.3.2020.)
[5] Shin Lee, Yoo Gyeong Hur: Three Innovations of Subway Line 9: Financing, Speed Competitiveness and Social Equity, University of Seoul, Downloaded from: https://seoulsolution.kr/en/content/metro-three-innovations-subway-line-9-financing-speed-competitiveness-and-social-equity (5.3.2020.)
[6] Portal visitkorea.or.kr, downloaded from https://english.visitkorea.or.kr/enu/TRP/TP_ENG_6.jsp (Accessed: 20.02.2020.)
[7] Railway Technology: Uijeongbu Light Rail Transit, Downloaded from: https://www.railway-technology.com/projects/uijeongbu-light-rail-transit/ (5.3.2020.)
[8] Briginshaw D.: Korean city opens automatic light metro, IRJ 2012., Downloaded from: https://www.railjournal.com/regions/asia/korean-city-opens-automatic-light-metro/#.T_yoifVQT2k (5.3.2020.)
[9] Official pages of the Neotrans company, downloaded from: http://neotrans.kr/eng (Accessed: 12.02.2020.)
[10] Official pages of the AREX line, downloaded from: https://www.arex.or.kr/main.do (Accessed: 05.02.2020.)
[11] Changhee Kim, Soo Wook Kim, Hee Jay Kang, Seung-min Song: What Makes Urban Transportation Efficient? Evidence from Subway Transfer Stations in Korea, Sustainability 2017., Downloaded from: https://www.mdpi.com/2071-1050/9/11/2054/pdf (5.3.2020)
[12] Seung-Jun Kim, Joon-Ho KO: (Metro) Seoul`s Project for Sustainable Safety on the Subway, The Seoul Institute, Seoul 2017., Downloaded from: https://www.seoulsolution.kr/en/content/3574
[13] Portal commons.wikimedia.org, downloaded from: https://commons.wikimedia.org/wiki/File:Seoul_Subway_Line_6_Hapjeong_Station_Platform.JPG (Accessed: 17.02.2020.)
[14] Korea Smart Card Co., Ltd: Leaflet Tmoney World, Seoul 2018. Downloaded from: https://eng.koreasmartcard.com/aeb/common/common/frontFileDownload.dev?fileNm=smartcard_en.pdf (5.3.2020.)
[15] Official pages of Korea Smart Card Co. Ltd, downloaded from: https://eng.tmoney.co.kr/en/aeb/material/material/material.dev;jsessionid=QTGvBIhQQmNKhbtc1wO68aCba9753ujUGnVYIsJwZxBRqZus4zvTx1xpRM63OQgu.czzw02ip_servlet_ksccweb (Accessed: 01.02.2020.)
[16] Diego Giron Estrada: SEOUL: Urban Development, Iglus Quarterly, 2019, Downloaded from: https://iglus.org/wp-content/uploads/2019/05/IGLUS-Quarterly-Vol-4-Issue-4-1.pdf (5.3.2020.)
[17] John Pucher, Hyungyong Park, Mook Han Kim, Jumin Song: Public Transport Reforms in Seoul: Innovations Motivated by Funding Crisis, Jurnal of Public Transportation, Vol. 8., No. 5, 2005.
[18] Seung-Jun Kim, Joon-Ho ko: Seoul`s Light-Rail Projects Driven by Private Investment for Poorly Serviced Areas, The Seoul Institute, Seoul 2017. Downloaded from: https://seoulsolution.kr/en/content/metro-seouls-light-rail-projects-driven-private-investment-poorly-serviced-areas (5.3.2020.)

ZVONIMIR REZO, Ph.D. student[1]
(Corresponding author)
E-mail: zvonimir.rezo@gmail.com
SANJA STEINER, Ph.D.[2]
E-mail: ssteiner@fpz.unizg.hr
CRISTIANA PICCIONI, Ph.D.[3]
E-mail: cristiana.piccioni@uniroma1.it
[1] Croatian Academy of Sciences and Arts, Traffic Institute
Kušlanova 2, 10000 Zagreb, Croatia
[2] University of Zagreb, Faculty of Transport and Traffic Sciences, Dept. of Air Transport
Vukelićeva 4, 10000 Zagreb, Croatia
[3] Sapienza University of Rome, Faculty of Civil and Industrial Engineering,
Dept. of Civil, Building and Environmental Engineering, Via Eudossiana 18, 00184 Rome, Italy

APPLICATION OF CONVENTIONAL METHOD IN DYNAMIC BUSINESS ENVIRONMENT: EXAMPLE FROM AIR TRAFFIC MANAGEMENT DOMAIN

ABSTRACT

Due to more frequent and significant changes occurring nowadays within Air Traffic Management (ATM) system in Europe, business reports have become an essential tool of decision-making. Usually such reports provide insight into the effects of planned or implemented changes, i.e. provide relevant information thus easing decision-making process. Thereby, within such business reports, with a purpose to synthesize data and extract useful information, various analytical methods are usually applied. It follows that analytical methods represent a basis for creation of business reports, while business reports represent a basis for the decision-making process. Accordingly, the application of proper analytical methods represents a crucial component of decision making. Simplified, if within business reports are applied analytical methods which result with partial findings, the decisions made will be of equal quality. In that context, this paper indicates the methodological shortcomings of data distribution method which is frequently applied within business reports in ATM domain. Also, it provides a brief overview of proposition of a novel methodological approach of data distribution analysis which goes beyond the conventional approach. Lastly, this paper provides a research background required to justify the need for introduction of novel approach of strategic planning of ATM system development in Europe.

KEY WORDS

Air Traffic Management; Strategic planning; Sturges' rule; Spatial statistics

1. INTRODUCTION

For the purpose of improving of their business position, many business organisations will firstly turn to implementation of performance measurement system. This is so because it's difficult to improve the state of something if it's not known the initial condition or what to strive for. Thereby, Air Navigation Service Providers (ANSPs), as well as other aviation related stakeholders, through performance measurement aim to improve their business positions, optimize resources, business effects etc. However, beside the motivation that streams from the need for improvement of the business situation due pressures coming from the business environment, the need for performance improvements for ANSPs also arises from regulatory requirements. More precisely, after

establishment of the Single European Sky initiative, the importance of performance measurement has considerably increased.

Despite above-mentioned, the practice shows that the implementation of performance measurement in ATM domain hasn't always resulted with actual measurable improvements. For example, it happens that although performance measurements indicate a need for improvement, they haven't been achieved. Usually, in such situations, there are several reasons why this is so. The reasons for failure mostly own from the fact that ATM system in Europe is complex system. However, failures also occur because frequently inputs or outputs of performance measurements were misinterpreted. There can be several reasons for that (e.g. due to ineffectively conceptualized methodological framework, due to application of erroneous methodological premises etc.). Thereby, the recognition of such failures, their correction and reduction of their occurrence in future can be seen as one of the aspects of performance improvements of ATM system in Europe. Therefore, before delivering business reports (information) it's always necessary to perform the validation of analytical methods used to create those business reports (information).

Performance measurement in ATM domain is mainly based on application of various analytical methods. Accordingly, it follows that within ATM domain analytical methods offer direct assistance and support to the decision-making process. That assistance and support usually manifests in two aspects. Firstly, different analytical methods are utilised during estimation of Key Performance Indicators (KPIs) values - according their methodological frameworks. Secondly, different analytical methods are applied again when obtained KPIs' values are further processed with a goal of their presentation within business reports. Thereby, it should be emphasized that the accuracy of both aspects directly depends on the accuracy of the applied analytical methods. In other words, within ATM domain, analytical methods applied can be considered as relevant as much as they accurately reflect real-world events.

Nowadays, data describing performances of ATM system in Europe is highly available - like never before. However, working with big data sets isn't always easy to represent. Therefore, in order to depict data distribution within business reports, various data visualization methods are applied. Thereby, data visualization represents a part science and a part art, where the challenge is to get the art right without getting the science wrong, and vice versa. Whenever visualizing data, data values are converted in a systematic and logical way into the visual elements that make up the final graphic. In doing so, it often happens that the same graphical representation someone perceives as important and informative, while it may be irrelevant to someone else. Since such situations are undoubtedly occurring within the ATM domain in Europe, the question arise why is that so? The answer on this basically simple, but actually quite complex question can be obtained by asking few, more precise, sub-questions such as: how data visualisations are actually made?; what are methodological limitations of data visualisation methods?; and lastly, by application of which visualisation methods the quality of the outputs can be improved?

Within ATM domain, business reports (i.e. analytics applied) mostly don't consider the spatial dimension of aeronautical data distribution [1]. However, as the result of omitting that data's component, such reports may deliver partial findings or may have biased estimation results. Hence, that raises the question of their quality and the quality of decision made based on such report. Moreover, this issue is of high relevancy for ATM in Europe as it represents a system with a high number of participating stakeholders [2] where each of them may have greater or smaller impact on the overall performance level of ATM system in Europe [3]. Hence, by correlating location of a certain event or phenomenon (e.g. capacity constraint) with its attribute value (e.g. minutes of delay), it's possible to determine the spatial reflection of such event or phenomenon. Therefore, business reports in ATM domain should be based on application of analytical methods that have possibility to analyse aeronautical data based on both, their attributive and spatial dimension. However, considering that nowadays there're no many such reports, the main goal of this research paper is to point the methodological shortcomings of frequently applied data distribution and

visualisation method. In that context, the further content of this paper gives an overview of currently applicable framework of data distribution analysis (which represents conventional approach). Thereby, an example from practice was introduced with a purpose to demonstrate methodological shortcomings of conventional approach. As an example it was used document published by the European Organisation for the Safety of Air Navigation (EUROCONTROL). Further, the paper provides a brief overview of proposition of a novel methodological approach of data distribution analysis that goes beyond the conventional approach. As result, this paper enriches existing literature since it, on the example from practice, identifies methodological shortcomings of frequently applied methodological framework of data distribution analysis. Lastly, this paper provides a research background required to support introduction of novel approach of strategic planning of ATM system development in Europe.

2. CONVENTIONAL APPROACH OF DATA MANIPULATION

In principle, a sense of data distribution among the variable of interest is most often obtained by data grouping method - so it can therefore be considered as conventional approach. Data grouping represents the breakdown of a data set *N* into a certain number of classes *k* according to the previously established modality x_i. Thereby, data grouping is quite useful method in cases when *N* is large enough, but may perform poorly in cases when data isn't normally distributed. After breakdown of a data set, the following phase is identification of comparable attributes. Statistical data $x_1, x_2 \cdots x_N$ is grouped so that similar values $x_i, i = 1,2 \dots N$ are placed in one class. That means that in one class are placed values belonging to the corresponding interval (a_i, b_i) so that $a_i \leq x_i \leq b_i$. Furthermore, in order to determine a_i and b_i values it's mandatory to determine the number of classes *k* and their width, i.e. size *h* which equals to:

$$h = \frac{x_{max} - x_{min}}{k} \tag{1}$$

Thereby, both, *k* and *h* depend on the size of the statistical set and the difference between its largest and lowest value. Additionally, it can be emphasised that the classes must be adjacent and are often (but not required to be) of equal size. Further, it can be highlighted that the number of classes *k* usually ranges between 5 and 15, but also a fact that there's no exact way how to determine *k*. Nowadays the most frequently applied method is so called the Sturges' rule - which was named after Herbert Sturges. According to Sturges' rule, the number of classes *k* for grouping a statistical set of x_N elements is approximated by the following expression:

$$n = \sum_{i=0}^{k-1} \binom{k-1}{i} \tag{2}$$

where the right-hand side of the equation by the binomial theorem equals to:

$$\sum_{i=0}^{k-1} \binom{k-1}{i} = \sum_{i=0}^{k-1} \binom{k-1}{i} (1)^i (1)^{k-1-i} = (1+1)^{k-1} = 2^{k-1} \tag{3}$$

Furthermore, by taking logarithms in base of 10 on both sides, Sturges' formula [4] equals to:

$$(k-1)\, log(2) = log(n) \Rightarrow k = 1 + \frac{1}{log(2)} \log(n) \approx 1 + 3.3 log(n) \tag{4}$$

After determining all the elements of equation, the next phase of conventional approach of data manipulation includes counting of the number of attributes in each class. The outcome of that is identification of frequency distribution. If some class *i* contains a certain number of f_i elements of statistical data set, that number represents a relative frequency f_r and it equals:

$$f_{r_i} = \frac{f_i}{N} \qquad\qquad i = 1, 2 \dots k \tag{5}$$

The last phase of conventional approach of data manipulation is visualization of obtained findings (data visualisation). Since they provide an accurate representation of the distribution of numerical

data, nowadays histograms are frequently used method of data visualization. Moreover, histograms represent a popular visualization method since the 19th century, i.e. after they were introduced by Karl Pearson [5]. In general, histogram is a convenient graphical object representing the shape of an unknown density function [6]. Hence, they can be applied to reveal the distribution of data values, especially the shape of the distribution and to reveal outlier values [7]. It is being constructed so that the bases of the columns must be proportional to the sizes of the classes, and if they aren't equal, the height of the columns must be proportional to the corrected frequencies. Lastly, it should be noted that for the construction of histograms, both, absolute frequencies or relative frequencies can be equally used.

3. APPLICATION OF CONVENTIONAL APPROACH OF DATA MANIPULATION IN AIR TRAFFIC MANAGEMENT DOMAIN

An example of application of conventional approach of data manipulation in ATM context can be found within annexes of EUROCONTROL's documents prepared by Enlarged Committee for Route Charges (Figure 1). Briefly, Enlarged Committee for Route Charges represents a tool of EUROCONTROL Member States and participating non-Member States with purpose to supervise the operation of the en-route charge system and to prepare the decisions [8]. Committee meets in March and June to provide the estimated unit rates for the following year, and then again in November to present the final values. Those meetings also represent the main forum for consultations with the Airspace Users (AUs).

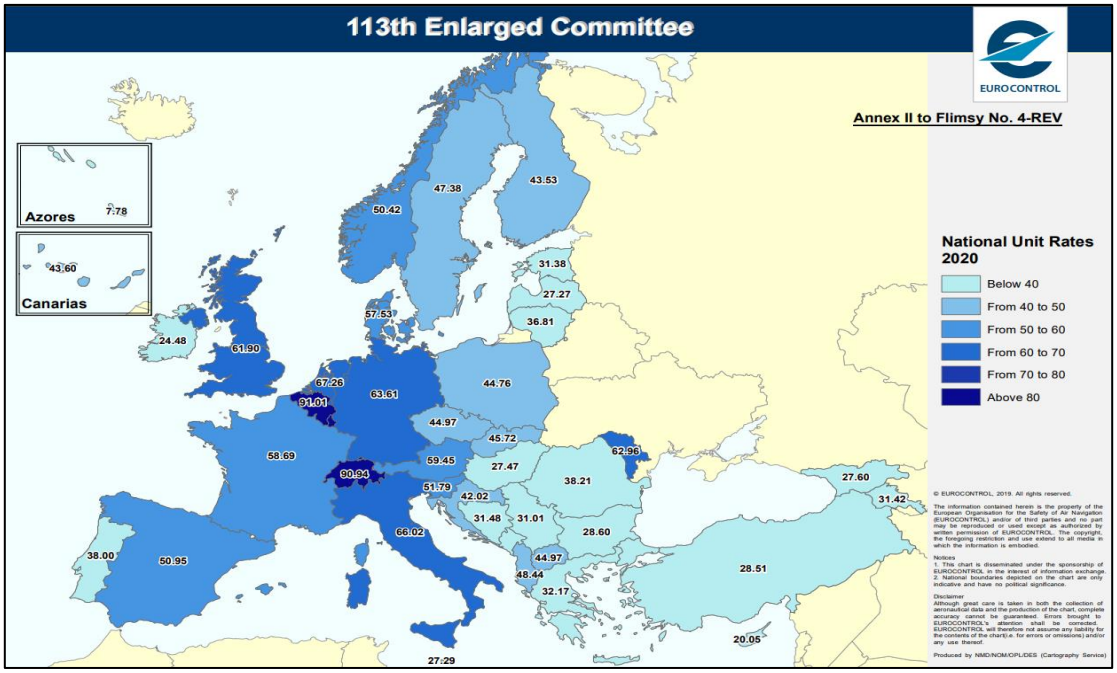
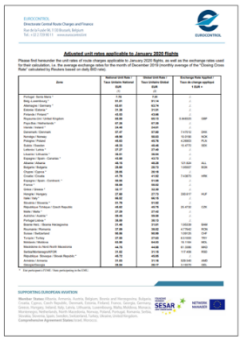
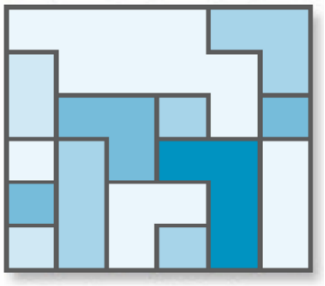


Figure 1 – EUROCONTROL's National Unit Rates 2020 overview made by data grouping method [9]

Furthermore, to facilitate later discussion and more easily identify methodological shortcomings, Figure 2 gives a conceptual overview of the process of the creation of Figure 1. Hence, a sense of data distribution among the values of an interest (in this case unit rate values) was determined by grouping data. Based on the (*1*) report containing unit rate values, (*2*) data manipulation was executed. Data manipulation was done according to equations presented within previous chapter (with the addition that the difference between classes was expressed by colour gradation). Lastly, (*3*) data visualization followed where, instead of being presented in form of histogram, the data was visualised using a map.



Distribution	f_i
Below 40	16
40 - 50	9
50 - 60	6
60 - 70	5
70 - 80	1
Above 80	2



(*1*) Report (*2*) Data manipulation (*3*) Data visualization

Figure 2 – Conceptual framework overview of conventional approach

4. NOVEL APPROACH OF DATA MANIPUALTION

In theory, the functionality of ATM system in Europe is based on collaborative and coordinated airspace and Air Traffic Flow Management (ATFM) [10]. However, in practice performance interdependencies between ANSPs are continuously occurring and affect day-to-day operations. The main reason why is that so is due to high level of inter-connectivity between ANSPs. For example, on average 93.43% of total number of Air Navigation Services provided during 2017 were delivered in cooperation of two or more neighbouring ANSPs [11]. Within such system, in case of occurrence of e.g. capacity shortage at area of responsibility of one ANSP, such event will also reflect on neighbouring areas (as aircraft will go through neighbouring areas instead of through originally planned area). This was recognised also by Button and Neiva [12] by arguing that since the different national ATM systems are not independent of their neighbours, there might be issues of spatial autocorrelation - meaning that the efficiency of one ANSP is dependent on the efficiency of neighbouring ANSPs. Furthermore, another example supporting the need for introduction of novel approach of data manipulation can be demonstrated by observing AUs' flight planning practice. As the result of differences between unit rate values of neighbouring ANSPs, AUs may prefer to fly through cheaper area with potentially longer trajectory, rather than on shorter and more expensive trajectory [13]. Accordingly, it can be concluded that spatial distribution of aeronautical data has important role in understanding the functionality of ATM system in Europe. However, as the current practice of data distribution analysis doesn't consider spatial distribution, it needs to be modified. Thereby, it should be modified by a novel approach of data manipulation which conceptual assumptions will lead to inclusive, smart and spatially-oriented growth. Such a novel approach of data manipulation should overcome conventional approach by solving its methodological flaws. Firstly, that refers to fact that within a conventional method data isn't georeferenced before it's processed. That's problematic because 80% of information requirements of policy makers are related to spatial location [14, 15]. Second methodological shortcoming is that findings (data distribution according to their attribute similarity) are shown by a map (and not by a histogram - what would be more proper). That's problematic because there are numerous analytical methods which, unlike conventional data manipulation method, are based on application of the spatial statistics. Thereby, that means that their conceptual assumption is set up so that every value needs to be processed in respect to its neighbouring values. Figure 3 shows an example of conceptual framework of novel approach of data manipulation with such conceptual assumption. Briefly, after defining variable of interest every variable is placed in context of its neighboring values. One of the ways how that can be done is by creating spatial weight matrix W_{ij}, i.e. square $n \times n$ matrix. As such data manipulation framework places focus on close neighborhood and considers spatial component of every variable (before its processing), it provides information that are reflecting real-world situations more precisely.

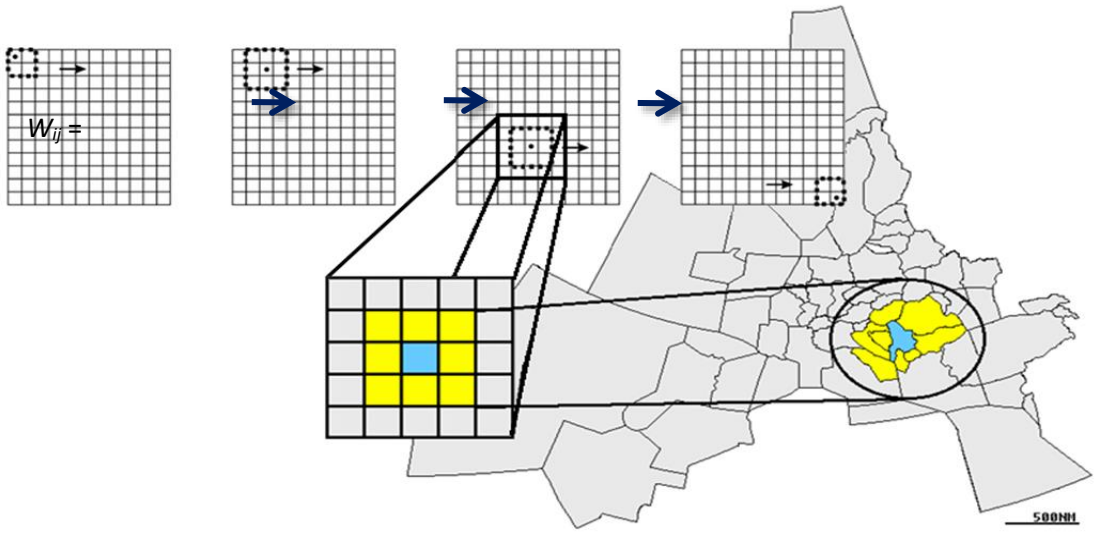


Figure 3 – Conceptual framework overview of novel approach of data manipulation

Furthermore, two more methodological flaws of application of conventional approach needs to be pointed out - and which both can be solved by application of novel approach. Firstly, the conventional method of data manipulation is conceptually quite static. Accordingly, it gives no information about the similarity level between neighbouring areas (since the similarity level is determined in respect to attribute similarity). Hence, it can't quantify performance interactions or interdependencies. Thereby, the failure to accurately capture performance interaction represents significant methodological drawback. As result, problems of partial understanding of (*1*) business environment, (*2*) improvement areas, (*3*) performance interdependencies, (*4*) trade-offs, (*5*) goal conflicts etc. occurs. Furthermore, when applying conventional approach, i.e. when grouping data, it's mandatory to determine the number of classes *k*. That number depends on the size of the data set *N* and the difference between the maximum x_{max} and minimum value x_{min} - and this is where the problem occurs. That's problematic as in case of existence of extremely high or low values, obtained results can be misleading. In cases with such data distribution, findings will indicate that, beside few outlier values, the most of values will fall into the same class. As they will be colored by same color' gradient, one may conclude that those values represent areas of similar modality x_i. Such a situation can be noticed on the example from ATM domain presented by Figure 4. In the most of cases the conventional approach of data manipulation will result with approximately symmetric data distribution (examples *a* and *d*). Opposite to that, data distribution of examples *b* and *c* is right-skewed, i.e. positively skewed. However, there is big difference between those two examples. Unlike example *c*, in case of an example *b*, the extremely high value exists and it differs significantly from the rest of values. As the difference between performances will be only indicated in case of different classes, most of them would be defined as areas of similar values. With the application of a novel approach, such situations won't happen. As the result, the benefits of application of a novel approach of data distribution analysis within ATM domain should be significant. For example, as expected benefits of application of novel approach it's possible to single out the possibility of (*1*) identification of homogeneous areas, (*2*) clearer identification of performance gaps, (*3*) easier identification of trade-offs situations, (*4*) identification of stakeholders which can achieve significant benefits with minor performance changes, (*5*) increase of the level of understanding of current and future ATM system design, (*6*) better understanding of cause-effect relationships, etc. Hence, the application of novel approach can be of great value to e.g. ANSPs in cases when it's needed to represent their interests at various meetings with other ANSPs, AUs, National Supervisory Authority (NSA), Functional Airspace Block meetings etc.

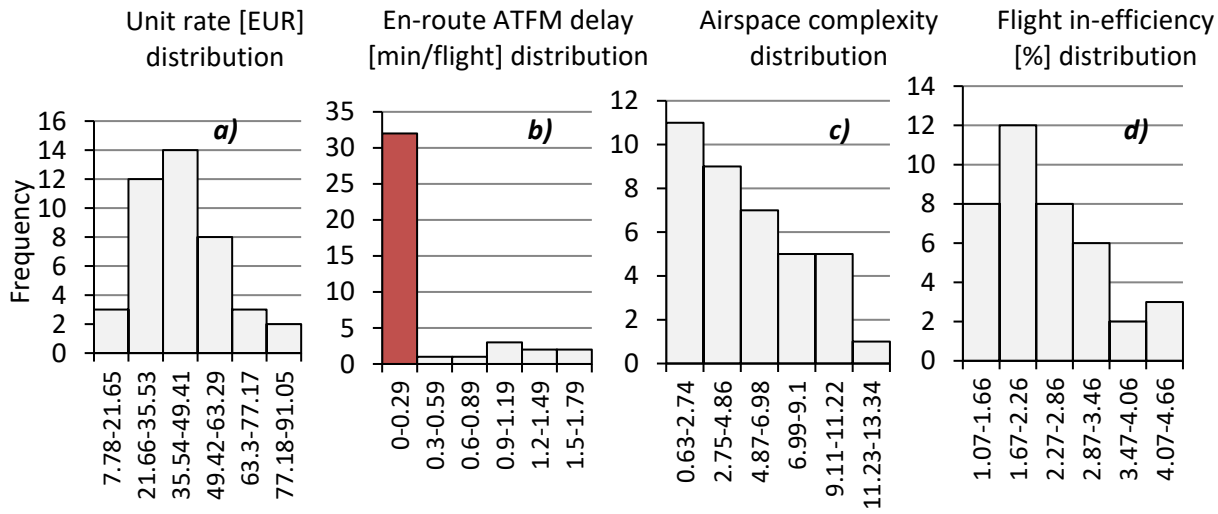


Figure 4 – Application of conventional approach on some of ATM related performance indicators [16, 17]

5. DISCUSSION

Nowadays, many successful businesses manage to grow simply because they understand their business environment, i.e. market strengths, weaknesses, opportunities and threats. Hence, it's not surprising that many executives, usually on the monthly basis, look for business reports with information about their business environment and development potentials. Thereby, since ATM system in Europe is a dynamic business environment characterized by its complexity and performance interdependencies, it's often the case that business reports need to provide a simple answer on complex issues.

The quality of a business report depends mostly on how much realistic do they reflect real-world situations. Then again, that depends on how much are credible applied performance indicators, metrics etc. So, in general, it could be defined that the main prerequisite of creation of any business report is credible performance measurement system. As such, performance measurement system provides a set of measures (financial and non-financial) that can support the decision-making process by collecting, processing and analysing quantified data of performance information [18]. Accordingly, the better the performance measurement system, the better will be the quality of the business reports.

The purpose of performance measurement system within ATM domain, as one of tools of strategic planning, is to provide information, primarily to ANSPs, but also to the AUs and NSA, in which direction ANSP goes, which and where corrective measures needs to be applied etc. Thereby, in order to have effective performance measurement system it's necessary to have reliable distributer of (*1*) input data describing business environment, (*2*) efficient communication and reporting network and (*3*) end-user who will know how to interpret received data or information. Although such a framework may sound quite simple, mistakes are often made in practice. This is so mainly due to poor inputs (garbage in, garbage out), misunderstanding of the data or information received, poor communication and reporting network, not knowing how to utilise obtained information etc. In case of recognition of such situations it's important to correct them. And, that brings us to the purpose of this paper.

Humans think visually, therefore spatially. Hence, it's often the case that by various options of data visualization it's depicted how certain variable of interest is distributed across area of interest. Since maps are a great way to do so, they represent one of most utilised option of data visualisation. This is so because maps usually allow summarization of the complex information in form of a clear and compact presentation. Moreover, maps are frequently used because (*1*) people understand

maps (at least, think they do), (*2*) because people like maps since they attract attention and (*3*) because they brighten up business reports and/or presentations. Thereby, in most cases maps tend to be intuitive to the readers or audience. However, their accurate interpretation can sometimes be very challenging. Particularly in cases when well-placed questions arise.

The main objective of maps is to deliver the right information. Accordingly, it can be defined that they are used as a mean of the communication. Thereby, two things are frequently forgotten. Firstly, presentation of statistical data on the map has its limits. Secondly, mapping statistical data correctly isn't an easy task. Map creation concerns making choices of the mapping method, the aggregation level, the area or discipline of study, the type of data, the graphic variables to be used etc. Besides that, it's frequently forgotten the difference between terms geographic and spatial data. Briefly, geographic data represents a collection of information that are used for graphical presentation of some feature and phenomena with relation to Earth's surface. On the other hand, spatial data is used to indicate some feature or phenomena related to space, but is distributed in three-dimensional space (any space, not only the Earth's surface), and, thus, have physical, i.e. measurable dimensions. Accordingly, spatial data has broader meaning, encompassing the term geographic data. Figure 5 shows an example of aforementioned where by removing the background (national borders), a spatial data is obtained.

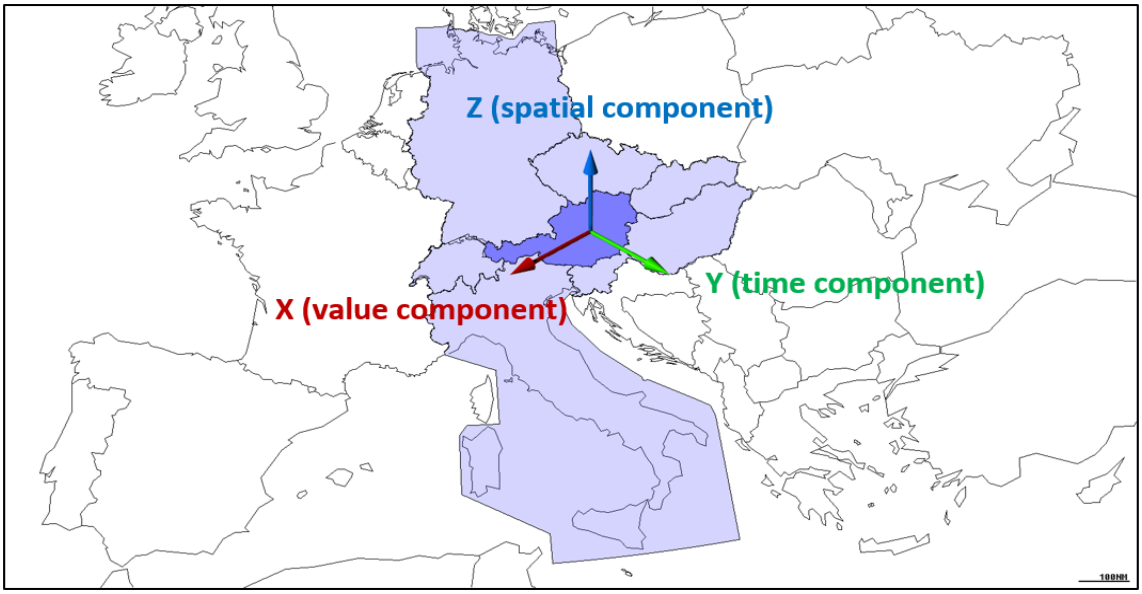


Figure 5 – An example of appreciation of all three aeronautical data features

Unlike humans, mathematics is very exact. Accordingly, it differs spatial statistics from traditional (or non-spatial) statistics that is typically used. Spatial statistics includes various analytical methods specifically designed for manipulation of spatial data. Thereby, in case that data needs to be presented on the map, spatial statistics and its analytical methods go beyond the analytical methods of traditional statistics. Since spatial statistics and its analytical methods use space-area, length, proximity, direction, orientation, notion of how the features interact with each other (through e.g. spatial autocorrelation measurement) right in the mathematics, their application results with more comprehensive findings.

Furthermore, the main difference between traditional and spatial statistics is the assumption of spatial dependency. That means that within spatial statistics the location of data, with respect to one another, plays an important role. Opposite to that, the traditional statistics are based on the assumption that data are free of something called spatial autocorrelation. As an index, spatial autocorrelation provides information about a spatially distribution of phenomenon that can't be captured by any other form of statistical analysis, and which can be vital for correct interpretation. Moreover, spatial autocorrelation gives a precise and objective value to something which would

otherwise have to be perceived subjectively and probably inaccurately from the map. Considering that ATM system in Europe is highly interdependent system, the application of analytical methods that fall under spatial statistics should be prioritised.

To sum up, it should be noted that "events" that are captured by the performance measurement system happen in the space and time. By ignoring that fact, analysis, i.e. business reports are going to be incomplete, while the obtained results would be misleading or partial. Considering aforementioned, the application of conventional data manipulation approach within ATM context is problematic because it based on the analysis of the data distribution outside of their spatial context. Thereby, the most significant problem arises from the fact that data visualisation is depicted on the map (and not on the histogram). The difference arises because map shows "where is what," while a histogram summarizes "how often" measurements occur (regardless where they occur). Hence, in order to provide accurate information, appropriate analytical methods also must be applied. Accordingly, presentation of unit rate values (or any other performance indicator) distribution by conventional approach should be replaced by utilisation of analytical methods that fall under spatial statistics. Lastly, Table 1 below summarizes the conceptual difference between application of the conventional approach and novel approach that is based on application of spatial statistics.

Table 1 – Comparison between conventional and novel approach of data distribution analysis

	Conventional approach	**Novel approach**
1.	Based on outdated traditional analytics	Based on innovative approach
2.	Based on raw data processing	Based on georeferenced data processing
3.	Intended for senior managers	Based on information sharing
4.	Simple, but less accurate analytical method	Complex, but more robust analytical methods
5.	Extreme values may lead to misleading conclusions	Extreme values don't have impact on results
6.	Unintelligible to interpret	Easy to interpret
7.	Leads to Airspace Users' frustration, abuses etc.	Better understanding of business environment
8.	Has a fixed framework	Modular design (depends on needs)
9.	Based on fragmentary approach	Based on holistic approach
10.	Doesn't consider spatial component of data set	Takes in account spatial component of data set
11.	Doesn't consider performance interdependencies	Takes in account performance interdependencies
12.	Mainly used to show the condition	Intended to improve performance
13.	Not applicable within other management systems	Complementary with other management systems
14.	Hinders continuous improvement	Promotes continuous improvement

5. CONCLUSION

In order to increase the efficiency of ATM system in Europe it's mandatory to apply appropriate analytical methods, i.e. to have accurate assessment tools which can provide information that will lead to better system' efficiency. In that context application of conventional approach of data manipulation, as it has been presented within this paper, is problematic as it can lead to erroneous decision making. Therefore, in order to get information that more accurately reflects the real-world situations (and so improve decision making), it's necessary to apply proper analytical methods.

For years non-spatial statistics has been used to depict spatial features or phenomenon. The main drawback of such an approach is that a conventional (or non-spatial) approach is based on assumption of spatial independence. Since ATM environment is highly interdependent system where performance of one ANSP can have an effect on performances of neighbouring ANSPs, application of conventional approach should be considered as inappropriate. Opposite to that, by application of various analytical methods, the spatial statistics enable testing of the existence of spatial patterns, determination of their distribution and characteristics, identification of spatial interactions, etc. However, since such analytical methods haven't been yet applied within ATM business environment at large scale, their application can be seen as a novel approach of data manipulation.

Lastly, it can be noted that presented issue mostly isn't yet recognized, and that within ATM domain one can often come across business reports that were created by application of conventional approach. Considering that, the question of quality of the information (business reports) provided arises. Hence, as the result, nowadays as advanced methodological frameworks can be distinguished ones that process aeronautical data based on spatial statistics - rather than on traditional statistics. Moreover, their application should be prioritised as they can provide more competitive information and so strengthen understanding of ATM business environment, identify performance interdependencies, trade-offs, goal conflicts, valorise the effects of applied strategies, concepts, projects etc. - what wasn't possible before, i.e. wasn't possible by the application of conventional approach of data manipulation.

REFERENCES

[1] Rezo Z, Steiner S. European Airspace Fragmentation Typology. International Journal for Traffic and Transport Engineering. 2020;10(1): 15-30.

[2] Rezo Z, Steiner S, Brnjac N. Cost Analysis of Air Traffic Flow Disruptions in Europe. Aviation Management and Economics Conference (AMEC). 6th November 2019, Vienna, Austria

[3] Rezo Z, Steiner S. South East Common Sky Initiative Free Route Airspace - implementation aftermath. Transportation Research Procedia. 2020;45: 676-683.

[4] Sturges H. The choice of a class interval. Journal of the American Statistical Association. 1926;21(153): 65-66.

[5] Pearson K. Contributions to the Mathematical Theory of Evolution II. Skew Variation in Homogeneous Material. Philosophical Transactions of the Royal Society of London. 1895;186: 343-414.

[6] Scott D. Sturges' rule. Wiley Interdisciplinary Reviews: Computational Statistics. 2009;1(3): 303-306.

[7] Hyndman R. The problem with Sturges' rule for constructing histograms. Monash University, Clayton, Victoria, Australia. 1995.

[8] Cogen M. An Introduction to European Intergovernmental Organizations. Routledge. New York, USA. 2016.

[9] EUROCONTROL. Enlarged Committee for Route Charges Information; paper Flimsy No. 4-REV [Internet]. [cited 2020 Jan 31]. Available from: https://www.eurocontrol.int/sites/default/files/2019-11/final-data-establishment-cost-bases-unit-rates.pdf

[10] Steiner S, Mihetec T, Rezo Z. Resolution of operational constraints imposed by fragmentation of European airspace. Proceedings of International Scientific Conference: Science and Traffic Development, 9-10 May 2019, Opatija, Croatia. p. 385-395.

[11] EUROCONTROL. Local Single Sky implementation monitoring (LSSIP) [Internet]. [cited 2020 May 2] Available from: https://www.eurocontrol.int/service/local-single-sky-implementation-monitoring

[12] Button K, Neiva R. Spatial autocorrelation in the European air navigation system. Applied Economics Letters. 2013:20(15): 1431-1434.

[13] Rezo Z, Steiner S, Škurla Babić R, Piccioni C. European airspace fragmentation: A cost-efficiency based assessment. ATRS 23rd World Conference, 1-5th July 2019, Amsterdam, Netherlands

[14] Biggs R, Garson D. Analytic Mapping and Geographic Databases. Sage Publications Inc. Newbury Park, USA. 1992.

[15] Franklin C, Hane P. An introduction to GIS: linking maps to databases. Database. 1992;15(2): 17-22.

[16] PRU Database [Internet]. [cited 2020 Feb 16] Available from: https://ansperformance.eu/data/

[17] Central Route Charges Office. Information on Conditions of Application of the Route Charges System, Conditions of Payment and Unit Rates. Brussels, Belgium, 2019.

[18] Gimbert X, Bisbe J, Mendoza X. The role of performance measurement systems in strategy formulation processes. Long Range Planning. 2010;43(4): 477-497.

ZVONIMIR REZO, Ph.D. student[1]
(Corresponding author)
E-mail: zvonimir.rezo@gmail.com
SANJA STEINER, Ph.D.[2]
E-mail: ssteiner@fpz.unizg.hr
ANDREA TIKVICA, mag.inf.[3]
E-mail: tikvica.andrea@gmail.com
[1] Croatian Academy of Sciences and Arts, Traffic Institute
Kušlanova 2, 10000 Zagreb, Croatia
[2] University of Zagreb, Faculty of Transport and Traffic Sciences, Dept. of Air Transport
Vukelićeva 4, 10000 Zagreb, Croatia
[3] Sedam IT
Koledovčina ulica 2, 10000 Zagreb, Croatia

AUTOMATED AERONAUTICAL DATA PROCESSING: RECOMMENDATIONS REVIEW AND LESSONS LEARNED

ABSTRACT

Aviation industry is one of the industries that have always been a forerunner of development and implementation of innovative technological solutions. The main reason of that is because without technological development, there is no development of aviation industry. Although they may not be a cutting-edge technology, development and implementation of technological solutions enabling automated data processing in aviation industry is of high importance. Their applicability primarily arises from the need for smooth and timely flow of accurate and high-quality information between aviation stakeholders. Moreover, aviation industry is safety-critical industry. So, transmission of high-quality aeronautical data and information that can be easily processed, stored and later re-used is a must. Accordingly, this paper outlines lessons learned that can be useful for development of future technological solutions intended for aviation stakeholders. In order to ease deployment of such technological solutions, this paper highlights the recommendations which should be followed. That primarily refers to review of what to look out for when designing, operating and contracting utilization of technological solutions enabling automated aeronautical data processing. Thereby, a special emphasis was placed on the study of relationship between automated aeronautical data processing and maintenance of aeronautical data and information' quality.

KEY WORDS

Aviation industry; automated data processing; aeronautical data quality; recommendations review

1. INTRODUCTION

Nowadays, many successful aviation businesses manage to grow simply because they understand their business environment [1]. In order to be competitive in the market, they must know how to e.g. optimize their performances to ones coming from their business environment. That requires from them to continuously be at the information source. What is positive also for them is that aeronautical data is becoming more accessible today. However, at the same time many aviation stakeholders started to face with difficulties how to interpret (and consequently exploit) the information obtained. Accordingly, the ability of development of new technological solutions with strong analytical capabilities, in response to market demands, becomes a key factor of individuals' market success in the future.

Functionality of future aviation industry is based on collaborative and coordinated airspace and air traffic flow management [2]. However, nowadays aviation management systems are generally based on old and disparate systems [3]. Poor data quality used by embedded software also makes significant effects on further development of safety-critical systems [4]. That's problematic as it threatens further development of aviation industry. The timely provision and publication of new or modified aeronautical data and/or aeronautical information is particularly important to the aviation industry. In addition, data transmission frequently includes a quite complex design of aeronautical data chain with numerous stakeholders involved and with a lot of transaction points - all of which play a critical role in producing and transmitting data of appropriate quality. Another problem is that within aeronautical data chain, still a significant part of the work is performed manually – on the paper. Also, there are issues of inefficient information, limited use of information, difficulty of applying new services, etc. [5]. As a result, aviation industry can be further improved through the development of aeronautical data and information sharing technological solutions and platforms [6]. In other words, business threats should be turned into opportunities as there is a growing need for technological solutions that can support further development of aviation industry by providing the right information, at the right time, to the right user(s). Therefore, aviation industry continuously looks for development and implementation of technological solutions which are turning processed aeronautical data into high-quality aeronautical information.

More recently, insurance of adequate quality level of aeronautical data and their transmission on between different stakeholders have become one of the fundamental components of further development of aviation industry [7]. However, in order to realise such idea, it is necessary to have an appropriate information management system followed by set of tools that allow sharing of aeronautical data and information [8]. As one of positive examples contributing to that goal it can be outlined System Wide Information Management (SWIM) concept. The main goal of SWIM is to provide aeronautical data promptly and accurately through integration of the aeronautical communication networks [9,10]. Thereby, the current international standard data exchange models handled by SWIM include AIXM (Aeronautical Information Exchange Model), FIXM (Flight Information Exchange Model) and WXXM (Weather Information Exchange Model). More precisely, AIXM is a global specification for the encoding and the distribution of digital aeronautical data/information, FIXIM is global exchange standard capturing Flight and Flow information while WXXM represents a global standard for management and distribution of weather information thus supporting aviation meteorology (MET) function [11]. As a result, SWIM concept has contributed significantly to seamless information access and interchange between all providers and users of aeronautical data and information.

Undoubtedly, aeronautical data and information of appropriate quality are required to ensure safe, efficient and competent future development of air transport market. Accordingly, the aim of this paper is to present how technological solutions enabling automated aeronautical data processing can support delivery of high-quality aeronautical data, i.e. aeronautical information. This was achieved by recommendations' review what to look out for when designing, operating and contracting utilization of technological solutions enabling automated aeronautical data processing. Considering that, the content of this paper outlines lessons learned that can be useful for development of future technological solutions intended for aviation stakeholders. That primarily refers to technical service providers, because they are business entities that usually provide some form of service facility or support to the data processing operations by supplying their technological solutions to aviation stakeholders. Lastly, since in recent time many research institutes have started to progressively develop their own technological solutions (where research is often for the purpose of national industrial development) they may find presented recommendations useful as well.

2. FROM AERONAUTICAL DATA TO AERONAUTICAL INFORMATION

Nowadays data and information are often used synonymously. However, it's important to differentiate information from data intuitively since the information represents data that has been processed. Accordingly, if obtained data is inaccurate, partial or processed incorrectly, information obtained will be the same (*Garbage-In-Garbage-Out*). In order to minimize occurrence of such situations, regulations and recommendations regarding the quality of aeronautical data and information have been introduced on international and regional level.

According to International Civil Aviation Organization (ICAO), term aeronautical data refers to data that has been created for aviation purposes and applies to the data from the point of origination to the point prior to its publication. Only when aeronautical data has been through the process of being validated and verified, compiled into a publication, published and lastly presented in a manner that the end user may utilize, it's considered to be aeronautical information [12].

On the regional level, the problem of inconsistent quality of aeronautical data and aeronautical information in Europe was solved by European Commission who adopted Commission Regulation (EU) 73/2010 of 26 January 2010 laying down requirements on the quality of aeronautical data and aeronautical information for the single European sky. Beside a greater legal significance over international recommendations, in principle this regulation gives more-or-less similar definitions. According to regulation (EU) 73/2010 [13] - which is also known as Aeronautical Data Quality (ADQ) regulation, aeronautical data means a representation of aeronautical facts, concepts or instructions in a formalized manner suitable for communication, interpretation or processing, while aeronautical information means information resulting from the assembly, analysis and formatting of aeronautical data. Furthermore, a definition of data quality - as a degree or level of confidence that the data provided meets the requirements of the data user in terms of accuracy, resolution and integrity [14], remained the same.

In order to ensure that provisions are applied progressively and with the purpose of achieving required quality, ADQ regulation has an impact on a wide range of parties. Moreover, it considers the individual capabilities and levels of involvement within the aeronautical data chain of every involved person or organisation. Thereby, the aeronautical data chain represents a conceptual framework of the phases and entities involved in aeronautical data and information transmission - from its origination through to end user. Considering that every person or organisation can have one or more roles within aeronautical data chain, it's important to understand its design and associated responsibilities. Thereby, despite possible different roles, all participants in an aeronautical data chain must ensure that data quality requirements are correctly established for the data's intended usage [15]. In that context, Figure 1 provides a simplified view of aeronautical data chain design. However, it should be noted that aeronautical data chain is, in practice, far more complex. That primarily refers to situation in Europe, where a substantial number of aviation stakeholders are involved [16].

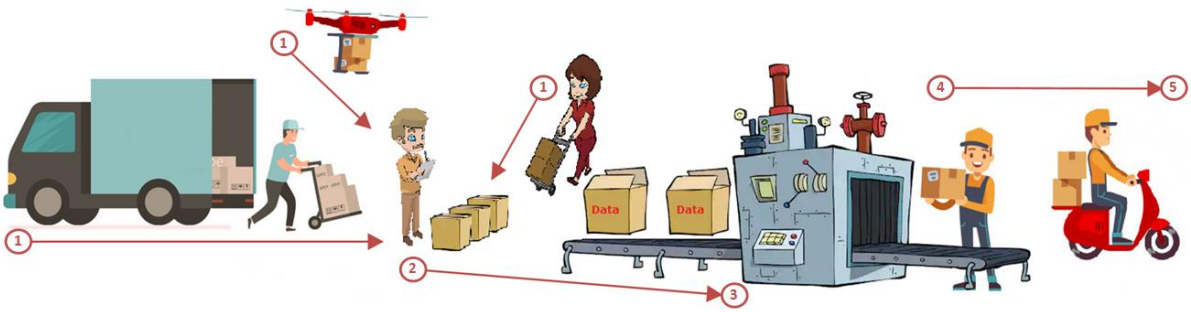


Figure 1 – Simplified view of aeronautical data chain design

Aeronautical data chain starts at some point in time when data value is associated with a data item, respectively when somebody has created this value. The person or organisation that undertakes the role of data creation is known as (1) data originator. However, it's important to emphasise that the data creation can refer to creation of the first value for a data item, or creation of a new modified value. Accordingly, this function can appear multiple times in a frame of aeronautical data chain. The next phase of aeronautical data chain is usually (2) data handling. Data handling refers to any action which requires interaction with aeronautical data and information regardless of whether the aeronautical data and information may be altered by that interaction, or not. Furthermore, data handling is usually followed by (3) data processing phase. Data processing includes conduction of any action which requires interaction with aeronautical data and which results in its alteration or the creation of new aeronautical data and/or aeronautical information. After new aeronautical data and/or information is obtained, in order to make it available for future use it needs to be stored. So, (4) data storage refers to entering aeronautical data and information into a repository in which it's held pending further use. Lastly, (5) data transfer includes the activities where obtained aeronautical data and aeronautical information are passed from one person/organization to another and so on until they reach the end user.

3. AUTOMATED AERONAUTICAL DATA PROCESSING

Safe and efficient provision of aviation services highly depend on the suitable aeronautical data and information. Moreover, in order to conduct both, operational and strategic functions, it's mandatory to have reliable data from which useful information can be obtained. For example, the provision of adequate data by Air Navigation Service Providers (ANSP), National Supervisory Authorities, airport operators, airport coordinators, airspace users and Network Manager is essential for the purpose of Commission implementing regulation (EU) 2019/317, i.e. for the purpose of performance' target setting and monitoring [17]. Accordingly, everything that is being recorded is done so for a reason.

Data is a vital resource of any business organization and must be managed. Thereby, business organizations must eliminate occurrence of situations where lots of data, but little useful information are generated. In order to ease data management, data processing has become an integral part of any business. Nowadays data processing is a topic that attracts huge interest - especially after automated data processing solutions have appeared. Automated data processing refers to development and implementation of technology that automatically processes data. This primarily refers to automation of four main stages of data processing cycle: data collection, data input, data processing and data output. Furthermore, the management of this technology includes hardware and software components and a group of people that are supervising data processing. In this context it's crucial to emphasize that the purpose of automated data processing is to enable quick and efficient processing of large amounts of data, sharing it with next intended user (regardless if it's human or machine) by minimal need for human interactions.

Some tasks are best performed by humans, some by application of different technological solutions and some a combination of the two [18]. In that context Wickens [19] concludes that automation should be used to perform functions in which humans are inherently limited or where the human brain is simply inferior. Accordingly, automation should be used to perform functions where human performance decrements are common - such as with tasks that are repetitive, that are monotonous and/or cause high workload. And applicability of automation in traffic also stems from there. Wickens [20] also defines automation as "a device or system that accomplishes (partially or fully) a function that was previously carried out (partially or fully) by a human operator". It can be deduced that development and implementation of technological solutions enabling automated data processing can be beneficial to aviation stakeholders because of faster, easier and more standardized means of aeronautical information generation. That would also enable benefits such as: (1) man-hours savings (financial savings), (2) time savings, (3) workload reduction, (4) continuous availability

of information, (5) reduction of error appearance, (6) avoidance of incorrect results interpretation, (7) optimization of human and machine interactions - with a goal to achieve a high degree of safety, (8) process standardization and its quality increase, etc. [21] Ultimately, it's important to highlight a fact that design of automated data processing is compatible with aeronautical data chain design. In simplistic terms, one is in function of the other – as it's shown by Figure 2.

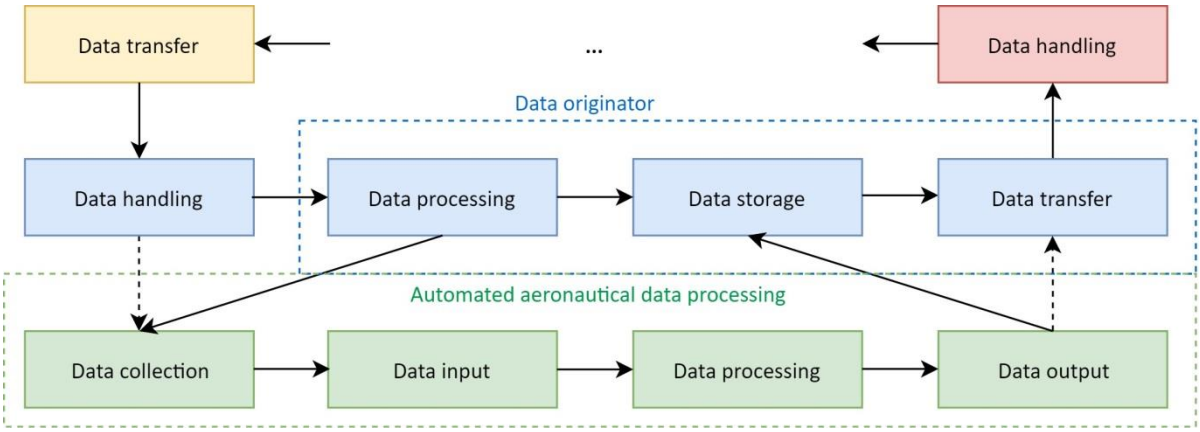


Figure 2 – Automated aeronautical data processing position within aeronautical data chain

A general underlying rationale to introduce automation in industrial environments is to replace human manual control, planning and/or problem solving for the purpose of minimizing the potential for human error [22]. Another point to make again is that automation minims the potential of error occurrence (due to human factor) and not complete human activity. Moreover, considering that business process automation improves control and reduces exposure to costly delays, errors and omissions [23], its application should be as much as possible pursued within aviation industry.

In order to provide maximized quality of data and information, it's essential that the applied technological solution (software) works properly. The development of any technological solution requires time and deep research. Data processing software are no exception. Hence before their deployment, software used for automated aeronautical data processing needs to demonstrate an appropriate level of assurance. In other words, it must undergo a validation and verification process. The validation of software means the process of ensuring that software meets the requirements for the specified application or intended use of the aeronautical data or aeronautical information. On the other hand, the verification of software means the evaluation of the output of an aeronautical data and/or aeronautical information software development process to ensure correctness and consistency with respect to the inputs and applicable software standards, rules and conventions used in that process [24].

4. RECOMMENDATIONS REVIEW & LESSONS LEARNED

Before deployment of technological solution which enables automated aeronautical data processing, the main question which should be asked is how aviation stakeholder aims to use it. There is a big difference if e.g. ANSP aims to utilize that solution within in-house operation or through outsourcing (e.g. through consulting services) where software is utilised in form of a service. If technological solution is going to be used as part of in-house operation (e.g. for performance monitoring), where only the latest obtained information will be published (which partly or entirely results from the application of the technological solution), then that technological solution needs to be aligned with tools and software requirements as it's specified in ADQ regulation. Otherwise, if technological solution is going to be used through consulting services, it doesn't need to be audited by National Supervisory Authorities. The important difference hides in definitions. ICAO's recommendations and regulation No 73/2010 are applicable only up to the moment when the aeronautical data and/or aeronautical information are made available to the next intended user.

Accordingly, if e.g. ANSP delivers obtained (raw) aeronautical data to person or organisation having technological solution that can further process it (with a goal to obtain more competitive information), in that case ANSP takes a responsibility of data verification and validation. In such a case, consulting organisation receives raw aeronautical data, and as new data originator, they enrich it by their expertise, turn it into useful information and lastly made available to ANSP for further use. In order to operate in this way, the consultant organisation should not collect the aeronautical data by themselves. Instead, they should use data collected and delivered from a contracting party (e.g. from ANSPs) or they may use data from other publicly available and relevant sources (e.g. from Performance Review Unit) for the benefit of the contracted parties. Figure 3 show an example of integration of technological solution enabling automated aeronautical data processing.

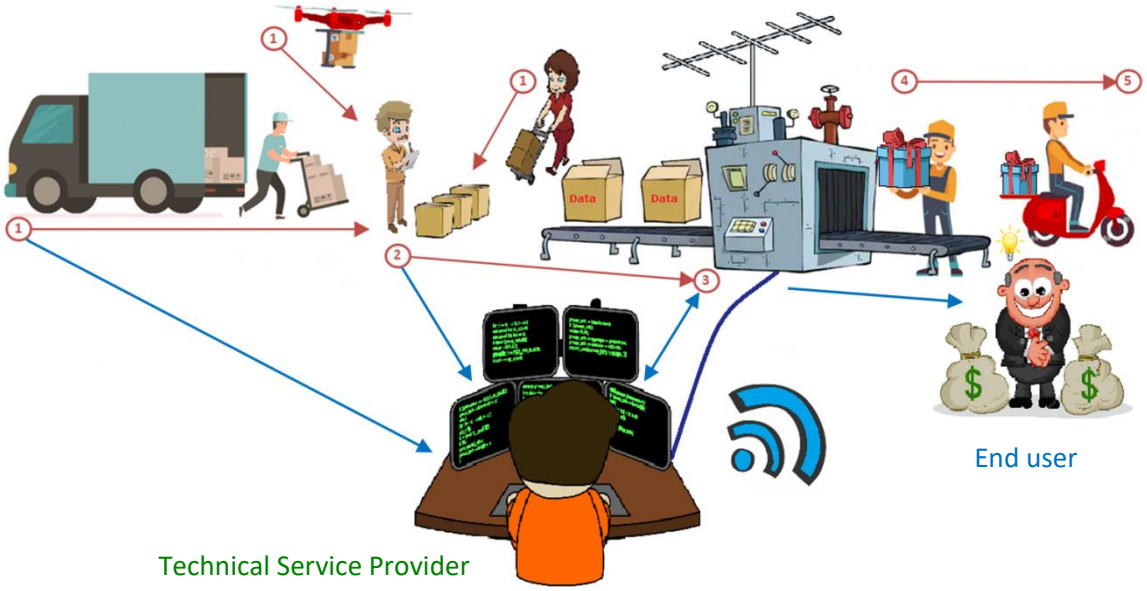


Figure 3 – Integration of technological solution enabling automated aeronautical data processing

So, in this way outsourcing can replace activities that have been traditionally performed in-house. Thereby, aviation businesses can reduce their expenses associated with overhead, labour, equipment, and technology. More importantly, they can obtain more competent information that sometimes they can find hard to reach. In doing so, outsourcing costs (cost of utilizing technological solution) can be covered from ANSP's cost base which consists of staff costs, operating costs other than staff costs, depreciation costs, cost of capital, and exceptional costs. More specifically, those costs fall under category of the operating costs other than staff costs and which can be incurred for the purchase of outsourced services as it's defined by Commission implementing regulation (EU) 2019/317.

Furthermore, ADQ regulation requires that ANSPs should ensure that any other party (e.g. technical solution provider) regulated by ADQ regulation or not, which is involved in the origination, production, storage, handling, processing, transfer or distribution of aeronautical data and aeronautical information, and which the ANSP interacts with, is made aware of the data quality requirements and adheres to them. Therefore, beside mentioned recommendation regarding contracting option, in order to properly design and operate technological solution which enables aeronautical data processing, it's desirable to adopt recommendations described within next sub-chapters. Listed recommendations also correspond to activities what needs to be done when applying technological solution in function of strategic Air Traffic Management - as it's shown by Figure 4.

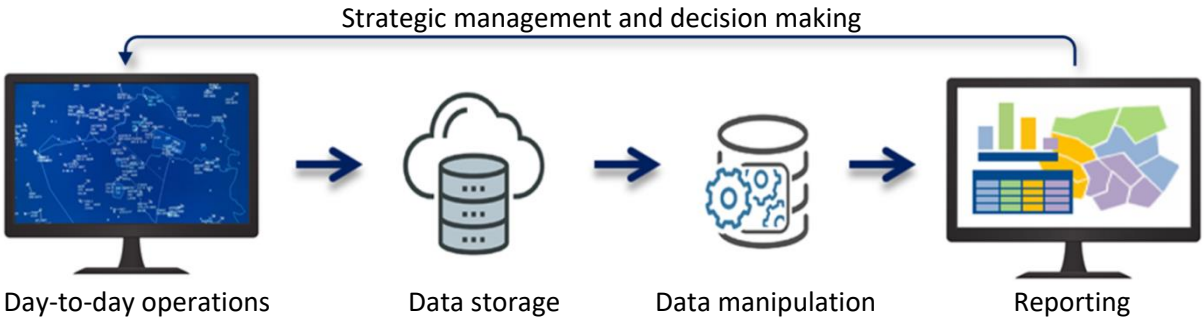


Figure 4 – Technological solution in function of strategic Air Traffic Management [21]

4.1 Verification and Validation

The quality of data analysis depends on inputs [25]. So, before processing aeronautical data it's recommended firstly to ensure that the quality of the input data used is enough to achieve the required quality of the output data. In other words, it needs to be ensured that data meets the requirements for the intended use. That primarily refers to application of technologies which may have methodological shortcomings in case that insufficient quality of the input data is used. In order to avoid occurrence of such situations, data validation and verification activities needs to be conducted.

Data validation is an important step of ensuring adequate data quality [26]. It represents the process of checking if data satisfies a certain criterion, i.e., that the product is adequate for its intended use, while verification is the process of checking that the data value meets its quality requirements. Furthermore, prior to use of technological solutions, parameters used needs to be also validated and verified. Moreover, all applied analytical methods (on which basis technologies operate) shall be documented. The software solution designer is responsible for verification and validation of applied technologies, methods and parameters. Also, designer has the responsibility of development and maintenance of technical and operations manuals. They should contain the necessary instructions and information required for efficient transformation of aeronautical data into aeronautical information. These manuals must be easily accessible and kept up to date.

Furthermore, quality assurance activities need to be done before running technological solution. The primarily goal of quality assurance activities is to provide support to the data manipulation activities. One of the means how to execute quality assurance is by conduction of safety and security assurance activities. In that context it's recommended to conduct security clearance of the personnel responsible for tasks of the origination, production, storage, handling, processing, transfer and distribution of aeronautical data or aeronautical information. Ultimately, it's recommended to conduct these activities repetitively and especially before application of data that has not been analysed before, further software development, hiring new staff etc.

4.2 Data Storage

At no time aeronautical data should be available to unauthorised persons. No matter if they are unauthorised employee of organisation owning technological solution or someone from outside world. Also, every step in the work flow process and all involved persons interacting with data have to be documented and verified [27]. Furthermore, the storage of aeronautical data needs to be protected by a suitable authentication process. For example, in order to view/read aeronautical data from database, it may be required to have an account protected by password. In such a way software enables conduction of further operations only to personnel who has been accredited.

Furthermore, technological solutions enabling automated aeronautical data processing should have appropriate level of security protection while performing data storage or transmitting aeronautical data to other organisations or to their technological solution. To simplify, intrusions into

their communication channels mustn't happen. In case that such event occurs, that represents a high safety risk. It's suggested not to use the software until the cause of the problem has been eliminated. In addition, it must be ensured that data cannot be accidentally changed. In that context particular attention for that should be given in case of utilizing technological solutions with lower degree of automation.

Another issue related to data storage needs to be highlighted. According to ADQ regulation, aeronautical data should be available during its period of validity. After it ceases to be valid, it needs to be available for at least 5 following years or until 5 years after the end of the period of validity, whichever is later. That also refers to any data item calculated or derived from original dataset. Because of the above-mentioned, increasing costs of maintaining technological solution will be gradually generated.

New or currently usable information is always worth more. Sometimes, in order to understand current information about e.g. business environment, it's necessary to conduct a trend analysis that includes some older dataset analysis. In order to achieve that, it's necessary to process older data and put it into function of new one. Practically speaking, if e.g. ANSP utilizes technological solution to provide him an information about how his business environment changed over time (e.g. because high traffic seasonality), data reflecting older day-to-day operations needs to be processed. The problem associated to data storing arises because, according to ADQ regulation, if software in 2020, for the purpose of new analysis, uses some older data (such as performance indictors from 2016), then that aeronautical data must be kept for another five years. Hence, it's actually more expensive to analyse archival data than current data (because than technological solution than requires higher storage capabilities). So, it's well recommended to plan capacity of databases more in-advance and foreseen associated costs before contracting further utilisation of technological solutions enabling automated aeronautical data processing.

In case that software owner/operator wants to avoid overfilling of the database, they can do it by taking advantage of the fact that ADQ regulation does not define the way how data/information should be archived. Accordingly, if they want to free up database capacity and thus improve the performance of the technological solution, they can export aeronautical data to one of the other digital formats and as such archive it.

4.3 Data Manipulation

The aeronautical data chain usually involves many organisations that routinely transmit data. To run system efficiently, data originators and those interacting with aeronautical data must operate in a consistent way [28]. Despite above-mentioned, aeronautical data is still being stored in different formats and repositories. Because of that, in order to manipulate separate datasets, a human intervention is frequently required. Consequently, such a data manipulation process is often more time-consuming, expensive and may be risky at times. Such an unwanted situation can be avoided by application of technological solutions that enable automated aeronautical data processing. Main reason is because during their development a high degree of interoperability must be taken into account. So, in order to simplify data manipulation process, it's recommended to develop highly interoperable technological solution.

Furthermore, to be able to execute data manipulation, whether human intervention may be required or not, it's recommended to use standardized data exchange formats. Their application will enable and ease data manipulation for next intended user. Standardized data exchange formats are also prerequisite for the interoperability of the two systems (solutions). In that context it's recommended that raw aeronautical data is digitally transferred from data originator to technological solution that enables automated aeronautical data processing. That practice should be applied wherever it's possible.

Lastly, it's about education, experience and data understanding whose combination leads to creation of new information from existing datasets. In order to avoid risk of occurrence of misinterpretation (due to insufficient level of any of the three above-mentioned segments), technological solutions should provide its user with feedbacks about performed actions such as whether the data manipulation was successfully performed, whether errors have occurred, etc. Accordingly, technological solutions' Graphic User Interface (GUI) should be user friendly. Besides that, it's recommended that they also provide, where it's possible, results interpretation, measurement scales etc. thus making it easier for the users to understand the output values. In this context, when manipulating aeronautical data and drawing conclusions from it, according to European Organisation for the Safety of Air Navigation (EUROCONTROL) [24] it's required to achieve a 95% confidence level in order to meet accuracy requirement. Accordingly, it's recommended that a technological solution after data manipulation activity is over, gives also a feedback to the software user with a statement of what accuracy was achieved.

4.4 Information Reporting

First of all, it's important to highlight that when it comes to reporting, aeronautical information obtained from raw data has its value. That is the most valuable part of the process where obtained information represents value added product. Accordingly, reports need to be appropriately protected. So, it's recommended to add information about person or organization that has turned aeronautical data into useful information. In accordance with the requirements of regulation (EC) No 552/2004 [29], aeronautical information should be consolidated in a report format and delivered in an electronic form.

Utilization of electronic form documentation enables one more thing that helps run process more smoothly. That refers to utilization of digital authentication signatures. Digital signatures are a security technique that helps to ensure data integrity during transmission from the data originator to the next intended user. Also, their application allows the user to authenticate that the sender of the data is legitimate. Thereby every report should contain digital authentication signature of the person or organisation that has created report. Beside digital signatures, every report should contain a date when report was completed and became available to the end user. Lastly, when data from a third-party supplier has been used, appropriate information regarding the data origin must be noted.

5. CONCLUSION

Aviation industry is a simple market which is complexly organized. Considering that, technological solutions that can simplify execution of day-to-day operations, maximize profitability or optimize operational costs are always welcomed. Within this paper recommendations review and lessons learned have been presented from aspect of development, contracting and operating technological solution that enable automated aeronautical data processing.

It can be defined that technological solutions that enable automated aeronautical data processing, because of their huge potential, are very well welcomed in aviation industry. The main reason why is because these solutions do not only eliminate the need to manually retrieve required information from multiple data originators or reduce the possibility of human error, but because they can also discover hidden knowledge.

Lesson learned tells us that development of in-house solutions in aviation industry is not always a best practice. Mostly because of the currently applicable ADQ regulation where in case that organisation regulated by civil aviation authority legally owns and internally uses technological solution, then it becomes a subject of periodical audits. Accordingly, this raises the question of whether or not to develop a technological solution whose purpose is to enable financial and time savings, workload reduction etc. when expected benefits will be compromised by introduction of new obligations, administration requirements etc. required by civil aviation authorities. Given that

the technological development of the aviation industry must not be conditioned by legal or administrative barriers, this scenario is not an option. So, to sum up, in order to avoid adverse outcomes, aviation stakeholder should not hesitate to use an outsourcing (e.g. through consulting services) and they should contract utilisation of technological solution in form of a service. Lastly, it should be mentioned that the practice where aviation stakeholder(s) can supervise development of technological solution, and later-on become its user, represents a best option for all involved parties.

REFERENCES

[1] Rezo Z, Steiner S. European air traffic market segmentation model: A cost-efficiency based assessment. German Aviation Research Society (GARS) 16th Aviation Student Research Workshop; 1 July 2019, Amsterdam, Netherlands

[2] Steiner S, Mihetec T, Rezo Z. Resolution of operational constraints imposed by fragmentation of European airspace. Proceedings of the International Scientific Conference: Science and Traffic Development, 9-10 May 2019, Opatija, Croatia, p. 385-395.

[3] Rusu L, Rahayu W, Torabi T, Puersch F, Coronado W, Taylor Harris A, Reed K. Moving towards a collaborative decision support system for aeronautical data. Journal of Intelligent Manufacturing. 2012;23(6): 2085-2100.

[4] Marques J, Yelisetty J. Exploring Validation Techniques to Ensure Correctness in Aeronautical Databases. International Journal of Engineering and Technical Research. 2019;9(10): 14-20.

[5] In-Seop Y, Sang-Uk K, Yun-Hyun J, Seon-Gook H, Sangbang C, Jae-Hak C, Hyo-Dal P. A Study on Processing Method of SWIM Data. International Journal of Computer Science and Network Security. 2014;14(8): 36-43.

[6] Dou X. Big data and smart aviation information management system. Journal Cogent Business & Management. 2020;7(1): 1-14.

[7] Dudek E, Kozłowski M. The Concept of a Method Ensuring Aeronautical Data Quality. Journal of KONBiN. 2016;37(1): 319-329.

[8] Rodríguez C, Bravo M, Benavides D, Siabato W, Moya J, Manso M, Bernabé M. Aeronautical Metadata Profile based on Geographic International Standards. Proceedings of the 8th Innovative Research Workshop & Exhibition, 1-3 Dec 2009, Brétigny-sur-Orge, France, p.1-9.

[9] Standley J. SWIM segment 2 deployment and utilization in NextGen R&D programs. Proceeding of the Integrated Communications, Navigation and Surveillance Conference (ICNS), 24-26 Apr 2012, Herndon, United States of America, p.1-5.

[10] Klein J, Morey S. Use of eram SWIM for NAS system enhancements. Proceeding of the Integrated Communications, Navigation and Surveillance Conference (ICNS), 10-12 May 2011, Herndon, United States of America, p.1-8.

[11] In-Seop Y. Plan to Establish the SWIM Local Server and Test-bed for SWIM. International Journal of Computer Science and Network Security. 2014;14(2): 47-53.

[12] International Civil Aviation Organization. Annex 15: Aeronautical Information Services. Montreal, Canada; 2010.

[13] EUR-LEX. Commission regulation (EU) No 73/2010 of 26 January 2010 laying down requirements on the quality of aeronautical data and aeronautical information for the single European sky [Internet]. [cited 2020 Jan 11]. Available from: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:023:0006:0027:EN:PDF

[14] EUROCONTROL. Specification for Data Quality Requirements. Brussels, Belgium; 2016.

[15] Xie W. Means for avionics manufacturers to define the aeronautical data quality requirements. Proceedings of the International Conference on Systems and Informatics (ICSAI2012), 19-20 May 2012, Yantai, China, p. 2383-2387.

[16] Rezo Z, Steiner S. European airspace complexity and fragmentation correlation research. Proceedings of the Research Workshop on Fragmentation in Air Traffic and its Impact on ATM Performance, 14-15 May 2019, Budapest, Hungary, p. 31-38.

[17] EUR-LEX. Commission implementing regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky and repealing Implementing Regulations (EU) No 390/2013 and (EU) No 391/2013 [Internet]. [cited 2020 Jan 11] Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0317&from=EN
[18] EUROCONTROL. Specification for Data Assurance Levels. Brussels, Belgium; 2018.
[19] Wickens CD. Engineering psychology and human performance. Scranton: Harper Collins; 1992.
[20] Wickens CD, Mavor A, Parasuraman R, McGee J. The future of air traffic control: Human operators and automation. Washington: National Academy Press; 1998.
[21] Rezo Z, Steiner S, Piccioni C. Potential of Geospatial Business Intelligence solutions for Air Traffic Management. Proceedings of the International Conference on Transport Science, 4-5 June 2020, Portorož, Slovenia.
[22] Bainbridge L. Ironies of Automation. In: Rasmussen J, Duncan KD, Leplat J, editors. New Technology and Human Error. Chickester: Wiley,1987; p.271-284
[23] Mohapatra S. Business process automation. New Delhi: PHI Learning Private Ltd.; 2009.
[24] EUROCONTROL. Guidelines for Supporting the Implementation of Commission Regulation (EU) 73/2010. Brussels, Belgium; 2017.
[25] Wilke S, Majumdar A, Ochieng W. A framework for assessing the quality of aviation safety databases. Safety Science. 2014;63: 133-145.
[26] Xie C, Gao J, Tao C. Big Data Validation Case Study. Proceedings of the 3rd IEEE International Conference on Big Data Computing Service and Applications, 6-8 April 2017, San Francisco, United States, p.281-286.
[27] Schroth R. Aeronautical Data Quality - A New Challenge for Surveyors. Proceedings of the 25th International Federation of Surveyors (FIG) congress: Engaging the challenges, enhancing the relevance, 16-21 June 2014, Kuala Lumpur, Malaysia, p.1-9.
[28] Wenguang X. Means for avionics manufacturers to define the aeronautical data quality requirements. Proceedings of the International Conference on Systems and Informatics (ICSAI2012), 19-20 May 2012, Yantai, China
[29] EUR-LEX. Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network. [Internet]. [cited 2020 Jan 12] Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R0552&from=EN

EUGENIA ALINA ROMAN, Ph.D.[1]
Corresponding author
E-mail: ea_roman@yahoo.com
VASILE DRAGU, Ph.D.[1]
E-mail: v_dragu@yahoo.com
MIHAELA POPA, Ph.D.[1]
E-mail: mihaela.popa@upb.ro
EUGEN ROŞCA, Ph.D.[1]
E-mail: eugen.rosca@gmail.com
[1] University Politehnica of Bucharest
Splaiul Independenţei 313, Bucharest, postcode 060042, Romania

SATISFYING FUTURE TRANSPORTATION NEEDS BY MEANS OF PUBLIC TRANSPORTATION

ABSTRACT

The increasing degree of motorization has led to traffic congestion and its negative effects (pollution, additional social costs, health problems, landscape degradation, increasing car accidents' number). The degree of motorization of the Bucharest city is about 685 cars per 1000 inhabitants and it is constantly increasing. In this conditions the measures of increasing the public transport attractiveness it becomes very topical. The paper aims to analyse the public transport system in Bucharest city to verify whether its development has been made in correlation with urban development and with real social needs. Analyses on the urban transport modes in terms of serving the territory and network's characteristics has been conducted. It is checked whether there is a correlation between the characteristics of the territorial system (surface, population, population density) and the urban public transport system (network length, network density). Depending on the socio-economic characteristics of the areas and their correlation with the networks' characteristics, there are formulated conclusions that can be the basis for the further development of the studied networks in order to meet the future mobility needs of the inhabitants and to increase the quality of life in the Bucharest city.

KEY WORDS

Sustainable mobility; transport network; public transport

1. INTRODUCTION

Movement as fast as possible has become an unanimously admitted goal of mankind. Concepts like gained speed and gained time are the determining attributes of travel while increasing travel speed is considered a measure of economic development.[1]

From the lifestyle evolution point of view, as an outcome of the increase of the speeds of movement, legitimate questions arise: do we really have a time gain? Can time be saved as a resource for other activities? Suffice it to say that under the conditions of a relative constancy of the travel time budget ("Zahavi's hypothesis") which proves its conservation at about one hour a day we see an increase in the length of travel (40 km in average daily in France, 70 km in the USA) [2]. This increase in travel area generates additional space, material and energy resources usage. Surprisingly, in terms of space consumed, there is an increased degree of motorization in developed cities where moving and stationary cars are devouring public space and generate congestion. [3]

Intensive use of personal car in daily trips has increased external negative effects and led to levels of congestion difficult to bear by those involved. Among the negative external effects induced by

traffic congestion we list: chemical pollution, noise, additional social costs, health-related effects, landscape degradation, increased risk of accidents and thus decreased quality of life. [4]

The external effects of car usage in daily trips represent the current main challenge of any urban transport system. It is well-known that about 50% of pollution comes from road transport and, in particular, from internal combustion engines. Within this context, different actions have been deployed in the last few decades to reduce pollution, such as acting on the vehicle technology or different types of fuels, and through different and sophisticated mobility/travel demand management policies or traffic flow control strategies. [5]

Although the term congestion is used extremely frequently, it has different interpretations for stakeholders with often divergent interests and points of view, who interfere on the transportation market. We can name here: *the person in charge of the transport infrastructure development strategy, the infrastructure user, the traffic engineer, the transport beneficiary and the transport economist*. For each of them the notion of congestion has different meanings depending on the degree of involvement in the transportation process. [6]

The *person in charge with the transport infrastructure development strategy* is interested in the elements of the infrastructure to take over the regulated flows for which they were designed. Otherwise, it means that the infrastructure has been oversized and that the financial resources used do not prove their efficiency.

The *user of the infrastructure* is interested in not being disturbed on the road by other traffic participants sharing the same infrastructure. From his point of view, the decrease in speed below that achieved on the motorway is interpreted as a beginning of congestion.

For the *traffic engineer*, congestion occurs much later, only when the traffic intensity reaches a threshold in the vicinity of the road capacity (maximum flow) of an arterial road and when at relatively small increases in traffic intensity there are relatively significant decreases in traffic speed flow displacement.

The *beneficiary of the transport* is able to highlight the congestion only insofar as his expectations regarding the duration of the journey or the movement of the goods as assumed by the carrier have not been met as a result, exclusively, of the extension of the duration of the itinerary on the given infrastructure.

The *transport economist* conceives congestion as an externality that forces those who are not the beneficiaries of a certain travel activity (riparians or even the entire population of an area or the planet, the other traffic participants) to pay the costs of the effects produced by the infrastructure users.

Bucharest ranks 4th in the top of the most congested cities in Europe compiled by the car navigation company TomTom. The company has compiled a report (*TomTom Traffic Index*) showing traffic congestion in 416 cities in 57 countries. In the global ranking, on the first 5 places is the city of Bengaluru (from India), with a congestion index of 71% (the percentage of additional time spent traveling compared to the hours spent outside peak hours) followed by the Philippines capital Manila (71%), the capital of Colombia, Bogota (68%), Mumbai (65%) and the city of Pune (59%) also in India. [7]

In the European top, on the first 5 places are Moscow (59%), Istanbul (55%), Kiev (53%), Bucharest (52% compared to 41% in 2015) and St. Petersburg (49%) and on the 14th places , 15th and 17th respectively are Paris (39%), Rome (38%) and London (38%). The level of congestion increased between 2018 and 2019 (in the last report an additional 239 cities were included in the list of congested cities), only a number of 63 cities registered measurable decreases. [7]

The plan proposed by the Bucharest Metropolitan Transport Association (an NGO structure established with the agreement of the General Council of the Municipality of Bucharest) aims at

creating a complex public transport network that would solve the current congestion problems. The goal for 2030 is to increase the number of public transport users from 20% at present to at least 80%. This objective must be achieved in the area with the highest population density in the country - over 8000 inhabitants/km^2.

From the data supplied by the Driving Licenses and Vehicle Registration Directorate of the Ministry of Internal Affairs – DRPCIV, information was obtained regarding the number of vehicles registered in Bucharest. Table 1 shows the situation of the number of registered vehicles between 1990 and 2019.

Table 1 – The number of registered vehicles between 1990 and 2019

Year	1990	1992	1995	2002	2003	2013	2018	2019
No. ff vehicles	336,928	377,206	468,414	655,042	695,365	1,125,591	1,381,620	1,457,889
Occupied area (km^2) (11m^2/vehicle)	3.71	4.15	5.16	7.21	7.65	12.39	15.20	16.04
% of the city are occupied by vehicles	1.56	1.75	2.17	3.03	3.22	5.21	6.39	6.74

Source: [8], [9]

From table 1 it is noticeable that the number of registered vehicles and occupied area has increased extremely fast and intensely.

2. SUSTAINABLE URBAN MOBILITY PLANNING

Sustainable development is one of the main challenges of the last millennium. The transportation sector has always both played a strategic role in the economic development of a country and a central focus of the political and scientific debate on sustainability. The main points of interest in this debate are the negative externalities produced by the daily movement of goods and people which impact both the environment and the quality of life. Nevertheless, beyond environmental ideals, sustainable development must also be socially acceptable, fair, and economically viable. [10], [11]

Environmental sustainability entails improvement in the quality of urban environment and reduction of emissions and energy consumption (greenhouse gasses emission variation; pollutant emission variation; impact variation in other sectors). By contrast, social sustainability entails improvement in the quality of life and social equity (e.g., easy access to transportation) and improved safety (e.g., reduction in the frequency of accidents). Finally, economic sustainability entails making mobility of people and goods more efficient and effective and ensuring that the economic benefits produced by the project are greater than the costs. [10]

From the above, it is clear that there must be a balance between the interventions made to increase the influence of the three pillars of sustainable development, social, economic and environmental.

Many transport policies are widely accepted as sustainable (ecological) but they are not always *eco-rational* i.e. not acting in the best possible way as defined by Carteni [12]. It is recognized for passenger transport that the policies for sustainable mobility [13], in which the use of cars is minimized, is the tool through which it is possible to reduce the externalities on the environmental level, but it is not always socially acceptable, fair, and economically viable. For example, the introduction of toll for the use of a road infrastructure seems one of the most common Transportation Demand Management policy aim to reduce car use and their emissions, but which is not popular among road users [14]. One of the major limits of these applied policies is that they do not take into account their impact on equity and on social sustainability. In the meantime, designing a toll (pricing) scheme in which the acceptance and equity measure are as a design variable, so stakeholder engagement is developed (that is the process of involving stakeholder concerns), which could lead to an environmental, social, and economic sustainability policy. [10]

Under these conditions, the predominant use of urban public transport in daily trips must be deliberately accepted by users without feeling a sense of coercion or social inequity. Meeting the requirements of sustainable development through the use of public transport must be achieved through persuasion / awareness so that the population involved does not feel social inequity or restriction of the right to choose the mode of transport or travel.

An evaluation analysis to estimate the *environmental, social* and *economic* impact produced by the transport infrastructure is reported in *Figure 1*.

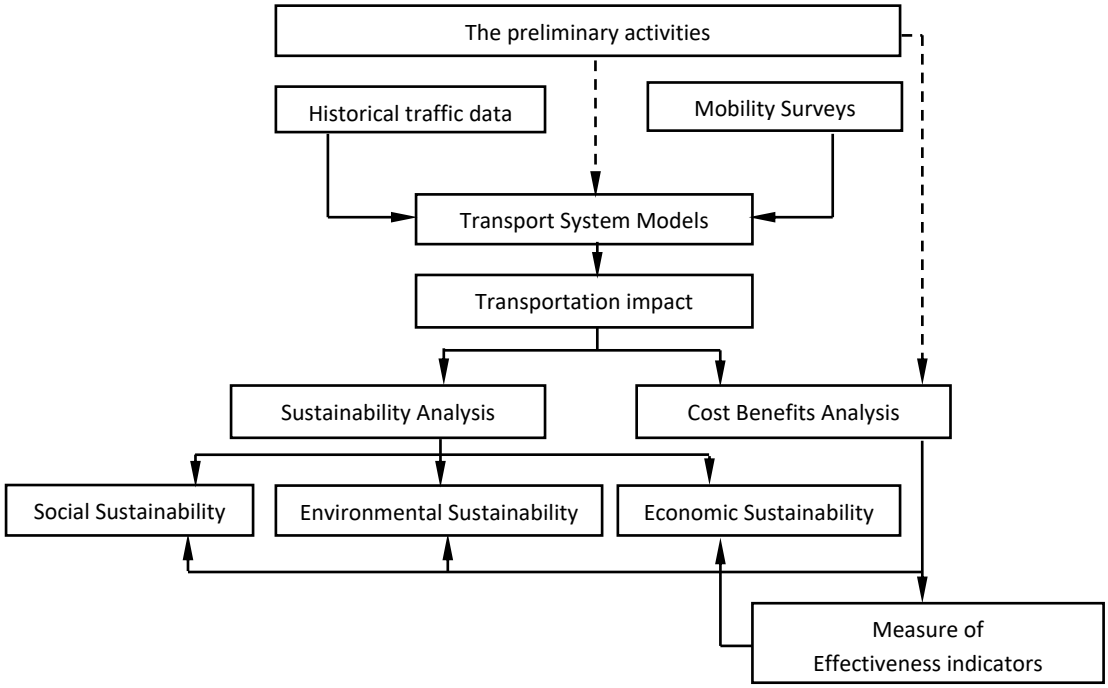


Figure 1 – Estimate the environmental, social and economic impact produced by the transport infrastructure
Source: [10]

Figure 1 shows that the impact of transportation is assessed both in terms of cost-benefit analysis and in terms of sustainability, it is known that the two aspects are often antagonistic in nature. In order to achieve a sustainable development in transport, significant costs must often be involved, which are often not found in benefits for the transport operator but only in social benefits (for example: the acquisition of electric means of transport, intelligent transport systems to reduce congestion and increase safety, ensuring fair rates).

The objectives of sustainable mobility can only be achieved if they are outlined for in the transport planning phase.

Classic congestion reduction measures focus exclusively on the development of road infrastructure leading to land usage, degradation of the natural landscape, increased risk of accidents and attracting new traffic, which will again lead to congestion and the process is cyclical until the expansion of road infrastructure is no longer possible. Thus is described a vicious circle of possibilities to eliminate congestion. Therefore, public transport must play an important role in meeting the unrestricted tavel needs of the population.

Since 2013, the European Commission has developed a guideline for the Development and Implementation of a Sustainable Urban Mobility Plan - SUMP, according to which each urban locality must achieve a SUMP through which to achieve a sustainable urban planning in transport. The differences between traditional planning and that based on sustainable urban mobility are presented in table 2.

Table 2 – Move from traditional transport planning to sustainable urban mobility planning

Traditional transport planning	Sustainable urban mobility planning
Focus on traffic	Focus on people
Primary objectives: Traffic flow capacity and speed	Primary objectives: Accessibility and quality of life, as well as sustainability, economic viability, social equity, health and environmental quality
Modal-focused	Balanced development of all relevant transport modes and shift towards cleaner and more sustainable transport modes
Infrastructure focus	Integrated set of actions to achieve cost-effective solutions
Sectorial planning document	Sectorial planning document that is consistent and complementary to related policy areas (such as land use and spatial planning, social services, health, enforcement and policing, etc.)
Short- and medium-term delivery plan	Short- and medium-term delivery plan embedded in a long-term vision and strategy
Related to an administrative area	Related to a functioning area based on travel-to-work patterns
Domain of traffic engineers	Interdisciplinary planning teams
Planning by experts	Planning with the involvement of stakeholders using a transparent and participatory approach
Limited impact assessment	Regular monitoring and evaluation of impacts to inform a structured learning and improvement process

Source: [15]

The creation of an efficient public transport system increasingly requires collaboration between independent organizations. Institutional reforms in Europe have created governance situations where collaboration between organizations is a critical issue, and examples include the integration of transport and land-use planning and the planning of large public transport projects. The organizational context of public transport, with several formal, discrete organizations that need to collaborate, raises questions about how functioning collaborations can be accomplished. [16]

Collective passenger transport as well as the so-called green journeys also lead to much higher transport capacities. *Figure 2* shows the transport capacity of a single lane measured in people/hour depending on the means of transport used. It is observed that the lowest capacity is for the case of a mixed traffic of vehicles and the highest for the railway traffic. The CAV notation has the meaning of connected and automated vehicle. [17]

A modern approach to sustainable urban planning in transport is the one based on TOD policies - Transit-oriented development [18]. Today, many cities have made large financial investments to use public transportation as a *hub* in sustainable public transport. TODs are compact, mixed-use developments that facilitate walking, cycling, and the use of public transportation through their urban design. Consequently, they are seen as a path to environmental sustainability by conserving resources and energy, using better use of urban space, reducing the number of km traveled by vehicles and shifting modal shift to greener modes of transport. [19]

TOD offers many social, environmental, economic and health benefits. It is associated with high-density, mixed-use urban development that brings many opportunities closer to residential locations and facilitates the choice of sustainable modes of transport (walking, cycling or using public transport) [20]. Therefore, TOD affects travel behavior mainly by increasing choice options and encouraging the use of non-motorized modes of transport. It is expected that people living in TOD will have a more sustainable, active lifestyle and less dependence on personal car.

The overarching role of mobility and transportation in modern societies has generated a fast growing field of social-science-based mobility's research. This rising field focuses on large-scale as well as regional movements of people, goods, capital, and information. The cross-fertilization of disciplines and academic traditions in this field brings about strong and innovative approaches concerning the future of cities that integrate the human as well as the systematic and the global scale of current transformations. [21]

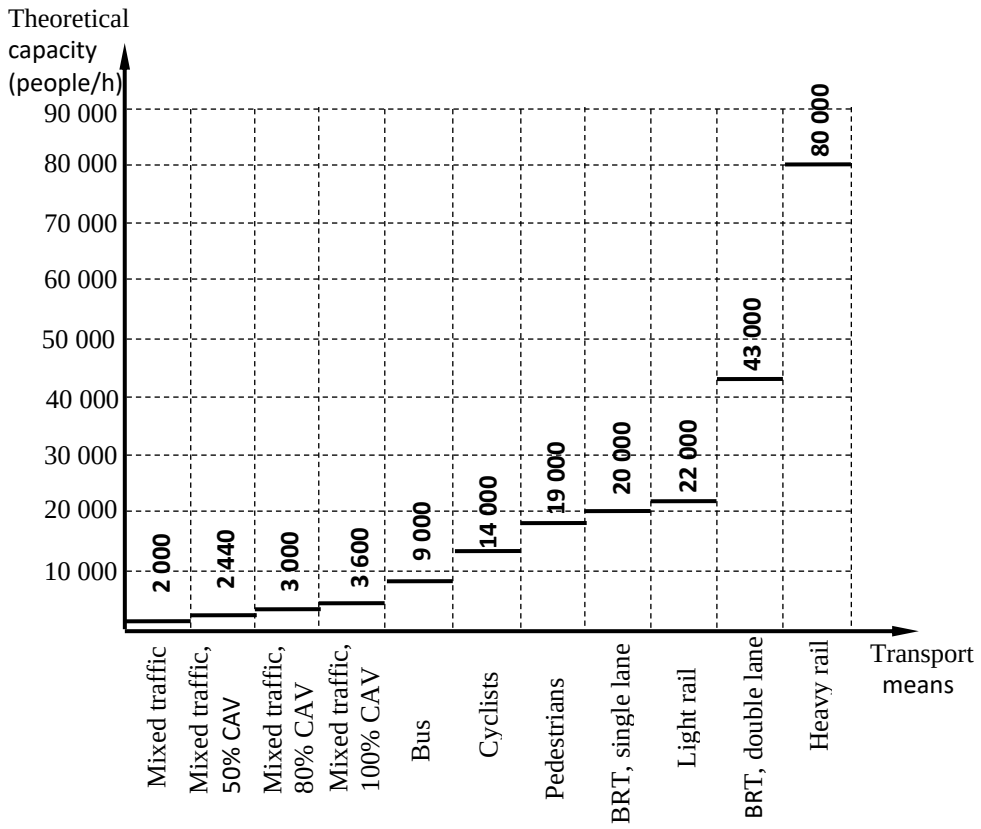


Figure 2 – Theoretical transport capacity of a lane depending on the means of transport/movement
Source: adapted from [17]

3. CASE STUDY

In order to reduce the accentuated congestion in the large urban agglomerations, one of the measures intensely promoted by the transport specialists is also the use of the public transport instead of the personal car. For this, the modes of public transport must be attractive for users and offer high quality traffic conditions, but also easier access conditions. These result from short access times to stations that depend on the density of transport's network or on the correlation that exists between the socio-economic characteristics and the transport's network. This is the case of dense networks in areas with high population density or in commercial areas or in industrial areas in order to satisfy, in superior quality conditions, the transport demand.

The need for mobility in Bucharest is met by the public transport system which is composed of subway (67 km) and surface public transport operated by the Bucharest Transport Company - STB. In this paper, the analysis was performed only on the urban surface transport modes considering the different administration of the two modes. Underground transportation is under the administration and management of Min. Transportation and surface transport under the administration and management of Bucharest City Hall.

The synthetic data valid at the end of 2018, regarding the surface public transport organized by STB are presented in table 3.

Based on these data, a correlation between the characteristics of urban public transport networks and the territorial characteristics was achieved. From an administrative point of view, the city of Bucharest is divided into 6 districts that are served by public transport through the company STB. The correlations refer to the properties of the transport networks (length, density) and the properties of the territorial system - the surface of the district, the population or its density. The intensity of the

correlation is the one that shows the quality of serving the territory with the urban public transport services and consequently the sustainability of the social system as a whole.

Table 3 – Synthetic data on surface public transport organized by STB

Number of means of transportation					
Year	**Trams**	**Trolleybuses**	**Buses**		
2018	486	265	1143		
2017	486	297	1147		
Hours in traffic (% achieved / scheduled)					
Year	**Trams**	**Trolleybuses**	**Buses**		
2018	96.97	98.48	98.72		
2017	97.74	97.11	98.45		
Mileage (% achieved / scheduled)					
Year	**Trams**	**Trolleybuses**	**Buses**		
2018	96.50	97.64	97.56		
2017	97.29	96.33	97.47		
Network length (km double-track)					
Trams		**Trolleybuses**	**Buses (Area)**		
			Urban	**Periphery**	
141		71	355	117	
Route length (km double-track)					
Trams		**Trolleybuses**	**Buses (Area)**		
			Urban	**Periphery**	
268		146	1126	216	
No. of public transport routes					
Trams		**Trolleybuses**	**Buses (Area)**		
			Urban	**Night**	**Periphery**
26		16	75	25	21
Parking and maintenance units					
Depots				**Bus parkings**	
Trams		**Trolleybuses**	**Trolleybuses**		
7		3	1	8	
7		3	1	8	

Source: [22]

In an attempt to determine whether there is a correlation between the properties of the network and those of the territorial system, the analysis is performed by subtracting from the area of the sectors the area of green spaces, lakes and leisure areas in general, which are not residential or workplaces, on the area of the city.

Unlike other European countries, Romania has a clearly deficient situation regarding the average area of green space per inhabitant, if we take into account that the WHO norm is 50 m^2/inhabitant, and the European Union standard is 26 m^2/inhabitant. Under these circumstances, the population of many cities in our country does not currently have the minimum need for green spaces (Bucharest has only an average area of 9.67 m^2/inhabitant). [23]

For the analysis of the quality of serving population with public transport in the areas delimited by the district of the Bucharest municipality, the data from table 4 were used.

The analysis of the correlation between the territorial characteristics and those of the transport network is performed by determining the correlation coefficient between the two considered quantities.

In figure no. 3 are represented the overlaid tram, bus and trolleybus networks from Bucharest city, operated by STB and the territorial administrative division in the six districts.

If n observations are made on a two-dimensional random variable a_1, b_1; a_2, b_2; ...a_n, b_n (the observations being related to the each sector's values), then the determination of the correlation coefficient C_c is made with the formula [26]:

$$C_c = \frac{\sum_{i=1}^{n}(a_i - \bar{a})(b_i - \bar{b})}{n \cdot s_a \cdot s_b} \quad (1)$$

Table 4 – The characteristics of the urban territorial system and of the transport network

Indicator			District						
			1	2	3	4	5	6	Total
Total Area (km²)			70	32	34	34	29	41	240
Leisure Area (km²)			2.68	3.56	4.47	2.90	1.72	3.30	18.63
Percentage leisure area			3.8	11.1	13.1	8.5	5.9	8.0	7.8
Useful area (km²)			67.32	28.44	29.53	31.1	27.28	37.7	221.37
Population			254,074	372,032	478,214	329,472	303,145	394,097	2,131,034
Population density (inhabitant/km²)			3,630	11,626	14,065	9,690	10,453	9,612	8,879
Population density / useful area (inhabitant /km²)			3,774	13,081	16,194	10,594	11,112	10,454	9,627
Public transportation network density (km/km²)			1.61	2.65	2.24	1.79	2.61	1.98	2.05
Public transportation network density per useful area (km/km²)			1.67	2.99	2.58	1.96	2.77	2.15	2.22
Public transportation network	Tram	%	18.0	24.1	17.8	12.3	13.7	14.1	100.0
		km	25.4	34.0	25.1	17.3	19.3	19.9	141
	Trolleybus	%	25.3	21.6	7.4	14.7	9.7	21.3	100.0
		km	18.0	15.3	5.3	10.4	6.9	15.1	71
	Bus	%	23.8	15.6	13.4	13.6	16.0	17.6	100.0
		km	84.5	55.4	47.5	48.3	56.8	62.5	355
	Total	%	22.9	17.3	15.5	12.4	15.4	16.5	100.0
		km	112.5	84.9	76.1	60.9	75.6	81	491

Source: [22], [23], [24], [25]

where $\bar{a}$ and $\bar{b}$ stand for the average values of a and b ;

n – number of measure pairs a_i and b_i;

s_a and s_b – standard deviation values for a and b.

Standard deviation values of a and b are calculated with relationship (2).

$$s_a = \sqrt{\frac{\sum_{i=1}^{n}(a_i - \bar{a})^2}{n}} \quad \text{and} \quad s_b = \sqrt{\frac{\sum_{i=1}^{n}(b_i - \bar{b})^2}{n}} \quad (2)$$

The correlation coefficient have values in the range from -1 to 1. If $C_c = 1$, then a and b are linked together by a linear functional dependence and both quantities vary in the same direction. If $C_c = -1$, then there is an inverse dependency.

The significance of the dependence between the two random variables is determined by assessing the values of the correlation coefficient. At a small selection volume (n less than 30… 50) the criterion defined by the relation 3 (C_r) can be used [26]:

$$C_r = |C_c| \sqrt{n-1} \geq 3 \quad (3)$$

If the inequality (3) is satisfied, then the obtained value of the correlation coefficient is considered real and the correlation exists. Otherwise, this deviation from zero of the evaluation is considered random.

The two-dimensional random variables considered and whose linear functional dependence was verified were:

1. Population and the total length of the public transport network in each district;
2. The area of the district and the total length of the public transport network in each district;
3. The usable area of the district and the total length of the public transport network in each district;
4. Population density and density of public transport network in each district;
5. Population density and density of the public transport network in each district (both density values being calculated for the usable area of the district);
6. Population and the useful density of the public transport network in each district;
7. Usable area of the district and useful density of the transport network.

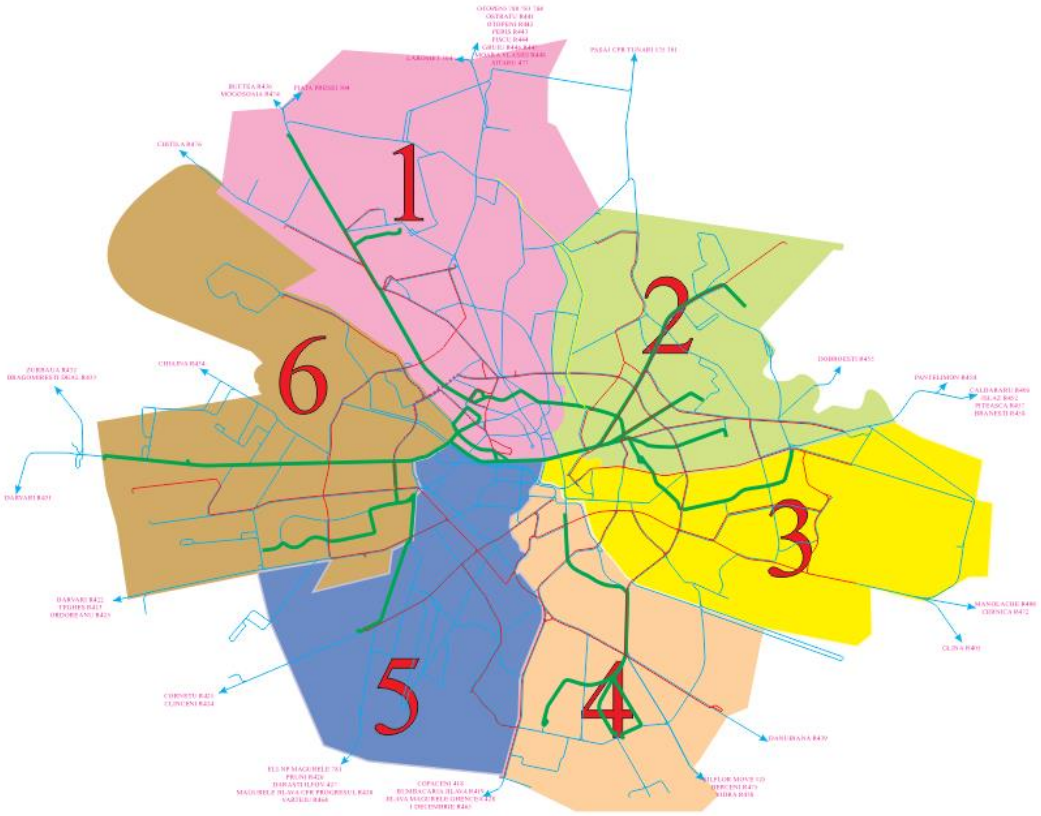


Figure 3 – The surface public transport network operated by STB

The result of the calculations are presented in table 5.

Table 5 – Identification of the linear functional connection between the considered variables

Variables \ Calculated values	$\bar{a}$	$\bar{b}$	S_a	S_b	C_c	C_r
Population (a_i) – Length of public transport network (b_i)	355,172	81.83	71,329	15.60	-0.44	0.98
District area (a_i) – Length of public transport network (b_i)	40	81.83	13.89	15.60	0.86	1.93
Useful district area (a_i) – Length of public transport network (b_i)	36.9	81.83	14.01	15.60	0.86	1.93
Population Density (a_i) – Density of public transport network (b_i)	9,846	2.15	3,164	0.39	0.67	1.50
Useful population Density (a_i) – Density of public transport network (b_i)	10,868	2.35	3,793	0.46	0.74	1.67
Population (a_i) – Density of public transport network (b_i)	355,172	2.35	71,329	0.46	0.44	0.99
Useful district area (a_i) – Density of public transport network (b_i)	36.9	2.35	14.01	0.46	0.76	1.70

From the analysis of the results presented in table 5 it is observed that we have a negative correlation between the population and the length of the public transport network (-0.44) which is in total contradiction with the principles of the sustainable development which stipulates that the development / expansion of urban areas should be done in accordance with the development of urban modes of transport. At the opposite pole, there are the variables district area - length of public transport network and useful district area - length of public transport network with a value of the correlation coefficient of 0.86 (but also quite far from unity) which could imply a good quality of service. However, this statement is debatable given that the service is addressed mainly to individuals and not to territories. From this point of view, the most important correlation would be the one between the population density - the density of the transport network, which for the analysed case varies between 0.67 and 0.74, values quite far from the unit. Equally far from the unit is the functional link between the population number - the density of public transport network (0.44).

In the analysis performed, important in the assessment is the correlation coefficient which must tend towards the value 1 to show that both quantities in question vary in the same direction and are linked by a direct linear dependence, which shows that the development of the transport network is correlated with territorial development. The significance of the dependency is given by the value of the correlation coefficient and the selection volume. In the present case, the selection volume is small and no relevant conclusions can be drawn regarding this significance.

In order to improve the situation, a detailed analysis of these correlations should be carried out on the development of areas with high population density and, depending on the results and the requirements of sustainable development, the public transport system should also be developed. Nowadays, TOD policies are the key to success in development of urban areas by creating polarizing axes around public transport.

4. CONCLUSIONS

In large cities, the traffic congestion and the pollution have reached alarming levels. For the city of Bucharest, the area occupied by parked vehicles reached 16.04km^2, which represents 6.74% of the city area. There are alarming values considering that the number of vehicles owned per 1000 inhabitants tends to reach the value of 700 vehicles and the congestion index has the value of (52%). Under these circumstances, other solutions must be found in order to reduce congestion because solutions for the development of infrastructure capacity can no longer and are no longer indicated to be used. The travel behavior of the inhabitants must be changed, who must understand that the most suitable method for reducing traffic congestion, pollution of any kind is the use of environmentally friendly modes of transport. Among them, for long distances, is the increasing use of public transport in large cities. For this, there must be an integrated development policy of urban teritorries and of public transport through which to achieve the so-called TOD policies. They aim at structuring/coagulating the transport modes around an axis given by the high capacity public transports. In the paper, we explored if urban expansion is correlated with the development of the public surface transport system that must take over more and more important flows and faces peak periods with an increasing amplitude and intervals.

Out of a total of 491km of surface public transport network, 355km (72.3%) represent the bus transport network. The transport made by buses has the advantage of a great flexibility in operation but the restrictions imposed by the environmental protection and those of sustainable development are not observed.

The trolleybus and tram networks are the least developed (27.7%) and they are the ones that should have the highest extension and density given the indisputable advantages of electric transport in large cities. These include the reduction of chemical pollution and especially the high transport capacity (for trams) which leads to compliance with the directions of sustainable development which

indicates that cities should not be allowed to develop except to the extent that they can be served by population high capacity transportation.

From the analysis of the linear functional connection it is observed that between the population of the districts and the total length of the public transport network, the correlation tends to be more negative, which is not at all in accordance with urban development (C_c = -0.44).

The best correlation that tends towards a linear functional connection is the one between the surface of the districts and the length of the public transport network (C_c = 0.86), the same value being for the correlation of the useful surface to the sectors and the length of the public transport network (C_c = 0.86).

No conclusion can be drawn on the significance of the dependence between the two random variables discussed because the values are very far from the indicated value, 3. The closest to this value are the area of the sectors and the length of the public transport network and districts and the length of the public transport network.

The analysis concludes that the expansion of the surface public transport network has not been developed in accordance with the needs of socio-economic areas and in the future the planning activity must be done in accordance with present and future development elements, taking into account that policies sustainable development will have to be rigorously respected in meeting the mobility needs of large urban agglomerations.

ACKNOWLEGEMENT

This work has been funded by the European Social Fund from the Sectoral Operational Programme Human Capital 2014-2020, through the Financial Agreement with the title "Scholarships for entrepreneurial education among doctoral students and postdoctoral researchers (Be Antreprenor!)", Contract no. 51680/09.07.2019 - SMIS code: 124539.

REFERENCES

[1] Raicu Ş, Costescu D. Teme ale mobilităţii contemporane – Examinări interdisciplinare [Topics of contemporary mobility - Interdisciplinary examinations], *Buletinul AGIR* nr. 2/2016, Romanian. Available from: https://www.buletinulagir.agir.ro/articol.php?id=2668 [Accessed 11th Febr 2019]

[2] Zahavi Y, Talvitie A. Regularities in Travel Time and Money Expenditures. *Transportation Research Record*, 750, 1980, 13-19.

[3] Crozet Y. Mobilité: Les gains de temps ne sont plus qu'ils étaient. Mobile, Immobile: Choices and Rights for 2030, *Ed. De L'Aube*, Forum Vies Mobiles, 2011, 68-79.

[4] Banister D. Reducing the need to travel, *Environmental and Planning B: Planning and Design*, Vol. 24, 1997, 437-449

[5] De Luca S, Di Pace R, Memoli S, Pariota L. Sustainable Traffic Management in an Urban Area: An Integrated Framework for Real-Time Traffic Control and Route Guidance Design, *Sustainability* 2020, 12, 726; Available from: doi:10.3390/su12020726 [Accessed 22th February 2020]

[6] Raicu Ş. *Sisteme de transport* [*Transport systems*]. Publishing house AGIR, Bucharest, 2007, Romanian

[7] Newspaper - *Univers ingineresc* [*Engineering universe*] nr.3 (697), 1-15 februarie 2020, Romanian

[8] Available from: https://www.drpciv.ro/

[9] Dragu V, Burciu Ş, Roman E. A. Dezvoltarea transportului public urban de mare capacitate – Soluţie pentru un oraş inteligent [Development of high capacity urban public transport - Solution for a smart city], *Buletinul AGIR* nr. 1/2017, Romanian. Available from: https://www.buletinulagir.agir.ro/articol.php?id=2818 [Accessed 26th March 2020]

[10] Henke I, Cartenì A, Molitierno C, Assunta Errico A. Decision-Making in the Transport Sector: A Sustainable Evaluation Method for Road Infrastructure, *Sustainability* 2020, 12, 764. Available from: doi:10.3390/su12030764 [Accessed 12th April 2020]
[11] Pagliara F, Biggiero L, Henke I. The Environmental Impacts Connected with Travelling to events: The Case Study of the City of Naples in Italy. *In Proceedings of the 2019 IEEE International Conference on Environment and Electrical Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)*, Genova, Italy, 11–14 June 2019
[12] Carteni A. Urban sustainable mobility. Part 2: Simulation models and impacts estimation, *Transport Problems*, 2015, 10, 5–16, [Accessed 1th May 2020]. Available from: https://www.exeley.com/transport_problems/doi/10.21307/tp-2015-001,
[13] Carteni A. A cost-benefit analysis based on the carbon footprint derived from plug-in hybrid electric buses for urban public transport services. *WSEAS Trans. Environ. Dev*. 2018, 14, 125–135.
[14] May A, Koh A, Blackledge D, Fioretto M. Overcoming the barriers to implementing urban road user charging schemes. *European Transportation Research Review* 2010, 2, 53–68. Available from: https://etrr.springeropen.com/articles/10.1007/s12544-010-0026-1 [Accessed 1 th May 2020]
[15] European Commission (2013) *Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan*. Available from: http://www.eltis.org/sites/eltis/files/guidelinesdeveloping-and-implementing-a-sump_final_web_jan2014b.pdf
[16] Pettersson F, Hreljab R. How to create functioning collaboration in theory and in practice – practical experiences of collaboration when planning public transport systems, *International Journal of Sustainable Transportation,* 2020, Vol. 14, No. 1, 1–13, Available from: https://doi.org/10.1080/15568318.2018.1517842 [Accessed 18th February 2020]
[17] Veryard D, Perkins S. *Integrating Urban Public Transport Systems and Cycling,* Summary and Conclusions of the Internetional Transport Forum-OECD, Roundtable on Integrated and Sustainable Urban Transport, 24-25 April 2017, Tokyo
[18] Olaru D, Moncrieff S, McCarney G, Sun Y, Reed T, Pattison C, Smith B, Biermann S. Place vs. Node Transit: Planning Policies Revisited, *Sustainability* 2019, 11, 477. Available from: doi:10.3390/su11020477 [Accessed 28th January 2020]
[19] Attard M, Shiftan Y. Sustainable Urban Transport – An Introduction. In Sustainable Urban Transport*;* Attard, M., Shiftan, Y., Eds.; *Emerald Group Publishing Limited*: Bingley, UK, 2015; p. 14–24.
[20] Nasri A, Zhang L. How Urban Form Characteristics at Both Trip Ends Influence Mode Choice: Evidence from TOD vs. Non-TOD Zones of the Washington, D.C.Metropolitan Area, *Sustainability* 2019, 11, 3403. Available from: doi:10.3390/su11123403, [Acessed 1th May 2020]
[21] Freudendal-Pedersen M, Kesselring S, Servou E. What is Smart for the Future City? Mobilities and Automation, *Sustainability* 2019, 11, 221. Available from: doi:10.3390/su11010221, [Accessed 1th May 2020]
[22] STB - Available from: http://stbsa.ro/docpdf/RAPORT%20DE%20ACTIVITATE%202018.pdf
[23] Chiriac D, Humă C, Stanciu M. Spaţiile verzi – o problemă a urbanizării actuale [Green spaces - a problem of current urbanization], *Calitatea vieţii*, XX, nr. 3-4, 2009, p. 249-270
[24] Available from: https://bucuresti.insse.ro/despre-bucuresti/
[25] Available from: https://bucuresti.insse.ro/wp-content/uploads/2019/07/POPULATIA-LA-1-IANUARIE-2019.pdf
[26] Dragu V. *Trafic urban şi suburban de călători – Îndrumar de laborator* [*Passengers Urban and Sub-urban Traffic – Student activities guide*], BREN Publishing house, Bucharest, 2001.

BERNHARD RÜGER, FH-Prof. Dr.[1]
E-mail: bernhard.rueger@tuwien.ac.at
[1] Vienna University of Technology, Research Center for Railway Engineering
Karlsplatz 13/230-2,A-1190 Wien, Austria

IMPROVED OPERATING QUALITY THROUGH OPTIMIZED VEHICLE LAYOUTS BY MEANS OF SIMULATION

ABSTRACT

In addition to customer comfort, the degree of capacity utilization and the passenger exchange time are key factors influencing the quality of rail operations and efficiency. Further important factors for the shortest possible passenger exchange time are the adequate and customer-friendly dimensioning of luggage racks as well as the overall layout and the arrangement of the doors.

KEY WORDS

efficient rail vehicles; interiors simulation; occupancy rate; dwell time

1. INTRODUCTION

The design and development of modern passenger coaches often follows the principle of seat maximisation, with the aim of transporting as many passengers as possible and thus increasing efficiency and economy.

However, the intensive scientific investigation of passenger wishes and needs as well as actual passenger behaviour under real conditions prove that instead of the expected increase in efficiency, in reality there is a loss of efficiency! In addition to a decline in passenger satisfaction, in reality the achievable seat occupancy rate decreases and the passenger exchange time increases noticeably. This in turn leads to more delays, which have to be reduced with higher energy consumption, and to a decrease in operational quality.

2. DATA BASIS - SIMULATION

Based on the twenty years of know-how of the Research Center for Railway Engineering at the Vienna University of Technology in cooperation with the company netwiss including: extensive investigations and data collection in the field of passenger behaviour in rail vehicles (observations of the behaviour of around 300,000 passengers in about 100 different types of vehicles, surveys of about 50,000 passengers and analysis of about 20,000 passengers during passenger exchange) algorithms were developed by the company netwiss that exactly map the specific behaviour of rail passengers. Taking into account different basic conditions such as travel purposes, age distribution or region-specific influences, this makes it possible to compare different vehicle layouts in order to find out which vehicle layouts are best suited for stowing luggage, which layout has the highest number of seats that can actually be used leading to a maximum seat occupancy as well as which layout has the shortest passenger exchange time (*Figure 1***Error! Reference source not found.**).

These special algorithms based on data from real operation led to the development of the vehicle simulation software **TrainOptimizer®** at www.TrainOptimizer.com. When planning or ordering new vehicles or when redesigning existing vehicles using the know-how described above, it is now possible with the help of TrainOptimizer® to determine with just a few clicks the most efficient layout variants in terms of best possible luggage stowage, highest possible seat occupancy and shortest possible passenger exchange times. The algorithms and thus the software TrainOptimizer® can be applied to all

public transport vehicles: from high-speed trains to intercity trains, local trains, metros, trams and buses.

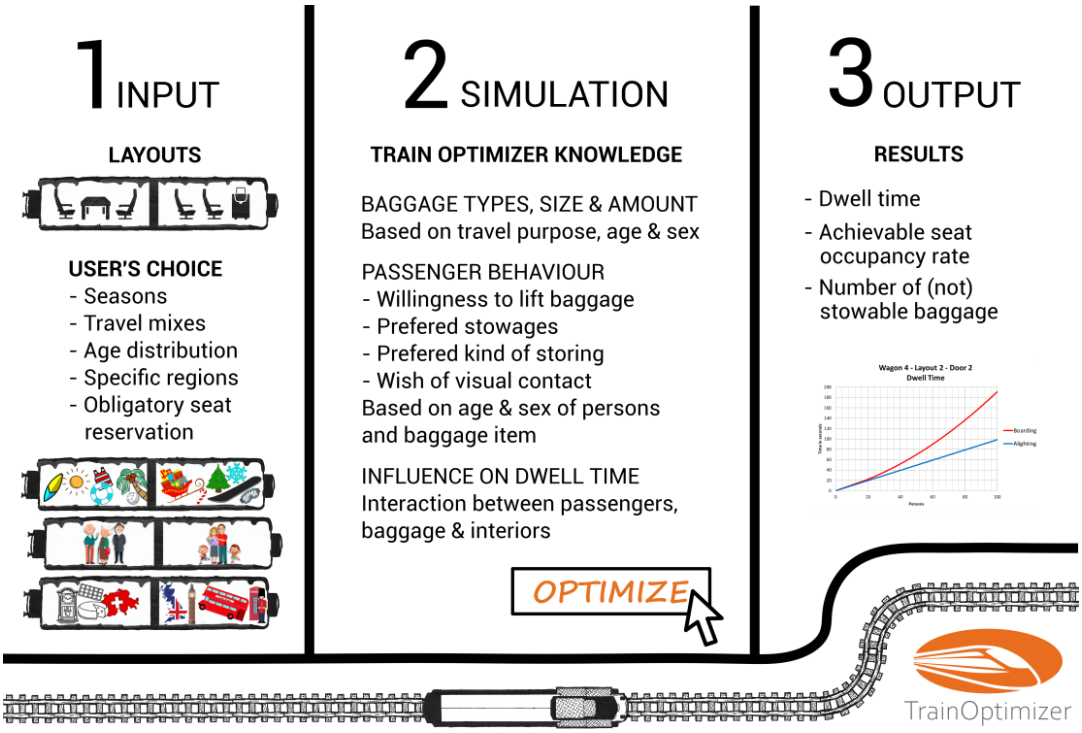


Figure 1 – Schematic functional sequence of TrainOptimizer®
Source: [7]

3. PASSENGER BEHAVIOUR VERSUS OPERATING QUALITY

There are two situations during a train journey in which the interaction of passengers with the existing vehicle layout has a significant impact on the quality of operation. They include boarding and deboarding as well as luggage storage during the journey, and both are directly related to one another.

3.1. Luggage Storage

Two factors have a significant impact on luggage accommodation. On the one hand, sufficient capacity must be available for the storage of luggage and on the other hand, passenger needs must be considered extensively with regard to luggage storage, which if disregarded will lead to negative behaviour from an operational point of view.

Passenger needs are simple and understandable but can become complex challenges when designing vehicles. The two main needs are [4]:

- Passengers do not want to lift larger pieces of luggage.
- Passengers want visual contact with their luggage.

3.1.1. Lifting and manipulating luggage

The primary distinction to be made is which luggage must be lifted. Smaller and lighter items of luggage are more likely to be lifted than larger and heavier items. The willingness to lift luggage can be divided into three *"comfort levels".* The ***"Comfort"*** level takes into account those travellers who are already willing to lift their luggage on their own initiative. The ***"Standard"*** level takes into account those passengers who are reluctant to lift their luggage but who do so when circumstances require it. The ***"Limit"*** level takes into account the luggage actually lifted in fully occupied wagons [4]. This limit value can only be determined with the help of the "observation" method described above. This is

because depending on the situation, passengers provide different information in surveys than they would in reality, especially in borderline situations in which they behave as if the train is fully loaded.

Parallel to the basic willingness to lift luggage, a distinction must be made as to the height to which luggage must be lifted. In this respect, readiness to lift is divided between two heights: the first being a height of about one metre, which is used for luggage racks and the second being the height of an overhead rack, usually about 1.8 metres [5].

Since the required lifting not only determines the stowability of luggage in racks and is therefore an essential factor in the quality of operations but also has a significant impact on passenger comfort and thus passenger satisfaction, it is desirable whenever possible to strive to always apply the 'comfort' level. In particular, this level should be applied in coach classes with a higher level of comfort such as first class or higher. In second class, the "Standard" level may also be applied where appropriate. The "Limit" level reflects the limit that can just about be reached. In practice, no more luggage than defined in this level will be lifted.

Furthermore, the willingness to manipulate luggage must also be considered. This refers to whether passengers are willing to tilt or turn luggage. This is particularly important for all those stowage spaces into which luggage must be "threaded" such as under seats or between seat backrests when seat spacing is tight. In general, passengers do not wish to manipulate their luggage for accommodation purposes and in practice do not do so. It must therefore be possible to stow luggage in the same way as it is transported by passengers. Trolleys transported in an upright position on two or four wheels must be parked in an upright position. Travel bags should be stored in a horizontal position if possible ideally at a height of approx. one meter, which corresponds to the middle compartment in luggage racks. Smaller or medium-sized trolleys, which passengers are more willing to lift, are often stored lying down in luggage racks, for example [5].

3.1.2. Visual Contact with Luggage

For about 90% of passengers it is important for reasons of subjective security to have their luggage in view during the journey. In order to establish visual contact, approximately 75% of passengers are also explicitly prepared to place their luggage in a manner which impedes seat occupancy or passenger flow (e.g. on or in front of seats or in the aisle) [4].

3.1.3. Storage Space Dimensioning

In addition to the above-mentioned principles, it is also essential to provide sufficient luggage storage capacity. For this purpose, precise knowledge of the average luggage volume in the intended area of use of the vehicles is important. Furthermore, luggage must always be viewed in three dimensions. In practice, the volume of luggage is often taken as a basis, but this corresponds to a one-dimensional view. Here, any cross-sectional areas, e.g. between seat backrests are often used and multiplied by the available depth, e.g. from aisle to window. All volumes obtained in this way are summed up to form a total volume for luggage storage in the vehicle, which makes large luggage storage capacities seem likely. In practice, many of these cross-sectional areas cannot be used at all as the dimensions of the luggage are larger than the respective cross-sectional areas!

3.2. Effects of Insufficiently Dimensioned Luggage Racks

Failure to comply with the above-mentioned requirements for luggage storage means that travellers are either unable to store their luggage at all because there is too little storage space available in practice, or they do not make sufficient use of the available racks because they do not meet the basic needs of visual contact or avoidance of lifting operations. This leads, for example, to overhead racks remaining partially unused and yet luggage not being stowed properly.

In both cases, pieces of luggage that cannot be stowed away are placed close to the passengers on or in front of seats or in the aisle. Non-stowable luggage results in seats being blocked and passengers

having to stand at full capacity. On average two to three pieces of luggage that have not been properly stowed will result in the effective loss of a seat [2].

3.3. Passenger Exchange

Passenger exchange is a highly complex process and an interaction between passenger characteristics and the overall vehicle layout. Passenger-specific influencing factors are age and gender, any physical restrictions and the luggage carried, which in turn depends on the chosen purpose of the journey.

The vehicle layout gives rise to three main areas with different influences. These are: the entrance door, the entrance area, which can also serve as a catchment area especially in local traffic and the entire interior, which essentially corresponds to the seating area. At the entrance door, the door width, the gap between platform and vehicle and the number of steps have a significant influence. The design of the boarding area determines how well passengers can continue into the seating area and how many passengers can remain in it in case of a bottleneck so that the train can still depart [3].

There are several influencing variables in the interior. The stowability of luggage has a significant influence. As described above, pieces of luggage that cannot be stowed are sometimes parked in the aisle area, where they block the flow of passengers. Another influence is the simplicity of luggage storage. Ideally, if passengers can deposit their luggage "in passing" and then go straight to the nearest seat, the flow of passengers is faster than if passengers have to manipulate their luggage several times for storage. The passenger flow slows down considerably especially when luggage has to be lifted to be stored in the overhead storage or when the distance between two seat backrests is too short and the luggage can only be stored by tilting, if at all [3].

Furthermore, the aisle width and possible alternative spaces have an important influence on passenger flow. The width of the aisle is important for the ease of movement with luggage as well as when people are busy stowing their luggage with other passengers trying to pass by.

4. DESIGN PRINCIPLES IN VEHICLES

In order to achieve a high degree of seat occupancy and at the same time the shortest possible passenger exchange time, the following principles must be observed:

4.1. Luggage Racks

The luggage racks should comply with the above principles of visual contact and avoidance of lifting, especially the lifting of large pieces luggage up to the height of the overhead storage. When dimensioning luggage racks, for reasons of efficiency reference may be made to the actual willingness of different passengers to lift luggage. Smaller and medium-sized pieces of luggage, which tend to be lighter, are placed by passengers to a greater extent in the overhead rack, larger pieces of luggage to a lesser extent of approx. 20% [4]. This means that the calculation may well be based on overhead storage but only to the extent that passengers are willing to use it and not per se for all luggage.

It is also important to note that luggage racks are well distributed in the seating area. This applies in particular to luggage racks and the space between the seats. A good distribution leads to appropriate use, as most travellers can see their luggage. At the same time, distribution also means that luggage can be more easily stowed by passengers, thus allowing passengers to change seats more quickly.

It is absolutely necessary to avoid placing luggage racks in the boarding area of vehicles, as these are only used up to approx. 30% for visual security reasons [5]. If they are used, the luggage being stowed very close to the boarding door may lead to a bottleneck of boarding passengers. The same applies to luggage racks in the interior of the vehicle that are located immediately after the entrance

to the seating area [3]. A distance of at least two rows of seats to the first luggage rack and a good distribution of the luggage racks along the entire vehicle is better.

In addition to the arrangement of the luggage racks, it is essential to know the exact quantity and type of luggage to be expected. The type of luggage or the appropriate mix determines the required dimensions of the luggage racks. Racks that are too narrow by only a few centimetres often mean that certain pieces of luggage cannot be stowed at all or only in such a way that there is no further useable free space, which makes the racks inefficient. At the same time, care must be taken to ensure that all luggage items can be accommodated in terms of quantity, especially for all those areas of use and travel purpose mixes where full utilisation of the vehicle is expected and desired. Under no circumstances should only the total volume of the luggage and also the luggage racks be determined and then compared with each other!

4.2. Overall Vehicle Concept

The entire vehicle concept has a significant influence on the passenger exchange time. This already starts with the rail coach bodies. Shorter and thus wider coach bodies have the advantage of allowing wider aisles in addition to the advantage of up to 50% lower tare weight per seat and the resulting effect of large energy savings [1]. Aisles with a width of more than 60cm allow up to 25% shorter passenger exchange times than those with a width of 50cm [3].

Another important factor is the arrangement of the doors. The classic arrangement at the two ends of the coach means that an average of 50% of the passengers per coach have to enter through one door and then also have to walk through the same interior. Since the boarding time in the respective coach interiors essentially follows a square parabola, a higher number of passengers passing through a cross-section leads to a disproportionate increase in passenger exchange time. If on the other hand, the doors are arranged in such a way that the passenger flow can be divided up when passengers enter the boarding area, the passenger exchange time can be significantly reduced [3]. On the one hand, the number of people entering the respective passenger compartment through a cross section is halved if the doors are well located, which leads to a noticeable reduction of the boarding time. On the other hand, the division of passengers also reduces tailback effects from the seating areas.

If the seating area follows immediately after a small interior, then tailback effects from the interior are very quickly shifted to the entrance. If the way to the seating area is longer, for example due to toilets or other obstructions, tailback effects from the seating area are also reduced [3].

In the seating area described above, consideration should be given to ensuring good division as well as correct and adequate planning of luggage racks. In addition, well-distributed spreading spaces should be created. This can be done by ensuring that tables in vis-á-vis seating groups do not reach as far as the aisle, but are approx. 10 to 15 cm shorter. Likewise, luggage racks should be moved away from the aisle; this creates equally good alternative space [4].

5. EXAMPLE LAYOUT COMPARISON

In the following, two layouts which are deliberately similar in structure are compared in order to illustrate the effects that the correct consideration of luggage racks has on the achievable seat occupancy rate and passenger exchange time. If the overall concept is fundamentally revised, for example by shortening the coach body and changing the arrangement of the entrance doors, even more significant differences can be seen.

The two layouts are fictitious examples and are not in actual use in the form shown. In both cases they are classic passenger coaches, in layout 1 with 100 seats and except for two small racks, mainly overhead racks for luggage storage. In layout 2, only 88 seats are available, and there are more suitable luggage storage options to meet passenger requirements (*Figure 2* & *Figure 3*). The luggage racks have

three compartments in all cases, measured from below at a height of 80 - 40 - 40 cm with the overhead rack above.

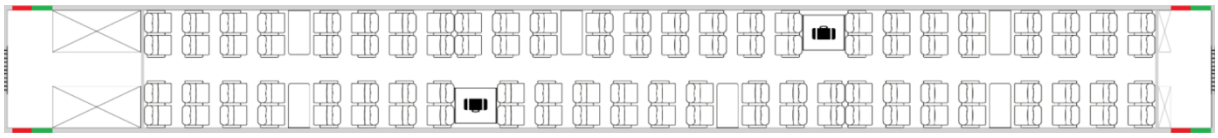


Figure 2 – Example layout 1
Source: [7]

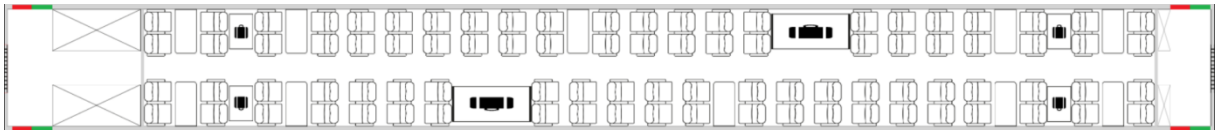


Figure 3 – Example layout 2
Source: [7]

Three equally fictitious travel purpose mixes are given below. One assumes that the majority of business travellers use the train, in a second example these are mainly holiday travellers and in a third example it is additionally assumed that an international airport is served on main travel days, which on average also induces a 20% higher luggage volume.

Luggage is considered to be only those items which are checked luggage in air travel. Luggage that may be taken on board an aircraft cabin is considered hand luggage and is not evaluated in the following; as it is assumed that it can in any case be accommodated or at least does not exert any serious negative influence.

As comfort level regarding the willingness to lift, the level "limit" is taken, which represents the limit actually occurring in real operation and should actually not be used as a basis for the calculations; as it no longer meets the expectations and comfort requirements. However, in order to show the limits of use this example deliberately uses "operator-friendly" calculations.

5.1. Luggage Accommodation and Seat Occupancy Rate

Figure 4 shows that 31 pieces of luggage are stowable in layout 1 and 66 in layout 2. On days with a higher proportion of business travel every second piece of luggage is not stowable in layout 1, but all pieces of luggage are stowable in layout 2. On days with a higher proportion of holidaymakers, two out of three pieces of luggage are not stowable in layout 1, while only 17 pieces of luggage are not stowable in layout 2 [7].

When travelling by plane on busy travel days, it can be assumed that the luggage volume is about 20% higher than when travelling by train on busy travel days [6]. This circumstance therefore represents an upper limit with regard to the amount of luggage. In Figures 4 and 5, "Airport" means that the purpose of the journey is to ensure that only air passengers are on the train. In this borderline situation, the share of non-stowable luggage is again increased but is rather a theoretical limit value consideration as it cannot be assumed that in practice all persons in the coach are air passengers with corresponding flight luggage.

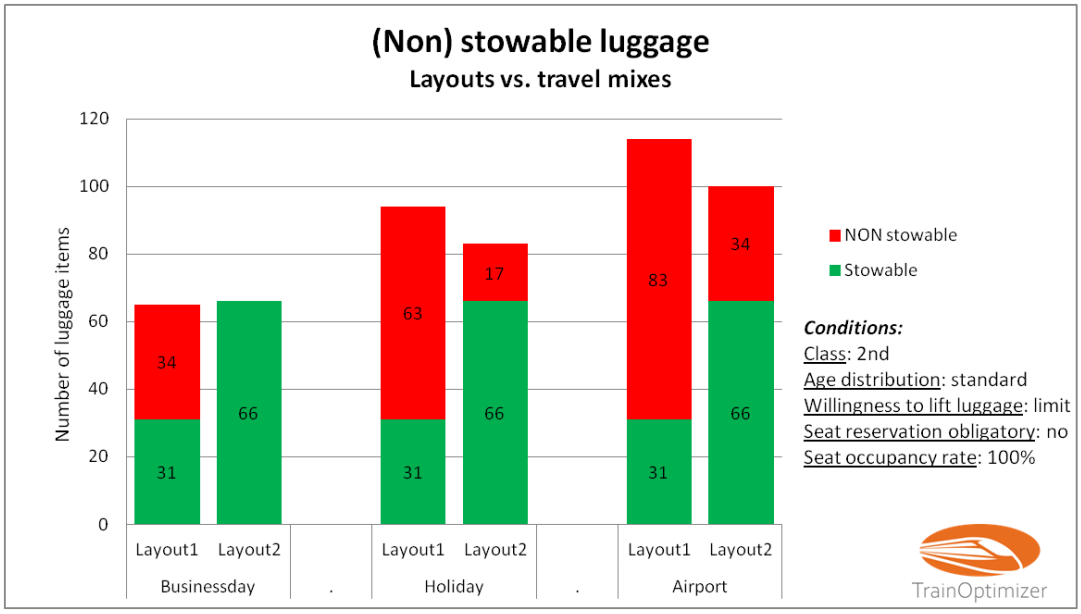


Figure 4 – (Non) stowable luggage in layout comparison
Source: [7]

In addition to severe comfort restrictions and general problems such as security problems or delays in passenger transfer caused by pieces of luggage that cannot be stowed properly, the pieces of luggage that cannot be stowed result in the fact that with layout 1 not all seats can be used in any of the travel purpose scenarios. Even on days with a higher proportion of business travel, only 89 of the 100 seats are available, and in layout 2 all 88 seats are available. On days with a higher proportion of holiday travellers, only 77 seats are actually available on average for layout 1 and at least 82 seats for layout 2 (*Figure 5*) [7].

This analysis clearly shows that there is no added value in maximising the number of seats, since in any case no more than 89 seats can ever be used. A reduction in the number of seats therefore not only leads to a noticeable gain in comfort for the travellers but also the majority of times to an even higher proportion of available seats.

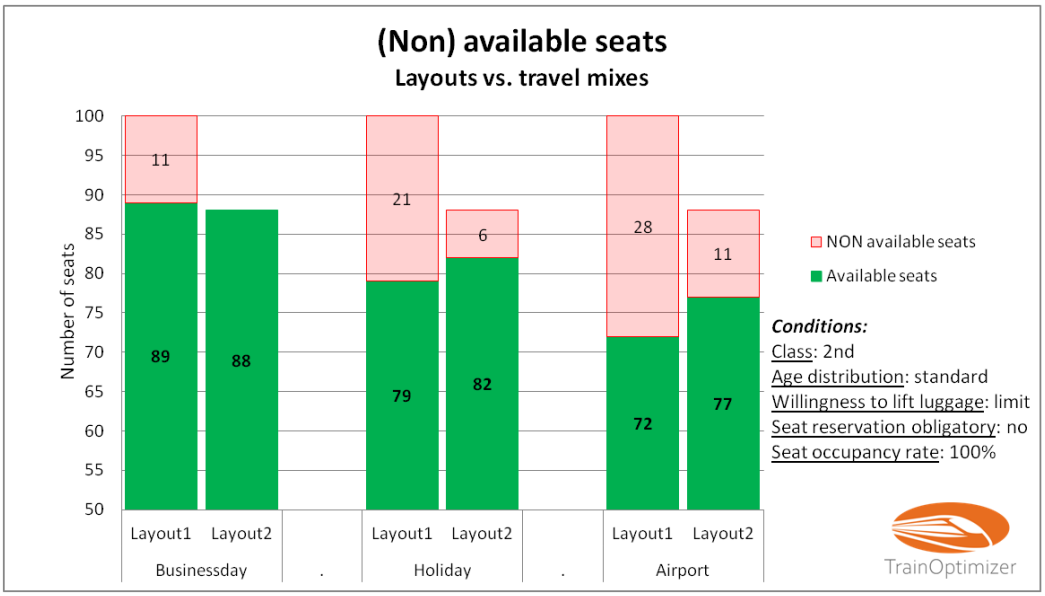


Figure 5 – (Non) available seats in layout comparison (depending on travel purposes)
Source: [7]

5.2. Passenger Exchange Time

The time required for boarding increases more than linearly as the number of passengers boarding increases (*Figure 6*). The calculations are based on a travel purpose mix with a higher proportion of holidaymakers. Furthermore, it can be seen that the time required for layout 2 with improved luggage accommodation (higher capacity, better distribution in the vehicle) and better siding possibilities increases to a lesser degree. For example, 40 boarding passengers need on average 210 seconds for layout 2, whereas the time required for 40 persons for layout 1 is already 50% higher with an average of 310 seconds [7].

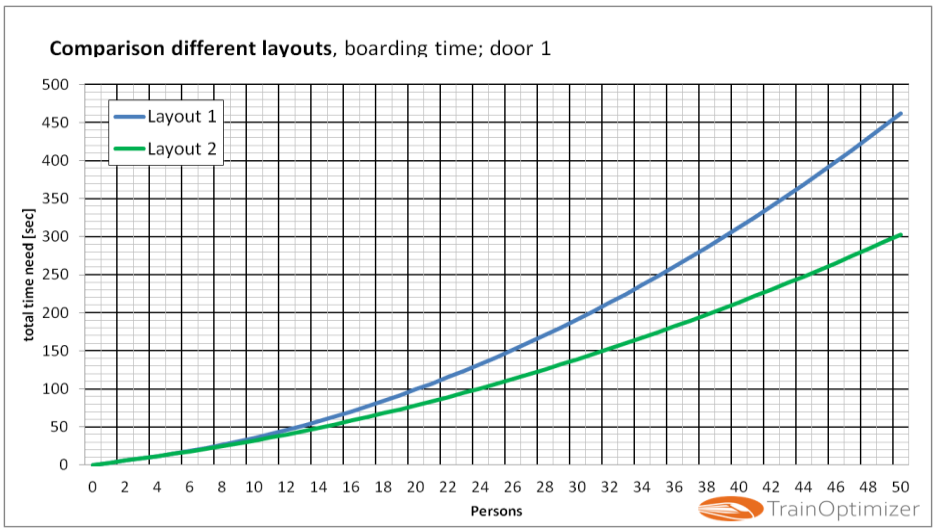


Figure 6 – Time required for boarding passengers during layout comparison
Source: [7]

The time required for a so-called 60% passenger exchange is shown in Figure 7. This includes both boarding and deboarding passengers. A 60% passenger exchange is a frequently requested comparative value for calculations which states that 60% of the passengers of a fully occupied coach exit and the same number of passengers enter. With layout 2, the lower number of seats per door also results in a three person lower number of passengers.

The boarding time for the 60% passenger exchange is just over three minutes, which is about 30% higher than for layout 2, and the total passenger exchange time including passengers deboarding still differs by 25%! [7]

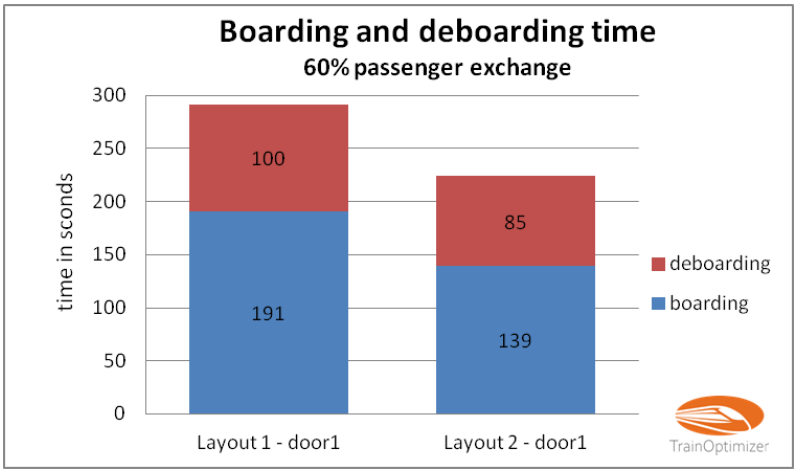


Figure 7 –Time required for a 60% passenger exchange in the layout comparison
Source: [7]

6. CONCLUSION

The vehicle layout and the associated interior design have an influence on operating quality in many ways. The correct and sufficient dimensioning of luggage racks has a significant influence. Luggage racks that do not meet passengers' basic needs, such as the desired visual contact with luggage or avoiding the lifting and manipulation of larger items of luggage, result in many items of luggage being stored in a manner that impedes passenger flow. This leads to a decreasing seat occupancy rate and significantly longer passenger exchange times. A lower number of seats if properly planned, leads to more seats being available in total even in absolute terms and to reduced dwell times.

The differences shown in this essay between the two **TrainOptimizer®** simulated variants, which differ from each other essentially only in the area of improved luggage accommodation, make it clear that with 12% fewer seats the proportion of usable seats remains at least the same or is even higher than in the seat-maximized variant with 100 seats. At the same time, the passenger exchange time is approx. 25% less with a 60% passenger exchange! If in addition to the improvement of the luggage systems, further principles for optimisation are taken into account such as shorter coach bodies with the resulting wider aisles or the arrangement of the entrance doors in the middle for short coach bodies, further significant improvements are possible especially in passenger exchange.

REFERENCES

Journal Article: Print

[1] Fritz F. The future of the railway. ZEV (Glasers Analen) 110. May 1986, 124-134
[2] Rüger B, Cis P. Auslastung in Eisenbahnwagen - Kapazität abhängig vom Verhalten des Fahrgastes (engl: Capacity utilisation in railway coaches - capacity depends on passenger behaviour); ETR - Eisenbahntechnische Rundschau. 3 (2010).
[3] Rüger B, Tuna D. Fahrzeugseitige Optimierungspotenziale zur Verkürzung der Haltezeit (engl.: Vehicle-side optimisation potential for reducing the dwell time). ETR - Eisenbahntechnische *Rundschau*. 09 (2008). 526 - 532.

Diploma and Bachelor Theses

[4] Plank V. Dimensioning of luggage racks in passenger trains. Diploma thesis. TU-Vienna; 2008.
[5] Feiel R. Luggage accommodation in long-distance trains - luggage racks; Bachelor Thesis. FH-St.Pölten, Department of Rail Technology and Mobility; 2015.
[6] Feiel R. Luggage volume in intermodal long-distance traffic. Master Thesis. FH-St.Pölten, Department of Rail Technology and Mobility; 2017.

Software

[7] Simulation with **TrainOptimizer®** simulation software - Beta Version, available on www.TrainOptimizer.com

FLORIN RUSCA, Ph.D.[1]
E-mail: florin.rusca@upb.ro
EUGEN ROSCA, Ph.D.[1]
E-mail:eugen.rosca@gmail.com
MUHAMMAD AZMAT, Ph.D., MSc.[2]
E-mail: mazmat@wu.ac.at
HERIBERTO PEREZ-ACEBO, Ph.D.[3]
E-mail: heriberto.perez@ehu.eus
AURA RUSCA, Ph.D.[1]
E-mail:aura.rusca@upb.ro
SERGIU OLTEANU, Ph.D.[1]
E-mail:sergiu.olteanu@upb.ro
[1] University Politehnica from Bucharest, Faculty of Transport
Spl. Independentei, No 313, District 6, Bucharest Romania
[2] Institute for Transport and Logistics, Vienna University of Economics and Business
Welthandelspl. 1, 1020 Wien, Austria
[3] University of the Basque Country, Faculty of Engineering Bilbao
P[0] Rafael Moreno "Pitxitxi", 2 48013 Bilbao Spain

MODELING THE TRANSIT OF CONTAINERS THROUGH QUAY BUFFER STORAGE ZONE IN MARITIME TERMINALS

ABSTRACT

The maritime container terminal allows the transfer of container flows from maritime vessels to the land transport network and vice versa. The transit capacity through the terminal is affected by the handling capacity of the equipment at the terminal, by the size of the storage areas and least by the technologies used in handling and storing the containers in the terminal. In this paper, the influence of these last two technologies on the duration of the process of unloading/loading of sea vessels within the terminal is analyzed. A discrete simulation model is used to evaluate the sizing method for short-term storage area located on the dock. The manner of allocating the flows of containers on it, as well as the working technology of the handling equipment, have an influence on the number of containers taken over, respectively loaded on the maritime vessels. The simulation model topology is developed following the existing physical structure of a container terminal from Constanta Port, in Romania. The obtained results can help the administration of the container terminal in optimizing the activity of handling, storing, and transferring the flows of containers from the maritime environment to the mainland and vice versa.

KEYWORDS

maritime terminal; productivity; simulation model; container terminal

1. INTRODUCTION

The connection between the mainland transport networks and the maritime vessels for the flows of containers is conducted in the container terminals located inside the seaports. The qualitative parameters of the level of service inside the terminal, such as the duration of the process of unloading/loading of maritime vessels, may influence the entire logistics chain, which is transiting the maritime container terminal. Therefore, it is necessary to analyse its influence on the process: the organization of the terminal in the area of action of quay cranes, the number of handling equipment, and not in the last case of the technology used within the process. If the productivity of the quay cranes is not following the productivity of the handling equipment within the terminal, the accumulation of

containers in the storage area on the docks can lead to blocking the unloading/loading process of the ship. This storage area acts as a buffer between the operations carried out by the quay cranes, and the rest of the operations carried out inside the terminal. The spatial limitation of this area, for constructive reasons, due, for example, to the existence of an active area of the quay cranes, does not allow an over-dimensioning of it, which could take over the lack of existing coordination in the productivity of the handling equipment within the terminal.

The main flow through the container terminal is from the mainland transport networks to the maritime vessels, respectively, from these last ones to the port hinterland (Figure 1). The discontinuity of the transport process leads to the necessity of storing the containers inside the maritime terminals while waiting for the maritime vessels or the means of terrestrial transport (trains or trucks).

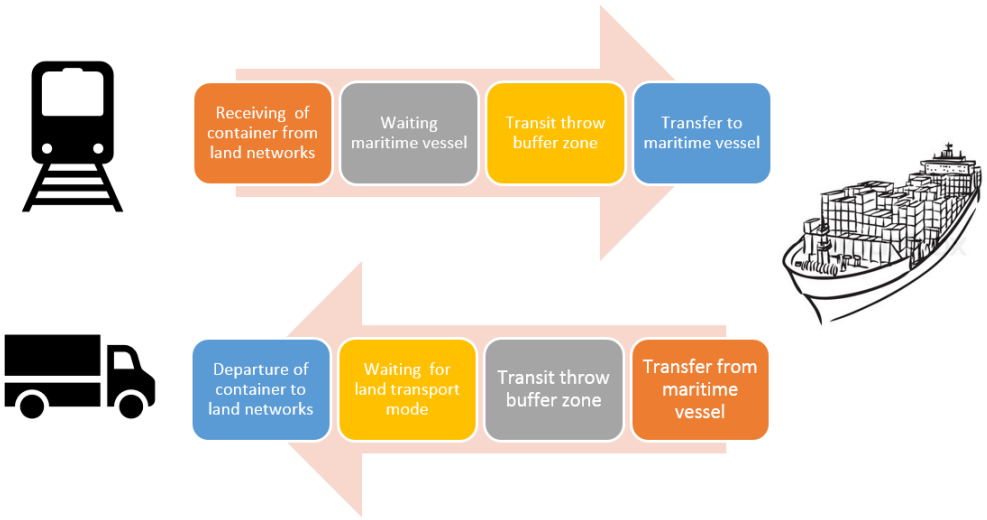


Figure 1 – The main activities inside the maritime container terminals

The transfer from/to the storage area of the container terminal to the maritime berth is conducted with the help of the handling equipment. If the productivity of quay cranes is higher than the total productivity of the handling equipment inside the terminal, the buffer storage area located on the maritime berth should be able to take over the containers that are to be loaded or which have been unloaded. In the case the storage capacity of the buffer area is reached, the duration of the process of unloading/loading of the vessels is increased. This fact can lead to negative economic issues for container terminal administration. For this reason, it is necessary to model the process of unloading/loading of maritime vessels, additionally, to model the process of transferring the containers from/to the buffer zone in order to choose the best working variant of the equipment from the terminal.

In case this modeling becomes difficult due to the stochastic character of the arrival of the ships in the port, in addition to the variation of the handling intervals of the containers, it is recommended to use the discrete simulation models developed with the help of dedicated software packages.

2. LITERATURE REVIEW

Research on the topic of maritime terminals is essential to specialists in the field. The decisional-making process inside of terminals is conducted on three decision levels [1]:

- design level (when is developed the structure of terminal, is decided the dimension of storage area, is calculated the required number of handling equipment, etc.)
- operative planning stage (when is decided quay crane and handling equipment assignment, rules for handling dangerous goods and terminal policies)

- operative stage (daily activities inside the terminal which include handling and storage activities, transfer from land network to maritime transport and reverse operation, etc.)

For all three decision levels in the modeling process of activities it is important to imply improving the quality parameters of the serving process. Some research is made to resolve scheduling problems inside the maritime terminal for handling equipment [2],[3]. For the optimization process of activity, an algorithm for path search, evolutionary algorithm, or discrete simulation is used [4]. The discrete models are an important option in this process for research carried out [5], [6]. The activity inside the maritime terminal is associated with a complex queuing system with serving stations and priority rules [7], [8], [9], [10]. The software used to develop this models can be dedicated to study maritime terminals like in case of Microport [11] or can be used software like Arena or Planimate® adapted for case of container maritime terminals [12], [13]. The developed simulation models are used to evaluate the required capacity for storage area [14], [15], [16], the influence of safety rules for the handling of dangerous goods [17], or to estimate the delay in activity induced by the reliability of handling equipment [18].

3. MODELING THE ACTIVITY

The transfer of the containers inside the terminal to and from the maritime vessels is carried out using the area located on the berth in the action area of the quay cranes. If this area is used for the temporary storage of containers unloaded from sea vessels before their transfer to the central storage area using the handling equipment of the maritime terminal (reach stackers, forklifts, etc.), it is called the buffer zone. At the same time, it is necessary to analyse how this area can influence the functional parameters of the terminal, such as the waiting time at the berth for maritime vessels, the length of the queue of the vessels waiting to enter the terminal, and so forth. In the case of the period of stationing at the berth required for carrying out the operations of unloading/loading of the container ships, there are important aspects such as the storage capacity of the buffer zone, the type of handling operations, the productivity of the handling equipment, the technology used, etc. The operations performed at the berth are the unloading process of the containers from the maritime ship, the loading process of the ships with containers, the operations of rearrangement of the containers on the maritime ship. From these, the last operation takes place only at the express request of the commander of the ship, having a supplementary tariff. For this reason, this operation will not be followed in the modeling process.

If only the containers unloading operation is considered, the model is developed in relation to the following assumptions [7]:

- The total productivity of handling equipments (Q_1) is lower than quay crane productivity (Q_2), meaning $Q_1 < Q_2$
- The average number of containers arrived per ship N_{cont} exceeds the buffer zone capacity C_{bzone}, meaning $N_{cont} > C_{bzone}$

Three methods for correlating the activity of container handling equipment within the terminal for unloading containers from sea vessels can be identified. In the first method (Figure 2), the productivity of the quay crane is reduced to an equal value with the productivity of the handling equipment when the capacity of the buffer zone is reached.

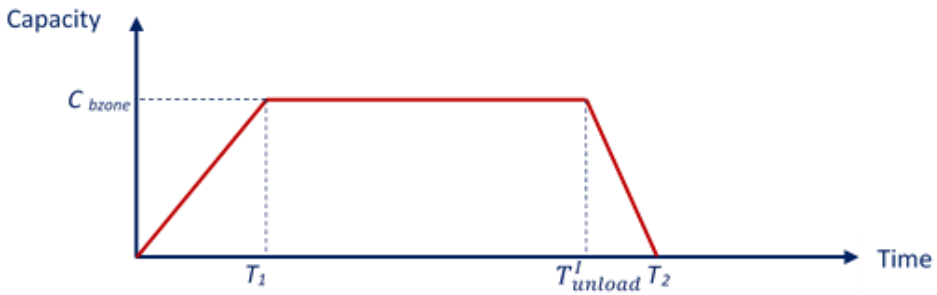


Figure 2 – The first correlation method for the unloading process

The productivity of the handling equipment and the productivity of the quay crane is shown in Figure 3:

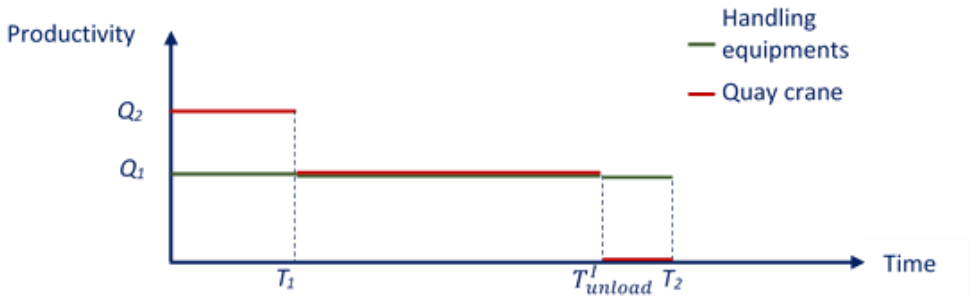


Figure 3 – The productivities of handling equipments

The time required for the transfer of the containers to the storage area of the terminal is determined by equation 1:

$$T_2 = \frac{N_{cont}}{Q_1} \tag{1}$$

The specified time interval for the unloading process of the maritime vessel is determined with the equation (2):

$$T^I_{unload} = T_2 - \frac{C_{bzone}}{Q_1} = \frac{N_{cont}}{Q_1} - \frac{C_{bzone}}{Q_1} = \frac{N_{cont} - C_{bzone}}{Q_1} \tag{2}$$

The second method for correlating the activity of the container handling equipment implies a reduction of the productivity of the quay crane to an intermediate value Q_3, $Q_1 < Q_3 < Q_2$, so that the capacity of the buffer zone is not exceeded (*Figure 4,5*).

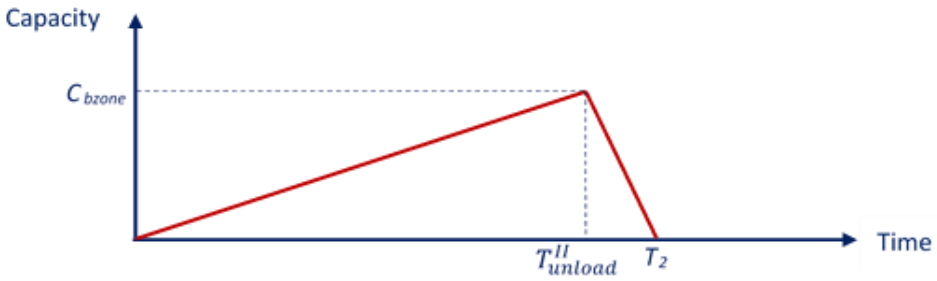


Figure 4 – The second correlation method for the unloading process

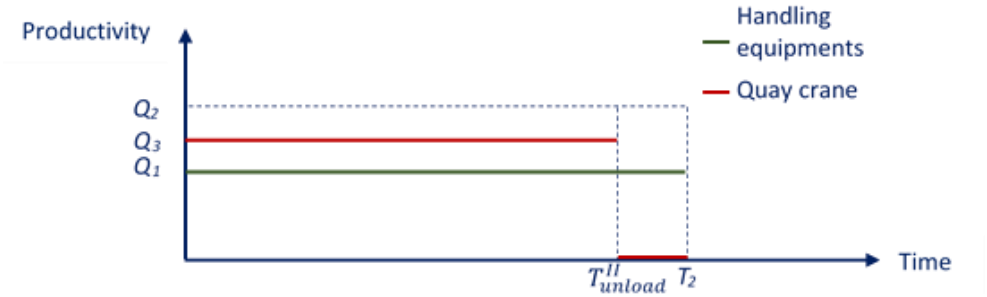


Figure 5 – The productivities of handling equipments

Also, for this method, the time interval required for the transfer of the containers in the storage area of the terminal is determined by equation 1. Additionally, the specified time interval required for the unloading process of the maritime vessel is calculated by with equation 2. The value of the average productivity of the quay crane is obtained by menos of equation 4:

$$T^{II}_{unload} = T^{I}_{unload} = \frac{N_{cont} - C_{bzone}}{Q_1} \tag{3}$$

$$Q_3 = \frac{N_{cont}}{T_{unload}} = \frac{N_{cont}}{\frac{N_{cont} - C_{bzone}}{Q_1}} = \frac{Q_1 N_{cont}}{N_{cont} - C_{bzone}} \tag{4}$$

The last method of correlating the activity of container handling equipment involves stopping the process of unloading containers from maritime vessels when the capacity of the buffer zone is consumed. (*Figure 6,7).*

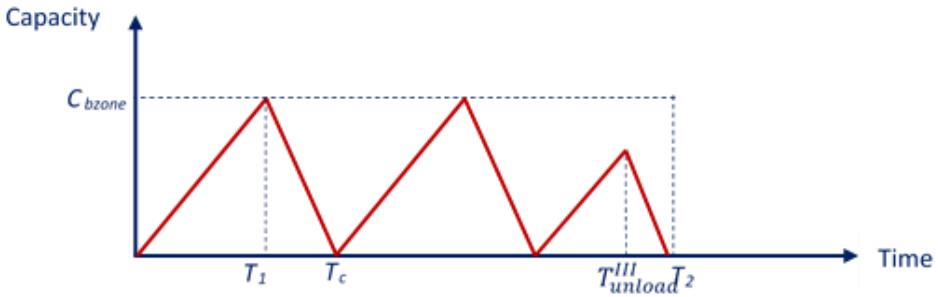


Figure 6 – The third correlation method for the unloading process

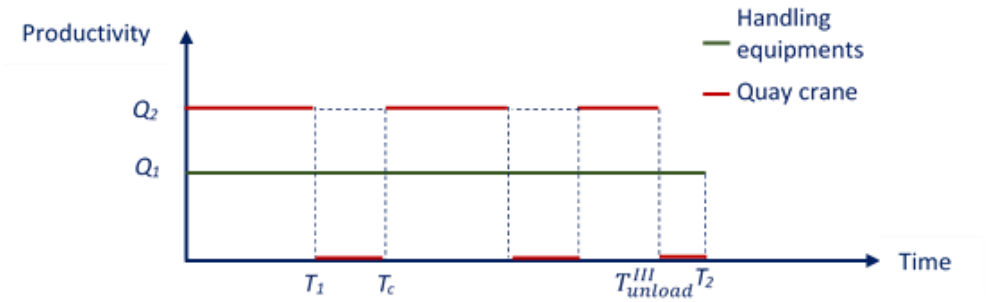


Figure 7 – The productivities of handling equipments

In order to be able to calculate the time interval required for the unloading process of the maritime vessel, it is necessary to determine the duration of an unloading cycle (*Equation 5*), and their number (*Equation 6*).

$$T_c = \frac{C_{bzone}}{Q_2 - Q_1} + \frac{C_{bzone}}{Q_1} \tag{5}$$

$$N_{cycles} = round\left[\frac{N_{cont}}{C_{bzone}}\right] \quad (6)$$

The number of unloading cycles is added to the last cycle in which a lower number of containers are unloaded ($N_{cont}^{last\ cycle}$) than the capacity of the buffer zone (Equation 7). In these conditions, the necessary time interval for the unloading process of the sea vessel is determined with equation 8.

$$N_{cont}^{last\ cycle} = N_{cont} - C_{bzone}N_{cycles} \quad (7)$$

$$T_{unload}^{III} = T_c N_{cycles} + \frac{N_{cont}^{last\ cycle}}{Q_2} \quad (8)$$

If the model represents loading operations for the sea vessel, three methods for correlating the activity of the handling equipment of the terminal with the quay crane are identified. All these methods start from the next assumption:

- The buffer zone is loaded to full capacity, C_{bzone}, before moment T_{load}^{start} when the loading process of N_{cont} starts on the maritime vessel using handling equipments with productivity Q_1

Based on the justifications of the loading process, three methods for correlating the activity of handling equipment are represented in Figures 8, 9, and 10, together with the productivities of the container handling equipment.

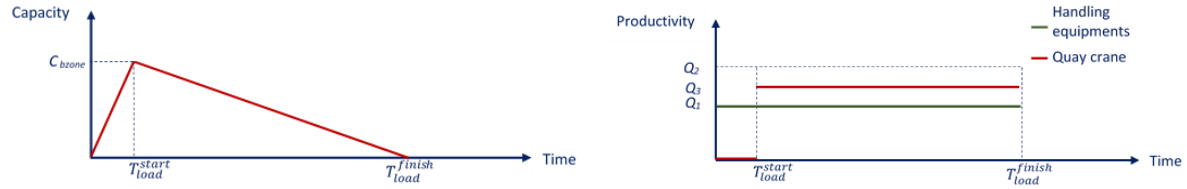


Figure 8 – The first correlation method for the loading process

The required time interval for loading the maritime vessel for the first method for correlating the productivity of the handling equipment is:

$$T_{load}^{I} = T_{load}^{finish} - T_{load}^{start} = \frac{N_{cont}}{Q1} - \frac{C_{bzone}}{Q_1} = \frac{N_{cont} - C_{bzone}}{Q_1} \quad (9)$$

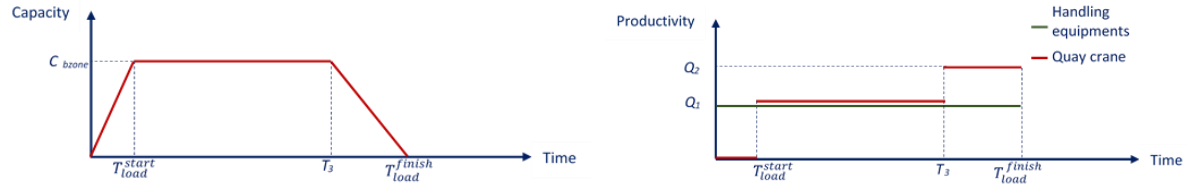


Figure 9– The second correlation method for the loading process

The required time interval for loading the maritime vessel for the second method for correlating the productivity of the handling equipment is:

$$T_{load}^{II} = T_{load}^{finish} - T_3 + T_3 - T_{load}^{start} = \frac{N_{cont}}{Q1} - \frac{C_{bzone}}{Q_1} = \frac{N_{cont} - C_{bzone}}{Q_1} \quad (10)$$

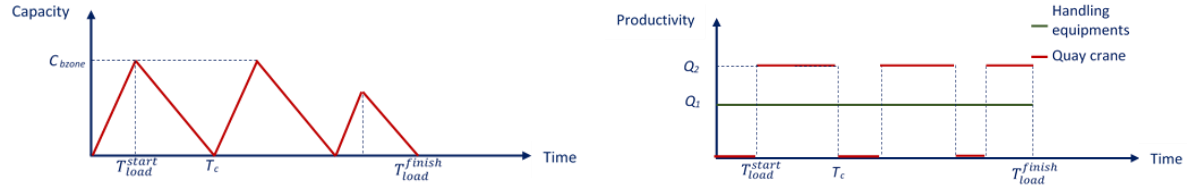


Figure 10– The third correlation method for the loading process

The required time interval for loading the maritime vessel for the third method for correlating the productivity of the handling equipment is:

$$T_{load}^{III} = T_c N_{cycles} + \frac{N_{cont}^{last\ cycle}}{Q_2} + \frac{N_{cont}^{last\ cycle}}{Q_2 - Q_1} - \frac{C_{bzone}}{Q_1} \quad (11)$$

If both unloading and loading operations are conducted for a maritime vessel, any of the methods can be used for correlating the productivity of the container handling equipment with the productivity of the quay crane. Testing the solutions used and identifying the optimal method to correlate the productivity combination can be performed with the help of discrete simulation models both during the download process and during the loading process.

4. DISCRETE SIMULATION MODEL

Using ARENA software, a discrete simulation model is developed to evaluate the correlation procedures between quay crane productivity and handling equipment productivity [19]. The model is developed using structural and technological data of a real container maritime terminal from Romania. The SOCEP terminal is a vital container port operator from the harbor of Constanta, having a capacity of over 500,000 TEU per year. The handling equipment includes shore Panamax cranes on the quay and straddle carriers. Other handling equipments inside the terminal are reach stackers and forklifts, but this are used for loading/unloading containters in relation with land network. The berth depth is 13,5 meters, and the length of the berths is 470 meters. Inside the terminal are two berths, and our simulation model are developed for one of them. The containers are unloaded from maritime vessels to a buffer zone using shore Panamax cranes. This is located on quay and have a limited capacity. From buffer zone the container are moved to main storage area using straddle carriers. The process is reversed for containers shipped to seagoing vessels. The simulation model contains three sub-models for the unloading process and three sub-models for the loading process. This combination allows having nine simulation paths. The structure of simulation paths for unloading and loading processes is represented in Figure 11.

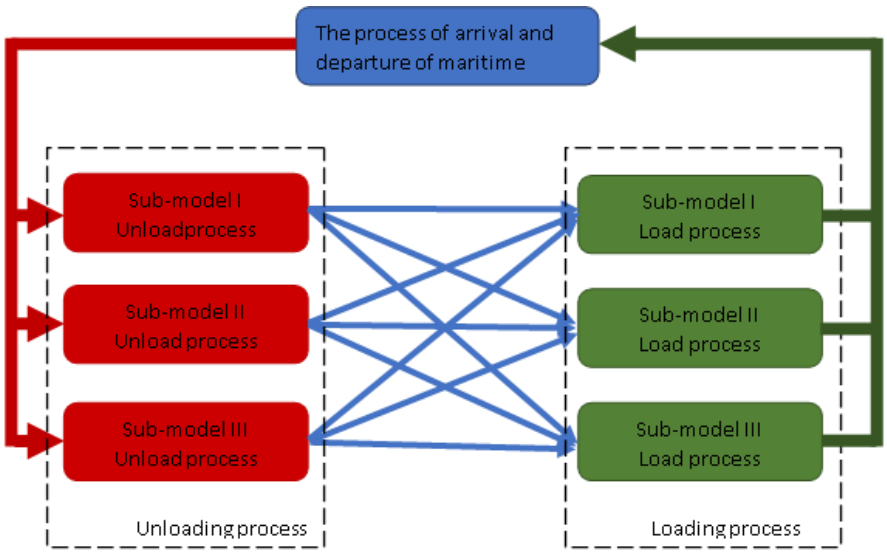


Figure 11 – The model structure for first nine simulation paths

To these paths, another six simulation paths are added, three of them when there are only container loading processes in action and another three when there are only container unloading processes in action (*Table 1*).

Sub-models for loading and unloading processes correspond to the following situation:

- Sub-model I unload process– the gantry crane works until the buffer zone is full and then its productivity is reduced to total productivity of straddle carriers (*Figure 3*);

- Sub-model II unload process –the gantry crane works at adjusted productivity, so in the situation when the buffer zone is full, all the containers can be unloaded from the maritime vessel (*Figure 5*);
- Sub-model III unload process – the gantry crane works until the buffer zone is full and then stops until straddle carriers transfer all the container to the main storage area (*Figure 7*);
- Sub-model I load process– the gantry crane waits for transfer of containers in the buffer zone at full capacity, and then its productivity is adjusted in such manner to have always at least one container to move on the maritime vessel (*Figure 8*);
- Sub-model II load process – the gantry crane, waits for transfer of containers in the buffer zone at full capacity and then its productivity is reduced to total productivity of straddle carriers until the last part of the process when the productivity is increased to its maximum value (*Figure 9*);
- Sub-model III load process – the gantry crane, works with productivity at maximum value but alternating working periods with periods of stagnation of the activity (*Figure 10*);

Table 1 – The simulation paths

Path	**Unload process**	**Load process**	**Path**	**Unload process**	**Load process**
I	Sub-model I	Sub-model I	**X**	Sub-model I	None
II	Sub-model I	Sub-model II	**XI**	Sub-model II	None
III	Sub-model I	Sub-model III	**XII**	Sub-model III	None
IV	Sub-model II	Sub-model I	**XIII**	None	Sub-model I
V	Sub-model II	Sub-model II	**XIV**	None	Sub-model II
VI	Sub-model II	Sub-model III	**XV**	None	Sub-model III
VII	Sub-model III	Sub-model I			
VIII	Sub-model III	Sub-model II			
IX	Sub-model III	Sub-model III			

The simulation run parameters are presented in Table 2:

Table 2 – Run parameters

No	*Parameter*	*Value*
1	*Simulation period*	*180 days*
2	*Warm period (to pass transient state)*	*30 days*
3	*Number of replications*	*10*
4	*Hours per day*	*24 hours*
5	*Number of vessels*	*infinite*

5. RESULTS AND CONCLUSIONS

The input variables for simulation are represented in Table 3. These data are introduced in the simulation model following the real data collected from the maritime container terminal. Some of them can record some variations depending on factors as human intervention, environment, commercial restrictions, etc.

Table 3 – Simulation input variables

No	*Parameter*	*Value*
1	*Number of quay cranes*	*1*
2	*Time interval for container manipulation with quay cranes*	*2.4 minutes*
3	*Number of straddle carriers*	*3*
4	*Time interval for container manipulation with straddle carrier*	*8 minutes*
5	*Time between maritime vessels arrivals*	*Exponential with λ=12,16,20,24*
6	*Buffer zone capacity (we consider the case of 40 ft containers) – number of containers*	*20, 40 containers*
7	*Mooring time*	*2 hours*
8	*Number of containers to unload*	*Uniform (20,100)*
9	*Number of containers to load*	*Uniform (20,100)*

From the simulation model, data about the queue of maritime vessels to enter at berth (Figure 12), the vessels' mean unloading time (Figure 13) and vessels' mean loading time (Figure 14) are collected.

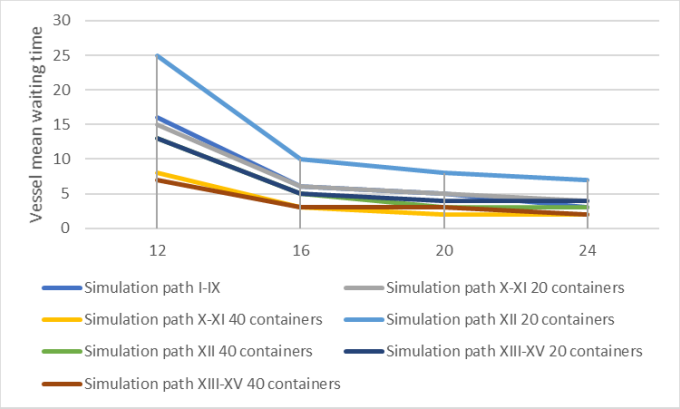


Figure 12– The waiting queue for the maritime vessels entering in terminal

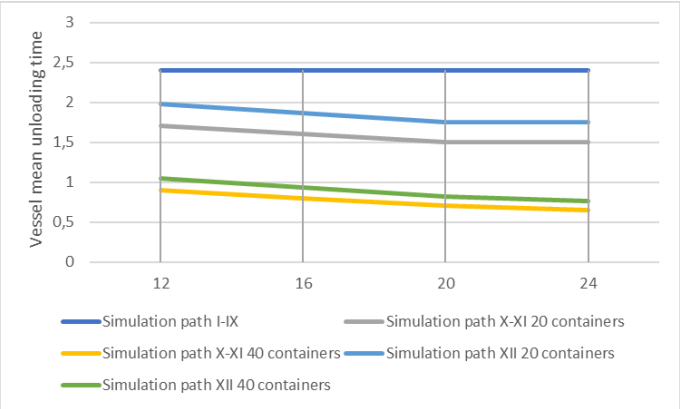


Figure 13– The vessel mean unloading time

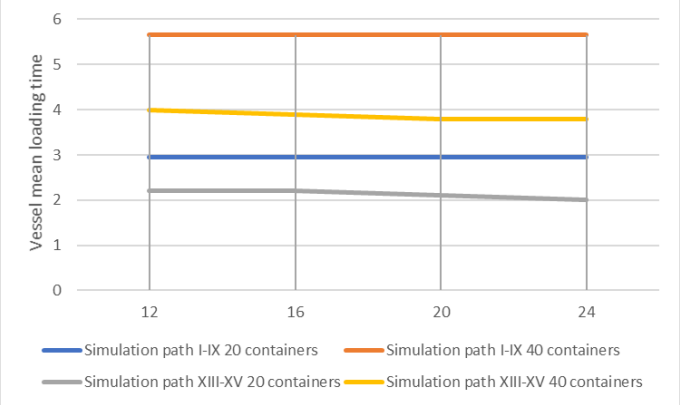


Figure 14– The vessel mean loading time

The size of the waiting queue for the maritime vessels entering the container terminal is influenced by the type of the processes that are performed in the terminal (unloading process for containers, loading process for containers, or both of them). When, within the container terminal, for a vessel, unloading and loading activities are carried out, it is observed that the technology of correlating the productivity of the handling equipment does not influence the size (length) of the waiting queue (simulation path I-IX). The reason is that the buffer capacity cannot be used between the loading and unloading processes. When a single process is performed the buffer zone can be used to perform some container handling operations from the storage zone to the buffer zone before the ship arrives at the terminal. When a maritime vessel performs only the unloading/loading process of containers, the simulation paths X and XI show approximately the same waiting time for entering at berth. In the simulation path XII, a more significant value for waiting time was recorded. The same results for simulation paths XIII-XV were noticed. The arriving time interval between maritime vessels has a direct influence on waiting time for entering at terminal berths for all simulation paths.

For the vessel mean loading time and unloading time obtained in simulation paths I to IX, the correlation between productivities of quay cranes and terminal handling equipment have no influence. However, for the simulation paths X to XII, the usage of the gantry crane until the buffer zone is full and then, stopping its activity (simulation path XII) induces an unloading time bigger in comparison with previous two simulation paths (simulation path X and XI). The capacity of the buffer zone influences overloading/unloading time in simulation paths X-XV. A more significant value for capacity allows obtaining lower values for the duration of the handling process from/to maritime vessel with 40-50% approximatively.

In conclusion, the correlation between productivities of quay crane and maritime terminal handling equipment is important only when it is necessary to unload containers from vessels or to load containers on the vessel. Also, the capacity of the buffer storage zone from quay influences the

duration of handling time of the containers from/to maritime vessels. When it is necessary to unload and load containers from/to maritime vessels, the productivity of terminal handling equipment is the determinant factor in assessing the maritime terminal activities parameters, namely: vessel's mean waiting time, mean unloading time or vessel mean loading time.

The obtained results can help the administration of the container terminal in optimizing the activity inside the maritime terminal. Future research is needed to describe the complexity of processes in maritime container terminals. Limitations of the simulation environment may affect the quality of the results obtained but the modeling structure can help to overcome this impediment.

REFERENCES

[1] Steenken D., Voß S., Stahlbock R. 2005. Container terminal operation and operations research - a classification and literature review. In Günther, H.-O., Kim K.H. (Eds.), *Container Terminals and Automated Transport Systems*, Berlin, Springer;2005. p.3-49.

[2] Bierwirth C., Meisel F. A survey of berth allocation and quay crane scheduling problems in container terminals. *European Journal of Operational Research*. 2010; 202(3): 615–627.

[3] Stahlbock, R., Voß S. Operations research at container terminals: a literature update. *OR Spectrum*. 2007;30(1):1–52.

[4] Kastner M., Pache H., Jahn C. Simulation-based Optimization at Container Terminals: A Literature Review. In: Jahn C., Kersten W., Ringle C.M. (Eds.) *Proceedings of the Hamburg International Conference of Logistics (HICL) – 28*. September 2019: p.11-135.

[5] Angeloudis P., Bell M.G.H. A review of container terminal simulation models, *Maritime Policy & Management.* 2011;38(5).

[6] Kotachi M., Rabadi, G., Obeid, M.F. Simulation Modelling and Analysis of Complex Port Operations with Multimodal Transportation. *Procedia Computer Science*. 2013; 20: 229-234.

[7] Dinu O, Rosca E, Dragu V, Rosca M, Ilie A. Optimization of the transfer function through handling productivity control in port container terminals. *Procedia Manufacturing.* 2017;22: 856-863.

[8] Özkan E.D., Nas S., Güler N. Capacity Analysis of Ro-Ro Terminals by Using Simulation Modelling Method. *The Asian Journal of Shipping and Logistics*. 2016;32(3):139-147.

[9] Iannone R., Miranda S., Prisco L., Riemma S., Sarno D. Proposal for a flexible discrete event simulation model for assessing the daily operation decisions in a Ro–Ro terminal, *Simulation Modelling Practice and Theory*. 2016; 61: 28-46.

[10] Azimi P., Ghanbari M.R. 2011. Simulation Modelling for Analysis and Evaluation of the Internal Handling Fleet System at Shahid Rajaee Container Port. *Engineering and Technology Proceedings*. 2011; 78: 644-655.

[11] Sun Z., Lee L.H., Chew E.P., Tan K.C., MicroPort: A general simulation platform for seaport container terminals. *Advanced Engineering Informatics*. 2012; 26(1): 80-89.

[12] Capodilupo L., Furiò Pruñonosa S., Marinacci C., Ricci S., Rizzetto L. Analytical methods and simulation models to assess innovative operational measures and technologies for rail port terminals: the case of Valencia Principe Felipe terminal *XII Conference on Transport Engineering CIT*. 2016.

[13] Cimpeanu R., Devine M.T., O'Brien C. A. simulation model for the management and expansion of extended port terminal operations. *Transportation Research Part E: Logistics and Transportation Review*.2017; 98: 105-131.

[14] Rusca A., Rusca F., Rosca E., Rosca M. Improving capacity of port shunting yard. In: *Progress in Maritime Technology and Engineering - Proceedings of the 4th International Conference on Maritime Technology and Engineering.* 2018: p. 35-42.

[15] Rusca F., Popa M., Rosca E., Rusca A. Capacity analysis of storage area in a maritime container terminal. In *Maritime Technology and Engineering III: Proceedings of the 3rd International Conference on Maritime Technology and Engineering (MARTECH 2016, Lisbon, Portugal, 4-6 July 2016)*. 2016: p. 92-99.

[16] Rusca F., Popa M., Rosca E., Rusca, A. Simulation model for maritime container terminal. *Transport Problems*. 2018; 13(4): 47-54

[17] Rusca F., Raicu S., Rosca E., Rosca M., Burciu Ş. Risk assessment for dangerous goods in maritime transport. In Soares, C. G., Dejhalla, R., & Pavletic, D. (Eds.) *Towards Green Marine Technology and Transport-Proceedings of the 16th International Congress of the International Maritime Association of the Mediterranean, IMAM* 2015:p 669-674.

[18] Rusca F., Rosca E., Popa M., Rusca A., Rosca M. The failure analysis of handling process in maritime container terminal. In Čokorilo O. (Eds.) *ICTTE Belgrade 2018 - Proceedings of the Fourth International Conference on Traffic and Transport Engineering*. Belgrad. 2018: p 298-304.

[19] Kelton W.D., Sadowski R.P., Sturrock D.T. *Simulation with Arena*. 5th edition. McGraw-Hill Professional. 2006.

MARKO SLAVULJ, Ph.D.[1]
E-mail: mslavulj@fpz.unizg.hr
DAVOR BRČIĆ, Ph.D.[1]
E-mail: dbrcic@fpz.unizg.hr
SLAVKO INIĆ, M.Sc.[2]
E-mail: slavko.inic@samobor.hr
MATIJA SIKIRIĆ, Ph.D. student[1]
E-mail: msikiric@fpz.unizg.hr
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, City of Zagreb
[2] City of Samobor
Trg Kralja Tomislava 5, City of Samobor

ANALYSIS AND PROPOSAL OF SOLUTIONS FOR PUBLIC TRANSPORT IN THE AREA OF STUPNIK MUNICIPALITY

ABSTRACT

Public transport is the backbone of urban mobility because of its undeniable benefits, such as high operational capacity, spatial and energy rationality, and social inclusion of all residents. In the context of sustainable mobility, it is necessary to achieve a change in the modal distribution of travel, to reduce the use of a passenger car, and to increase travel by public transport and other sustainable modes of travel (walking and cycling). It is therefore necessary to make public transport as attractive as possible in order to achieve the desired modal distribution of travel in favour of public transport. The paper consists of an analysis that made a complete insight into the existing state of public transport of passengers in the Municipality of Stupnik, and based on the obtained data, solutions for the Municipality of Stupnik regarding the organization of public transport were proposed and presented.

KEY WORDS

public transport; transport technology; bus route; quality of service; route organization

1. INTRODUCTION

Public transportation (also called mass transportation) is the movement of people within urban areas using group travel technologies such as bus, train, subway and tram [1]. Public transport of passengers in the municipality of Stupnik is organized as bus transport. Most of the inhabitants of the Municipality using public transport fulfil their needs for transport by bus, and only a small part uses the railway (HŽ Passenger transport), i.e. the railway station in Hrvatski Leskovac. The article is based on the data and conclusions of two studies "Analysis of public transport in the territory of the Municipality of Stupnik" and "Proposal of a solution for public transport of passengers in the territory of the Municipality of Stupnik". In the second chapter an analysis was made whit a complete insight into the existing state of public transport of passengers in the Municipality of Stupnik. The analysis included the passengers counting on bus routes, the analysis of gravity areas and the accessibility of public transport stops, a survey on passenger characteristics and travel patterns, and a survey on the quality of public transport. Based on the obtained data, in the third chapter a proposal of solutions for the Municipality of Stupnik regarding the organization of public transport was made. Finally, a discussion and a conclusion are presented.

2. ANALYSIS OF THE CURRENT STATE OF PUBLIC TRANSPORT IN THE MUNICIPALITY OF STUPNIK

The municipality of Stupnik is located in the western part of Zagreb County. It borders with the City of Zagreb in the north, east and south, in the northwest with the Municipality of Sveta Nedelja, and in the west with the City of Samobor. The total area of the municipality of Stupnik is 24,87 km2. According to the 2011 census, the municipality has a population of 3,735. Territorially, the Municipality of Stupnik comprises three settlements (Gornji Stupnik, Donji Stupnik and Stupnički Obrež). Population density is 149.3 inhabitants / km2, from which it can be concluded that the Municipality of Stupnik is quite sparsely populated in terms of its characteristics and belongs to the suburban settlements of the City of Zagreb, i.e. the Zagreb County.

The aim of the analysis in the study was to:

- Analyse the existing supply and demand of public transport in the municipality of Stupnik;
- Research and demonstrate the accessibility of public transport stops;
- Research routes and line alignment in the municipality of Stupnik;
- Research the traffic connection of Stupnik Municipality with surrounding cities and municipalities (Zagreb, Samobor, Sveta Nedjelja, Klinča Sela, Jastrebarsko, etc.);
- Research the travel lines of the residents of Stupnik Municipality;
- Evaluate the state of public transport in the municipality of Stupnik.

For the analysis of the current state of public transport, the following methods were used:

- Counting passengers on public transport routes;
- A survey of travellers to gain insight into travel habits and their characteristics;
- Survey of passengers in order to gain insight into the subjective assessment of the quality of public urban transport in the observed area;
- Gathering data through GPS loggers to obtain the characteristics of public transit routes.

2.1. Catchment Areas

Public transport in the area of the Municipality of Stupnik is performed by the Zagreb Electric Tram operator from Zagreb d.o.o. (hereinafter ZET). The analysed area is shown in Figure 1.

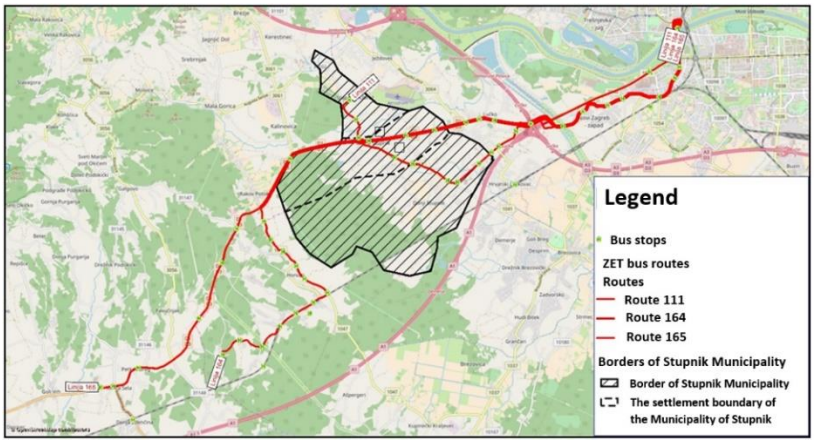


Figure 1 – Spans of bus lines in the municipality of Stupnik
Source: [5]

There are three bus routes operated by ZET:

- 111 Savski most – Stupnički Obrež;
- 164 Savski most – Horvati;
- 165 Savski most – Klinča Sela.

All three bus routes serve as transport collectors and provide passengers with traffic connections to the Savski most terminal in Zagreb, where passengers can continue to use other ZET's tram and bus routes.

Bus route 111 passes Karlovac Road, Gospodarska Street and Sveti Benedikt Street, and ends via Stupničkoobreška Street in Stupnički Obrež. It is mainly used for travellers in the area of Donji Stupnik and Stupnička Obrež. The route is 14,7 km long in the direction of Stupnički Obrež and the same in the direction of the Savski most, the total length of the line is 29,5 km. There is one bus on the line, and according to the ZET timetable [12], the cycle time is 70 minutes on weekdays, which is also the sequence of vehicles. Depending on the period, an 88-seat solo bus or a 149-seat articulated bus operates on the line, which makes the offered operational capacity of 75 passengers per hour for solo and 128 passengers per hour for articulated buses.

Bus route 164 passes through Karlovac Road and Gornjostupnikčka Street and continues along Horvati Street to Komar. In addition to transporting passengers in the area of Gornji Stupnik, it is used to transport passengers from the place along Horvati Street all the way to Komar. The route is 23,4 km long in the direction of Horvat and the same in the direction of the Savski most, the total length of the line is 46,8 km. There are two buses operating on the line, and according to the ZET timetable [12], the cycle time is 100 minutes on weekdays, so the sequence of vehicles is 50 minutes. The usual 88-seat solo buses are on the line, which makes the offered operational capacity of 106 passengers per hour in peak workload.

Bus route 165 passes through Jadranska Avenue and Gornjostupnička Street and continues west to Klinča Sela. In addition to transporting passengers in the area of Gornji Stupnik, it is used for transporting passengers to the Klinča Sela area. The route is 22,7 km long in the direction of Horvati and 22,8 km in the direction of the Savski most, the total length of the line is 45,5 km. There are two buses operating on the line, and according to the ZET timetable [12], the cycle time is 100 minutes on weekdays, so the interval of vehicles is 50 minutes.

There are no railway lines in the area of Stupnik Municipality, however, in the immediate vicinity of the Municipality (900 m airline), there is a railway of international and regional significance, near which is the Hrvatski Leskovac railway station. The average journey time to Zagreb Central Station is 12-14 minutes. There are 12 departures daily (weekdays) in the direction of Zagreb Main Station and 13 departures in the direction of Hrvatski Leskovac.

2.2. Public Transport Stops

There are 12 bus stops in the municipality of Stupnik. Bus stops are constructed as bus stops and as stops located on the traffic lane. A field survey of the bus stop infrastructure found that most bus stops did not comply with the regulations in the "Regulations on bus stops" (NN br. 119/07) [11]. Figure 2 graphically shows the exact locations of bus stops in the municipality, and shows a radius of gravity of 800 meters, which corresponds to a walking distance of 10 minutes. The bus stops in Gornji Stupnik are located on the route of three bus lines (111, 164 and 165), while in the other two settlements there are bus stops served by only one bus line (111). It is evident that the settlements Gornji Stupnik and Stupnički Obrež are completely covered by the gravity zone of bus stops, while the settlement Donji Stupnik is not. The railway station in Hrvatski Leskovac with a radius of 800 meters does not touch the border of the Municipality of Stupnik. The railway station is 5.3 km from the center of Gornji Stupnik, 3.5 km from Donji Stupnik, and 7.2 km from Stupnički Obrež.

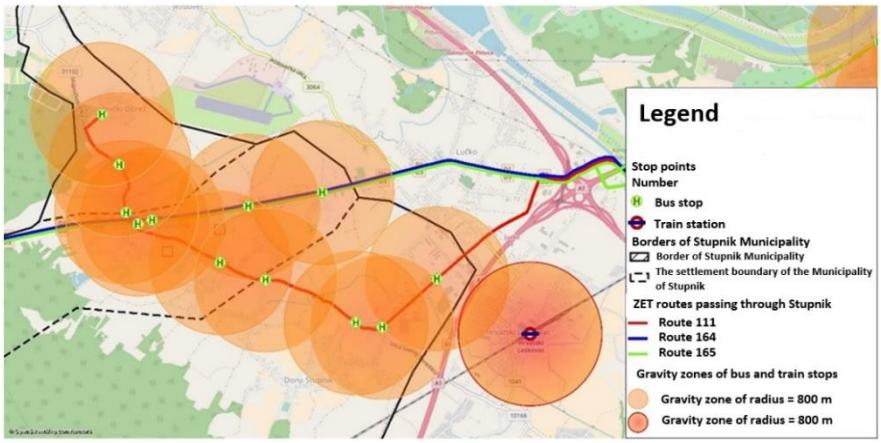


Figure 2 – Gravity zones of bus and railway stops in the municipality of Stupnik (radius = 800 meters)
Source: [5]

2.3. Cycle Times

For each line, the driving times, standstill times are shown individually, while the terminal hold times are obtained by subtracting the standstill time and the driving time from the half-cycle time (given in the timetable). Figure 3, Figure 4 and Figure 5 show the times for lines by periods and directions. Times are categorized into:

- dwell times at stops (highlighted in yellow);
- driving time between stops (highlighted in green);
- terminal dwell times (refers to destination terminal - highlighted in red).

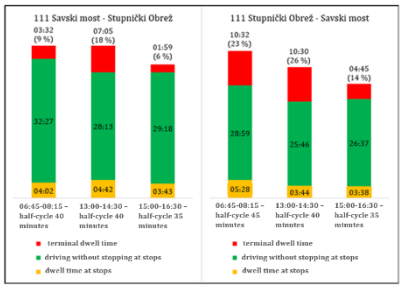


Figure 3 – Cycle times on route 111
Source: [5]

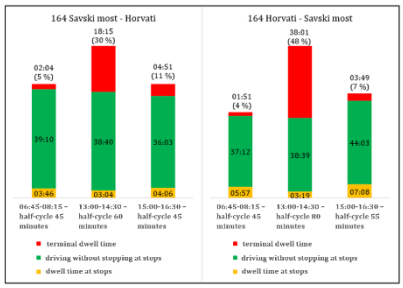


Figure 4 – Cycle times on route 164
Source: [5]

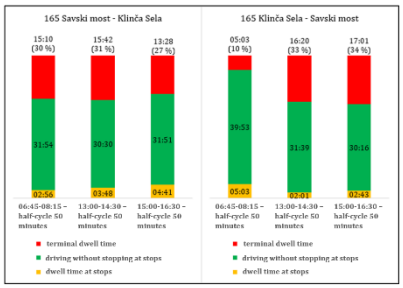


Figure 5 – Cycle times on route 165
Source: [5]

The high dwell times of line 164 between 13:00 and 14:30 are the result of longer vehicle breaks in both directions according to the ZET timetable [12] and are not relevant for showing the timetable utilization. The time display serves to check the optimal utilization of the timetable, which is considered through two aspects:

- estimation of minimum terminal dwell values - the lowest possible value obtained is within the recommended two-minute values required for the necessary driver actions at the terminal;
- estimate of terminal dwell averages - drivers on all lines spend more than 30 minutes resting at terminals during business hours.

2.4. Operating Speed

Operating speed (or commercial speed) is the average speed of travel between two terminals on a line, that is, the speed defined in this way also includes journeys between stops and dwell at stops. [8]

It has been observed that the lines have typical values of suburban transport speeds above 25 km/h, and in the case of the 165 line the speeds are also greater than 35 km/h, that is, the line has high dynamic performance. Line 111 has the lowest speed values because it is the shortest, has more

densely distributed stops along the route, and line 165 is characterized by long distances between stops (especially distances near the Savski most terminal), and most stops are in areas of lower population density, so vehicle distractions public transport by other traffic is minimal. Speed can be influenced to a greater extent by the traffic load on the Jadranski most in Zagreb in the morning and late afternoon rush hours.

3. ASSESSMENT OF THE QUALITY OF PUBLIC TRANSPORT SERVICE

There are many indicators of the quality of transport service, but only the most significant ones have been used. And these are the following [10]:

- Punctuality and regularity. This means that the carrier agrees to perform the agreed transport exactly according to the current timetable. It is also obliged that the contracted transportation is performed regularly (every day) with all planned capacities on the lines. Interference caused by third parties which cannot be influenced or prevented by the carrier is considered to be a justified reason for deviating from the planned accuracy and regularity. In case of failure of an individual vehicle on the lines, the carrier is obliged to arrange a replacement bus.
- Passenger safety and protection. The carrier is responsible for the safety of the passengers. This safety is guaranteed by preventive constructive measures on vehicles and the education and control of the work of transport personnel. In addition, the carrier is obliged to ensure all passengers with a valid travel ticket from the possible consequences of road accidents involving his vehicles.
- Carrier staff's attitude towards passengers. Carrier staff are required to provide passengers with assistance during their stay on the bus.
- Cleanliness of the vehicle. The carrier is required to maintain the cleanliness of the vehicle (internal and external). In case of major pollution of the vehicle in traffic, the carrier is obliged to pull the vehicle into the garage and clean the vehicle and send a replacement vehicle as needed.
- Informing passengers. The carrier is obliged to inform passengers about the operation of the transport as follows:
  - correct signal signs and nameplates;
  - informing passengers about timetable changes.

The results of the passenger survey in the municipality of Stupnik are shown in Table 1. The survey was conducted on a sample of 242 respondents.

Table 1 – Customer satisfaction with bus transportation

Quality indicator	**Average rating Ratings from 1 (inadequate) - 5 (excellent)**
Timetable accuracy	3
Frequency of vehicle arrival	2
Crowds inside the vehicle	2,5
Vehicle route	2,5
Transfer between modes / vehicles	2,7
Vehicle comfort	2,8
Cleanliness of the vehicle	2,7
Quality of infrastructure (stops, terminals)	2,5
Safety	3
Drivers	3,2
Transport service price	2,8
Ticket sales channels	2,9
Informing passengers	2,7
The culture of road users	2,5

Source: [5]

When assessing the quality of the existing transportation service, for all quality factors, the respondents are usually undecided, while the following are the main reasons for satisfaction:

- vehicle comfort;
- safety;
- drivers.

The main reasons for dissatisfaction were expressed by the following:

- timetable accuracy;
- frequency of vehicle arrival.

4. PROPOSAL FOR IMPROVEMENT OF PUBLIC TRANSPORT SERVICE

Based on the collected and analysed data from Chapters 2 and 3, a proposed solution was prepared for the Municipality of Stupnik. In order to improve the state of public transport and reduce costs for the Municipality of Stupnik, the study proposes three scenarios of possible solutions in accordance with the regulations of the Republic of Croatia and the EU.

4.1. Calculation of the Cost Per Kilometre in the Municipality of Stupnik

The first step was to calculate the cost per kilometre for the carrier, for which two methodologies were used. The first calculation is based on the methodology developed for the purposes of the Study of the Faculty of Transport Sciences (FPZ), while the second is based on the guidelines set out in Directive 2009/33 / EC of the European Commission [4].

The first methodology for calculating the cost per kilometre

Cost per kilometre calculations include all costs that are incurred or may be incurred in arranging public transportation in an area. [2] These costs can be divided into four main groups: the cost of purchasing the vehicle itself (without additional capital or interest costs) together with the costs of maintenance and technical inspections, the costs of propulsion materials (fuel, tires, engine oil), the costs of labour and administration costs.

The first methodology involved the following cost categories [6]:

- Cost of vehicle technical inspections;
- The cost of tolls;
- The cost of mandatory car insurance;
- Cost of Casco Insurance;
- Costs of extra-routine maintenance;
- Unscheduled maintenance costs;
- Gross Cost II. for traffic staff;
- Cost of tires;
- Average fuel consumption;
- Cost of transportation manager;
- Ticket issuance costs;
- Cost of cleaning service;
- Office rental cost;
- Other material costs;
- The cost of renting a bus parking lot;
- Cost of bookkeeping services.

The second methodology for calculating the cost per kilometre

Using the Clean Fleets methodology developed under Directive 2009/33 / EC to calculate the operating costs of the life cycle of a public transport vehicle. The methodology is used as a fundamental methodological approach to calculate the total cost of owning a vehicle.

The second methodology included the following cost categories [4]:

- General conditions;
- Acquisition costs;
- Operating cost per vehicle;
- Maintenance cost per vehicle;
- Taxes and other cost/subsidies per vehicle;
- End of life (vehicle life span);
- Cost per kilometre according to LCC methodology.

The estimated total costs (including the costs of mobile workers and other possible costs) were calculated for the three vehicle categories (M3, M2 and M1), and based on an average annual mileage of 70,000 kilometres, compared to each other in Table 2.

Table 2 – Comparison of the results of the methodologies for determining the price per kilometre

Methodology for calculating cost per kilometre	City (solo bus) (M3)	Minibus (M2)
First - FPZ	15,82 HRK	12,08 HRK
Second - LCC	16,16 HRK	12,37 HRK
Deviation	+2,2%	+2,4%

Source: [6]

The result confirms the satisfactory accuracy of the FPZ methodology calculation, and the same cost per kilometre value was used for further analysis.

4.2. Three Scenarios

The study analysed three possible scenarios for improving public transport and, based on scientific facts and expertise, proposed an optimal model for future public passenger transport in the municipality of Stupnik.

The first scenario

Several different variants were considered with the existing one. Due to the insufficient width of roads (in the area of Donji Stupnik, the width of the roads is between 4.10 meters and 5.50 meters) and the limitation of the maximum load capacity (Maglajci Street and Jugova Street) of max. 10 tons, the motor vehicle in question on the modified 111 line could be an M2 minibus or an M1 van. The variants discussed are:

- Existing number of lines with some modification of line 111 (including settlements in Donji Stupnik and traffic via Jadranska Avenue) - M2 and M1 bus categories;
- Existing number of lines but no line 165;
- Existing number of lines but no line 164;
- Substitution of line 164 with some modification of line 111 (including settlements in Donji Stupnik and traffic via Adriatic Avenue) - M2 and M1 bus categories;
- Removal of line 165 with some modification of line 111 (including settlements in Donji Stupnik and traffic via Jadranska Avenue) - M1 and M2 bus categories;

Due to the cycle time between 65 and 90 minutes on individual routes, the demand for travel, the inability of another form of transportation and the relative distance to the City of Zagreb, three shifts are required.

Table 3 – Relationship between estimated annual cost of ZET and cost per kilometre from FPZ methodology

Type of calculation	Cost of existing organization	The cost of the existing organization without line 165	The cost of the existing organization without line 164
FPZ Calculation; City (solo) bus	1.749.789,04 kn	-26,55%	-36,92%
Cost as calculated per km by ZET	2.395.557 kn	-21,66%	-31,94%
Index (ZET/FPZ)	-27%	-32%	-33%

Source: [6][7]

The second scenario

The future carrier is not ZET, the future carrier towards the City of Zagreb will be selected through a public tender. The selected public carrier will also need to enter into a Public Transport Service Agreement, which means that the organization of the transport, the volume and quality of transport, tariffs and the method of covering the costs will be agreed, if the costs cannot be covered from the ticket prices and controls.

In order to open the possibility for greater use of the railway, it is recommended to introduce a new bus line that would take passengers from the entire municipality to the Hrvatski Leskovac railway station. Since Hrvatski Leskovac is in the administrative area of the City of Zagreb, the new line should be in the category of inter-county lines. The aforementioned transport could be done by minibuses and departures would be adapted to departures from the train station Hrvatski Leskovac.

The third scenario

The municipality of Stupnik can set up its own transport company to provide public transport for passengers from its area. The best solution for residents and the Municipality comes through the organization of Integrated Transport, which should reduce the cost to carriers through optimization of transport costs and which, in addition to the Municipality, would include the County and the State in subsidizing. However, this transport is probably certain for several more years, although it is being worked on. The proposal also included the possibility of organizing a new public transport line in the municipality of Stupnik, as shown in Figure 6.

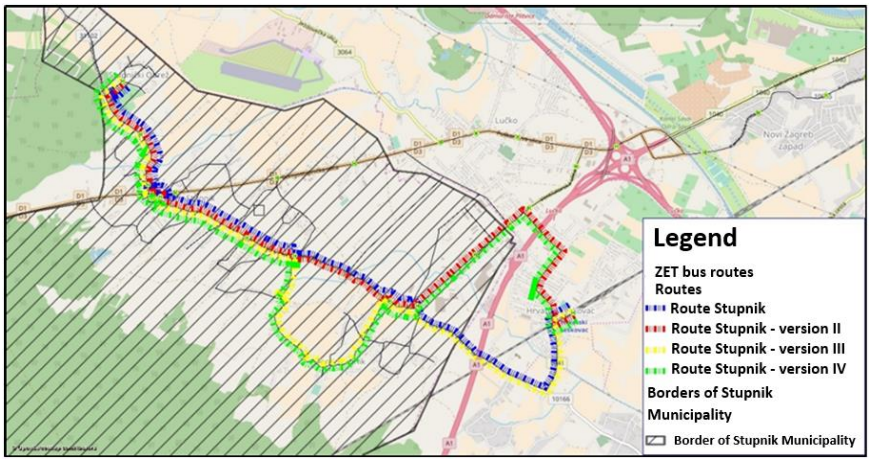


Figure 6. Proposal of a new bus line (4 versions) Stupnički Obrež - Hrvatski Leskovac railway station
Source: [6]

The function of the line itself would be to enable the residents of all settlements in the Stupnik municipality (primarily employees, students and schoolchildren) a good connection with the railway, with which they could reach the centre of Zagreb within a period of 30 minutes, and therefore would operate exclusively on weekdays.

For the third scenarios, a CBA analysis of two-variant variant solutions was made depending on the planned procurement of the vehicle type (Figure 7):

- Solo diesel bus Euro VI standard (M3);
- Mini city bus diesel Euro VI standard (M2).

The analysis was approached with the assumption that the highest cost of investing in one's own company may be equal to the subsidy that the Municipality of Stupnik pays annually to the Zagreb Electric Tram for public passenger transport. Modern methods of evaluation of investment projects are based on an account with discounted values, which contributes to the reality of evaluation, i.e. taking a certain time frame, where the project is viewed in a dynamic form.

Of the methods based on the discount account, the following were applied to evaluate this project:

- Net present value (NPV);
- Return on investment method.

Net present value implies the net benefit of the investment determined by discounting for a certain period with an appropriate calculated rate of future income and expenses. In fact, the difference between income and expenses reduced to the initial investment period is identified as net present value.

Return on investment is defined as the number of periods in which the initial investment input is equated with the net investment income.

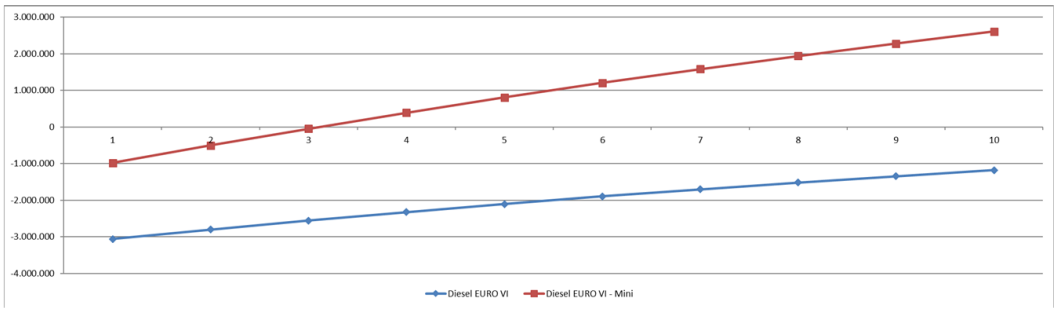


Figure 7 – Term of return on investment over a 10-year period
Source: [6]

Variant 1, i.e. the application of the city solo bus, diesel EURO VI has an NSV < 0, and is not suitable for implementation, while Variant 2, i.e. the city minibus, diesel EURO VI, has an NSV > 0, and is suitable for implementation. Table 4 shows the return on investment according to the analysed variants on an annual basis. The analysis showed that Variant 2 (Diesel EURO VI - Mini city bus) has a payback period of four years, while in Variant 1 this period is more than 10 years (which was the subject of consideration - the economic life of the vehicle).

Table 4 – Investment return period in years

Variant	Return on investment period
Solo diesel bus Euro VI standard	> 10 years
Mini city bus diesel Euro VI standard	4 years

Source: [6]

If the Municipality of Stupnik decides to organize the transport independently, the purchase of minibuses (vehicle M2) that have positive values within the CBA analysis (NSV > 0 and a return period of four years) is imposed as a reasonable choice.

5. DISCUSSION

Buses operate at low capacity compared to trams or trains and can operate on conventional roads, with relatively inexpensive bus stops serving passenger pick-up. Therefore, buses are commonly used

in smaller cities and rural areas, as well as for transport services that supplement other types of transit in large cities. [2]

Typical values of the transport speeds characteristic of suburban lines with values above 25 km/h were measured on the analysed bus lines, and in the case of the 165 line, speeds were higher than 35 km/h. Line 111 has the lowest speed values because it is the shortest and has more widely distributed stops along the route, and line 165 is characterized by large interstitial distances with most stops located in areas of lower population density, so that interference with public transport by other traffic is minimal.

There are 12 bus stops in the municipality, and most bus stops are located on the roadway of the pavement and are not in compliance with the regulations. The settlements of Gornji Stupnik and Stupnički Obrež are covered by a gravity zone of 800 m distance to bus stops, while this is not the case for one part of the settlement Donji Stupnik.

An analysis of the modal distribution of trips by residents of the Municipality showed that the largest share of commuting, school trips and other needs in the direction of the City of Zagreb is done by car (57%). Public transportation contributes 37% to mode distribution, while bicycle with 2% share does not play a significant role. [5] It is estimated that the modal distribution of traveling by personal vehicle is too high for the purpose of traveling to work, school and other activities. [2]

Analysing the transport supply, it can be concluded that all three lines serving the area of the Municipality (especially in peak periods of the day for the purpose of going to work and school) have sufficient capacity, bus units are filled on average by 24% (line 111), i.e. 15-17% (lines 164, 165). [3] [5]

Three scenarios were considered in the Study [6]:

1. Proposal for improvement of the existing organization of passenger transport organized by ZET;
2. Proposal of the organization of public transport service in the territory of Stupnik Municipality by other carriers (not ZET);
3. Proposal for the organization of public transport, establishing its own transport company, with its own resources.

The mentioned scenarios were selected based on the set project task, and analytically processed according to the scientific facts and professional knowledge of the project team. Regardless of the accepted scenario, the Municipality of Stupnik may alternatively access the future transport community, i.e. integrated passenger transport.

6. CONCLUSION

Summarizing the scenarios, their advantages and disadvantages, we believe that the most rational variant is scenario 1, in which the Municipality of Stupnik should achieve the following in negotiations with the Zagreb Electric Tram:

- Reduce cost per kilometre (according to FPZ calculation methodology);
- Substitute one of the ZET lines (164 or 165);
- Increase the frequency of departures on Line 111, with the potential change of route along Jadrnska Avenue.

The quality of the service is extremely important for changing the modal distribution, that is, attracting more passengers to use public transport, especially those who use a car for everyday travel. The average ratings given by users of the bus (2.7) and rail (3.0) transport are quite low, indicating the need to improve transport services. Also, it is necessary to find a solution for travel by public transport during weekends and holidays, which is not satisfactory. Also, the need for residents of Stupnik to travel on Saturdays, Sundays and public holidays to the City of Zagreb and other settlements is much lower, i.e. there is less demand for this type of travel.

Since in the future students will travel to Zagreb by public transport because they generally have no other options, the question is how to stimulate a group of employed residents of the municipality of Stupnik to travel by public transport. Stimulating employed residents to move from personal transportation to public transport should be set as one of the key future goals of the municipality and the public transport operator.

REFERENCES

[1] Brčić D., Slavulj M. Urbana mobilnost. Fakultet prometnih znanosti. Zagreb. 2019.
[2] Brčić, D., Ševrović, M. Logistika prijevoza putnika. Fakultet prometnih znanosti. Zagreb. 2012.
[3] Brčić, D., Šimunović, Lj., Slavulj, M. Upravljanje prijevoznom potražnjom u gradovima. Fakultet prometnih znanosti. Zagreb. 2016.
[4] Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles. European commission. Strasbourg. 2009.
[5] Fakultet prometnih znanosti. Analiza javnog prijevoza na području Općine Stupnik. Fakultet prometnih znanosti. Zagreb. 2018.
[6] Fakultet prometnih znanosti. Prijedlog rješenja javnog prijevoza putnika na području Općine Stupnik. Fakultet prometnih znanosti. Zagreb. 2018.
[7] Općina Stupnik i Zagrebački holding d.o.o. Ugovor o subvenciji za prijevoz putnika i prtljage na području Općine Stupnik. 2013.
[8] Štefančić, G. 2008. Tehnologija gradskog prometa I. Fakultet prometnih znanosti. Zagreb.
[9] Štefančić, G. 2010. Tehnologija gradskog prometa II. Fakultet prometnih znanosti. Zagreb.
[10] Vuchic, V. R.: Urban Transit Operations, Planning and Economics, John Wiley and Sons, Inc., 2005.
[11] Zakon o cestama (Narodne novine br. 84/11, 22/13, 54/13, 148/13, 92/14)
[12] Zagrebački električni tramvaj. Croatia. [Online]. Available: http://www.zet.hr/. [Accessed: 18-April-2018]

VLATKA STUPALO, Ph.D.[1]
(Corresponding author)
E-mail: vstupalo@fpz.unizg.hr
TOMISLAV FRANC, M.Sc. /mag. ing. traff.[1,2]
E-mail: tomislav.franc1@gmail.com
ANDREJ DÁVID, Ph.D.[3]
E-mail: andrej.david@fpedas.uniza.sk
ANTE MRVICA, Ph. D.
E-mail: mrvica.ante@gmail.com
[1] University of Zagreb, Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[2] HUBBIG d.o.o.
Avenija Dubrovnik 15/12, 10020 Zagreb, Croatia
[3] University of Zilina, Faculty of Operation and Economics of Transport and Communications
Univerzitna 8215/1, 010 26 Zilina, Slovakia

PRODUCTIVITY ANALYSIS OF SOLID BULK CARGO TERMINAL: CASE STUDY PORT OF SPLIT

ABSTRACT

Solid bulk cargo is of great importance to the world economy and industry. This cargo is transported in bulk form, ie without a special transport packaging. Such mode of transport greatly affects the transport technology and technique that must be used when handling such cargo at the port terminal. Solid bulk cargo also requires special characteristics of the ships used to carry this commodity. In the research part of the paper transport dynamics inside Port of Split was analysed. Quantitative analysis was performed using Eurostat's statistical database and Croatian's Bureau of Statistics database. From this analysis it can be concluded that Port of Split is one of the crucial ports in Croatia for loading of solid bulk cargo.

KEY WORDS

solid bulk cargo; transport; handling; terminal; analysis, Port of Split

1. INTRODUCTION

More than four fifths of world merchandise trade by volume is carried by sea. Although in 2018 volumes increased at 2.7%, which was below the historical average of 3.0% from 1970–2017 and 4.1% in 2017, total volumes reached a milestone in 2018, when all time high of 11 billion tons was first time achieved on UNCTAD record. Dry bulk commodities, followed by containerized cargo, other dry bulk, oil, gas and chemicals, contributed the most to this growth [1].

Transportation of large quantities of solid bulk cargo from their sources to the place of processing is a key part for development of industries that require this type of cargo. Containerization of the maritime transport market has introduced changes in the transport of solid bulk cargo and the use of containers for transportation of solid bulk is becoming more common. Nonetheless, since industries that require solid bulk commodities require large quantities of such commodities it is more cost effective to transport large quantities of these commodities at once than through individual containers. To ensure efficiency of this kind of transportation, solid bulk cargo terminals are highly specialized facilities that enable fast loading and unloading of a ship [2].

Port of Split, considering the already mentioned value of solid bulk cargoes for industry, handles significant quantities of such cargoes within the Croatian framework. The cement industry and the

food and chemical industry are of great importance to the Croatian economy and require the transport of solid bulk cargo, either import or export, and the Port of Split is one of the key factors in this industrial chain.

Main objective of this paper was to analyse importance of Port of Split in the transportation of solid bulk cargo. To do so at the beginning of the paper main groups of solid bulk cargo were analysed. This analysis was followed with the analysis of main features of solid bulk carriers. Division of these ships according to their size was analysed, followed with the analysis of terminal devices for loading and unloading of the cargo in/from bulk carriers, organisation of terminal storage area and main sources of pollution at the terminal. Quantitative analysis of the solid bulk cargo traffic in the Port of Split was performed using mainly data from the Eurostat database, to show the quantities of solid bulk cargo handled at Port of Split and other maritime ports in Croatia, and from the database of Croatian Bureau of Statistics to display the quantities of different solid bulk cargo at Port of Split. From the performed analysis it can be concluded that solid bulk cargo is important cargo for Port of Split.

2. SOLID BULK CARGO

According to the transport and unloading/loading needs, maritime cargo can be divided into general cargo, solid bulk cargo and liquid (bulk) cargo. Bulk cargo are goods which are loaded in bulk, ie without packaging. Therefore, the term bulk cargo also includes liquid cargo, since it is a commodity in a liquid state which is usually loaded in bulk, ie without packaging.

In English literature two terms appear when referring to bulk cargo in “dry” or “solid” state. According to the Wärtsilä Encyclopedia of Marine Technology [3][3] terms *dry bulk cargo* and *solid bulk cargo* are synonymous and refer to the following type of goods: iron ore, phosphate, coal, grain, sugar etc. *International Maritime Code for Solid Bulk Cargoes* (IMSBC Code) [4], hereinafter: IMSBC Code, and the *Regulations for the certification of maritime ships, cargo transportation*[1] [5][4] uses the term *solid bulk* instead of the term *dry bulk.* Also, CargoHandbook.com [6] database, on transportation of cargoes in the marine industry set up by BMT, uses the term *solid bulk cargo* as type of the cargo when referring to the problems with ventilation of ship cargo spaces during the ocean voyage. Considering previously mentioned in the continuation of this work the term *solid bulk cargo* is used, except in referenced tables where terminology used by the source is used.

IMSBC Code [4] and *Ordinance on the loading and unloading of bulk and other cargoes in ports*[2] [7] defines *solid bulk cargo* as any cargo, other than liquid or gas, consisting of a combination of particles, granules or any larger pieces of material generally uniform in composition, which is loaded directly into the cargo spaces of a ship without any intermediate form of containment. IMSBC Code [4] divides solid bulk cargo into three groups:

- Group A – consists of cargoes which may liquefy if shipped at a moisture content in excess of their transportable moisture limit (TML).
- Group B – consists of cargoes which possess a chemical hazard which could give rise to a dangerous situation on a ship.
- Group C – consists of cargoes which are neither liable to liquefy (Group A) nor to possess chemical hazards (Group B).

Solid bulk cargo is often the only cargo on board [8]. Therefore, cargo characteristics have impact on the construction and on the capacity of the ships and transportation means. When deciding on transportation technology, unloading/loading technology, means of transportation and on way of

[1] Translated by authors

[2] Full title: *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* (translated by authors)

storage – it is important to consider physical and technical characteristics of the specific solid bulk cargo [9].

Appendix I (individual schedules for solid bulk cargoes) of the IMSBC Code [4] consists of a list of solid bulk cargos which has following format for the properties of the cargos: (i) tentative bulk cargo shipping name; (ii) description of the cargo; (iii) characteristic of the cargo filled in the table (angle of repose, bulk density [kg/m^3], stowage factor [m^3/t], size, class, group); (iv) hazard – clarifies the hazard of carriage of the cargo and determines types of requirements, if necessary; (v) stowage & segregation; (vi) hold cleanliness; (vii) weather precautions; (viii) loading; (ix) precautions; (x) ventilation; (xi) carriage; (xii) discharge; (xiii) clean-up, and if necessary specifies the emergency procedures and remarks for the cargo. Cargo listed in this appendix should be transported in accordance with the provisions in its schedule in addition to the provisions in sections 1 to 10 and 11.1.1 of the IMSBC Code. If a solid cargo, proposed for carriage in bulk, is not listed in this appendix, the shipper shall, prior to loading, provide the competent authority of the port of loading with the characteristics and properties of the cargo in accordance with section 4 of the IMSBC Code. Based on the information received, the competent authority will assess the acceptability of the cargo for safe shipment [4].

Solid bulk cargo makes up a large part of maritime cargo transport. Major solid bulk commodities, iron ore, grain and coal, in 2018 [1] accounted for more than 40% of total dry cargo shipments, followed by containerized trade with 24% and minor bulk with 25.8%. Remaining volumes were made of other dry cargo, including break bulks. (see Figure 1). A trade in iron ore represents 28.2% of global solid bulk trade, followed by coal with 24.1% which account for nearly half of global maritime trade (see Table 1). [1]

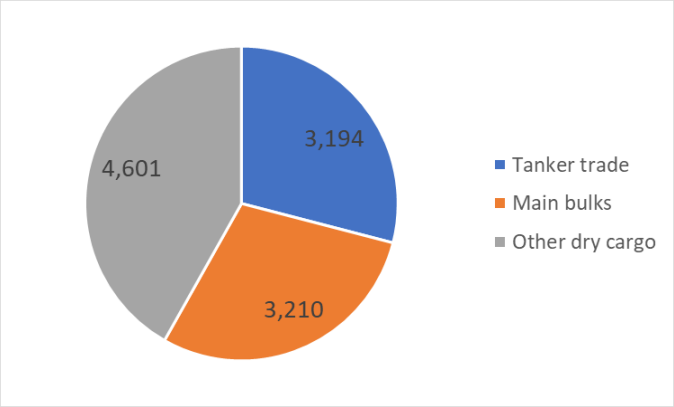


Figure 1 – International maritime trade in 2018 (million tons loaded)
Note: Main bulks includes iron ore, grain and coal only, while data relating to bauxite/alumina, phosphate, minor bulk, containerized trade and residual general cargo are included under other dry cargo
Source for data: [1]

Table 1 – Dry bulk trade, 2017-2018 (million tons and annual percentage change)

	2017	**2018**	**Percentage change 2017-2018**
Major bulks of which:	*3,151*	*3,210*	*1.9*
Iron ore	1,473	1,476	0.2
Coal (steam and coking)l	1,202	1,263	5.1
Grain (wheat, coarse grain and soybean)	476	471	-1.1
Minor bulks of which	*1,947*	*2,020*	*3.7*
Steel products	392	390	-0.5

Forest products	365	378	3.6
Total dry bulks	**5,098**	**5,230**	**2.6**

Note: UNCTAD secretariat calculations are based on Clarksons Research [10]
Source: [1]

3. BULK CARRIERS

Bulk carriers were developed in the 1950s to carry large quantities of non-packed commodities such as grains, coal and iron ore [11] as well as to ensure the cost-effectiveness of the transportation process. As defined in the Chapter II-1 and Chapter XII of SOLAS [12] term *bulk carrier* refers to a ship which is intended primarily to carry dry cargo in bulk, including such types as ore carriers and combination carriers. Chapter IX of SOLAS [12] has similar definition but adding that bulk carrier is a ship which is constructed generally with single deck, top-side tanks and hopper side tanks in cargo spaces.

In available literature and market analysis different classifications of bulk carrier were identified, with different values for size of DWT (Table 2).

Table 2 – Different classification of bulk carriers

Classification	Duran and Martin[a) 1] Size (DWT)	BIMCO[b)] Size (DWT)	BRS BROKERS[c)] Size (DWT)
Small Ships	<10,000	N/A	N/A
Handysize[2]	10,000-39,999	10,000 – 39,999	25,000-67,999
Handymax	40,000-59,000	40,000 – 64,999	N/A
Panamax	60,000-99,999	65,000 – 99,999	68,000-84,999
Babycape & Post-Panamax	N/A	N/A	85,000-120,000
Capesize	100,000-200,000	100,000+	>120,000
VLOC[3]	> 200,00	200,000 – 350,000	N/A
Valmax	N/A	380,000 – 400,000	N/A

Note: [1] The classification was self-made by authors with data from UNCTAD and Barry Roglyano annual review. [2] BRS brokers defines this classification as Supramax & Handysize. [3] Duran and Martin defines this classification as VLOC & ULOC (Very Large Ore Carrier / Ultra Large Ore Carrier).
Source: [a)] [13], [b)] [14], [c)] [15]

Currently one of the largest bulk carriers used for transportation of solid bulk cargo is MS Vale Brasil (402,347 DWT). It belongs to the Valemax fleet and it is used by Brazilian ore company Vale do Rio Doce (VALE) to transport iron ore from Brazil to European and Asian ports (Cf. [16], [17]).

Manoeuvrability of the ship as well as principal ship dimension which are: length overall (L_{OA}), length between perpendiculars (L_{PP}), beam (B) and full-load draught (T_{FL}) are important to consider when designing and planning port area. In Table 3 typical ship dimension, from ROM 3.1 series [18] (esp. **R**ecomendaciones para **O**bras **M**aritimas, engl. Recommendations for Maritime Works (which is also referred in PIANC document[19]), for bulk and multipurpose carriers are shown. Latest information on ship dimensions and design can be also found in sources such as Lloyd's Register Fairplay Data. For planning a berth area principal ship dimensions are crucial in designing of the berth and choosing the unloading and loading equipment in the port or terminal.

Table 3 – Average dimensions of bulk and multipurpose carriers

Dead Weight Tonnage (DWT)	Length overall (L_{OA}) [m]	Length between perpendiculars (L_{PP}) [m]	Beam (B) [m]	Depth (T)[1] [m]	Draught (D) [m]
400,000	375.0	356.0	62.5	30.6	24.0
350,000	362.0	344.0	59.0	29.3	23.0
300,000	350.0	333.0	56.0	28.1	21.8
250,000	335.0	318.0	52.0[2]	26.5	20.5

200,000	315.0	300.0	48.5	25.0	19.0
150,000	290.0	276.0	44.0	23.3	17.5
125,000	275.0	262.0	41.5	22.1	16.5
100,000	255.0	242.0	39.0	20.8	15.3
80,000	240.0	228.0	36.5	19.4	14.0
60,000	220.0	210.0	33.5	18.2	12.8
40,000	195.0	185.0	29.0	16.3	11.5
20,000	160.0	152.0	23.5	12.6	9.3
10,000	130.0	124.0	18.0	10.0	7.5

Note: 1 Not listed in PIANC Appendix C. 2 In PIANC Appendix C the value is 52.5 m
Source: [18]; [19]

4. HANDLING SYSTEMS IN THE PORT

What kind of equipment is used in a port or a terminal also depends mostly on its size, i.e. on the amount of cargo passing through that port or terminal. Other parameters such as the size of the terminal surface itself and the distance to the storage areas must be also considered for the selection of the handling equipment.

Loading and unloading of the cargo in/from bulk carrier is done by shore-based equipment or ship-borne equipment [8] and it is necessary to ensure that this equipment can access each part of the ship cargo hold. Therefore, these types of ships are usually equipped with wide hatches. During the loading process specific safety concerns must be taken into consideration to ensure that cargo cannot shift during a voyage which can cause stability problems. Also, large hatch covers must be watertight and secure [11]. Today, the process of loading and unloading of solid bulk cargo is almost completely mechanized, thus minimizing the ships time in a port.

For bulk carriers there is a variety of unloading and loading systems and equipment available with a wide range of capacity. Some equipment's are continuous, others are discontinuous. Typical unloading equipment for bulk carriers are grabs, pneumatic systems, vertical conveyors, bucket elevators, slurry systems and self-discharge vessels. Self-discharge vessels are usually equipped with deck-mounted grab cranes, or with a continuous unloading system inside of the vessel hold. Typical loading equipment are ship-loader which arrangements differs depending on the commodity in question and on the type of berth, they can be stage as travelling, linear, radial [8].

Depending on the unloading/loading system used in the port four type of terminals for unloading/loading of bulk carriers can be differentiate: conventional export terminals, conventional import terminals, multiple-use berths and offshore terminals for slurried bulk [20].

5. PORT STORAGE AREA

Depending on the type of commodity the storage area in the port is usually set as open storage area, shed, silo, or slurry pond [20].Open storage area is usually used for storage of goods that do not suffer serious degradation when exposed to weather conditions, while closed storage area (e.g. silo, shed) are used for goods that can degrade when exposed to the weather.

In the port, for open storage area, common practice is to use combined stacking and reclaiming devices [20].Stackers are traveling machines with a stacking boom with belt conveyor while reclaimers are similar traveling machines equipped with also a reclaiming device (e.g. bucket wheel and an intermediate belt conveyor). Stackers and reclaimers can be standalone devices, or they can be built into one the same device. Except for these devices common practice is to also to have a bulldozer in the storage areas in order to push parts of the stockpile within reach of the reclaimer [8].

The choice between using silos or shed is usually based on economics. Silos are usually selected when storage time is short and for goods in fine powder form (for dust-control reasons) , e.g. grain,

cement. Closed storage areas usually are equipped with different types of conveyors systems and pipes and hoses for pneumatically handled cargo, while sheds are usually also equipped with some type of bulldozers to scrap the material from different part of the shed into below-ground-level hoppers, which delivers the material to conveyor belt (cf. [20]).

Except of the unloading and loading of the cargo in the storage area, also other processes can be performed such as: blending of different grades of goods (e.g. for iron ore or coal), processing (e.g. bagging of cement, grains, sugar), weighting (e.g butch weighting or continuous weighting) and sampling (for more see: [8]).

6. POLLUTION PROBLEMS

As already stated in the previous chapter most of the solid bulk cargo inside of the port is manipulated by conveyors, stacking and reclaiming devices, pipes and hoses and ship-borne equipment. Their operations create dust that can be carried by wind, which can contaminate nearby cargo handling machinery and other facilities at the terminal, as well as adjacent residential areas, if any. In order to minimize the lifting of dust during cargo handling, the handling machinery should be closed as much as possible and maintained in tip-top condition so that the handled cargo not spill over [20].

When planning the solid bulk terminal, it is important to consider safety aspects (e.g. dust explosion), environmental aspect (e.g. dust, noise) and climatic aspect prevailing at the terminal location (e.g. in very cold areas, special low temperature steel is used for the construction of load filling equipment).

Reasons for the pollution at the terminal for solid bulk cargo can be divided into the adverse effects of port construction and of port operations. Environmental consideration that should be consider while constructing the port is effects of dredging and reclamation on marine flora and fauna, marine and air pollution, noise and vibration. All port operations, such as manoeuvring and berthing of ship, loading and unloading of cargo to/from ship and other transportation means, storage of cargo, create a certain level of environmental pollution. Therefore, environmental consideration that should be consider during the port operation are: maintenance dredging, water pollution caused by cargo handling, air pollution caused by cargo handling and storage, noise pollution caused by ship operations, land transportation and cargo handling as well as pollution caused by dirty cargo [20].

While the adverse environmental effects of port construction only occur during port construction and are depending on the type and degree of the work, the adverse effects of port operations are present throughout the whole time of terminal operation and for this reason it is important to prevent them as much as possible.

7. ANALYSIS OF THE TERMINAL FOR SOLID BULK CARGO IN THE PORT OF SPLIT

Port of Split is a port open to international public traffic, and according to its size and significance it is a port of particular (international) economic interest for the Republic of Croatia [21].

Terminal for solid bulk cargo at Port of Split covers an area of 21,600 m^2, of which 10,000 m^2 is open storage area and 11,600 m^2 is closed storage area. The length of the operational wharf is 550 m, and the depth of the sea at all berths is 11 m, which enables the reception of ships up to 40,000 t of carrying capacity. The most manipulated cargoes are sugar, coal, salt, cereals and fertilizer. In addition to the regular handling of cargo (unloading/loading) there are possibilities for additional activities at the terminal, such as sorting, palletizing, bagging or weighing of the goods. The terminal is connected to the railway and road network of the Republic of Croatia so that with the storage of goods it is possible to perform direct manipulation of goods from and to wagons or trucks [22].

Solid bulk cargo is the main cargo in Port of Split. On average more than 60% of total handled cargo in the port is solid bulk goods. In 2019 58% of total handled cargo was solid bulk, while this share in 2018 was 64%, and in 2017 68% (Table 4).

Table 4 – Gross weight of total and dry bulk goods transported to/from Port of Split

Year	Total ['000 t]			Dry bulk goods ['000 t]		
	Total	*Inwards*	*Outwards*	*Total*	*Inwards*	*Outwards*
2019	1,942	935	1,007	1,122	320	802
2018	2,099	939	1,165	1,340	374	966
2017	2,245	953	1,296	1,537	433	1,104
2016	2,116	1,151	966	1,263	477	786
2015	2,451	1,076	1,375	1,602	452	1,149
2014	2,503	1,081	1,422	1,475	531	944

Note: Outwards – port of loading, Inwards – port of unloading.
Source: [23]

In Croatia in 2019 total 18.07 mil of tonnes of goods was handled in Croatian main ports.[3] In 2019 most of the cargo 38% was handled in port of Omišalj which handles liquid bulk goods only. In all other ports, except Omišalj, 11.81 mil of tonnes in total was handled of which 30% in port of Ploče, followed with 28% in port of Rijeka, 25% in port of Bakar and 16% in port of Split [23] (Table 5).

Table 5 –Gross weight of total goods transported to/from Croatian main maritime ports

Reporting unit	Gross weight of total goods per year ['000 t]					
	2014	*2015*	*2016*	*2017*	*2018*	*2019*
Croatia	13,977	15,287	15,844	18,264	19,290	18,065

Source: [23]

Port of Split is the second busiest maritime port in Croatia in terms of total solid bulk goods handled, after port of Ploče. In 2019 49% of total solid bulk cargo in Croatia was handled in port of Ploče, followed with 26% in port of Split. In 2017 and 2016 contribution of port of Split was 35%, while 43% and 45% was contribution of port of Ploče. More than 70% of total solid bulk goods handled in the main maritime ports in Croatia, from 2016 to 2019, was handled in these two ports each year (Table 6).

Table 6 – Gross weight of total dry bulk goods transported to/from Croatian main maritime ports

Reporting unit	Gross weight of total dry bulk goods per year ['000 t]					
	2014	*2015*	*2016*	*2017*	*2018*	*2019*
Croatia	5,145	5,558	3,634	4,339	4,893	4,385
Ploče	1,747	1,697	1,627	1,886	2,225	2,163
Split	1,475	1,602	1,263	1,537	1,340	1,122
Bakar	1,156	1,143	427	669	1,099	902
Rijeka	379	1,117	318	320	230	198

Source: [23]

Port of Ploče and port of Bakar are mostly ports of cargo unloading from the ships with 88% of inwards solid bulk cargo in 2019 for port of Ploče, and 100% for port of Bakar. Port of Split is primarily port of loading of solid bulk cargo with 75% of outwards solid bulk cargo in 2019. (Table 7, Table 8).

[3] Note: There are six maritime ports of particular (international) economic interest in the Republic of Croatia, there are (from north to south): Rijeka, Zadar, Šibenik, Split, Ploče and Dubrovnik. Dubrovnik is manly passenger port. Eurostat definition of a main port [24]: *"A main port is a statistical port which has annual movements of no less than 200 000 passengers or recording more than one millions tonnes of cargo. For ports selected on the basis of only one of these cargo or passenger criteria, detailed statistics are required only for that transport."* Port of Zadar is not listed in the Eurostat database mar_go_am_hr [23] while data for port of Šibenik were not available.

Table 7 – Gross weight of inward dry bulk goods transported to main Croatian maritime ports

Reporting unit	Gross weight of inwards dry bulk goods per year ['000 t]					
	2014	*2015*	*2016*	*2017*	*2018*	*2019*
Croatia	3,567	4,179	2,624	3,067	3,789	3,320
Ploče	1,589	1,614	1,469	1,702	2,106	1,908
Split	531	452	477	433	374	320
Bakar	1,156	1,143	426	669	1,099	902
Rijeka	261	970	251	263	210	190

Note: Inwards – port of unloading.
Source: [23]

Table 8 –Gross weight of outwards dry bulk goods transported from main Croatian maritime ports

Reporting unit	Gross weight of outwards dry bulk goods per year ['000 t]					
	2014	*2015*	*2016*	*2017*	*2018*	*2019*
Croatia	1,600	1,384	1,012	1,346	1,106	1,064
Ploče	158	84	159	184	119	255
Split	944	1,149	786	1,104	966	802
Bakar	n/a	n/a	0	n/a	n/a	n/a
Rijeka	118	148	67	57	21	7

Note: Outwards – port of loading. n/a - not available
Source: [23]

In 2019 most of the solid bulk goods handled in the Port of Split, in accordance with classification NST 2007, was other solid bulk goods (69%), followed with agricultural products (16%), ores (9%) and coal (6%). There is a big variation in amount of the ores and coal handled yearly in the port, with big drop in 2018 for ores, and in 2014 and 2017 for coal. As mentioned before most of the solid bulk cargo is loaded in the port (in 2019 71%). All the agricultural products in 2019 were loaded, there was no unloading of this product, while 65% of ores and 72% of other solid bulk cargo was also primarily loaded in the port. Coal is dry goods which is primarily unloaded in the port (Table 9).

Table 9 – Traffic of goods by type of cargo, direction, and weight of goods in Port of Split (in tonnes)

Type of cargo*	Direction	Year					
		2014	2015	2016	2017	2018	2019
Dry bulk goods *of which:*	Total	1,474,809	1,601,848	1,263,446	1,537,277	1,339,811	1,122,301
	Loaded	943,784	1,149,446	786,340	1,104,303	966,145	802,020
	Unloaded	531,025	452,402	477,106	432,974	373,666	320,281
Ores	Total	45,809	233,240	50,506	17,041	2,788	106,136
	Loaded	37,813	233,240	45,001	17,041	-	69,391
	Unloaded	7,996	-	5,505	-	2,788	36,745
Coal	Total	7,893	29,878	16,704	5,500	65,511	69,784
	Loaded	-	-	450	-	-	-
	Unloaded	7,893	29,878	16,254	5,500	65,511	69,784
Agricultural products (e.g. grain, soya, tapioca)	Total	308,599	349,860	299,000	211,830	204,049	173,962
	Loaded	227,121	342,967	281,000	185,385	193,882	173,962
	Unloaded	81,478	6,893	18,000	26,445	10,167	-
Other dry bulk goods	Total	1,112,508	988,870	897,236	1,302,906	1,067,463	772,419
	Loaded	678,850	573,239	459,889	901,877	772,263	558,667
	Unloaded	433,658	415,631	437,347	401,029	295,200	213,752

*Note: *Type of goods by Classification of goods for transport statistics NST 2007, Sections.*
Source: [25]

European port with similar amount of cargo, as port of Split in 2018, was French port Le Havre with 1,366 thousand tonnes of solid bulk goods, which makes 2.1% of its total port cargo [26]. In 2018 majority of cargo in port of Split was solid bulk cargo, i.e. 64% of total cargo was solid bulk cargo (Table 4). Top European ports, with majority of solid bulk goods handled in the ports are Iskenderun (solid bulk goods made 75.8% of total cargo), Riga (67.6%), Constanta (64.3%), Dunkerque (63.1%), Taranto (58.3%) and Amsterdam (43.7%), but they had significantly more cargo handled in the port (Table 10). Comparing the amount of solid bulk goods handled in these ports and in the port of Split it can be seen that amount of solid bulk goods in the port of Split was 3.1% of solid bulk goods in port of Iskenderun, 5.8% of solid bulk in port of Riga, 5.3% of Constanta, 5.2% of Dunkerque, 11.3% Taranto and 3.1% of Amsterdam (Table 10).

Table 10 – Gross weight of dry bulk goods handled in 20 top European ports (in '000 t and percentage of total)*

Port	Country code	Year					
		2016		2017		2018	
		['000 t]	% of total	['000 t]	% of total	['000 t]	% of total
Rotterdam	NL	77,210	17.9	74,804	17.3	74,799	16.9
Iskenderun, Hatay	TR	34,319	85.7	42,470	76.7	43,540	75.8
Amsterdam	NL	43,786	45.4	44,585	45.3	43,474	43.7
Hamburg	DE	30,426	25.3	30,818	25.9	30,710	26.1
Dunkerque	FR	22,142	60.1	24,239	62	25,923	63.1
Constanta	RO	23,185	61.8	23,654	63.4	25,435	64.3
Riga	LV	21,803	60.9	20,394	63.5	23,234	67.6
Izmit	TR	21,232	32.2	23,683	32.6	22,440	31
Aliaga	TR	16,747	33.4	17,740	32.2	17,338	32.5
Immingham	UK	15,712	28.9	14,056	26	16,507	29.7
Marseille	FR	12,958	17	13,615	18	14,986	19.8
London	UK	15,328	30.4	15,644	31.4	14,879	28
Antwerpen	BE	12,588	6.3	11,840	5.9	13,015	6.1
Taranto	IT	11,992	57.2	12,227	60.7	11,880	58.3
Sines	PT	5,863	12.2	6,361	13.7	5,186	11.7
Botas	TR	10,648	13.6	6,195	8.7	4,404	7.3
Barcelona	ES	4,437	11.3	4,466	9	4,225	7.7
Wilhelmshaven	DE	3,104	12.7	4,180	14.8	4,120	14.6
Tallinn	EE	3,545	17.8	3,958	20.9	3,916	19.2
Tees & Hartlepool	UK	2261	8.4	3519	12.4	3870	13.4
Trieste	IT	905	1.8	2437	4.4	3702	6.5
Valencia		2476	4.3	2279	3.8	2544	4.1
Bergen		2687	6	2856	5.9	2266	5.1
Ambarli		2570	8.1	2397	6.9	1949	5.8
Southampton		2367	6.6	2109	6.1	1930	5.6
Genova		1416	3.1	1662	3.3	1851	3.6
Algeciras		1621	1.9	1942	2.3	1608	1.8
Le Havre		1888	3.1	2238	3.4	1366	2.1
Peiraias		473	1.2	353	0.8	422	0.8
Göteborg		91	0.2	143	0.4	77	0.2

Note: In the table 30 port with
Source: [26]

8. CONCLUSION

From the performed analysis it can be concluded that Port of Split is one of the most important port in Croatia in terms of the amount of loaded solid bulk cargo in the ports, although it is not included in top 20 European main ports. Solid bulk cargo in the Port of Split makes up majority of handled cargo and most of them are loaded to a ship. Majority of the loaded cargo are agricultural products (sugar, salt, cereals) and ores, while coal is mostly unloaded in the port. Other most manipulated cargos are fertilizers.

Due to the availability of only Eurostat databases and database of Croatian Bureau of Statistics the question about the big drop in the amount of ores handled in the 2018, and in the amount of coal in 2014 and 2017 were not answered. Therefore, recommendation for the future research is analysis of industries that uses Port of Split to transport their goods or to import the necessary goods for their business through this port. Also, future research should address the subclassification of type "other dry bulk goods" of Croatian Bureau of Statistics which makes 69% of total solid bulk cargo in the Port of Split.

REFERENCES

[1] UNCTAD. *Review of Maritime Transport 2019.* New York, US: United Nations Conference on Trade and Development; 2019. Available from: https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf [Accessed 2nd of May 2020].

[2] Franc T. Analiza produktivnosti terminala za suhi rasuti teret na primjeru morske luke Split [*Productivity Analysis of Dry Bulk Cargo Terminal: a Split Maritime Port Case Study*]. M.Sc. thesis. Zagreb, Croatia: Faculty of Transport and Traffic Sciences of University of Zagreb; 2019. Available from: https://urn.nsk.hr/urn:nbn:hr:119:517929 [Accessed 4th April 2020]. Croatian

[3] Wärtsilä Encyclopedia of Marine Technology. *Dry bulk cargo, solid bulk cargo.* Available from: https://www.wartsila.com/encyclopedia/term/dry-bulk-cargo-solid-bulk-cargo [Accessed 4th July 2019].

[4] IMO. *International Maritime Solid Bulk Cargoes Code (IMSBC Code). Resolution MSC.268(85).* International Maritime Organization; 2008. Available from: http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Maritime-Safety-Committee-(MSC)/Documents/MSC.268(85).pdf [Accessed 9th of August 2019].

[5] Republika Hrvatska. *Pravila za statutarnu certifikaciju pomorskih brodova. Prijevoz tereta. [Regulations for the certification of maritime ships, cargo transportation].* Issue 069. Zagreb: Narodne novine; 2018. Croatian

[6] CargoHandbook.com. *Solid bulk cargoes.* Available from: https://www.cargohandbook.com/Solid_bulk_cargoes #Solid_bulk_cargoes [Accessed 2nd of May 2020].

[7] Republika Hrvatska. *Pravilnik o rukovanju opasnim tvarima, uvjetima i načinu obavljanja prijevoza u pomorskom prometu, ukrcavanja i iskrcavanja opasnih tvari, rasutog i ostalog tereta u lukama, te načinu sprječavanja širenja isteklih ulja u lukama. [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].* Issue 051. Zagreb: Narodne novine; 2005. Croatian

[8] Ligteringen H, Velsink H. *Ports and terminals*. 2nd ed. Delft: Delft Academic Press; 2017.

[9] Baričević H, Vilke S, Poletan Jugović T. *Tereti u prometu*. Rijeka: Pomorski fakultet u Rijeci; 2010. Croatian

[10] Clarksons Research. Dry Bulk Trade Outlook. 2017;23(12). Available from: https://www.crsl.com/acatalog/dry-bulk-trade-outlook.html [Accessed 2nd of May 2020].

[11] International Maritime Organization (IMO). *Bulk Carrier Safety.* Available from: http://www.imo.org/en/OurWork/Safety/Regulations/Pages/BulkCarriers.aspx [Accessed 2nd of May 2020].

[12] IMO. *International Convention for the Safety of Life at Sea (SOLAS)* – 1974. Consolidated edition 2020.

[13] Duran E, Martin A. Vessel dimensions: A key factor to the design and location of dry bulk terminals. *Journal of Maritime Reasearch*. 2016;13(1): 41-46. Available from: https://www.jmr.unican.es/index.php/jmr/article/view/362 [Accessed 4th of May 2020].
[14] BIMCO. *Dry bulk shipping: uncertainty mounts against a backdrop of weaker growth in chinese imports.* Available from: https://www.bimco.org/news/market_analysis/2019/20190220_2019_01_drybulk_shipping [Accessed 5th of September 2019.].
[15] BRS Group. *Dry Bulk Review.* Available from: https://www.brsbrokers.com/assets/review_splits/BRS-Review2019-02-Drybulk.pdf [Accessed 3rd of May 2020].
[16] *Maritime connector*. Available from: http://maritime-connector.com/worlds-largest-ships/ [Accessed 5th of September 2019.].
[17] *Vessel Tracking.* Available from: http://www.vesseltracking.net/article/ms-vale-brasil [Accessed 5th of September 2019.].
[18] ROM 3.1-99. *Recommendations for Maritime Works. Series 3 – Planning, management and operation in port area. Designing the Maritime Configuration of Ports, Approach Channels and Harbour Basins*. Madrid, Spain: Puertos Del Estado; 2007. Available from: http://www.puertos.es/es-es/ROM/Paginas/ROM-widispe.aspx [Accessed 4th of May 2020].
[19] PIANC. *Harbour Approach Channels Design Guidelines.* PIANC Maritime navigation commission. Report number: 121, 2014. Available from: https://www.wtwales.org/sites/default/files/files/ABP12_P%20-%20PIANC%20Harbour%20Approach%20Design%20Guidelines%20(2014).pdf [Accessed 3rd of May 2020].
[20] Agerschou H, Dand I, Torben E, Ghoos H, Juul Jensen O, Korsgaard J, Land J, McKay T, Oumeraci H, Buus Petersen J, Runge-Schmidt L, Svendsen H. *Planning and design of ports and marine terminals*. 2nd ed. London: Thomas Telford Publishing; 2004.
[21] *Lučka uprava Split.* Available from: https://portsplit.hr/lucka-uprava-split/ [Accessed 4th of September 2019]. Croatian
[22] *Luka d.d. Split*. Available from: http://www.lukasplit.hr/services/terminal-za-rasuti-teret/ [Accessed 4th of September 2019]. Croatian
[23] Eurostat. Database. *Maritime transport. Gross weight of goods transported to/from main ports – Croatia*. Index: mar_go_am_hr. Last update: 2nd of March 2020.
[24] Eurostat. *Maritime transport (mar). Reference Metadata in Euro SDMX Metadata Structure (ESMS).* Available from: https://ec.europa.eu/eurostat/cache/metadata/en/mar_esms.htm [Accessed 4th of May 2020].
[25] Croatian Bureau of Statistics. *PC AXIS Databases. Transport and Communications. Traffic in Seaports. Traffic of goods by type of cargo, tonnes.* Matrix: SS_PP4. Latest update: 14th of February 2020. Croatian
[26] Eurostat. Database. *Maritime transport. Main annual results. Top 20 ports - gross weight of goods handled in each port, by type of cargo (main ports).* Indeks: mar_mg_am_pwhc. Last update: 22nd of February 2020.

TOMISLAV SUNKO, univ.spec.naut. [1]
E-mail: tomosunko@gmail.com
LUKA MIHANOVIĆ, Ph.D. [1]
E-mail: luka.mihanovic@morh.hr
TONI MIŠKOVIĆ, mag.ing.el. [2]
E-mail: toni.miskovic@pce.hr
DAVOR VODOPIJA, M.Edu.[1]
E-mail: dvvodopija@yahoo.com
[1] Croatian Defence Academy "Dr Franjo Tuđman"
Ilica 256b, 10000 Zagreb, Croatia
[2] Marine Electronic Center Ltd. (PCE d.o.o.)
Zrinsko-Frankopanska 209, 21000 Split, Croatia

THE ROLE OF HUMAN FACTOR IN RECENT ACCIDENTS OF US NAVAL SHIPS

ABSTRACT

This paper points to the problem of safe navigation of naval ships in the era of high automatization of the ships, emphasizing the decisive importance of human factor for the safety of the ship in every sense even today. A case study compares different accidents of the US Navy ships in similar circumstances and in a relatively short time distance. In the paper the circumstances which led to the collisions, facts and sequences of events have been investigated. The fact is that due to the specifics of modern warfare warships approach the mainland, which significantly makes the task more difficult for the crew in terms of safety of the ship. However, the collision analysis has shown that collisions could have been avoided, that is, the main cause of the accident was a human error. Regardless the prevailing view that high automatization of ship systems makes a warship safer, the paper stresses that basic seamanship skills are essential for the safety of navigation, not only for naval ships, but also for all participants of maritime transport.

KEY WORDS

warship; US Navy; ship crew; automatization; collision; human error

1. INTRODUCTION

An analysis of merchant ships' collision is a standard procedure after a maritime accident, in order to point out failures and prevent future incidents [1]. However, analyses of naval ships collisions are rare and not easily accessible to the public. Nevertheless, the seriousness of the collision of the US Navy destroyers USS John S. McCain and USS Fitzgerald in the year 2017. forced the Navy's leading people to analyze it thoroughly and point out serious failures [2].

According to world leading maritime defense reference resources Combat Fleets of the World [3] and Jane's Fighting Ships [4], warships can be classified according to several criteria:

- basic purpose,
- type of propulsion,
- construction material,
- area of operation and
- basic ship armament.

Depending on their tonnage and combat power destroyers today are often above former cruisers and represent leading ships of almost all the world's navies, except for the United States and Russia.

Ships of a certain type are usually classified after the first ship of the same characteristics [5], so Arleigh Burke destroyer class was named after the first ship of this class.

They are conceived as basic protective vessels of a carrier strike group - the most powerful force of the US Navy [5]. The US Navy destroyers USS John S McCain and USS Fitzgerald, as representatives of the mentioned class of ships, belong to the Carrier strike group number five, based in the port of Yokosuka, Japan. They are permanently engaged as a part of the US Pacific Fleet.

By developing joint warfare, where the navy is just one segment of military operations in a certain area, this class of ships has obtained a multipurpose role [6]. The particularity of this class of ships is an integrated complex system of sensors and computers supporting decision-making procedures and operating the ship's weapons systems. Such a demanding role requires an outstanding efficiency of the crew. This is the reason why, following the collision of these ships, the work conditions of the crew on U.S. Navy vessels as well as other factors affecting them underwent an analysis. It has been indicated that, considering the expected tasks, the crew was overloaded. A possibility of a terrorist or cyber-attack on essential ship systems has also been taken into consideration as one of the possible reasons of the collision. The conduct of the ships' crew in the conditions of dense traffic, which characterized the both cases, has also been scrutinized. However, all the reports stress the fact that ship crew members do not have enough time for practicing basic maritime skills and navigation procedures, which proved to be an essential factor in the both cases.

2. A NAVAL SHIP AS AN EQUAL PARTICIPANT IN THE INTERNATIONAL MARITIME TRAFFIC

The greatest difference between the use of a warship today and the former concept of warfare at sea, is in its approaching to the mainland [6]. Certain ships not only enable an overall approach to solving of crises and conflicts, but it also projects a significant power from the sea onto the mainland as a part of modern network-centric warfare. However, approaching to the coast increases the possibility of a threat, so it is necessary to enhance the ship's protection in every way.

The basic principle is to remain invisible or as much invisible as possible. Due to this reasons ships are constructed so that radar, acoustic, magnetic or infrared image is drastically reduced. In order to achieve this, special techniques of shaping the hull and superstructure are applied [5]. All the visible surfaces are mutually slanted, whereas construction materials and coatings are composite and reduce the radar reflection drastically. The efficiency thereof is stated by the fact that a Zumwalt-class destroyer, which is 180m long, on the radar screen has an image of a fishing vessel [7]. In addition, warships are not subject to international conventions in relation to the obligation of having the AIS (Automatic Identification System) system switched on [8]. Such a feature in transit navigation areas, in the vicinity of the mainland, sometimes represents an essential source of information. As opposed to merchant ships sailing from point A to point B with the safest route without changing their course and speed, the mission of a warship is completely different [9]. Ship's navigation is often of secondary importance, i.e. it serves as a support to a ship carrying out numerous combat or non-combat tasks. This means that their route is often unpredictable, subject to sudden changes of the course and speed, beyond the comprehension of someone working on a merchant ship. Safety of navigation in merchant marine is regulated over conventions by the International maritime organization [10]. These regulations do not apply to naval ships, but it doesn't mean that the safety of the ship is neglected. Every war ship has its specific systems, but safety of navigation comes first.

The number of people on the command bridge represents another significant difference. In the merchant navy, a deck officer and a helmsman are on the command bridge during the watch, whereas on the command bridge of a warship there are often more than ten members of the crew specialized only in their fields [2]. During the navigation this number of people can render making of navigation decisions more difficult in the situations when a quick and correct decision is needed.

In deference to commanding bridge of typical merchant vessel, there are far too many personnel on Navy ships, which is sometimes annoying and it can be a problem in particular situations [11]. The US Navy is famous for its system of assistants and handlers, even when it comes to simple devices [12]. In terms of navigation, regardless of modern technology, there is an unwritten rule which says that in case of dense traffic, officers on the watch communicate by way of radio when announcing or confirming their intentions in order to avoid possible misunderstandings which might lead to collisions at sea. The US Navy is an exception here as well. Feeling superior at sea due to capabilities of their ships, and especially when maneuvering is concerned, officers/commanders of US Navy ships rarely or hardly ever respond to radio calls from ships in that particular area. Taking into consideration the facts that their AIS is switched off and that their radar image does not correspond to the actual size of a ship, this ignoring can be very dangerous [11].

Masters of merchant ships are always suspicious about navy ships crew competence and their navigational behavior in international maritime traffic, with particular regard to handling a ship in congested waters. Navy ships maneuvers features are much better comparing to merchant ships, which are bigger and slower and often restricted in maneuvering. Therefore, responsibility in critical situations is often on navy ships [11]. Relevant factors in these debuts are ship's pilots, who embark on board navy ships as well as on board biggest merchant vessels. Piloting navy ships, they often find fault with complying basic navigational procedures like disrespected International collision regulations and ignoring bridge to bridge radio communications.

3. ACCIDENTS OF US NAVAL SHIPS IN 2017

In 2017 four maritime incidents happened involving American Navy Pacific fleet, which is considered as unacceptable. In January, American cruiser USS Antietam grounded because of navigational fault, whilst in May cruiser USS Lake Camplain collided with a South Korean fishing boat. Booth incidents were assessed as avoidable and the blame was with the crew. But these two incidents caused only material damages, and it didn't raise much noise.

However, two destroyer's incidents in June and August 2017 resulted with 17 crew members dead, which is why significant and deep reviews among Navy had followed.

3.1 USS Fitzgerald – ACX Crystal Collision

On the morning of 16 June 2017, the USS Fitzgerald destroyer departed the homeport of Yokosuka, Japan, conducting a military operation "Freedom of Navigation Operations" (FONOPs). USS Fitzgerald collided with the merchant ship ACX Crystal on 17 June 2017 at 01:30 AM, local time. The accident happened in Sagami Wan bay, approximately 56 nautical miles southwest from Yokosuka. ACX Crystal bow struck USS Fitzgerald on the starboard side below the waterline which caused enormous damage. Visibility and sea conditions were favorable in the moments of collision. Figure 1 shows the time sequence, and the route of USS Fitzgerald destroyer before the collision of the ships. The blue dashed line shows the direction of navigation of the destroyer as well as the chronological order of her positions (highlighted in white spaces). Positions and time sequence of the navigation of ACX Crystal merchant ship are shown in orange [2]. The green dashed line and the purple dashed line show the other ships which were in the vicinity of the collision location.

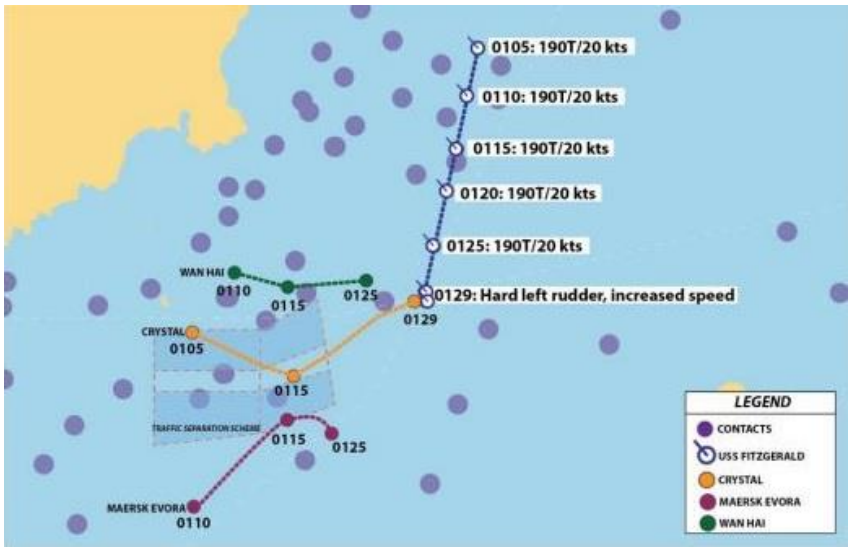


Figure 1 – Illustration Map of Approximate Collision Location
Source: [2]

Search and Rescue (SAR) operation at sea was launched in a very short time, in order to find seven missing American sailors in the area surrounding the collision site. The Japanese Coast Guard and the US SAR teams consisting of ships, tug boats, helicopters and aircraft were involved in this action as well as USS Fitzgerald. The collision between USS Fitzgerald and merchant ship ACX Crystal resulted in the deaths of seven U.S. sailors, due to impact with the USS Fitzgerald s berthing compartments, located below the waterline of the ship. Also, three sailors were injured [2]. After the collision, USS Fitzgerald sailed under her own power to the homeport, assisted by two tugboats dispatched from the Port operations in Yokosuka Naval Base.

ACX Crystal is a Philippines flagged container ship, 222,6 meters length, 30.1 meter wide, with a gross tonnage capacity of 29060 tons. In the time of the collision, ACX Crystal was loaded with 2900 containers carrying from Nagoya to port of Tokyo. ACX Crystal did not suffer any significant damage in the collision, and there were not injured crew members.

The evening before the accident, at 11:00 PM, local time, in accordance with the standard procedure, the Commander and the executive officer left the commanding bridge, leaving control of the ship to the officer of the deck (OOD). Around 01:00 AM, 17 June, the destroyer was found in the situation of crossing courses with three ships which were seen over the starboard side. One of them was ACX Crystal [2].

In that moment the destroyer should have maneuvered in order to avoid the collision, in accordance with the International Regulations for Preventing Collisions at Sea [13]. Instead, the destroyer continued her navigation on the same course and at the same speed.

A few minutes prior to the collision, OOD and his two assistants has been discussing the changing of the destroyer's course due to the ships seen on the radar, but they had not taken any maneuvers, which eventually led to the collision [2].

The analysis after the ships collision showed that they had not used the radio communication bridge to bridge; neither had they called the Commander Officer as required by the procedure in case when the ships safety is threatened [2].

The ship combat information center's crew is also partially responsible for the collision regarding the sensor they operated. They should have warned the crew on the command bridge of the critical situation.

Despite the fact that ACX Crystal had the advantage of passage, the merchant ship was also responsible for the collision because it had not taken the appropriate maneuver to avoid the collision according to the Maritime Safety Information (MSI) [14]. It should be emphasized that the sea waterways leading to Tokyo bay are navigationally extremely demanding because of the large number of commercial vessels entering and leaving the biggest Japanese ports of Tokyo and Yokohama.

3.2 USS John S. McCain – Alnic MC Collision

The USS John S. McCain destroyer sailed from her military homeport Yokosuka, Japan, on May 26, 2017, commencing a six month deployment in the Western Pacific. On August 21, 2017, the destroyer was heading to Changi Navy Base in Singapore for a routine port visit. On that day, at 05:24 AM, about 50 nautical miles east of Port of Singapore, while approaching the Singapore Strait and Strait of Malacca, USS John S. McCain destroyer collided with the merchant ship Alnic MC. In a very short time, a SAR operation at sea was launched, with the aim of finding 10 missing American sailors in the area surrounding the collision site. Singaporean, Malaysian, Indonesian, Australian and US SAR teams consisting of patrol ships, helicopters and tugboats were involved in the action of searching the area for the missing crew.

In the collision of two ships, the American destroyer suffered significant damage to the hull after a hole was torn beneath the waterline, which led to flooding of nearby compartments, crew sleeping areas, machinery and communications rooms. Ten American sailors were killed in the collision, and 48 were suffered injuries that required medical treatment [2]. After the collision, USS John S. McCain sailed under its own power toward the port at Changi Naval Base, Singapore, as a result of crew's resiliency and successful damage control and engineering repair efforts.

Figure 2 shows the time sequence, as well as the route of the USS John S. McCain destroyer before the collision of the ships. The blue dashed line shows the direction of navigation of the destroyer as well as chronological order of her positions (white circles). The white lines indicates the traffic separation scheme. The positions and time sequence of navigation of Alnic MC merchant ship are shown in orange [2].

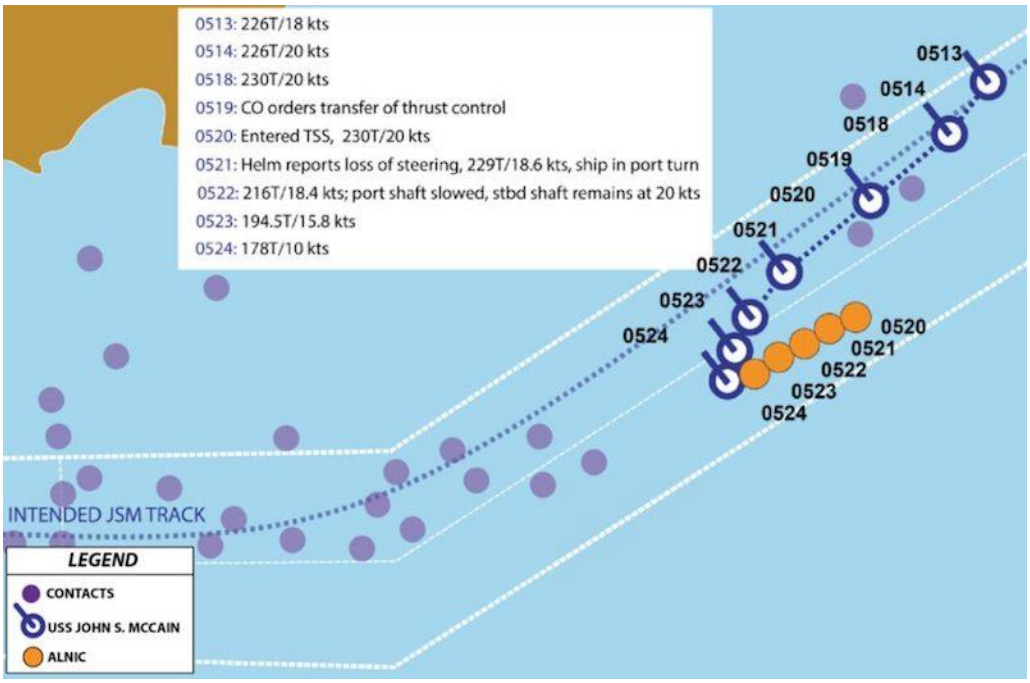


Figure 2 – Graphic representation of the ships' time sequence up to the collision of USS John S. McCain destroyer and Alnic MC merchant ship
Source: [2]

Alnic MC is a Liberia flagged oil and chemical tanker, 183 meters long, with a total carrying capacity of 50760 tons. At the time of the collision she was carrying 12000 tons of fuel. Luckily the hull of the ship remained undamaged so that loaded cargo did not leak into the sea nor the tanker suffered any major damage. Also, there were no injured crew members [2].

The Commander Officer of USS John S. McCain destroyer came to the command bridge at 01:15 AM local time, exactly as the US Navy instructions require in the case of sailing in the area of heavy traffic at night.

The executive officer came to the command bridge at 04:30 AM, because the destroyer was entering the traffic separation scheme leading to the port of Singapore, which is known as a very demanding route. At 05:19 AM, the Commander noticed that there were some difficulties in keeping the ship at the commanded course. In order to keep the ship's course steady, the steering was transferred to a backup helm station. This unplanned shift caused confusion and misunderstandings in the watch team, obviously not trained well enough for such situations. Consequently, the ships' course changed abruptly to the port side, which eventually led to the ship's collision [2].

3.3 Consequences

As a result of the accidents, the US Navy relieved several senior officers, including 7th Fleet commander himself. There has been an investigation led by the Navy, which includes charges against 17 crew members of both destroyers [15].

An additional hearing of the commanding officers (CO) of both destroyers involved in the incidents was also appointed, in order to determine their guilt in these fatal cases. They were charged of very serious imputation such as negligent homicide and dereliction of duty [15]. Eventually, former CO of USS John S. McCain pleaded guilty to negligence in collision case whilst military court-martial process against former CO of USS Fitzgerald's still continues [16].

Senator John S. McCain III, chairman of the Senate Armed Service Committee, was very critic in his statement regarding these accidents [17]. He demanded not to cut defense capabilities, especially training, and also underlined that both accidents happened in a short period of time, killing more solders in peace time then in engagement with the enemy which is not acceptable.

The US Navy 7th Fleet had temporarily postponed all operations for a while, in order to refresh training of the ships' crews. The trainings are focused on safety and security with particular topics on risk management and communication skills.

4. ANALYSIS OF THE ACCIDENTS

The destroyers' accidents consequences were fatal and they required intensive analyses and immediate reaction. American Navy is the leading world naval power, and human loss in accidents during peace time requires search for mistakes and lessons learned in order to prevent this to happen again. The official review of the accidents, especially the destroyer's collisions showed that, besides some objective circumstances, the crews of the ships reacted unprofessionally and very confused what was the main cause of the accidents [2]. Unprofessionalism is a very hard imputation for such representative ship as a destroyer and it raised many issues regarding concept of the Navy ships crew recruiting and training.

Analyzing details before and during accidents, the official review especially pointed out negligence in safety and navigational standard procedures [18]. Also, it was obvious that the crew and commanding officer were not confident in using navigational equipment, even basic one.

Table 1 shows the main findings in the accidents analyzes.

It is obvious that human error was the leading factor which led to the catastrophes.

The Officer of the Deck (OOD), the person responsible for safe navigation of the ship, obviously failed to maneuver as required. He also did not sound the danger signal nor tried to contact CRYSTAL on Bridge to Bridge radio. Moreover, the Commanding Officer was not called on the bridge as prescribed by Navy procedures in case of dangerous situation.

Additional teams in the Combat Information Center and the rest of the watch team on the bridge also failed to provide the OOD input and information [18].

Table 1 – Analysis of ship accidents causes

	SHIP NAME			
ISSUE	**USS John S. McCain (DDG 56)**	**USS Fitzgerald (DDG 62)**	**USS Lake Champlain (CG 57)**	**USS Antietam (CG 54)**
Poor Planning	X	X	X	X
Bridge/CIC Communication Failure	X	X	X	X
Bridge-to-Bridge Communication Failure	X	X	X	N/A
Radar Improperly Tuned	X	X	X	X
No EXTREMIS Call	X	X	X	X
Fatigue/fatigue Management	X	X	X	X
Outdated CO Guidance	X	X		X
Failure to follow CO Standing Orders	X	X	X	X
Poor Log Keeping	X	X	X	X
PBED not adhered to	X	X	X	X
Lack of Communication between Bridge / CIC	X	X	X	X
Poor Self-Assessment and training	X	X	X	X

Source: created by authors

Table legend:

Acronym	Definition
CIC	Combat Information Center
N/A	not applicable or not available
CO	Commanding Officer
PBED	Plan, Brief, Execute, Debrief

5. DISCUSSION

In the last 2 decades many things in global warfare scene have changed. Projection of naval power at sea has become much more complex and demanding, facing new threats and expanding areas of operation. All these concern particularly to the US Navy as a global leading maritime power. In this section, new challenges and demands are discussed.

5.1 New Challenges

In October 2000 the American destroyer USS Cole (Arleigh Burke class) was attacked by terrorists. The attack was carried out at the Aden anchorage (Yemen port in Bay of Aden, close to Bab el Mandeb strait) by the terrorist organization Al-Qaida. Terrorists hit the ship with a small boat full of explosives, which killed 17 crew members and injured 39 [19]. This was a sort of turning point in new warfare concept which faced new untraditional and unconventional threats. Besides warships, submarines and aircrafts, new hostile threats arise by the use of small crafts, hardly seen on radar.

The terrorist attack in September 11 2001 surprised, but also awaked the government of the USA, showing they need to improve their state security in the way of preventive global action [6]. In 2002

the USA established National homeland security policy, with the main goal to prevent terrorist attacks. That includes strategy of preventive acting, far away from USA, which results in much more complex mission for the American Navy.

According to this new concept, the Navy is be deployed on a regional basis, close to crisis regions, with the prime task to deter potential aggressor from threatening American territory and their interests across the oceans [6]. The Chinese Navy ambitions in the Pacific and Indian Ocean are a matter of special US concern. Back from battles in World War II against Japan, the Pacific has been representing a special US interest.

China nowadays represents a new considerable US Navy opponent. They show it participating in the Somalia anti-piracy campaign, in humanitarian missions throughout the world and also by showing new efficient combat systems onboard their ships. Moreover, Russia is also empowering its navy by conducting aggressive missions in Ukraine and Syria which provides US military presence around the world in order to meet these growing regional threats. Together with the new US strategy pointed out, these facts raise expectation and complicate missions of their naval forces and demands enhanced navy capabilities.

5.2 Enhanced Demands

According to new expectations, the Navy has been developing a modern warships concept for the next 20-30 years. Meanwhile, present ships must be deployed much more than they used to be. The crew of the ships spends much more days at sea, raising their capabilities in combat and peacekeeping missions [12]. The basis of every ship's efficiency is regular maintenance and crew capabilities. Naval ship's crews must be well trained in every aspect of the ship safety procedures, starting with navigation and propulsion department together with modern combat systems. Modern naval ships such as cruisers and destroyers are particularly demanding ships. Their crews have to pass intensive and long lasting training before they embark the ship. These trainings includes lectures on basic skills as well as on new technologies. In addition, any procedure regarding basic navigation skills must be trained in different types of simulators. The usage of the simulation devices is essential in gathering skills needed for efficient control of vital ship's systems. Different to merchant ships, the command and control system onboard naval ships is the most important segment of crew's training. There are usually more than 5 commanding levels which enables optimal control of the ship. To achieve coherence among these levels needs time [11]. Figure number 3 shows the operative cycle of the leading American navy ships (cruisers and destroyers) from 2015 till 2017. There is a big difference between home based ships and ships engaged in foreign waters. US based ships spent only 6 months deployed at sea, whilst had enough time for training (11 months) and maintenance (5 months). Also, they were available for 5 months waiting for deploying. This schedule enables optimal conditions for missions – well trained and rested crew and properly serviced ship.

The spain based fleet spent 8 months in maintenance and only 4 months in training the crew. These ships were engaged at sea for 12 months in two years period which also makes significant effort.

However, Japan based ships did not have time for training at all. Other than maintenance (8 months), the rest 16 months ships were deployed in missions, without time for crew preparation.

Obviously, increased tasks for the Japan based US navy was not met by an adequate number of ships, which explains this enormous effort. Moreover, logistics, personal and any other aspect of support are not as good as in home land ports. This is also one of the reasons of lower ship's efficiency. It is reasonable to expect crew mistakes and unfortunately, that eventually happened.

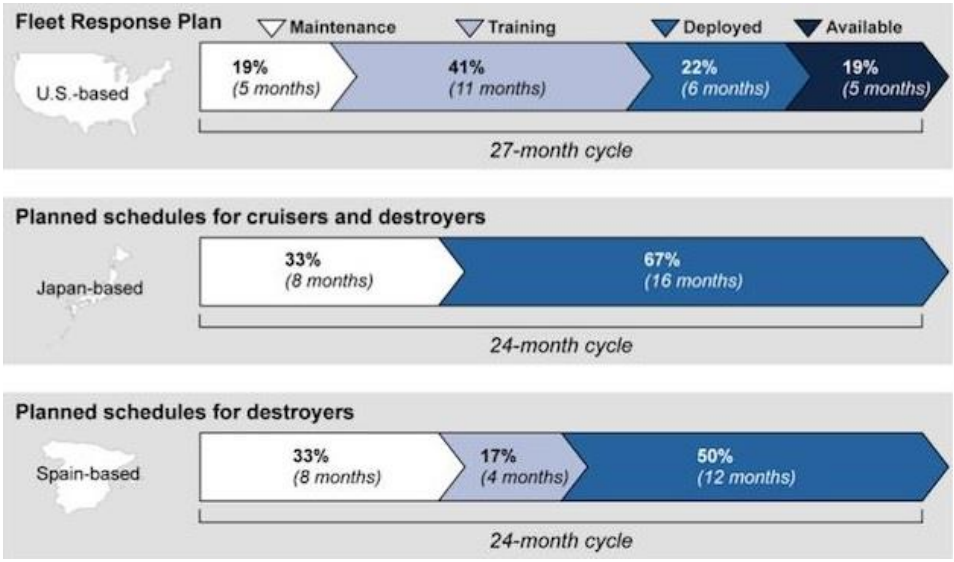


Figure 3 – Percentage of time Navy allocates to training and maintenance versus being deployed and available in two years period
Source: [12]

Right after these incidents, the similarity with another ship accident 15 years ago was pointed out [12]. In a short period of time, American navy submarines participated in four different collision and grounding accidents. Analyses of two years operative cycles of submarines also showed a huge effort of the crews who did not enough time for training and rest. They worked much more over standards, also because of the lack of a sufficient number of submarines. In comparison to war ships, merchant ships are obligated with international conventions in order to ensure enough time for rest for the crew to prevent fatigue [20].

Considering many terrorists attacks all around the world, there was even an assumption that the merchant ship ACX Crystal deliberately hit the destroyer. Cyber-attack was also a part of the official investigation. Destroyers have highly automatic ship's systems, vulnerable to cyber intrusions [21]. In 2013 the American Navy suffered a serious cyber-attack from Iran, so there was a fear that could happen again. First reports after USS John S McCain collision referred to an alleged steering gear system problem which was the main reason of suspect in possible cyber-attack. A special expert team flown to the scene in order to investigate a possibility of cyber intrude. In the future, their intention is to make this investigation of the possibility of a cyber intrusion a standard procedure in accident analyses of every ship or submarine. The cyber probe will be part of all official Navy investigations [22]. Leading cyber warfare experts had already given solutions regarding these types of attacks, suggesting shutting down the system and resetting it, but the leading Navy commanders are not satisfied, because it can be very dangerous.

6 CONCLUSION

A navy ship is a military ship where the crew is under military command and every crew member must strictly comply with ship procedures. Navy officer's education and training is a complex and long lasting cycle, particularly emphasizing the ability to command and lead people as defined in military practice. Besides standard navigation skills and the usage of modern navigational equipment, naval officers must apply tactical navigation knowledge in order to complete ship's missions. In addition, naval ships are usually fast and officers on board shouldn't ever hesitate commanding the ship. Check lists and further formal practice are established in order to minimize mistakes and to control every single crew member in every situation. Moreover, Navy culture relies on the use of many assistants, sometimes confusing each other.

This system of strict complying with orders has many disadvantages [11]. It does not encourage thinking, intuition and the ability to make a good and timely decision. However, these characteristics are essential traits of a competent officer of the watch, particularly in special and dangerous situations. Waiting for orders and only acting according to instructions with passive approach sometimes can endanger the ship. After all, Navy Releases Collision Report for USS Fitzgerald and USS John S McCain Collisions stated that both accidents were avoidable, showing the incompetence in basic seamanship skills. The reactions of the USS Fitzgerald crew had been evaluated as unacceptable, without any compliance with safety procedures. Moreover, the main cause of USS John S McCain collision was a sudden turn of the ship to port side, after confusion of the commanding officer and his crew in the moments when they discovered a main steering system failure [2]. Considering that, navigation officers are too much confident in modern navigation equipment. The US Navy 7th Fleet has a plan to raise a level of training and certification for crew members through their more frequent participation in basic seamanship skills training and basic navigation lessons. Proficiency in navigation is fundamental before the crew is familiar with specific combat systems knowledge. To accomplish such demanding task, it takes long and intensive training. Training of modern naval ship's crew includes simulation of potential ship's systems failure such as propulsion damage, fire or flooding onboard etc. It is usually a very challenging training, where seamanship skills are implied. Solving navigational problems onboard a destroyer should be routine, but obviously lack of training and crew fatigue was fatal.

It is worth pointing out that, as a result of all the reviews, many US politicians renew their demands for new ships for the Navy. Common conclusion is that 355 new ships is optimum number which could fulfil all the demands [23]. These modern automated ships are operated by fewer crews. This is efficient from the economic perspective, however, potentially dangerous if these men lack necessary skills. Similar challenges apply to the merchant marine. There are usually about 320 crew members on board Arleigh Burke class destroyer. In comparison, on board newest Zumwalt class destroyer only 158 members are programmed, which makes significant decreasing of the crew [7]. This manning reduction started many discussions about safety of the ships, with the main objection how to solve ship's damage control with less people on board. Common opinion is that automatization makes ships more efficient and safer, saving time to react properly. Modern ship designs of Navy Vessel simply that these are almost invisible to potential enemies. However, the problem is that they are invisible to other participants of marine traffic, too. This characteristic is dangerous in congested water navigation conditions. Having previously been a regular practice not to show AIS data to surrounding merchant ships which is recognized as a navigational problem, the new order is to turn on AIS in areas of heavy traffic conditions. However, it seems like the fundamental factor of the ship efficiency, her crew, is underestimated. A return to the basics of seafaring as a starting point for training all navigational crews of warships is a basic conclusion that emerges as a lesson learned from the collision of two American destroyers.

The basics consist of training people how to rely on their eyes and ears and how to use binocular in order to gather proper visualization and perception of the present situation in order to predict and react properly.

And last but not least, the crew must have enough time to sleep, otherwise, any kind of training is useless. Only highly trained crew, ready to act, makes things functional.

It is a painful realization that the deaths of 17 people and enormous material damage to such valuable ships were caused by beginners' mistakes. This may serve as a warning to prevent similar things in the future. This time mistakes are very expensive and reforms are already announced [24]. The estimated cost is between $400 and $500 million over the next five to six years, including periodic, standardized seamanship training and enhanced capabilities of navigation basics.

It is obvious that a higher level of technology of all the shipboard systems on a warship does not necessarily contribute to a higher level of safety at sea.

REFERENCES

[1] Švetak, J., Accident Investigations in the Merchant Marine, Pomorstvo, 2 (2007) p. 9-18

[2] Department of the Navy (2017), Memorandum for distribution, Office of the chief of naval operations, 2000 Navy Pentagon, Washington, DC, Available from: http://www.navy.mil/submit/display.asp?story_id=103136 [Accessed 15th Apr 2020]

[3] Prézelin, B. (2016), Combat Fleets of the World - 2016 edition

[4] IHS Jane's Fighting Ships (2016/2017), Coulsdon, United Kingdom

[5] Brlić, M. (2002), Razarači i fregate za 21. stoljeće, Zagreb, p. 18.-21.

[6] Department of the Navy (2015), A Cooperative Strategy for 21st Century Sea power, Pentagon, Washington, DC, p. 3.

[7] Bićanić, Z., Sučević, S. (2016), Brodovi novih sposobnosti, Kapetanov glasnik, Split, p. 36.-39.

[8] Russo, M. (2017), Teroristički napadi trgovačkim brodovima?, Kapetanov glasnik, Split, 2017, p. 63.-68.

[9] Sučević, S. (2016), Ratni brodovi – ravnopravni sudionici u međunarodnoj plovidbi, Kapetanov glasnik, Split, p. 40.-42.

[10] Nikcevic - Grdinic, J. Legal regulations in the function of ensuring ship safety, Pomorstvo, 29 (2015) p. 30-39

[11] Konrad J. (2017), Ball Diamond Ball – The U.S. Navy's Failure to Reorient to Danger, Available from: http://gcaptain.com/ball-diamond-ball-u-s-navys-failure-reorient-approaching-danger/ [Accessed 15th Apr 2020]

[12] US Naval Institute News (2017), Chain of Incidents Involving U.S. Navy Warships in the Western Pacific Raise Readiness, Training Questions, Pentagon, Washington, DC, Available from: https://news.usni.org/2017/08/21/chain-incidents-involving-u-s-navy-warships-western-pacific-raise-readinesstraining-questions [Accessed 15th Apr 2020]

[13] Jašić, D., Belamarić, G., Gundić, A. (2011), Pravila o izbjegavanju sudara na moru, Sveučilište u Zadru, Pomorski odjel Zadar, p. 43.

[14] Žanić - Mikuličić, J., Kasum, J., Jugović, A. Distribution of Maritime Safety Information and Improvement Measures for Safety of Navigation, Naše more, 65(3)/2018., p. 164-168

[15] US Naval Institute News (2017), More Punishments Issued for Fatal Western Pacific Destroyer Collisions; Dates Set for Initial D.C. Criminal Hearings, Pentagon, Washington, DC, Available from: https://news.usni.org/2018/02/01/punishments-issued-fatal-western-pacific-destroyer-collisions-dates-set-initial-d-c-criminal-hearings [Accessed 15th Apr 2020]

[16] Stars and Stripes (2018), No dismissal in court-martial of USS Fitzgerald commander, Available from: https://www.stripes.com/news/pacific/no-dismissal-in-court-martial-of-uss-fitzgerald-commander-1.561838 [Accessed 15th Apr 2020]

[17] G.captain.com (2017), John McCain Blames Navy And Congress For Lack Of Training, Available from: https://gcaptain.com/john-mccain-blames-navy-lack-training/ [Accessed 15th Apr 2020]

[18] Department of the Navy, Comprehensive review of recent surface force incidents, Commander, U.S. Fleet Forces Command, 1562 Mitscher Ave., Suite 250, Norfolk, VA 23551-2487, p. 115-116, 2017.

[19] Naval History and Heritage Command (2000), U.S.S. Cole (DDG-67) Senate Resolution Concerning Terrorist Attack in Aden, Yemen, on 12 October 2000 Pentagon, Washington, DC Available from: https://www.history.navy.mil/research/library/manuscripts/c/u-s-s-cole-ddg-67-senate-resolution-concerning-terrorist-attack-in-aden-yemen-on-12-october-2000.html [Accessed 15th Apr 2020]

[20] ILO Maritime Labour Convention – MLC, 2006

[21] US Naval Institute News (2017), Cyber Probes to be Part of All Future Navy Mishap Investigations After USS John S. McCain Collision, Pentagon, Washington, DC, Available from: https://news.usni.org/2017/09/14/cyber-probes-part-future-navy-mishap-investigations-uss-john-s-mccain-collision [Accessed 15th Apr 2020]

[22] U. S. Fleet Cyber Command / TENTH Fleet Strategic Plan (2017), U. S. Fleet Cyber Command / TENTH Fleet 2015 – 2020, Available from: https://www.public.navy.mil/fcc-c10f/Documents/FCC-C10F_Strategic_Plan_2015-2020.pdf [Accessed 15th June 2020]
[23] Marinelink.com (2017), Wicker Calls for 355-Ship Navy, Available from: https://www.marinelink.com/news/wicker-calls-ship430856 [Accessed 15th Apr 2020]
[24] Reuters.com (2017), U.S. Navy orders back-to-basics reforms after deadly collisions, Available from: https://www.reuters.com/article/us-usa-navy-crash/u-s-navy-orders-back-to-basics-reforms-after-deadly-collisions-idUSKBN1D22SF [Accessed 15th Apr 2020]

JURE ŠARIĆ, M.Sc.[1]
E-mail: jure.saric@ccaa.hr
ANDRIJA VIDOVIĆ, Ph.D.[2]
E-mail: avidovic@fpz.unizg.hr
IGOR ŠTIMAC, Ph.D.[2]
E-mail: istimac@fpz.unizg.hr
TOMISLAV MIHETEC, Ph.D.[2]
E-mail: tmihetec@fpz.unizg.hr
[1] Croatian Civil Aviation Agency
Ul. grada Vukovara 284, 10000 Zagreb
[2] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb

SPECIFICITY OF THE FRANJO TUĐMAN AIRPORT POSITION IN THE FUNCTION OF INCREASING REGIONAL COMPETITIVENESS

ABSTRACT

Franjo Tuđman Airport is the largest and most important airport in the Republic of Croatia. An important element in the success of an airport's operations is its geo-traffic position, whereby it acquires specificity with respect to the potential of the region in which it is located. Each airport has its own specificities in business and development strategy that are directly correlated with geo-traffic, socio-economic, security-political factors and airport capacity. The availability of highly competitive airport services, including runways, passenger terminals and ground services, as well as connectivity to trans-European networks and corridors, is crucial for airport competitiveness. The purpose of the paper is to analyse the traffic connections of Franjo Tuđman Airport with other modes of transport and to determine the impact of other airports located in the gravity area on the traffic effects of the airport. The aim of the paper is to identify the procedures by which Franjo Tuđman Airport would enhance regional competitiveness.

KEY WORDS

geo-traffic positioning; airport; traffic congestion; gravity zones; traffic corridors

1. INTRODUCTION

Air transport is one of the most profitable industries in the world economy. With its widespread availability and accessibility, air transport has a very strong influence on the development of world trade and tourism. Aviation is crucial for the European Union. It drives economic growth, creates jobs, facilitates trade and allows people to travel. Today European aviation represents 26% of the world market, contributing €510 billion annually to Europe's Gross Domestic Product, and supporting 9.3 million jobs in Europe [1]. Viewed from a broader perspective, it has been characterized as the fastest and safest branch of transport for the transportation of people and goods, which significantly contributes to the development of the global economy, political stability and enhancement of social values. A well-developed strategy for the development of air transport with a balanced approach to individual entities of the air transport system is needed to ensure the competitiveness of the European air transport sector and to benefit from rapid market changes and to facilitate the development of the economy [2]. From the point of view of geo-traffic and socio-economic factors, the importance of positioning an airport on major transport corridors and the proximity of developed industrial centres will significantly influence its strategic and sustainable development. This is primarily related to the positioning of the same, as a major hub airport, which according to the type of business model of air carriers in operational terms prefers network airlines with a developed

network of destinations and significant developed transfer and transit traffic. This paper analyses the existing infrastructure of roads close to the airport, as well as the possibilities of connection to the trans-European corridors. Also, from the aspect of determining the potential of the airport, the impact of other airports in the immediate vicinity in relation to the gravitational area of Franjo Tuđman Airport is analysed. The specificity of Franjo Tuđman Airport's geo-traffic position in the function of increasing regional competitiveness is primarily reflected in the expansion of the airport's capacity and the possibility of providing services to air carriers, which, in comparison with the competing airports in the surrounding area, represents an efficient and secure system for acceptance and dispatching of aircraft and passengers.

2. A HISTORICAL OVERVIEW OF FRANJO TUĐMAN AIRPORT DEVELOPMENT

The development of the airport and passenger terminal has varied over the years, adapting to the transportation needs for the receiving and dispatching of aircraft, passengers and cargo. In 1959, a passenger building and apron were built at Pleso, and in the autumn of the same year a civil air traffic airport was opened. The company for airport services is called "Zagreb Airport" and was founded in 1961 and started operating on April 20, 1962. The scope of work of the company was related to the maintenance, reconstruction and construction of the airport, the acceptance and dispatch of aircraft, loading, unloading of goods and providing passenger services [3]. A chronological overview of the development of the Franjo Tuđman Airport terminal is shown in Figure 1.

Airport building (1959.)



Model of passenger terminal (1976.)



Extended passenger terminal (2012.)



New passenger terminal (2017)

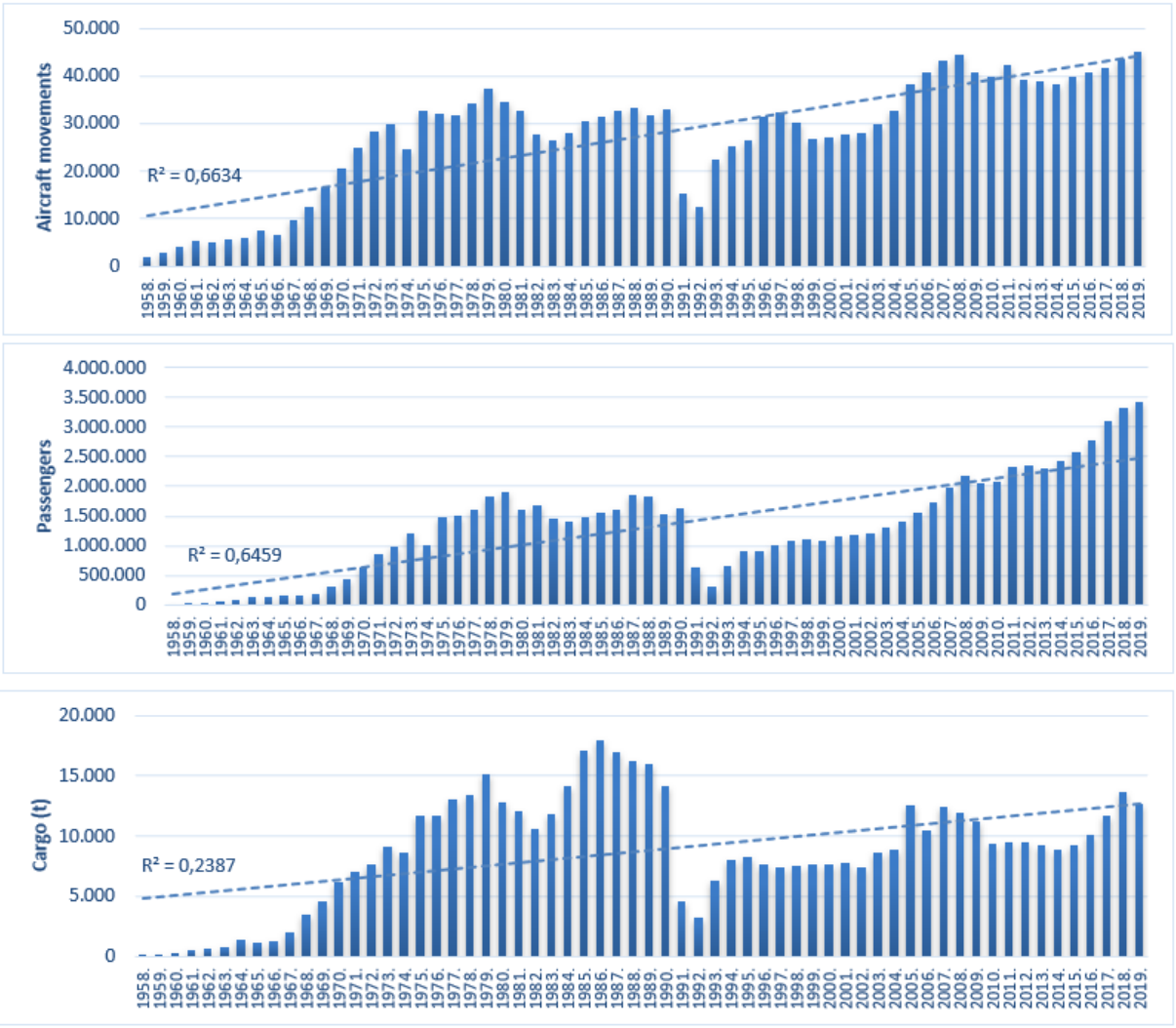


Figure 1 – Overview of the development of the passenger buildings of Franjo Tuđman Airport
Source: [4]

In mid-1966, Zagreb Airport changed its name to Zagreb Airport. The new terminal building was opened in 1967, had an area of 5,000 m^2, the runway was restored and extended, and the platform was expanded to 60,000 m^2. A new administration building with a control tower was also built. In this way, Zagreb became a respectable international airport, with traffic increasing every day, both in regular and non-scheduled traffic. Almost 10,000 aircraft and about 180,000 passengers were flown, and freight traffic reached 2,000 tones. The next major renovation of the airport was in 1974, when "Zagreb Airport" was closed for two months.

The runway was reconstructed and extended to 3,252 m, and 45 m widened, radio navigation equipment and airport equipment was modernized. A modern equipped annex of 3.680 m^2 was built next to the terminal building and was intended for international traffic. In 1982, work began on expanding the airport's capacity. The passenger building was upgraded for 4,000 m^2, and other necessary infrastructure was being built for a customs station, freight forwarding, cargo areas and a modern fire station. In preparation for the organization of the Universiade, in 1987 a new apron of

36,000 m2 was built. Aircraft positioning capacity increased from 15 to 22. Following an International Public Tender for Zagreb Airport Construction and Management, Government of the Republic of Croatia 29.02.2012. made a decision on the selection of the most favourable offer (ZAIC-A Ltd. England) in the process of awarding a public works concession for the construction of a new passenger terminal (NPT) of Zagreb Airport worth € 331 million and the management of the existing and newly constructed terminal of Zagreb Airport and associated infrastructure for 30 years. The Concession Agreement entered into force fully on December 5, 2013 and on that day ZLZ d.o.o. handed over all assets to management at Zagreb International Airport Jsc. in accordance with the Concession Agreement. Ownership structure of MZLZ dd: Aéroports de Paris Management 20.77%; Bouygues Bâtiment International 20.77%; the Marguerite Fund 20.77%; IFC 17.58%; TAV Airports 15.00%; Viaduct, 5.11% [5]. At a session held on 24 February 2016, the Government of the Republic of Croatia adopted the Decision on the name of Zagreb Airport. This decision defines the name of the Zagreb airport as containing the name of the first Croatian President, Dr. Franjo Tuđman. The new passenger term was built within the agreed period of 36 months. It was officially opened on March 21, 2017 and released on March 28, 2017. years. The graph 1 below shows the statistics of movements of aircraft, passengers and goods at the Franjo Tuđman Airport from 1958. to 2019.



Graph 1 – Travel statistics at the Franjo Tuđman Airport from 1958 to 2019
Source: [6]

3. GEOGRAPHICAL ANALYSIS OF FRANJO TUĐMAN AIRPORT LOCATION

Air transport is the fastest form of transport and provides passengers with quick and quality access to the airport. Today, traffic congestion is occurring in large cities as well as in the city's driveways, therefore high capacity roads with level crossings are being used as solutions.

Airport's catchment area is the geographic area from which airport can reasonably expect to draw commercial air service passengers. It is defined by several factors, including geographical and access considerations and proximity of alternative aviation facilities. However, airport use by airport's catchment area population is affected by a variety of factors, including proximity to a competing airport(s), airfares, destinations offered, capacity (airline seats), flight frequency and low-cost carrier presence at nearby airports. [7]

There are many papers that analyse factors that drive passenger airport choice. Authors in paper [8] analyse methodology to assess the size of airport catchment areas and the airport's market shares therein using a MNL (Multinomial Logit model) passenger choice model. This methodology is applied to Amsterdam Airport Schiphol. The results show that the size of its catchment area differs considerably by destination. The methodology shows to airports the effects of changes to service level offerings (in terms of frequencies and fares) on their catchment area and the market shares therein. Authors in paper [9] also use MNL model for estimation of the airports' catchment areas and airports market shares for three regional airports (Ljubljana Jože Pučnik Airport (LJU), Venice Marco Polo Airport (VCE) and Trieste Pietro Savorgnan di Brazza Airport (TRS)). The results indicated that the three airports have relatively small core catchment areas and that the market share rapidly decreases with the increasing access time to airport. Authors in paper [10] presented a free available dataset, the CORINE land cover that helps dealing with the biases caused by pre-defined and heterogeneous census district boundaries in airport catchment area analysis in Europe. By using this dataset and a conventional GIS software, authors proved that it is possible to measure the size of the population within catchment areas at the same spatial level for all EU airports, allowing for consistent comparisons among airports. By using the CORINE/GIS approach, the size of the population in the catchment areas of all European airports was determined. In paper [11] the potential catchment area of Polish regional airports was determined. Authors used isochrones of 1h and 2h road access to the airport for catchment area determination.

All airports have a road access and it is the basic access to the airport. Larger airports also have rail links to the city or cities they serve, thus solving bottlenecks near airports using multiple modes of transport (multimodal transport). They are connected to the rail network of a city, region or state, or are built solely to connect the airport and the city centre. A wide range of specifications and laws govern all aspects of the life cycle, from airport planning to construction and commissioning especially through the ICAO standards adopted and recommended practices [12], [13], [14]. Analysing from a traffic point of view, the connection of the basic network of transport infrastructure with the trans-European networks and corridors is one of the basic goals and an important prerequisite for the even transport development of the Republic of Croatia. The EU is therefore continuously making efforts to build the necessary roads and to integrate the national road network into a single TEN-T (Trans European Network - Transport) network. Road transport is the most developed, most important form of land communication, and it carries the largest number of passenger and freight traffic. The existing motorway network is well developed and allows good connections within the country. Motorway national and international routes originate at the Zagreb bypass: A1 Zagreb - Split, A2 Zagreb - Macelj, A3 Bregana - Zagreb - Lipovac, A4 Zagreb - Goričan, A6 Zagreb - Rijeka and A11 Zagreb - Sisak (under construction) [15]. When defining the parameters of important roads to an airport, the intensity of traffic flows, the travel time on the roads and their intersections, the capacity of the roads, the speed of traffic flows, waiting at traffic lights and at individual turns, etc. should be taken into account. The area of analysis should be selected to include a wider network of roads that will be affected by the future traffic solution (Figure 2).



Figure 2 – Road network in the vicinity of the airport with prominent public transport lines
Source: Created by authors by using Google Earth application

The main connection between the City of Zagreb and the Franjo Tuđman Airport is the D30 state road, which continues to Radnička Road and connects the City of Zagreb with the new passenger terminal via the Homeland Bridge. The Zagreb Bypass, because of its close proximity to the airport, can be seen as an important link for connecting Franjo Tuđman Airport and the wider gravitational area, which enables the connection between Kosnica and Jakuševec. Access to the wider gravity area on the south is provided by the A11 motorway through the Velika Gorica junction south. The airport "Franjo Tuđman" provides access not only to the city of Zagreb, but also to other cities located in the functional region of Central Croatia, such as: Velika Gorica (≈3 km), Varaždin (≈87 km), Čakovec (≈106 km). Koprivnica (≈98 km), Bjelovar (≈88 km), Virovitica (≈153 km), Daruvar (≈129 km), Zabok (≈51 km), Zaprešić (≈33 km), Kutina (≈83 km), Sisak (≈46 km) and Karlovac (≈59 km). The connection between these cities and the Franjo Tuđman Airport has been made via several motorways (A1, A2, A3, A4, A11) and state roads with Zagreb as the starting point or destination [15].

The possibilities of using railway infrastructure in connecting Franjo Tuđman Airport to Zagreb have been discussed in many planning documents from 1970 to the present but have not been verified by flow simulation. The existing Sesvete - Velika Gorica - Sisak railway line is located relatively close to the Franjo Tuđman Airport but is currently not in the function of traffic connections. It can be assumed that the realization of this mode of transport will depend on the planned solutions for the wider area of Velika Gorica and the increase of passenger traffic at the airport. For the purpose of connecting the airport and the city, as well as the wider surrounding area, it is necessary to build a new rail link and several connections on the existing network, which would provide access to the airport from all directions. Therefore, it is necessary to plan the light rail route between the main station and the airport along the corridor Radnička Road, Homeland Bridge, Kosnica junction to the new passenger terminal (light metro, light city rail, track width 1.435 mm, light axle loads due to the load capacity of the Homeland Bridge).

In the first phase, this could be a turning point, but since the optimum cost-effectiveness for this mode of transport is about 10 million passengers, it would be necessary to take the route to the Velika Gorica railway station (connection to the Sisak railway) and thus attract a far greater number of passengers [9]. In order to identify the potential of the Franjo Tuđman Airport region, a gravity

zone was created to gain insight into the population, road connectivity to the airport, and the overlap of the gravity zones of competing airports. The Strategy for Transport Development of the Republic of Croatia points to the need to address bottlenecks near airports, that is, to use multiple modes of transport (multimodal transport) [17]. The realization of the above is extremely important in order to increase the overall competitiveness of Franjo Tuđman Airport in the coming years. An insight into the catchment areas of several airports, such as Frankfurt Hahn, Vienna Airport or Katowice Airport, shows that in most cases the gravity zones around the airport are shown only with a circle with a radius of some distance (100 - 300 km). This is considered imprecise. Therefore, a real estimation of the duration of travel by road was made, which showed that the coverage area in the areas where the motorways are located is much larger, while at the same time it is reduced on local roads. The main criterion considered in this analysis was the arrival of vehicles (passengers) at Franjo Tuđman Airport by road. For the purpose of developing of the catchment area, three applications were used Via Michelin, Google Maps and Google Earth. With those applications, the length of the trip has been detected from Franjo Tuđman Airport till the point based on 60, 90 and 120 minutes driving on each direction following road classifications and speed limits. Based on the area, which is covered by those driving times, several criteria were used to calculate how many potential inhabitants could use Franjo Tuđman Airport as a primary choice. After calculation, those three catchment areas are divided as follows [2]:

- Zone 1. (60 minutes' drive- green zone in Figure 3.).
- Zone 2 (90 minutes' drive - blue zone- in Figure 3).
- Zone 3. (120 minutes' drive - red zone in Figure 3.).

By looking at the population and county data that were covered, the following population results were obtained through 3 zones:

- Zone 1 - 1,641,295 inhabitants
- Zone 2 - 2,226,248 inhabitants (total zones 1 and 2)
- Zone 3 - 3,241,568 inhabitants (total zones 1, 2 and 3).

Figure 3. shows the coverage of the gravity zone through the three above-mentioned weather criteria with visible highways.

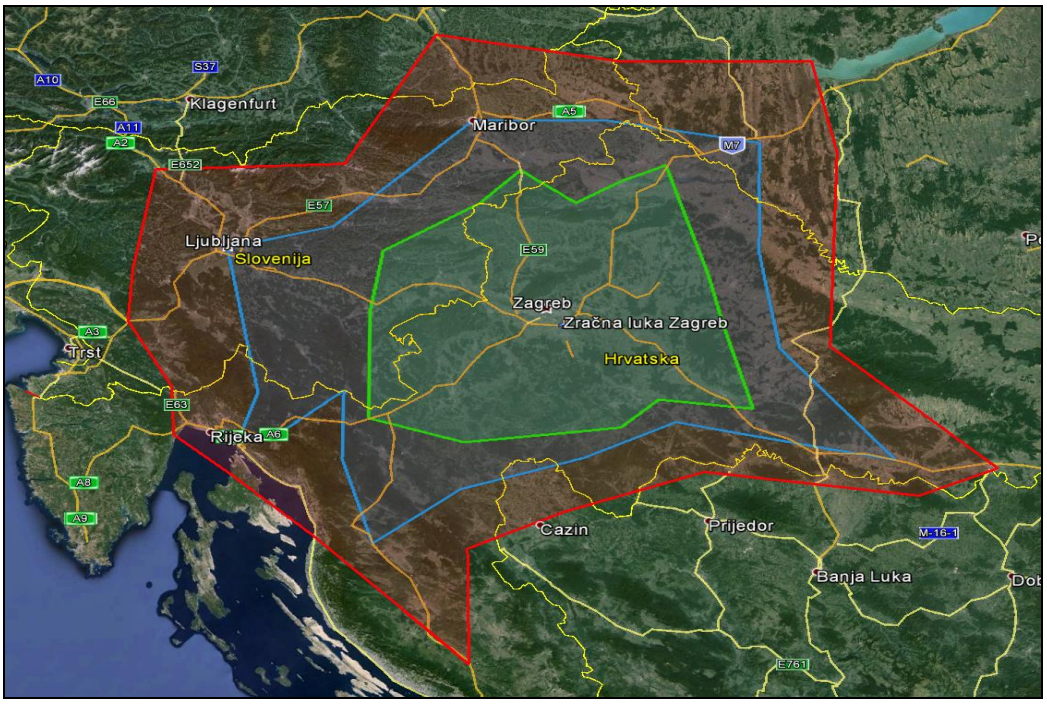


Figure 3 – Gravity zone coverage through three-time criteria with road network representation
Source: [4]

The time criterion shown with the lines, as well as the travel time itself, is an important factor in planning the overall trip to a particular destination. The availability of high-speed traffic to and from the airport largely depends on the choice of the airport of departure or arrival, thus indicating that the above-mentioned time criteria indicate that the developed transport infrastructure and its connection to the urban and non-urban transport networks certainly give a competitive advantage over the airports in environment. Figure 4 shows the overlap of the gravity zones of the airports Zagreb, Belgrade, Ljubljana, Zadar and Pula in the period of driving by car 2 hours from the airport.

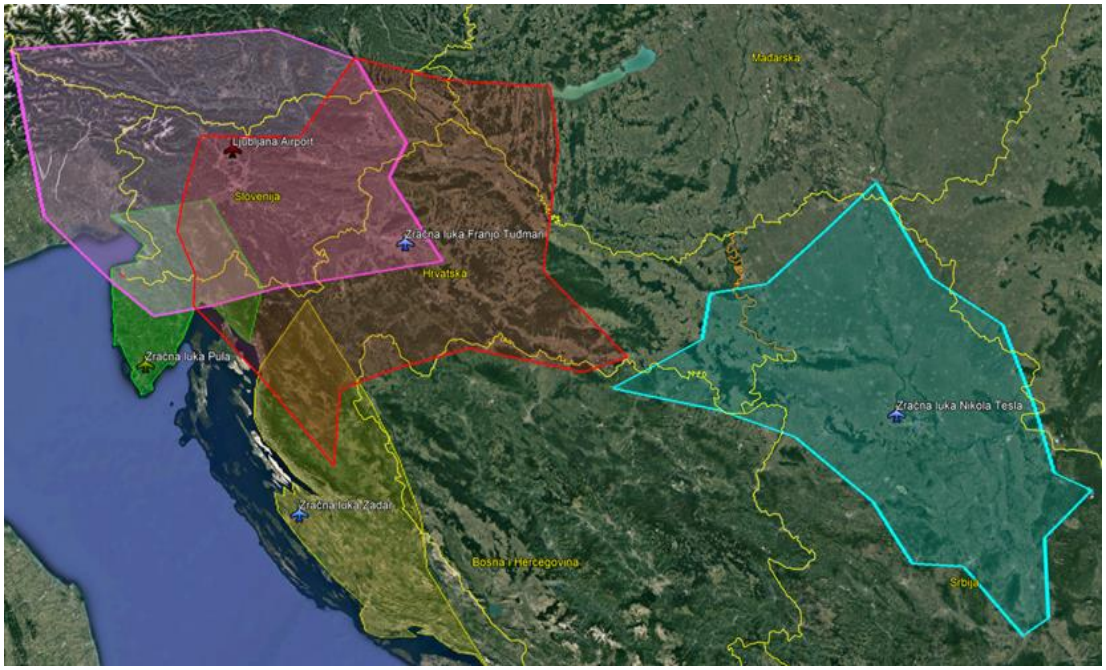


Figure 4 – Overlapping gravity zones of Zagreb, Ljubljana, Zadar, Pula and Belgrade Airports
Source: [4]

The gravity zone of Franjo Tuđman Airport, considering the gravity segment of 120 minutes of driving by road infrastructure, completely covers the Ljubljana Airport, but also vice versa, which indicates the potential competitiveness of the airports. The development of flight plans and airport offers for various charter or scheduled destinations and the development of infrastructure and capacity will determine the strategic position in attracting passenger and freight traffic in the future. Pula and Zadar airports are in direct overlap of the gravity zone of Franjo Tuđman Airport, which can lead to the takeover of a part of passengers, especially during the summer due to the wide network of low-cost carriers. The gravity zone of Nikola Tesla Airport, with a driving time of 120 minutes, does not directly overlap with the gravity zone of Franjo Tuđman Airport, but from the aspect of strategic positioning of the airport as a major regional hub, it is a significant competitor to the Airport of Franjo Tuđman in the transportation of passengers and goods.

4. COMPETITION AIRPORT ANALYSIS IN THE REGION

IATA developed a framework called Air Transport Regulatory Competitiveness Indicators (ATRCI). Air transport regulatory competitiveness is defined as the set of institutions, policies, and factors that determine the economic benefits that the economy can derive from aviation. In that document it was shown that ATRCI uses both quantitative and qualitative data that are normalized from 0 to 10. To define what will generate competitive advantage, five key determinants of the ease of doing business have been identified in the document and those are:

1. *Passenger Facilitation* (visa requirements, open skies agreements, passenger information and border control processes). These measures support easier movement of persons around the globe and contribute to economic development and growth.
2. Cargo Facilitation (trade facilitation and e-freight). These measures enhance shippers' experience by enabling the seamless cross-border movement of goods.
3. Supply Chain Competitiveness (airport and passenger charges and taxes, airport and air traffic management charging process, fuel supply management, labour efficiency).
4. Infrastructure (available runway and terminal capacity and slots). Air transport depends largely on available infrastructure and how efficiently congested infrastructure is utilized.
5. Regulatory Practice (regulatory framework, legal framework, regulatory implementation). [18]

Despite the rising cost of fuel and the threat of international terrorism, air transport is developing rapidly in Croatia and throughout the region. Split, Dubrovnik, Zagreb, Ljubljana and Belgrade have seen significant increases in passenger air transport in recent years, while the last three airports are also struggling to become regional centres, with increasing funding. Thus, the plans of Zagreb, Belgrade, Ljubljana airports for business models and construction of infrastructure essential for the acceptance and dispatching of aircraft, passengers and goods are being realized. The concessionaires of these airports are Zagreb International Airport dd, concessionaire at Franjo Tuđman Airport, VINCI Airports at Nikola Tesla Airport, and Fraport Slovenia in Ljubljana, as part of the Fraport AG Frankfurt Airport Services Worldwide. The intention of the concessionaires, given the long-term management model, is to build adequate infrastructure and improve business conditions to enable airlines to launch new routes, resulting in increased traffic and better connectivity of capitals with other airports in the EU and worldwide.

Ljubljana Airport infrastructure is evolving in line with traffic and will continue to do so in the future, becoming an important regional tourist, distribution and logistics centre. The management system includes buildings, land owned by Fraport Slovenia, other land (air and ground areas) and buildings outside the airport for which Fraport Slovenia was granted a 40-year concession by the Republic of Slovenia. The existing passenger terminal is being upgraded; expected to open in the summer of 2021. An additional 10,000 m² will be built, including a new passenger departure hall with a total of 22 check-in counters, 5 security lines, 3 luggage-return carousels, a new luggage storage space, a large duty-free store, a new office lounge as well as renovated food, beverage and promotional spaces [19]. A record 1,818,229 passengers travelled through Ljubljana Airport in 2018, which is 7.7% more than the year before, on regular flights to 34 airports in 24 countries [20]. The location of Ljubljana Airport provides the airport with an important role in the transport system and tourism industry in the country. The exceptional position at the crossroads of Europe has given Ljubljana Airport a special role within the countries with key European regional airports. The gravity area of Ljubljana extends to the southern parts of neighbouring Austria and northeaster Italy, as well as to tourist sites in Croatia. It covers a population of more than 4 million people.

French "VINCI Airports" officially took over the Nikola Tesla Airport in Belgrade with the payment of 501 million euros. In this way, the company started concession management that will last for 25 years. Total investment of "VINCI Airports" in Belgrade airport amounts to 1.46 billion euros, which includes a one-time fee, which amounts to 501 million euros, then a minimum annual concession fee, as well as capital investments in "Nikola Tesla". In 2018, 5 million passengers passed through Nikola Tesla Airport, an increase of 5.4% compared to the previous period in 2017 to 62 destinations in Europe and the world with 25 airlines [21]. For connecting flights, Etihad's strategy for Air Serbia in the region is certainly a threat to Zagreb's Franjo Tuđman Airport, as Etihad is ready to develop Belgrade as a regional hub for its subsidiaries, and previously Belgrade aimed to position itself as the leading low-cost airport in Southeast Europe.

Zadar Airport has seen a significant increase in the number of aircraft operations and passenger traffic in the last few years, due to the increased interest in the travel tourist markets and the increasing share of arrivals of low-cost airlines (LCC). In 2019, there were 777,662 passengers, an increase of 33.93% over 2018. Aircraft and passengers are highly seasonal in nature and the airport has significant differences between summer and winter flights. The further development strategy must focus on the development of the so-called point-to-point networks, mainly used by low-cost airlines with the largest share of traffic, such as Ryanair, easyJet and Eurowings. The strategic development document (Main airport development study for Zadar Airport) plans further development of the airport infrastructure, above all the passenger terminal, as well as other infrastructure facilities on the air and ground side (reconstruction and upgrading of runways, taxiways, apron, ...) meeting the needs of growing aircraft and passenger traffic. Currently, Zadar Airport has the capacity of a passenger building and an apron below the level of existing traffic, and in order to increase its competitiveness and positioning in the air transport market, it will need to accelerate plans for the development of existing infrastructure.

Pula Airport is one of nine airports and the fifth busiest in Croatia. In 2019, the airport exceeded its record for passenger numbers ever, 777,568, an increase of 8.3% over the previous year. The highest number of passengers ever flown through the airport during July 2019 in one month was 186,159 passengers, reflecting the high seasonality of the same, comparing traffic during the other months of the year, especially in the winter flight schedule. The airport infrastructure meets high standards of security for the acceptance and dispatching of aircraft, passengers and goods, while the existing manoeuvring areas are able to accommodate a larger number of passengers than before. Pula Airport makes a great contribution to the development and promotion of Istria's tourism, with close proximity and good transport links to the EU's market through the airport, as well as a road link through the Istrian Ypsilon. The tourism development strategy of this area will serve as a basis for the further development of the airport's infrastructure in a very dynamic tourism market, which will provide the Pula Airport with a long-term competitive advantage and position.

In addition to the aforementioned analysis of airports in the immediate vicinity of Franjo Tuđman Airport, a wider environment was also analysed. As developed in the competitive analysis of Franjo Tuđman International Airport, the airport must take into account the competitive environment, whether from major European airports in a region such as Vienna (market leader in Eastern Europe), Budapest, nearby Ljubljana and Belgrade, whose gravitational area partially overlap Zagreb, that is, Croatian airports located mainly on the Dalmatian coast due to tourist traffic [22]. An overview of the growth in passenger traffic and the leading airlines of major airports in the wider competitive environment are presented in Table 1.

Table 1 – A statistical overview of airports in a wider competitive environment

IATA Code	City	Passengers 2018	Growth% 2017/2018	Leading carrier (s)
VIE	Vienna	27.000.000	10,6 %	Austrian Airlines
BUD	Budapest	14.867.491	13,5 %	Wizzair, Ryanair, easyJet, Lufthansa
SKP	Skopje	2.158.258	15,5%	Wizzair
TGD	Podgorica	1.208.525	14,5%	Montenegro Airlines
SJJ	Sarajevo	1.046.635	9,3%	Turkish Airlines
GRZ	Graz	1.030.939	7,5%	Lufthansa
BEG	Belgrade	5.600.000	5,4%	Air Serbia
LJU	Ljubljana	1.812.411	7,7 %	Adria Airways

Source - Official Airport Website

5. POTENTIAL DEVELOPMENT OF FRANJO TUĐMAN AIRPORT IN THE FUNCTION OF INCREASING REGIONAL COMPETITIVENESS

Favourable transit location and overall communal infrastructure, qualified workforce, scientific, professional, educational, health, financial, banking and other institutions, tradition of providing various services, size and quality of the economy are key potentials of Zagreb's development strategy. Zagreb is an important international commercial and business hub, as well as the traffic intersection of Central and Eastern Europe.

Franjo Tuđman Airport is Croatia's largest airport, transporting 3.4 million passengers in 2019 (+ 2.8% compared to 2018). Croatian airports had 11.4 million passengers in 2019, an increase of 8.42%. Compared to coastal airports, Franjo Tuđman Airport has a significantly less pronounced seasonality. The main focus in order to increase the regional competitiveness of Franjo Tuđman Airport is to strengthen transport development (aeronautical and non-aeronautical revenues). In order to fully achieve these goals, Franjo Tuđman Airport relies on a clear route development strategy that promotes Zagreb as a key destination and "Preferred Airport in Central and Southeastern Europe", thereby strengthening links with all airlines, especially with hub carrier Croatia Airlines, which is also a national air carrier. Studies [23] and [24] propose a general framework for assessing airport expansion and new development projects, as well as a methodology for analysing the impact of one of the least understood and often neglected elements of such a framework - connectivity. The strategy of the Government of the Republic of Croatia was to attract private investors to secure sources of financing for the expansion of existing infrastructure. By selecting a concessionaire, the Concession Agreement signed in the form of a public-private partnership includes the plan for the development of Franjo Tuđman Airport through the construction of a new passenger terminal and associated infrastructure. The functional concept of construction was based on the following criteria through two phases: the first phase - the reception and departure of 5 million passengers a year, the second phase - the reception and departure of 8 million passengers a year.

As defined in the Concession Agreement, the quality of service level must meet the service level C according to IATA standards. This directly affects the competitiveness of the airport, as they become commercial centres that, in addition to their regular operations, focus on maximizing the use of the space they own, developing additional projects. This applies primarily to projects outside the concession area, which is reserved for the further development and expansion of the airport and its complementary facilities. Key projects that further strengthen the airport's competitiveness are the Airport City project and Cargo City project. Since these projects are planned outside the concession area, their realization is the task of Zagreb Airport d.o.o. The Airport City project includes an airport hotel, a railway vehicle station connecting the city of Zagreb and Velika Gorica with the New Passenger Terminal, business facilities and other facilities common in Europe and the world for such projects. Global and local trends (in the segment of tourist offer) support the hypothesis that the arrival of tourists in the future will be the main generator of growth in the number of passengers transported by air in the Republic of Croatia. In 2018, 18.7 million tourist arrivals were recorded, which is 7% more than in 2017 [25]. Franjo Tuđman Airport is committed to optimizing the growth of all other commercial activities. With such a goal and a commercial plan for the new terminal, several actions are being taken to help Franjo Tuđman Airport become more familiar with the passenger profile and needs of other business partners. A strong commitment to service excellence was reaffirmed when Franjo Tuđman Airport was awarded the Best Quality Airport (ASQ) award for the airport in the European region in the 2-5M / PAX (passengers) category. Zagreb International Airport is working on two aspects to further improve Zagreb's position, externally to build a better MZLZ reputation in the public, develop routes and tourist offer, and internally to build employee confidence and the new challenges and changes they expect to improve regional competitiveness. Table 2 shows strengths, weaknesses, opportunities and strengths (SWOT analysis) for Franjo Tuđman Airport.

Table 2 – SWOT analysis of Franjo Tuđman Airport

Strengths	***Weaknesses***
• Strong brand and position of Croatia on the international market • Strategic geographical position and good transport connections with Europe • Largest airport in Croatia and one of the largest airports in the region • The main base of national carrier Croatia Airlines • New infrastructure (terminal, apron) • Lowest seasonality compared to other Croatian airports • Large catchment area • High concentration of natural, cultural and historical heritage provides potential for tourism • Short distances to cross country borders from Zagreb Airport • Ideal position for development of intermodal centre (air, road, railway) • No runway capacity constraints in the long term (max location capacity 12 mil. passengers) • Convenient and quick access to the highway • The existing infrastructure also satisfies the landings of the largest aircraft • The level of education and experience of the staff is at a satisfactory level	• Competition with airports whose catchment areas overlap Zagreb Airport • The national carrier has over 54% of share in total passenger traffic • Competitive domestic airports during summer session • Lack of accommodation capacities, especially hotels of higher categories • Weak supply diversification, especially outside the main tourist season • Uncoordinated connections between different transport branches • Lack of Airport City and Cargo City
Opportunities	***Threats***
• Positive tourism trends in Croatia and Zagreb from different parts of the World • Significant unserved markets – huge potential • Space for development LCC network (now only 5%) • Full member of EU state • Soon status of Schengen regime • Signed ECAA agreement (liberalized access to the EU market) • Better coordination of the transport and tourism sector and flight and timetables • Increasing the quality of existing accommodation capacities	• Influence of long-term global crisis – e.g. pandemic of COVID-19, a possible recession • Price sensibility of the market • Low-cost airlines base(s) development at neighbour airports in Croatia and outside Croatia • Risk of possible bankruptcy of Croatia Airlines due to financial problems • Escalation of jet fuel prices • Desperation of potential passengers to competitive airports • Airline protectionism • Decline in air passenger traffic • The lack of a clearly defined long-term strategy for the development of the national airline • Lack of development of cargo infrastructure

Source: Made by Authors

6. CONCLUSION

Air transport is a powerful driver of economic growth, job creation, trade and mobility in Europe, and is of great importance for the European economy and for consolidating its leading position in the world. The development of air traffic in neighbouring countries and globally has led to the constant expansion of airports and large investments in their infrastructure. The economic recovery process in these countries is also reflected in the growing interest in travel that has for many years driven the growth of travellers within the European average. European airports are nowadays widely recognized and have a significant economic and social impact on surrounding regions, and Zagreb is no exception. These effects far outweigh the direct impact of the airport's operations on its neighbours, extending to the wider benefits that the availability of air services brings to regional business interests and consumers.

Franjo Tuđman Airport provides key infrastructure to support regional, social and economic growth. In order to strengthen its competitiveness in the environment, Franjo Tuđman Airports must consider a competitive environment either from major European airports in the region, such as Vienna (market leader in Eastern Europe), Budapest, nearby Ljubljana and Belgrade whose gravity areas partially overlap Zagreb , respectively Croatian airports located mainly on the Dalmatian coast due to tourist traffic. Given the high seasonality of all airports, they are constantly being adapted to accommodate the larger number of passengers expected by all projections of passenger and non-seasonal passenger traffic growth and establish flexible organizational capacity to increase operational capacity.

Demand forecasting is crucial for airport planning and air traffic management, but airline dynamics create uncertainty about investment. Franjo Tuđman Airport is the largest airport in Croatia and one of the largest airports in the region and has the lowest seasonality in comparison with other Croatian airports, which enables yearlong traffic and connections with other destinations outside Croatia and is positioned as a desirable destination outside the tourist destination season. Sudden changes in airline strategies and changes in the share of models have had a significant impact on airport operations worldwide. Short distances to Zagreb relative to the borders of other surrounding countries (including Slovenia, Bosnia and Herzegovina, Austria, Hungary and Serbia) and a large gravity area (inland up to 200 km and outward reaching more than 500 km in the southeast), surrounded by is a modern system of road infrastructure and quick access to the city center, which represents a significant competitiveness of the airport itself. It can be expected that the proportion of arrivals by air will continue to grow, due, inter alia, to the growing affirmation of Croatia in the markets from which arriving by air is the optimum choice in terms of distance (markets of Western Europe, such as France and the UK, or Northern Europe), such as the countries of Scandinavia, Benelux, etc.

A strong investment plan for the development of airport content and capacity, and a reliable consortium consisting of proven companies with a good international reputation, which provide adequate support to the management of Franjo Tuđman Airport, raise standards, requirements and oversight. Therefore, more attention needs to be paid to the application of innovations in transport technology and the achievement of compliance with new technological standards.

Such predispositions related to the built-up modern infrastructure, the continued growth of the Croatian economy (greater Southeast European GDP) and the status of a full-fledged EU Member State (access to Croatian regions by financial means) put Franjo Tuđman Airport ahead of competition in the environment.

REFERENCES

[1] European Commission. Aviation: Open and Connected Europe. Brussels, 8.6.2017
[2] Ministry of the Sea, Transport and Infrastructure. Transport development strategy of the Republic of Croatia 20174 – 2030, August 2017.
[3] Zagreb Airport Ltd. 50 years of Zagreb Aerodrome, Zagreb, Croatia, 2012.
[4] Štimac I. *Optimization of shares of Airlines in Airport capacity*. PhD Thesis, Faculty of Transport and Traffic Sciences. Zagreb, Croatia, 2017.
[5] Zagreb International Airport Jsc. Annual Financial Report for 2018. Zagreb, 2019.
[6] Zagreb Airport. Available from: http://www.zlz-zagreb-airport.hr/hr/statistika [Accessed 02nd February 2020]
[7] Airport Cooperate Research Program (ACRP). Defining Your Airport's Catchment Area, https://crp.trb.org/acrp0331/defining-your-airports-catchment-area/ [Accessed 2nd June 2020]
[8] Lieshout, R. Measuring the size of an airport's catchment area, Journal of Transport Geography Volume 25. November 2012, Pages 27-34

[9] Paliska, D., Drobne, S., Borruso, G., Gardinac, M., Fabjan, D. Passengers' airport choice and airports' catchment area analysis in cross-border Upper Adriatic multi-airport region. Journal of Air Transport Management, Volume 57, October 2016, Pages 143-154
[10] Suau-Sanchez, P., Burghouwt G., Pallares-Barbera M. An appraisal of the CORINE land cover database in airport catchment area analysis using a GIS approach. Journal of Air Transport Management, Journal of Air Transport Management 34 (2014) 12-16
[11] Augustyniak, W., Olipra, L. Potential catchment area of Polish regional airports. Journal of International Studies, Vol. 7, No 3, 2014, pp. 144-154.
[12] ICAO. *Airport Economics Manual*. Doc 9562, Third Edition. ICAO. Montreal, Canada, 2013
[13] ICAO. *Annex 14, Volume I, Aerodrome Design and Operations.* Eighth Edition. ICAO. Monteral, Canada, July 2018
[14] ICAO. *Manual on Certification of Aerodromes*. Doc 9974, First Edition. ICAO. Monteral, Canada, 2001
[15] [15] Gradski ured za strategijsko planiranje i razvoj Grada. Razvojna strategija Grada Zagreba za razdoblje do 2020. godine. Zagreb, 2017.
[16] Gradski ured za prostorno uređenje, izgradnju Grada, graditeljstvo, komunalne poslove i promet. *Cestovno-željezničke veze zračne luke Zagreb i centra grada – Prijedlog.* Zagreb, 2012.
[17] [17] Vlada Republike Hrvatske. *Odluka o donošenju Strategije prometnog razvoja Republike Hrvatske za razdoblje od 2017. do 2030. godine*. NN 84/17.
[18] IATA Economics. Air Transport Regulatory Competitiveness Indicators, 2019
[19] Fraport Slovenia Ltd. Available from: https://www.fraport-slovenija.si/ [Accessed 16th December 2019.]
[20] Fraport Slovenia Ltd. Sustainability Report 2018. Available from: https://www.fraport.com/ [Accessed 16th December 2019]
[21] Belgrade Airport. Available from: https://www.vinci-airports.com/en/airports/belgrade-airport [Accessed 16 December 2019]
[22] Zagreb Airport. Strategic Marketing Plan. Zagreb International Airport Concession, Zagreb, 2019.
[23] Smit M, Koopman M, Faber J. Aviation Policy Development Framework. CE Delft, Delft, Netherlands, 2013
[24] Venables A J, Laird J, Overman H. Transport Investment and Economic Performance: Implications for project appraisal. UK Department for Transport, London, UK, 2014
[25] Državni zavod za statistiku. Dolasci i noćenja turista u 2018. Available from: https://www.dzs.hr/Hrv_Eng/publication/2018/04-03-02_01_2018.htm [Accessed 03rd February 2020]

MARKO ŠOŠTARIĆ, Ph.D. [1]
E-mail: marko.sostaric@fpz.unizg.hr
MARKO ŠEVROVIĆ, Ph.D. [1]
E-mail: marko.sevrovic@fpz.unizg.hr
MARIJAN JAKOVLJEVIĆ, Ph.D. student [1]
E-mail: marijan.jakovljevic@fpz.unizg.hr
MARKO ŠVAJDA, Ph.D. student [1]
E-mail: marko.svajda@fpz.unizg.hr
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, Zagreb

PARKING LOT MANAGEMENT IN FUNCTION OF REDUCING GREENHOUSE GAS EMISSIONS

ABSTRACT

Due to the large number of motor vehicles in cities there is an increasing need for planning parking systems. This problem is particularly pronounced in the cities of Southeast Europe, where the implementation of sustainable transport planning has only just begun.

The current traditional approach to solving the problem of parking in urban centres results in number of other problems that affect the sustainability of the entire transport system of urban areas. In addition to having a negative impact on the transport system, parking significantly impairs the quality of life of citizens through increased pollution from emissions and noise caused by frequent cruising for free parking space. The negative impact of traffic and parking system on the life quality has also been recognized by the European Union which through new regulations is putting increasing emphasis on reducing emissions and noise from the traffic system.

KEY WORDS

parking; parking policy; parking supply; parking demand; parking space reservation

1. INTRODUCTION

The development of cities increases the degree of motorization which leads to traffic congestion, air pollution, noise pollution and many other negative impacts. To raise the life quality in urban areas, it is necessary to reduce the use of personal vehicles to a acceptable level.

One personal vehicle spends 90% of its time in rest, so parking is a big problem in terms of rational use of urban space. Therefore, it is necessary to choose the optimal parking policy that will satisfy for parking spaces demand. Parking system plays a major role as an element in the overall traffic system, due to the possibility of managing traffic demand in urban areas.

One of the main causes of increased number of cars in cities is the suboptimal parking policy which results with disbalance between parking supply and demand. The consequences of that are numerous traffic jams, congestion, and traffic accidents as well. Accordingly, abovementioned results have a negative impact on the city's ecosystem, which has been disrupted due to the large number of cruising for parking. [3]

Previous research in parking policy field confirms that the optimization of the parking supply management system directly affects parking demand, i.e. the number of vehicles in traffic flow. Likewise, many world researches confirm large number of cruising with the purpose of searching for free parking spaces in cities. [2] [4] [5]

The subject of this paper is ecological efficiency analysis of an innovative system that allows checking the availability and reservation of parking spaces in real time with aim of the reduction of greenhouse gas emissions in city centres. The system works in such a way as to allows drivers to check the number of free parking spaces near their desired destination and reserve their desired space. The user who wants to reach a certain location enters the desired address via the mobile application and gets insight into the availability of parked spaces in the area. Occupied parking spaces are marked with red colour, and free ones, which is possible to reserve are marked with green colour. The reservation of a free space starts a payment process and lifts the ramp which ensures a reservation of a desired parking space until reaches it.

2. METHODOLOGY

Greenhouse gas emissions calculation refers to products of the internal combustion of fuel, namely carbon monoxide (CO), carbon dioxide (CO2), nitrogen oxide (NOx), particulate matter (PM) and volatile organic compounds (VOCs). The calculation methodology is based on the Intergovernmental Panel on Climate Change (IPCC) guidelines, according to the Revised 1996 IPCC Guidelines and the 2006 IPCC Guidelines for National Greenhouse Inventories. The latest 2006 IPCC Guidelines for National Greenhouse Inventories distinguish three different levels of greenhouse gas emissions calculation that differ according to the quality degree of data collection used in the calculation and to the complexity degree of the calculation. The most credible pollutant gas emissions calculation is obtained using a layered approach of the third level (Tier 3). Tier 3 methodology calculates emissions based on large data amount (traffic counting, vehicle structure, road network length and operating speed). The methodology for developing the reference model of greenhouse gas emissions used in this Study is shown in the flow diagram in figure 1.

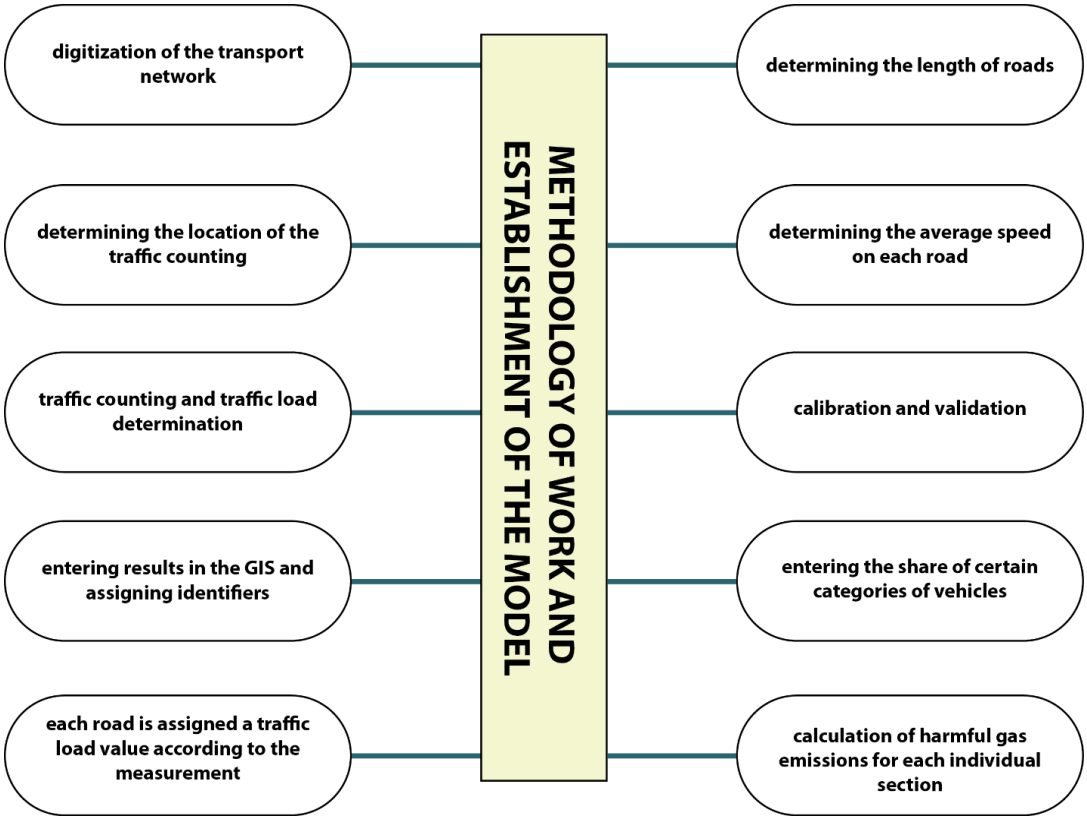


Figure 1 – Methodology for developing a model of greenhouse gas emissions in road transport in the area of the implemented SPARK SENSE system

In the process of calculating harmful gas emissions, relevant input data were collected. By counting the traffic, data on traffic load, vehicle category and traffic flow speed were obtained. Total emissions are calculated by combining activity data for each vehicle category with appropriate emission factors. The emission factors vary according to the input data.

The greenhouse gas emissions reference model in this paper refers to the results obtained in the *Spark Sense Environmental impact study*, which was an integral part of the entire Spark Sense project in which data were collected through field measurements. The emission reference model contains the amounts of greenhouse gas emissions in area of the pilot project implementation of the new Spark Sense system in two streets in the city of Pula.

In the first step, an emission model of the current state was created. Following an emission model after system implementation was created. After that, the reduction of greenhouse gas emissions caused by the implementation of the system was determined.

The results analysis determined the emissions of greenhouse gases depending on the reduction of traffic load, the vehicles number in the observed area. After the system implementation, a significant traffic load reduction in the subject area was determined, which indicates the implemented system efficiency and the direct system impact on parking demand. The results refer to the two observed streets where a system of 30 parking spaces total has been implemented [1].

The subject methodology for calculating greenhouse gas emissions was selected in accordance with the existing good practice of developed European Union countries and for its needs a field research of traffic flows was conducted with available relevant databases analysis on fleet characteristics and average speeds and emissions.

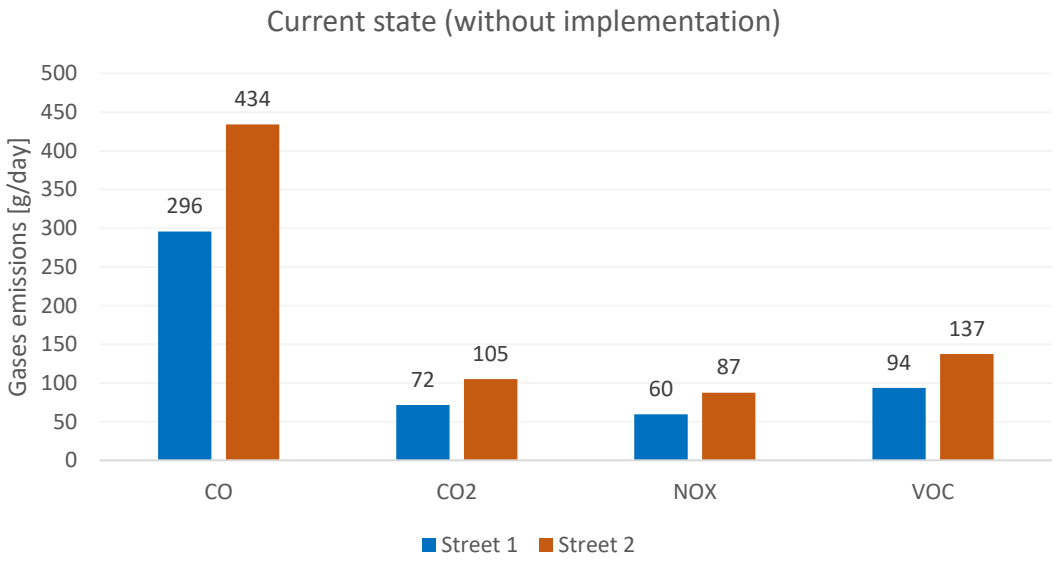
2.1 Greenhouse Gas Emissions in the Current State

Based on the described methodology, the quantities of greenhouse gas emissions in current state were calculated, without the system implementation. The initial assumptions used to calculate the emission, based on field research, are shown in Table 1.

Table 1 – Data input – Current state [1]

	Current state (without implementation)	
ID	1	2
STREET	Street 1	Street 2
SPEED [km/h]	25	25
LENGTH [km]	0,13	0,17
VEHICLES PER DAY (AADT)	2.652	2.977

The results of the emission model of the current state on the analysed sections for a characteristic day outside the tourist season are shown in Graph 1.



Graph 1 – Emissions of greenhouse gases in the current state [1]

2.2 Greenhouse Gas Emissions After System Implementation

To reduce the error probability to minimum values as well as better interpretation of the obtained results, and thus better usefulness system quantification, two scenarios have been defined:

- Scenario 1 presents a pessimistic scenario – total traffic load reduction by 15% on the roads on which the subject system is implemented.
- Scenario 2 presents a realistic scenario - total traffic load reduction by 35% on the roads on which the subject system is implemented.

The scenarios were defined on the field researches basis that are conducted as a part of the Spark Sense Environmental impact study project [1], global research in a parking system field, data analysis on the coefficients of variation and customer satisfaction surveys. The coefficient of variation represents the vehicles number that changed in the parking lot during the observed period and is calculated as the ratio of the total recorded parking hours of all vehicles and the parking spaces number (capacity). Based on the data analysis of the coefficients of variation in parking spaces where the system is implemented, the cruising was determined, the number of vehicles cruising for free parking spaces. Greater usability of a parking spaces where the system is implemented is also determined.

The project also carried out a customer satisfaction survey to determine the user's opinion of the parking systems observed on the existing parking system and on the new implemented system. The results analysis shows that most respondents are having problems finding parking spaces, which more than one-third of the respondents seek for more than ten minutes. The survey results confirm the reduction in the number of cruising for parking by implementing the system.

The results of the greenhouse gas emissions amount at the observed locations for the scenario concerned are presented and described below.

Scenario 1

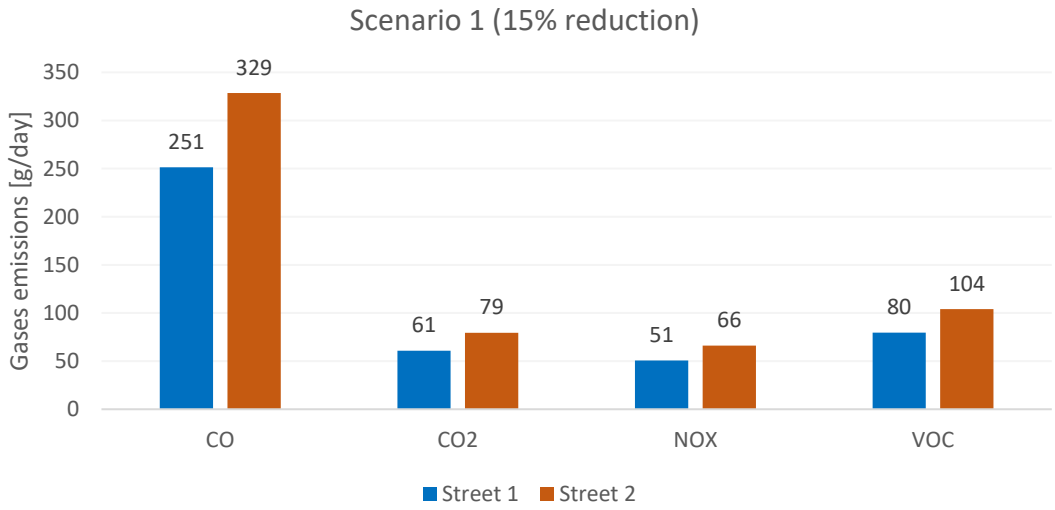
A 15% reduction in the vehicles number is a pessimistic scenario. It is assumed that the implementation of the system concerned will reduce the load on roads by at least 15%. The initial assumptions used to calculate the greenhouse gas emissions amount according to scenario 1 are shown in Table 2.

When calculating the greenhouse gas emissions in scenario 1 at the locations concerned, the following input parameters were used: traffic flow speed, road length and number of vehicles per day (AADT). The traffic flow speed parameters and road length were used as in the existing state, and the traffic load, number of vehicles, was reduced by 15%. Accordingly, on the street 1, the traffic load in Scenario 1 is 2.254 vehicles per day, and 2.253 vehicles per day in street 2.

Table 2 – Data input – Scenario 1 [1]

	Scenario 1 (15% reduction)	
ID	1	2
STREET	Street 1	Street 2
SPEED [km/h]	25	25
LENGTH [km]	0,13	0,17
VEHICLES PER DAY (AADT)	2.254	2.253

The results of the emission model after the pessimistic scenario system implementation on the analysed sections for a characteristic day outside the tourist season are shown in Graph 2. The methodology used in the emission of greenhouse gases calculation in scenario 1 is the same as for the emission of greenhouse gases calculation in the current state.



Graph 2 – Greenhouse gas emissions – Scenario 1 [1]

Scenario 2

A reduction of the vehicles number of 35% is a realistic scenario confirmed by numerous world surveys as well as conducted field research and surveys. Namely, according to world research and previous experience on similar research in urban areas on roads with an implemented street parking system, it was determined that every third vehicle cruising for free parking space. [2]

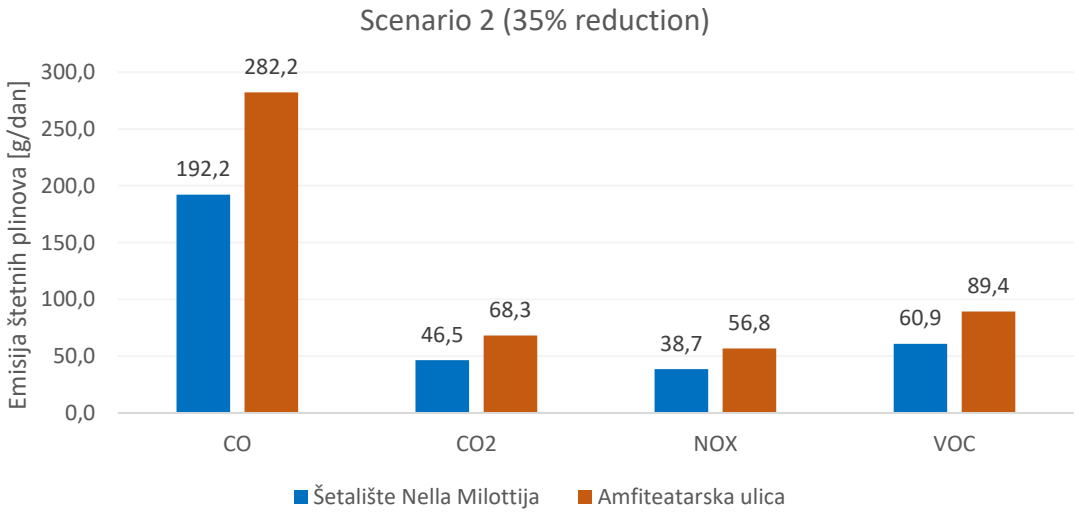
When calculating the greenhouse gas emissions in scenario 2 at the locations concerned, the following input parameters were used: traffic flow speed, road length and number of vehicles per day (traffic load). The parameters for traffic flow speed and road length were used as in the existing state and in scenario 1 and the vehicles number was reduced by 35%. Accordingly, on the Street 1, the traffic load in Scenario 2 is 1.724 vehicles per day, and 1.935 vehicles per day in Street 2.

The initial assumptions used to calculate the greenhouse gas emissions amount according to scenario 2 are shown in Table 3.

Table 3 – Data input – Scenario 2 [1]

	Scenario 2 (35% reduction)	
ID	1	2
STREET	Street 1	Street 2
SPEED [km/h]	25	25
LENGTH [km]	0,13	0,17
VEHICLES PER DAY (AADT)	1.724	1.935

The results of the emission model after the system for a realistic scenario implementation on the analysed sections for a characteristic day outside the tourist season are shown in Graph 3. The methodology used in calculating the greenhouse gas emissions in scenario 2 is the same as for the calculation of greenhouse gas emissions in the current state.



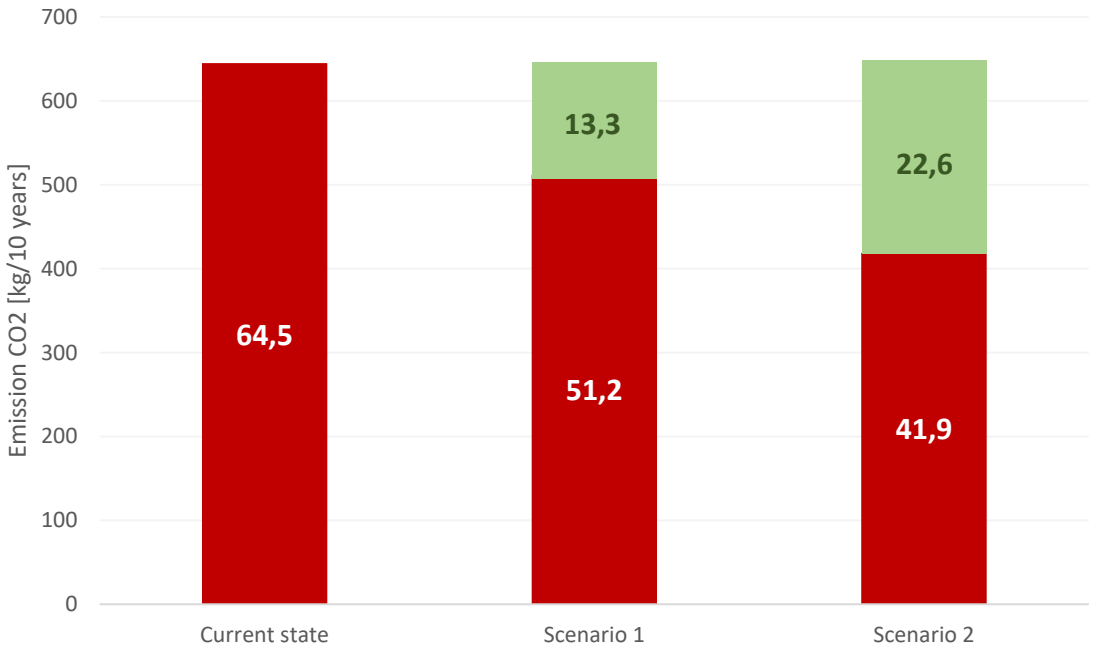
Graph 3 – Greenhouse gas emissions – Scenario 2 [1]

2.3 Comparative Analysis of Results

The detailed emission data of the greenhouse gases in the current state (without the system implementation) in scenario 1 (decrease in traffic for 15%) and in scenario 2 (decrease in traffic for 35%) are presented below.

The analysis of the results shows the greenhouse gas emissions depending on the reduction vehicles number in the observed area. In the first scenario, CO_2 emissions decreased over a period of one year is 13,3 kilograms while in the second scenario the reduction was found to be 22,6 kilograms. It is important to emphasize that the results refer to the two observed roads on which a system of a total of 30 parking spaces has been implemented.

Graph 4 shows the comparison of CO_2 emissions in the current state, in scenario 1 and in scenario 2. The CO_2 emission results are expressed in kilograms per year.



Graph 4 – Reduction of the CO2 emissions in the current state, in scenario 1 and in scenario 2

Table 4 shows a comparison of emissions of other greenhouse gases in the current state, in scenario 1 and in scenario 2. The emission results of the greenhouse gases are expressed in kilograms per year.

Table 4 – Greenhouse gas emissions in the current state, in scenario 1 and in scenario 2 [kg/year] [1]

	Street 1		
	Current state	**Scenario 1**	**Scenario 2**
Emission CO [kg/y]	107,9	91,7	70,2
Emission CO2 [kg/y]	26,1	22,2	17,0
Emission NOX [kg/y]	21,7	18,5	14,1
Emission PM [kg/y]	0,7	0,6	0,4
Emission VOC [kg/y]	34,2	29,1	22,2
	Street 2		
	Current state	**Scenario 1**	**Scenario 2**
Emission CO [kg/y]	158,4	119,9	103,0
Emission CO2 [kg/y]	38,3	29,0	24,9
Emission NOX [kg/y]	31,9	24,1	20,7
Emission PM [kg/y]	1,0	0,7	0,6
Emission VOC [kg/y]	50,2	38,0	32,6

In the case of the system implementation in the whole city centre, cruising for parking would be reduced, which would result in a greenhouse gas emissions reduction to a much greater extent. The result of the implementation of the system in the city centre is presented below.

In the central part of the city of Pula there are around of 2220 parking spaces and about 19 kilometres of road network. The central zone of the city is shown in the figure 2. The calculation used the average AADT assumption of 4000 vehicles for each road. An average driving speed in the city centre of 25 km/h was also determined.

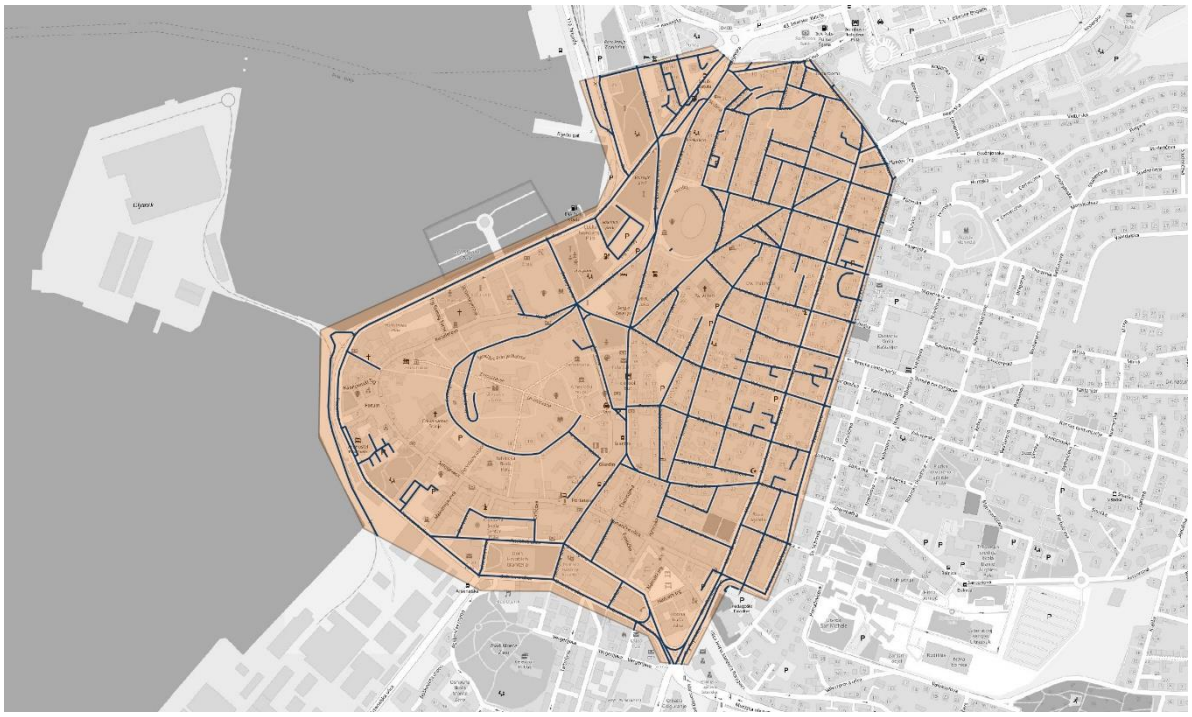
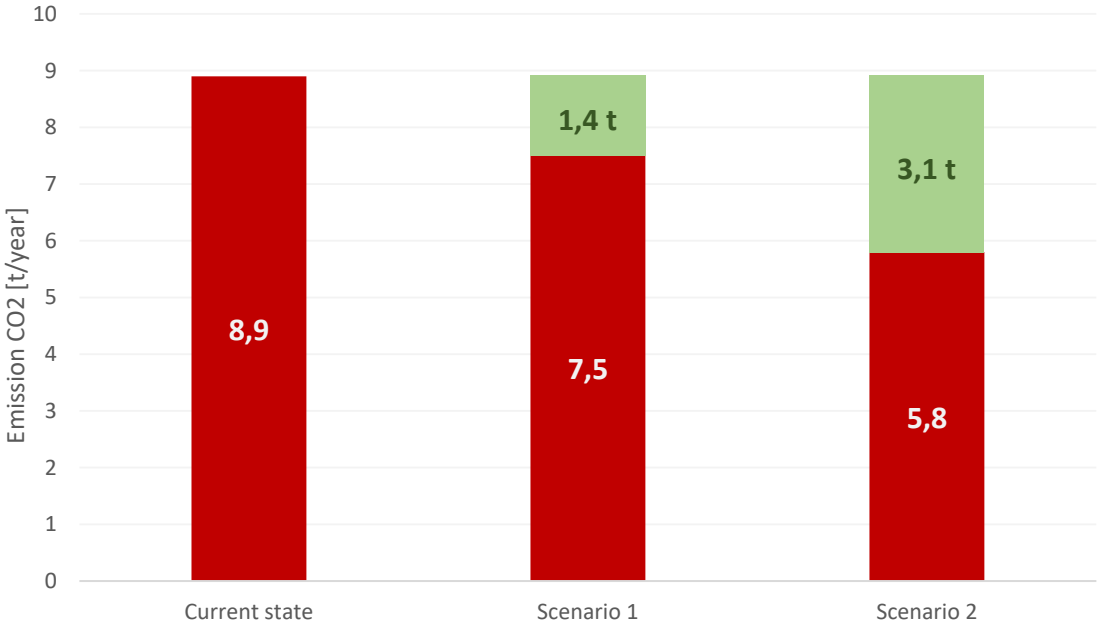


Figure 2 – The city centre of Pula

Analysis of the results shows that the annual CO_2 emission in the city centre is 8,9 tons. In the first scenario (15% reduction), CO_2 emissions decreased over a period of one year is about 1,4 tons while in the second scenario (35% reduction) decrease was found to be about 3,1 tons.

Graph 5 shows a reduction in co2 emissions in the city centre area in the current state, in scenario 1 and in scenario 2. The CO_2 emission results are expressed in tons per year.



Graph 5 – Reduction of the CO2 emissions in the city centre

3. CONCLUSION

Current trend of urban planning puts sustainable forms of traffic in the first place, so the main priority is given to pedestrians, cyclists and public urban transport, while the use of personal cars is trying to be minimized. Likewise, it is impossible to completely remove passenger cars from city centre, so it is necessary to provide certain parking capacities. Parking as an important traffic subsystem presents a powerful tool for the entire traffic system management. Therefore, it is necessary to choose an optimal way to manage the parking supply to minimize traffic congestion and meet the demand for parking spaces.

The system implementation that allows checking the availability and reservation of parking spaces in real time leads to a reduction in cruising for parking and total number of vehicles in the coverage area of the implemented system.

The vehicles number is the most important input parameter for the greenhouse gas emissions calculation. Accordingly, a forecast of a reduction in the cruising for parking due to the system implementation concerned was made.

Based on a detailed Tier 3 methodology, the quantities of greenhouse gas emissions were calculated in scenario without the system implementation and in scenario with the implemented system which reduces the total traffic load in the observed area.

The results analysis confirmed the reduction of the greenhouse gas emissions because of implementation of checking availability and parking reservation system in the observed area. Accordingly, it can be concluded that the overall system efficiency is high and that its implementation directly affects the life quality in urban centres.

REFERENCES

[1] Šoštarić M, Ševrović M, Jakovljević M. Spark Sense - Environmental impact study. 2019.
[2] Shoup D. Cruising for parking. 2006.
[3] Höglund P. Parking, energy consumption and air pollution. 2005.
[4] Cao J, Menendez M. Quantification of potential cruising time savings through intelligent parking services. 2018
[5] Ommeren J, Wentink D, Rietveld P. Empirical evidence on cruising for parking. 2012.
[6] Caicedo F. Real-time parking information management to reduce search time, vehicle displacement and emissions. 2010.
[7] Wang J, Zhang X, Zhang M. Parking permits management and optimal parking supply considering traffic emission cost. 2016.
[8] Čuljković V. Influence of parking price on reducing energy consumption and CO2 emissions. 2018.

KRISTINA TEČEC, Ph.D. student[1]
E-mail: kristina.tecec@koncar-kev.hr
DENIS ŠIPUŠ, Ph.D. student[2]
E-mail: denis.sipus@fpz.unizg.hr
BORNA ABRAMOVIĆ, Ph.D.[2]
E-mail: borna.abramovic@fpz.unizg.hr
[1] KONČAR – Electric Vehicles Inc.
Ulica Ante Babaje 1, 10090 Zagreb, Croatia
[2] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

ANALYSIS OF DIAGNOSTIC SYSTEMS IN INTEGRATED PASSENGER TRANSPORT

ABSTRACT

This paper presents concept and activities related to the application of the diagnostic system for planning operation and maintenance of railway vehicles. It offers the leading digital technologies that enable better access into the operational phenomena of specific subsystems/equipment on the vehicle, especially those that have been assessed as safety-critical. Monitoring these indicators allows the detection process, which would ultimately end up in failure and unplanned costs, caused by the sudden failure of a railway vehicle and its delays in service. The research is also focused on the Integrated Passenger Transport Systems (IPTS) as a part of diagnostic systems in railway vehicles.

KEY WORDS

integrated passenger transport systems; diagnostic systems; life cycle cost

1. INTRODUCTION

Investment decisions, concerning the purchase of rolling stock, require costs benefit evaluation of applying different, alternative solutions.

They can concern, among others, technical parameters of rolling stock, expected maintenance costs and operational costs, reliability or sources of financing. Technical parameters of rolling stock are determining not only investment costs. They also have a significant influence on the level and the deployment of maintenance costs in the vehicle life cycle. They are also a factor of creating the competitiveness of public transport, in railway, towards the aprivate cars.

Total cost for the contracting authority, from rolling stock purchase project preparation till the end of its operation, including its scrapping (utilisation) is the most reliable parameter in assessing the investment decision of rolling stock purchase.

The methodology of calculating these costs, defined as life cycle cost (LCC), has been improved in recent years based on experience from the exploitation of new generation vehicles. The presentation of methodological principles of projecting these costs is an essential purpose of this article [1].

The rail network is a crucial component of any surface transport network. It is relatively benign to the environment in comparison with road transport. It also helps decrease congestion in the already hectic roads of the World. Supporting the growth of rail transport has significant economic and environmental benefits since it increases the potential of passengers and tonnage of goods that can be transported in a cost-efficient manner. For passengers, lower travel prices increase the level of mobility potential, both for business as well as leisure purposes, helping spread the wealth in all

regions of a country and its neighbours. By reducing the cost of transporting goods across a country and beyond its borders, it is possible to lower prices and increase competitiveness of domestic industries. Therefore, rail transport is considered as the backbone of the entire transport system in several developed and developing countries. Improving the efficiency of rail transport has profound positive consequences for the economy and society as a whole. However, for rail industry to increase its positive impact, it needs to move towards a 24-hour operation. This is currently impossible to implement due to the significant technical challenges that need to be overcome concerning reliability, availability, maintainability and safety (RAMS) of railway assets.

An additional problem that needs to be overcome is the eradication of delays and disruption due to rolling stock and infrastructure faults. Unfortunately, the nature of the rail network is such that faulty rolling stock and infrastructure components can result in considerable delays and disruption. The rail industry needs to ensure that railway systems are reliable, minimising the likelihood of unpredictable faults, and in certain extreme cases, the occurrence of derailments [2].

2. INTEGRATED PASSENGER TRANSPORT SYSTEMS

The integrated public transport system (IPTS) is a special kind of public transport. The basic of this IPTS is formed by the public mobility in a uniform transport, tariff and information system. Every transport mode, which is integrated into the IPTS has to cooperate with the other parts of the transport system. This cooperation is crucial because most passengers perceive it, and the passengers are on top of the IPTS – they are the beginning and the end of the system. Simplicity and clarity are other essential characteristics. The passenger has to be in every talk about the IPTS [3].

The term IPTS covers the integration of individual modes of public transport into a single transport unit when using the uniform tariff and passengers handling system, and uniform carriage conditions of passengers with the integrated telematics, communication, controls and automation technologies that significantly contribute to improving the quality of public transport services.

The offer of more attractive carriage opportunities for passengers is the crucial advantage of IPTS.

IPTS include the latest technologies, infrastructure, and services as well as the operations, planning and control methods that are used for the carriages of passengers, and freight as well recently.

Speaking of the matter of the integrated transport systems within public passenger transport, the issue of intermodality cannot be forgotten. It is understood as the passengers' utilisation of various modes of transport in one travel. Passenger transport intermodality requires the integration of journeys and information, as well as coordination and service in intermodal terminal points and coordinating the timetables and ticket unification. Continuous travelling requires suitable land utilisation and urban planning. Improving the intermodality in passenger transport is the crucial aspect of the development of an efficient integrated transport system [4].

Integrated Passenger Transport System is recognised as the most important way of organising local passenger transport in many developed countries and the entire European Union.

Such systems exist in the vast majority of Western European countries and some other developed countries of the World. They have justified their introduction with their quality work. Still, they work on their improvement, both technically and technologically, as well as from the aspect of customer service, does not stop. Public transport has numerous environmental, energy, infrastructural, economic and safety advantages over an individual, therefore, it deserves intensive application and development [5].

3. DIAGNOSTIC SYSTEM SOLUTIONS

All businesses need equipment to deliver services or manufacture goods. Over time, this equipment will degrade, but with proper maintenance, the degradation can be controlled, and failed equipment can be restored to operational status. Run-to-failure maintenance is performed when equipment or systems break down. In preventive maintenance, equipment is maintained as a precautionary measure to prevent failure. Finally, condition-based maintenance recommends maintenance actions based on the condition of the asset. The railway is a superior mode of transport if capacity, speed and environment are the main criteria; it also plays a crucial role in densely crowded regions [6].

Modern railway vehicles always demand higher performances with the consequence that, to maintain high safety levels and low life cycle costs, better maintenance scheduling is required. A right level of reliability of the vehicle can be achieved if the maintenance process is correctly scheduled, acting on the vehicle components promptly and before their conditions become critical. This requirement can be fulfilled by reducing the maintenance periods, but this solution leads to higher costs. The application of onboard monitoring systems can be a better solution in terms of costs, allowing scheduling the maintenance process based on the data measured on the vehicle [7].

Exploring the available diagnostic solutions in the market for maximum fleet availability and efficiency stands out the major equipment suppliers: German company Siemens, Canadian Bombardier, French companies Alstom and Thales, Swiss company ABB, Chinese Huawei, Japanese companies Fujitsu, Hitachi and Toshiba. the Spanish companies CAF and Indra, the Finnish companies EKE-Electronics and Nokia, the British company Atkins, the companies Cisco, IBM, DXC from the USA

Below is a summary of several commercially available diagnostic system solutions. Compact solutions, tailored to solve problems with pre-configured settings, offering enough freedom to end-users are considered. Such diagnostic systems provide a greater ability to adapt the system configuration to the needs of the end-user in collaboration with the equipment supplier.

3.1 SmartVision™ System of the Company EKE Electronics

The SmartVision ™ is a diagnostic system of the Finnish company EKE Electronics. The SmartVision™ Remote Condition Monitoring System (RCMS) collects and analyses key data from the train fleets. The train status and diagnostic information can be used to improve maintenance, processes and operations. SmartVision™ is modular and the following applications can be implemented: Online Monitoring, Condition Monitoring, Predictive Analytics, Trains on Map, Driving Assistance. The system enables remote access, on-line analysis of current train data to maximise fleet availability and efficiency while reducing maintenance costs by managing and maintaining available resources more efficiently [8].

SmartVision™ Data Acquisition is performed by Gateways placed in each train. The Gateway collects data from the train and sends it to the wayside. It is possible to collect different data from different types of rolling stocks. SmartVision™ allows centralising all fleet diagnostics and monitoring into one single system.

The SmartVision™ Gateway is modular and can be designed to collect data from virtually any onboard system, either via direct connections to sensors and systems, or by simply connecting to an existing train network which already collects the required information.

Remote Input/Output Modules (RIOM) can be used to collect data on the train to reduce cabling. New sensors can also be added if needed. Then, the information gathered is transferred wirelessly to the wayside via 3G/4G or Wi-Fi, from where it is sent to the SmartVision™ server to be stored and processed.

The onboard Gateways are built by selecting the interface modules required for each particular train type. The available communication interfaces include Ethernet, MVB, CAN, Serial Links as well as digital and analogue inputs, to name a few.

This modularity makes SmartVision™ suitable for fleets made of several types of rolling stocks, from various manufacturers and from different generations (shown in Figure1).

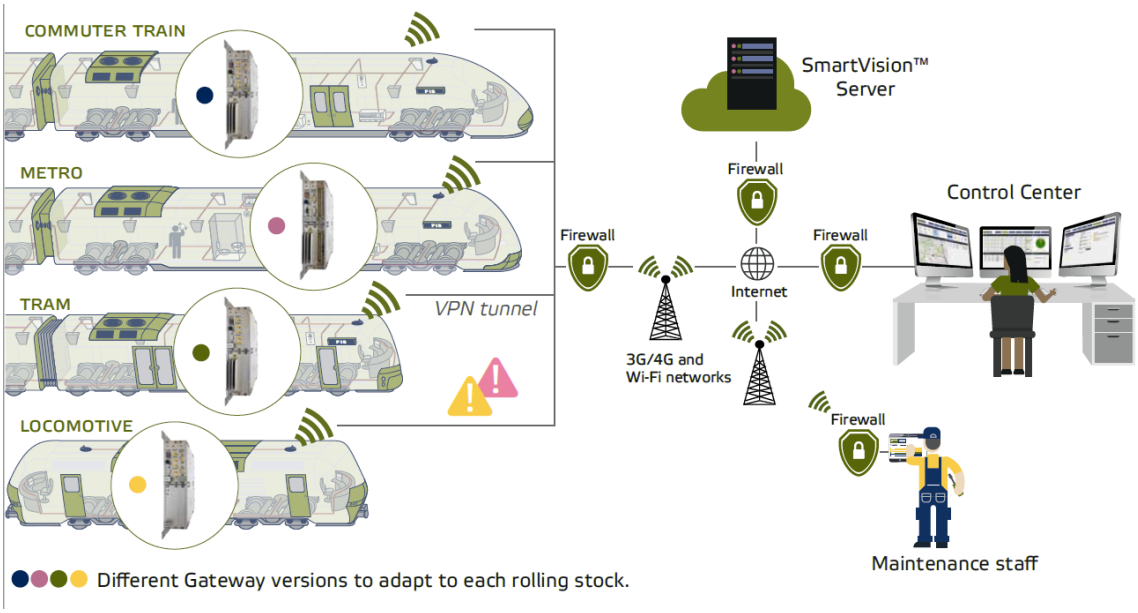


Figure 1 – Example of SmartVision™ Multifleet Setup
Source: [8]

3.2 LeadMind – a Digital Platform from CAF

A Spanish company CAF presented digital platform LeadMind, at the Rolling Stock Maintenance Summit 2018 in London. This tool monitors, stores and interprets data transmitted by the rolling stock, the operator and infrastructures. LeadMind turns this data into valuable information, converting this into savings, safety and service.

By developing new products, tools and techniques, CAF can monitor and diagnose in real time all factors involved in railway maintenance. The system is based on Machine Learning and Big Data technologies that offer substantial benefits, and guarantee efficient fleet management, operation and maintenance [9].

Similar to the system described above (by EKE Electronics), this is also a modularly designed solution that simply adapts to the user's needs. The information collected and processed is presented to the user, making it available in the process of deciding what action is required to maintain a complete rolling stock [10].

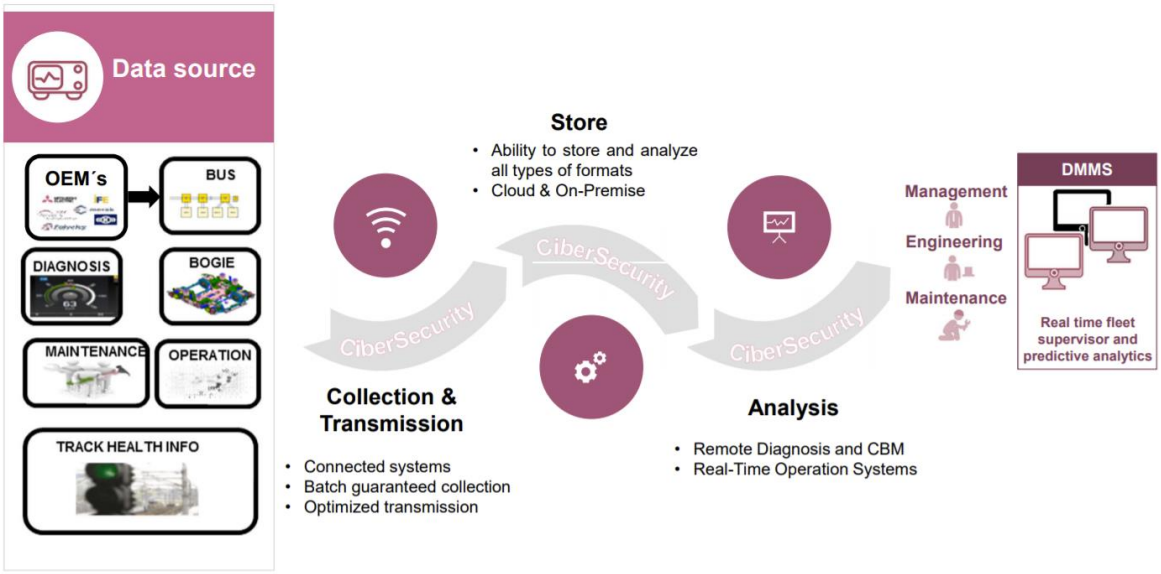


Figure 2 – LeadMind system – process flow
Source: [10]

3.3 Siemens Solutions

Figures Offering solutions for implementing railway monitoring systems from Siemens, one of the major global suppliers of rail "digitalisation" equipment/services, includes various diagnostic systems with remote access such as the Nexus series:

- Monitoring systems to support the monitoring and maintenance of fixed railway infrastructure: NexusRemote (RCM - remote condition monitoring), is an application that monitors the condition of the train tracks remotely. Nexus RCM can be supplied as a standalone system or as part of the Nexus Voice cab radio. Using the additional capacity of the new Nexus cab radio processor, together with the addition of a sensor card and accelerometer, the application can measure and record the motion of the train across three axes as it moves along the track. A GPS unit provides the train's position to the cab radio [11],
- Driver support systems for monitoring the condition and maintenance of fixed railway infrastructure (the network of railway corridors, automatic switches) such as: The Nexus Loadster C-DAS (C-DAS - Connected-Driver Advisory System), will enable the provision of scheduling, routing and speed restriction updates in real-time which has the power of optimising the train's performance, energy and reduce risk [12].

Siemens' MindSphere is a cloud-based, open Internet of Things (IoT) operating system, enables industries worldwide to link their machines and physical infrastructure to the digital World easily, quickly and economically. Harnessing data from virtually any number of connected, intelligent devices, enterprise systems and federated sources allows for analysis of real-time operational data. This analysis then leads to optimised processes, resource and productivity gains, the development of new business models and the reduction of operations and maintenance costs. Companies leveraging MindSphere boost performance, sharpen their competitive advantage and realise much more profitability [13].

A detailed description of the system operation is shown in Figure 3.

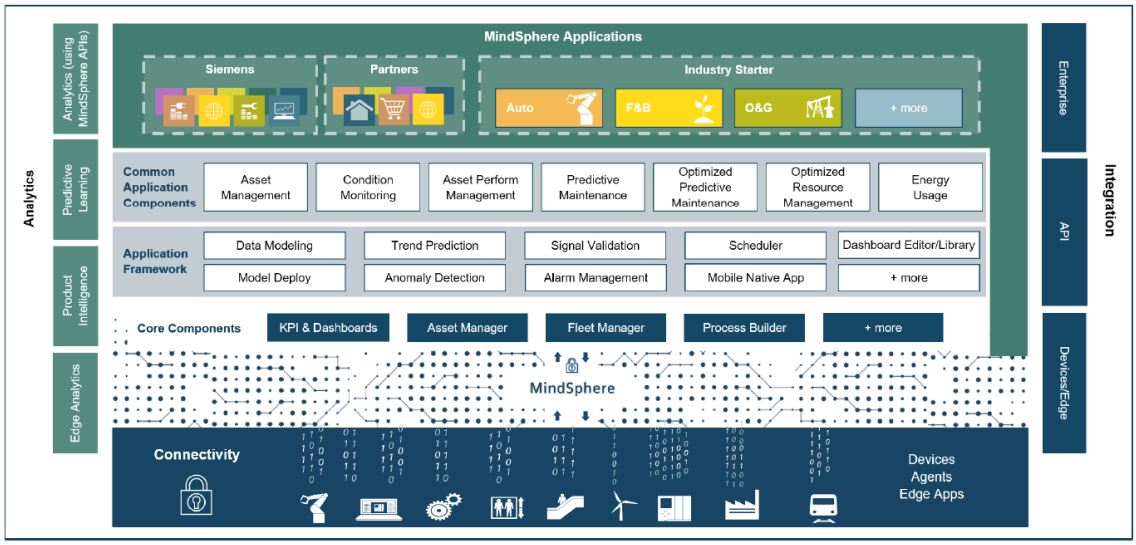


Figure 3 – System architecture of Siemens Mindsphere [13]
Source: [10]

4. CONCLUSION

Cost-benefit analysis has a key role in the purchase of rolling stock. The life span of rolling stock is long (up to 50 years) and, besides the cost of procurement of vehicle, life cycle costs have a significant impact on cost-benefit analysis. Cost of maintenance has an essential role in life cycle costs.

Availability and reliability of rolling stock are significant factors which influence the planning of and execution of timetables in Integrated public transport systems. They are in direct relation to maintenance activity performance.

Diagnostic systems like the ones described in this document can have a significant influence on the performance of maintenance activities as they highlight preventive maintenance instead of corrective one. Selection of diagnostic systems is essential for rolling stock operator as it brings a reduction of maintenance costs (preventive vs corrective) and increases availability and reliability of rolling stock. By doing that diagnostic systems also give a positive contribution to Integrated public transport systems.

This paper presents three commercially available diagnostic system solutions from well-known manufacturers. Compact solutions, tailored to solve discussed problems with pre-configured settings, offering enough freedom to end-users are considered. Each end-user decides freely which of the offered systems (or any other similar) is the best choice for his use according to his own needs.

REFERENCES

[1] Raczyński J. Life cycle cost as a criterion in purchase of rolling stock. MATEC Web of Conferences. 2018.
[2] Zheng H. Integrated railway remote condition monitoring. [PhD thesis]. University of Birmingham. 2017.
[3] Kopecká P, Švetak J. The Integrated Public transport system. Sci J Marit Res. 2013; 1:149-56
[4] Stopka O, Bartuška L, Kampf R. Passengers' Evaluation of the Integrated Transport Systems. Naše more. 2015;62(3): 153-157.
[5] Abramović B. Integrirani prijevoz putnika. Interni nastavni materijal. Fakultet prometnih znanosti. Zagreb. 2016
[6] Palo M. Condition-Based Maintenance for Effective and Efficient Rolling Stock Capacity Assurance. [PhD thesis]. Lulea University of Technology. 2014.

[7] Bosso N, Gugliotta A, Zampieri N. Design and testing of an innovative monitoring system for railway vehicles. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit. 2018; 232(2): 445–460.
[8] EKE Electronics, SmartVision™ Remote Condition Monitoring System (RCMS), system overview, overview brochure. Available from: https://www.eke electronics.com/images/eke/Brochure/ EKE_SmartVision_Brochure.pdf [Accessed 13th Feb 2020].
[9] CAF. Available from: https://www.caf.net/en/sala-prensa/nota-prensa-detalle.php?e=261 [Access sed 13th Feb 2020].
[10] CAF Lead Mind digital train. Available from: https://www.icai.es/wp-content/uploads/2019/ 06/CAF-LeadMind-Digital-Train.pdf [Accessed 13th Feb 2020].
[11] Siemens Nexus RCM (Remote Control Monitoring) Available from: https://assets.new.siemens.com/ siemens/assets/ public.1558615037.5306efb6-17b9-477e-ac8a-c3d6941c291f.nexus-rcm-data-sheet.pdf [Accessed 13th Feb 2020].
[12] Driver Advisory System C-DAS (Nexus Lodestar) Available from: https://assets.new.siemens.com/ siemens/assets/api/uuid:142ca641-f8c7-404a-a1c7-3b61f6cc43e5/version:1558615134/nexus-c-das-brochure.pdf [Accessed 15th Feb 2020].
[13] Siemens MindSphere. Available from: https://www.plm.automation.siemens.com/media/global/ en/Siemens-MindSphere-Whitepaper-69993_tcm27-29087.pdf?stc=wwiia420000&elqTrackId= e0d65-20bc42f4e44952b0a7cf107f372&elq=bd16b7e2cfde40d2870a60f631fbb0c2&elqaid=29 [Accessed 15th Feb 2020].
[14] Siemens. Available from: https://www.mobility.siemens.com/global/en/portfolio/rail/services/ digital services/railigent.html [Accessed 14th Feb 2020].

LEO TIŠLJARIĆ, M.Sc.[1]
E-mail: ltisljaric@fpz.unizg.hr
DOMINIK CVETEK, M.Sc.[1]
E-mail: dcvetek@fpz.unizg.hr
MARIO MUŠTRA, Ph.D.[1]
E-mail: mmustra@fpz.unizg.hr
NIKO JELUŠIĆ, Ph.D.[1]
E-mail: njelusic@fpz.unizg.hr
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

MIXED IMPACT OF THE COVID-19 PANDEMIC AND THE EARTHQUAKE ON TRAFFIC FLOW IN THE NARROW CITY CENTER: A CASE STUDY FOR ZAGREB-CROATIA

ABSTRACT

Congestion is one of the key problems faced by traffic engineers and authorities. The application of Intelligent Transport Systems (ITS) is one of the main approaches to solve this constant problem. The ITS is particularly significant in cases of post-disaster occurrences such as flood, fire, or earthquake. The new pandemic caused by SARS-CoV-2, named COVID-19, has elements of a post-disaster events. So far, not many researchers deal with its impact on the traffic flow caused by it. Besides that, there is a lack of research on the effect on the traffic flow caused by earthquakes. In this paper, we try to investigate traffic flow trends before and during the COVID-19 pandemic. Additionally, we analyze traffic flow during the earthquake, which hit Zagreb on Sunday 22nd March 2020 at 6:24 AM. The results of this study can be useful for traffic managers dealing with post-disaster traffic management strategies.

KEY WORDS

Traffic Flow; Dwell Time; Pandemic; Occupancy; Earthquake; COVID-19

1. INTRODUCTION

Many traffic experts and companies around the world deal with congestion issues and try to find various solutions to mitigate this problem. Congestion is a big issue in most cities around the world and significantly affects citizen mobility. The phenomenon is characterized by lower vehicle speeds, increased travel times, arrival unreliability, and longer vehicular queueing [1]. Congestion is a non-linear function, so as a road approaches its maximum capacity, small changes in traffic volumes can cause proportionately more significant changes in congestion delays [2]. It can be non-recurrent or recurrent occurring on a daily, weekly, or annually bases caused by recurring bottlenecks, network demand greater than capacity, or poor traffic light signal plan timing. A non- recurrent congestion is unexpected and usually unpredictable or with small predictability. It can be caused by traffic incidents, vehicle breakdowns, work zones, weather, or special events [3].

Analysis of the traffic flow in cases of natural disasters is necessary to manage the unexpected and potentially harmful situations. Authors in [4] study regional traffic flow in a high-density area under sudden fire disaster. In [5], authors use network modeling during flooding disaster to produce a response plan for road users. Authors in [6] proposed a post-disaster traffic control optimization method for better use of road capacity and reduced network connectivity change. In [7], authors developed an earthquake transportation emergency decision-making optimization. Authors in [8] were estimating a state of the traffic flow after an earthquake.

The new COVID-19 pandemic can be aligned with an unexpected disaster. It forced the government to impose various measures to assist in limiting the spread of the virus that mostly resulted in movement restrictions. Consequently, traffic flow and traffic congestion are reduced or fade away. According to INRIX, personal travel is down for 46 percent nationwide, while truck travel is down for 13 percent. This may indicate that consumer demand is still strong, as stated in [9].

In this paper, we investigate the impact of COVID-19 government measures on traffic flow in the narrow city center. We compared the speed and volume during the average working day with its corresponding values during the COVID-19 pandemic. Furthermore, an earthquake hit Zagreb on Sunday 22nd March at 6:24 AM. The speed and the volume values are compared in the near earthquake time with the previous day. We found that shortly after the earthquake there were many more vehicles on the road if compared to normal conditions. This is attributed to the psychological effect of fear, where citizens choose to drive a vehicle rather than stay in or around their buildings.

The rest of the paper is organized as follows. In Section 2, a description of used methods is given. Section 3 gives a description of the used equipment and the test site where measurements were made. Section 4 brings discussion of the obtained results and Section 5 gives concluding remarks.

2. METHODOLOGY

Given the set of counting data collected by the radar-based traffic sensor, this paper aims to present the impact of the natural disasters on the traffic parameters in the narrow urban center. This section briefly describes the three main steps of the methodology used in this paper that includes: (i) data collection, (ii) data preprocessing, and (iii) traffic parameter estimation methods.

2.1 Radar Data

The radar data collection system consists of a radar detector or scanner, power supply, casing, and equipment for mounting. A radar detector is designed to be mounted mainly on lighting poles or above the road and detects passing vehicles, collects data, sends, and store data on a server.

Radar detectors constantly scan the detection zone in search of targets - vehicles. Successful detection means that a detector correctly counts a vehicle passing in the scanned traffic lane. A radar detector can store data from passing vehicles. It detects timestamp, speed, vehicle length, traffic lane, and direction. An example of a recorded radar dataset is shown in Table 1. Besides providing only detection, a radar detector can be used to calculate plentiful traffic data at micro-location such as volume, occupancy, speed profile. This data can be separated by direction and traffic lane.

Table 1 – Example of one datapoint captured by the radar sensor

Timestamp	Speed	Length	Lane	Direction
1/6/2020 12:00:00 AM	50 km/h	3.5 m	2	1

2.2 Volume and Occupancy

Volume and occupancy are traffic flow parameters which can be easily collected using a traffic point detector. Combination of their values is often used to present traffic flow conditions.

Volume (q_T) is as a number of vehicles passing throw defined road section in the defined interval T [10],

$$q_T = \int_0^T q(t) \ [\text{veh/h}]. \tag{1}$$

Radar detector used in this case study cannot measure occupancy directly. Therefore, occupancy can be calculated from vehicles' speed and length.

Occupancy is defined as the percentage of time a point on the road is occupied by vehicles [11], [12], or as the total dwell time of all vehicles in the detection zone of a detector in the observed interval *T*,

$$OCC = \frac{\sum tocc_i}{T} \ [\%], \tag{2}$$

where *OCC* is the percentage of occupancy, $tocc_i$ is occupancy time (dwell time) of the ith vehicle, *n* is the total number of vehicles in the observed interval *T*. Vehicle occupancy time $tocc_i$ is a function of vehicle speed, vehicle length, and detection zone length,

$$tocc_i = \frac{L_i + L_D}{v_i} \ [\mathrm{s}], \tag{3}$$

where L_i is length of the ith vehicle, v_i is the speed of the ith vehicle, and L_D is the length of the detection zone.

As it can be read from (3), occupancy and speed are correlated. Our test site is far enough away from the intersection, and for small congestion levels, this site can be treated as a site of free flow traffic. Because of that we decided to use vehicles' speed to present changes in the traffic flow. In our case the mean speed $\overline{v_t}$, averaged in defined time intervals is used to characterize the traffic flow.

$$\overline{v_t} = \frac{1}{n}\sum_{i=1}^{n} v_i \ [\mathrm{km/h}], \tag{4}$$

where *n* is the number of vehicles in defined time intervals, v_i is the measured speed of the ith vehicle.

2.3 Data Preprocessing

In this research, traffic parameters on average working days from 2019 were compared to the traffic parameters during the two mentioned disasters. Traffic data was captured during the 2019 and the beginning of 2020. The average working day of 2019 was calculated by considering traffic parameters captured at all working days and aggregated in the 15- min intervals. For the 2020, data is captured from 1st of January to the 11th of April, as shown in Figure 3. To extract the accurate estimation of average traffic conditions from 2019, the raw radar data were preprocessed by applying:

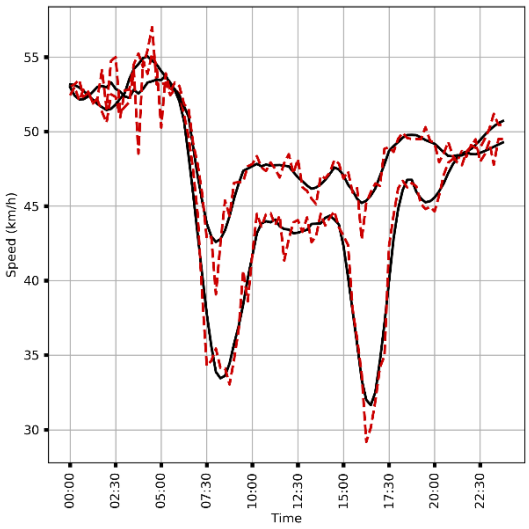


Figure 1 – Examples of the raw (red) and smoothed (black) speed profiles in the summer months and the rest of the year.

(i) seasonal filtering, (ii) data aggregation, (iii) anomaly removal, and (iv) smoothing. Seasonal filtering is one of the most important steps in the filtering process of the traffic data, especially in countries like

Croatia with developed tourist seasons [13]. The experiment showed that traffic parameters like speed behave differently due to the lack of traffic volume in cities belonging to the continental part of the country. On the other side, the Mediterranean cities showed the contrary behavior because of the increase in traffic volume due to larger amounts of tourists (Figure 1). Therefore, summer months, July and August, were excluded from the case study because the City of Zagreb is in the continental part of the country.

The traffic data mention in most of the literature sources is aggregated into the 5-, 15- or 60- min intervals [14,15]. In this research, data is aggregated into 15-min intervals by extracting the average of observed traffic parameters. To achieve greater accuracy, the anomalies from the data were removed by using standard statistical methods. Firstly, the 25th percentile data point Q1, datapoint on the 75th percentile Q3, and the interquartile range Q3-Q1 were calculated. Then, all the data that had a lower value than Q1-1.5*IQR and the data with higher values than Q3+1.5*IQR were declared as anomalies and, therefore, excluded from the experiment.

For the smoothing of the traffic parameters showed as the time-series data, the Savitzky-Golay method is used [16]. The method presents a digital filter for the smoothing that performs a least-squares polynomial fitting when the filter coefficients are convolved with the input signal. The results of the smoothing are shown in Figure 1.

3. EQUIPMENT FOR MEASUREMENTS AND TEST SITES

Equipment for measurements used in this case study includes a radar traffic detector, a solar-powered system independent of outside power source for counting the total number of vehicles, and measuring their speed, occupancy, and volume. The radar detector used for the overall flow measurement was Frequency Modulated Continuous Wave Radar (FMCW), model Huston SpeedLane, working in 24 GHz K-band. This radar is specifically designed for portable or permanent traffic data



Figure 2 – The location of the radar traffic counter in the City of Zagreb (Miramarska street)

measurement and collection [17]. The photovoltaics power supply system contains a solar panel, a battery, and a charge controller. Data acquisition was conducted in Zagreb near the underpass - Miramarska street. All equipment was mounted on the concrete pole, and the exact location of the radar is shown in Figure 2.

4. RESULTS AND DISCUSSION

In this study, we used an average working day from 2019 in comparison with working days in March and April 2020, when COVID-19 pandemic and earthquake in Zagreb occurred. The day when the earthquake with the magnitude of 5.5 M_L hit Zagreb was 22nd March 2020.

The comparison was made based on the time-series plots of traffic parameters recorded on the weekly basis from the beginning of 2020 to the date of the earthquake. The traffic parameters used for the comparison are speed and volume. The mutual interactions of the parameters were observed as well as the change of the parameters in 15-min intervals during the day.

Figure 3 shows the time-mean speed data collected from January to April 2020 aggregated on a weekly basis. The speed profiles that show the speed data after the 16th of March show a speed that is close to the speed limit of 50 km/h, and there are no signs of recurrent morning and afternoon

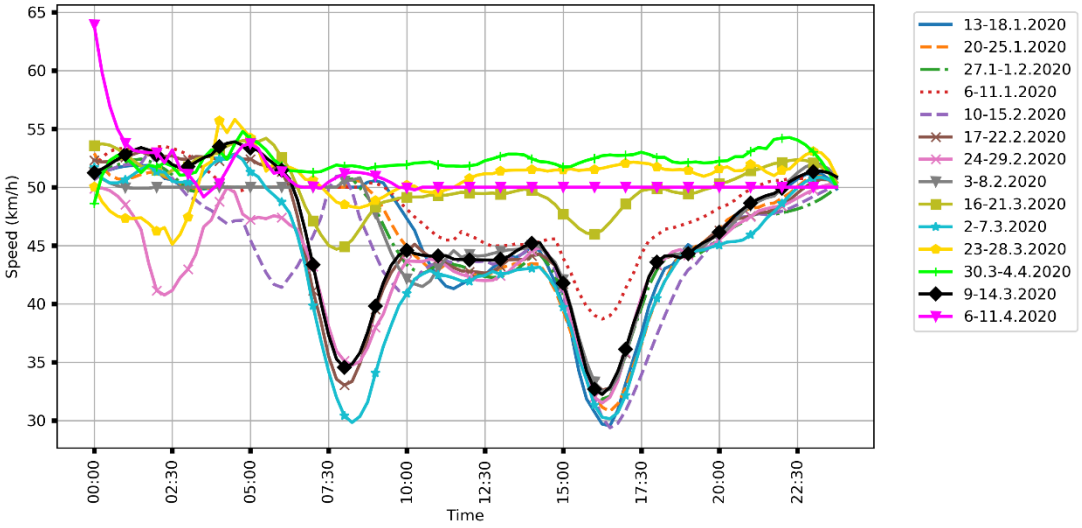


Figure 3 – The speed profiles aggregated on the 15-min intervals using data measured by radar sensor during the 2020 collected on the weekly basis

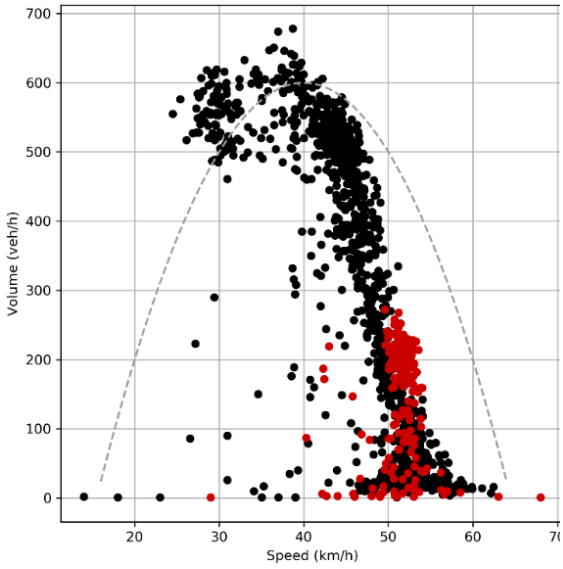
congestions in the rush hours that are usually beginning at 7:00 AM and 3:00 PM. These lines show weeks when the earthquake in Zagreb and COVID-19 government measures for restricted movement

have coincided. As expected, a substantial increase in speed can be noticed due to the smaller number of vehicles on the roads.

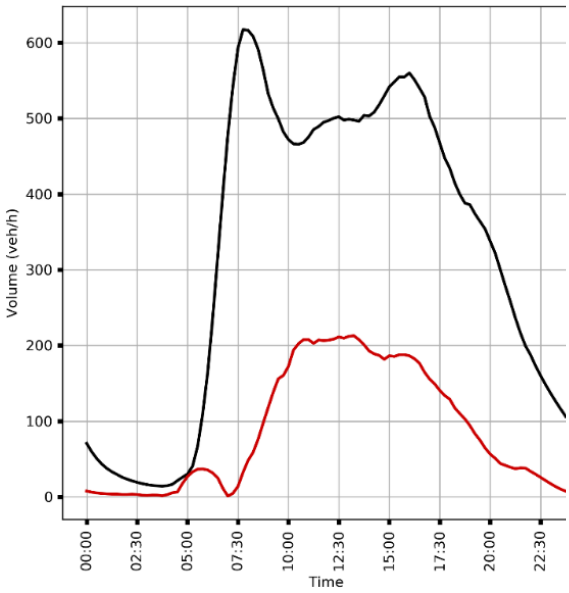
Figure 4 a) shows a comparison of speeds and volumes of an average working day in 2019 labeled with black dots and the week when an earthquake occurred labeled with red dots. Each point on the scatter plot shows the value of speed on the *x*-axis with corresponding volume on the *y*-axis within 15-minute intervals. The speed values recorded during the disasters indicate a significant shift towards the higher average speeds compared to the average working day in 2019, with very few points having low speed values. This observation can be explained by fewer vehicles on the road due to the mentioned restrictions, which allowed the drivers to achieve the speed that is near the speed limit.

Figure 4 b) the red line shows the traffic volume in the week when the earthquake and COVID-19 government restrictions coincided. It can be noticed that the overall traffic volume is reduced by one third due to the COVID-19 pandemic and the earthquake compared to the normal conditions during an average working day in 2019 showed with a black line. Also, there is no recurrent congestion common for morning and afternoon peak hours, which is, in normal conditions, accompanied by the increase in the traffic flow.

The next phenomenon occurred on the day of the earthquake 22nd March 2020 Sunday at 6:24 AM. Figure 5 shows that there was a much larger volume of vehicles at the time of the earthquake (red line) than the day before (black line). We attribute this to the psychological effect caused by the earthquake. In the time near the earthquake, citizens choose to drive around in the vehicles rather than stay in or around their buildings. That effect lasted a few hours until the fear of the second strike of the earthquake ended [18].



a) Relations of the volume and speed for the average working day in 2019 (black) and the week with COVID-19 restrictions (red)



b) Traffic volume profiles for an average working day in 2019 (black) and the week with COVID-19 restrictions (red)

Figure 4 – Traffic parameters comparation

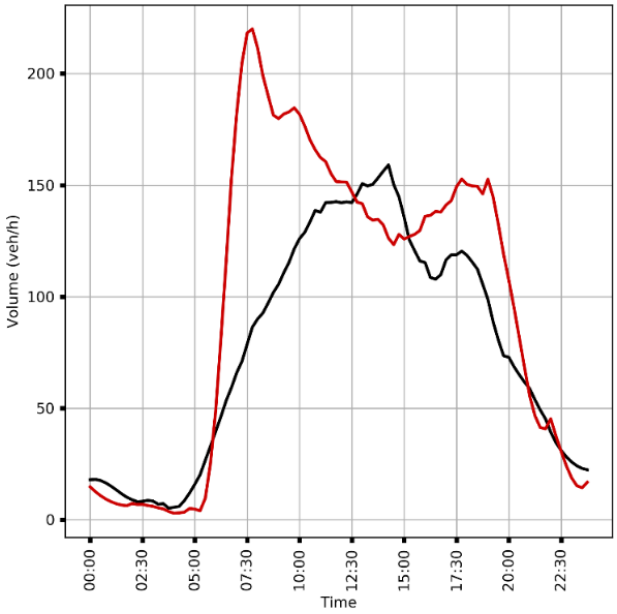


Figure 5 – Comparison of the traffic volume profiles on the day of the earthquake (red) and the day before (black)

5. CONCLUSIONS

This paper presents an analysis of the traffic state parameters in a case of disaster events. For the use case, the City of Zagreb is used as a city affected by the COVID-19 and the earthquake simultaneously. The data in the form of the traffic parameters were collected on the weekly basis in 2020 and compared to the average working day from 2019. Before the usage, data was preprocessed by applying seasonal filtering, data aggregation, anomaly removal, and smoothing. Worldwide, the COVID-19 pandemic brought great economic losses. In addition, an earthquake occurred in Zagreb and brought consequences for city traffic flow. This research shows that in such a situation, a longer period is required to stabilize traffic in a city and return it to normal traffic flow. This paper shows that only one radar detector can be a valuable source of the information because it can provide useful insights into extraordinary situations like earthquakes and COVID-19 pandemic, emphasizing the importance of real-time traffic data collection for implementation in an intelligent transport system.

This research showed some notable traffic mobility patterns during the natural disasters. One of the important patterns related to the psychological effects of the disasters is captured during the time after the earthquake. The traffic volume was unexpectedly increased due to the fear of staying in the old buildings in the city center. This information and captured pattern could be useful for the large amount of the interdisciplinary studies like influence of the psychological effects on the mobility pattern during the crisis. This information also gives the insights for traffic managers dealing with post-disaster traffic management strategies.

Future work will include wider research area including more versatile sensors for traffic data collection. The comparison to other traffic data collection techniques is required to validate the results and conclusions given in this research. The data fusion of more than one type of data like Bluetooth and GPS data could give more actionable and useful traffic insights as different traffic patterns can be extracted.

REFERENCES

[1] Falcocchio JC, Levinson HS. Road Traffic Congestion: A Concise Guide. Switzerland: Springer, Cham; 2015.
[2] Litman TA. Congestion Costs. In: Transportation Cost and Benefit Analysis II. 2nd ed. Victoria Transport Policy Institute; 2009.
[3] Anbaroğlu B, Cheng T, Heydecker B. Non-recurrent traffic congestion detection on heterogeneous urban road networks. Transp A Transp Sci. 2015 Oct;11(9):754–71.
[4] Lin C, Yu Y, Wu D. Traffic Flow Catastrophe Border Identification for Urban High-Density Area Based on Cusp Catastrophe Theory : A Case Study under Sudden Fire Disaster. Appl Sci. 2020;10(9):1–19.
[5] Othman MH, Abdul AH. Impact of Flooding on Traffic Route Choices. EDP Sci SHS Web Conf. 2014;11(1):1–9.
[6] Shao Z, Ma Z, Liu S, Lv T. Optimization of a Traffic Control Scheme for a Post-Disaster Urban Road Network. Sustainability. 2018;10(68).
[7] Fan L, Tangqing L. Study on Optimization of Earthquake Transportation Emergency Management. Proc 7th Int Conf Innov Manag. 2010;(1):1858–63.
[8] Otsuka RP, Work DB, Song J. Estimating post-disaster traffic conditions using real-time data streams. Struct Infrastruct Eng. 2016;12(8):904–17.
[9] Pishue B. COVID-19 ' s Impact on Freight : An Analysis of Long-Haul Freight Movement During a Pandemic. INRIX Research. 2020;
[10] HCM 2010 : highway capacity manual. 5th ed. Washington, D.C.: Transportation Research Board, National Research Council; 2010.
[11] Hall FL. Two Traffic Stream Characteristics. TRB Special Report 165 - Revised Monograph on Traffic Flow Theory. 2001.
[12] May AD. Traffic flow fundamentals. Prentice Hall; 1990.
[13] Zochowska R, Grzegorz K. ITS services packages as a tool for managing traffic congestion in cities. In: Sladkowski A, Pamula W, editors. Intelligent Transportation Systems - Problems and Perspectives. 2015. p. 81–103.
[14] Carić T, Fosin J. Using Congestion Zones for Solving the Time Dependent Vehicle Routing Problem. Promet-Traffic;Transportation. 2020;32(1):25–38.
[15] Erdelić T, Vrbančić S, Rožić L. A model of speed profiles for urban road networks using G-means clustering. In: 2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics, MIPRO 2015. 2015. p. 1081–6.
[16] Savitzky A, Golay MJE. Smoothing and differentiation of data by simplified least squares procedures. Anal Chem. 1964;(36):1627–39.
[17] Huston RADAR [Internet]. [cited 2020 Apr 3]. Available from: www.houston-radar.com
[18] Earthquke track [Internet]. [cited 2020 Apr 2]. Available from: https://earthquaketrack.com/quakes/2020-03-22-05-24-03-utc-5-4-10

ALEXANDER WASIAK, Erasmus student[1]
E-mail: aa.wassiak@gmail.com
MATEVŽ OBRECHT, Ph.D.[1]
E-mail: matevz.obrecht@um.si
[1] University of Maribor, Faculty of Logistics
Mariborska cesta 7, 3000 Celje, Slovenia

ANALYSING SINGLE TRANSPORT MODES TO REDUCE FOOD MILES

ABSTRACT

As number of world's citizens is growing, more food is needed to feed them. It requires more efficient food supply chains and more food related transport services, meaning that food travels on longer distances. This as well as generally whole process of delivering, packaging and life cycle of produce can seriously impact the environment by green-house gas emissions. This manuscript focuses on food miles and other environmental impacts of food supply chain. It analyses the differences between transporting the same item with different single transport means as well as on proposing and comparing solutions for reducing food miles with different transport modes, reducing distance from production to plate and sustainable food consumption.

KEY WORDS

Food miles; supply chain management; transport modes; environmental impact

1. INTRODUCTION

As globalization and transport advances people can enjoy food from all corners of the world, from different regions, countries, which are hundreds and thousands kilometres far from each other and even from different continents. For example, in Poland oranges, bananas or watermelons are not planted but people can enjoy them throughout the year.

However, thinking about how many miles the food item had travelled before it has reached our plate and how it has affected the environment as well as how many litres of petrol has been burnt and consequently emissions emitted in air and how much energy has been used to the whole process is becoming more and more relevant from economic, environmental and customer's perspective. Even though not many people are aware of the term "food miles".

First time, the concept of "food miles" was showed in the mid- 1990s, as SAFE Alliance (now known as Sustain) has published ground-breaking article about environmental, social and economic problems caused by globalization of food supply systems. This holistic idea has been superseded by focusing on affects on environment made by transporting food on long distances. The simplified massage is that today food transport is unnecessary and excessive and further means worse and nearer means better [1]. One of definition of food miles is" Food miles are used to calculate how much greenhouse gas emissions are generated during transit. This process accounts for the distance all the way from production to consumption. The idea is that the more we consume foods with high "food miles" the more we contribute to global warming˘[2]. Generally, food miles is a distance that food travel from place of origin to the plates and connects environmental impacts with travelled distance.

As far as food miles are concerned, they have big influence and a lot of consequences not only on environment but also on people's life. First of all transporting food on long distances has a big impact on environment as green-house gasses (GHG) are emitted to the atmosphere while fuel is burnt. Amount of released GHG depends on mean of transport, which was used to transport a load as well as of technologies and distance.

The greatest emission of carbon are consequence of flight transport which is environmentally least appropriate transport mode [3] but is also the fastest one. It emits almost one hundred times more GHG emissions per kilometre than maritime transport. Therefore the need to distinguish between different modes of transport is highlighted. The hierarchy of emission intensity runs from sea, to rail, to road to air- with the last being by far the most greenhouses gas intensive mode of transport [3]. It means that if we eat an apple that grew and has been shipped from Argentina, its GHG are relatively small. On the other hand, if we eat a banana that has grown and has been shipped by airplane from Brazil then GHG are much higher but this does not necessary mean that transporting food by flight transport is the worst possibility. Wilson writes that if we consider life cycle perspective, even when food has been flown in, it can sometimes still be less carbon intensive than things grown locally. This is because the carbon intensity of production in Africa or south America for example may be many fold lower than the one in Europe. This consequently mean that it offsets the emissions from the food miles [4]. The food miles are therefore not only the distance travelled but also the whole food supply chain - process of planting, growing, preparing, packaging, transporting, generally on whole life cycle of the product.

Weber and Matthews analysis about food emissions breakdown found that in the US food emissions 83% of them are a result of food production, 5% of wholesaling and retailing food, and 11% from transporting it [3]. It clearly shows, that final delivery (e.g. transport to the retailer from the producer) is actually just a small part of the whole food related GHG emissions. When people think about food miles most of them see just food transport but transport is actually in average only 11% of all GHG emissions of the whole process.

Secondly more food miles means more trucks on the roads, what may cause increasing of congestion in cities and on highways, slower traffic, land use for roads, noise pollution, stress etc. There are also organizations, which make very broad researches about food and the most sustainable way to not only transport it but to comprehensively study every stage of food item life. One of the tools that enable comprehensive environmental assessment is also Life Cycle Assessment (LCA). LCA is a tool for that considers environmental impacts of raw materials, production, distribution, use and end-of-life phase and can be calculated per unit of different food items [4, 5]. LCA focuses not only on GHG or climate change but can (depending on the chosen methodology) assess up to 15 different impact categories (e.g. fossil fuel use, mineral use, radiation, water pollution, VOC, nitrification, eutrophication, etc.) therefore it must be mentioned that food miles are a valuable insight into environmental impacts of food supply chain but not as comprehensive as LCA.

In Garnett's report (2003) it is shown that food transport in UK is approximately 3.5% of total UK's GHG emission. Report also noted that there is strong correlation between shorter distance and lower emissions. However, there were many exceptions resulted from differences in the efficiency of production systems and in the mean of transport used and logistics as well. There was suggestion that the elements of a lower carbon food system are following such as; to use seasonal and indigenous fresh produce grown during its natural growing season that is also well adapted to the local environment (meaning that it will be less transport intensive and produce fewer overall GHG emissions than non- indigenous foods or those imported out of season). Another proposal is efficient manufacturing; minimal use of temperature- controlled storage; local clustering; minimizing journey distance; logistical efficiency (e.g. the fuel efficiency, carbon neutral fuels and transportation technologies, efficient supply chain management and operations etc.). In addition loads should be consolidated and vehicles as full as possible while they are in use [1] meaning also when they are returning to the production site.

Even though this paper is focused mainly on transport mode related emissions, it has to be noticed that focus on food miles can distract us from the real issue in the food processing industry. Important thing is how much meat and diary products we consume in our daily diet, not where animals are reared up [6]. Livestock production is very emission, energy and water intensive, wherever it is cultivated and

accounts for app. 18% of global GHG. For comparison all the world's cars, trains, planes and boats accounted for a combined 13% of global GHG emissions" [7].

2. METHODS

In this case study a practical example of one item transported by different means of transport is analysed and carbon footprint that it left behind itself is examined.

The items, which will be transported are oranges. They will be transported from Spain to Poland. Oranges are not planted in Poland. Mostly they are imported from Spain.

The distance between Spain (Madrid) and Poland (Warsaw) is 1423 miles (2289km). It means that oranges, which are transported from Madrid to Warsaw have to travel 1423 miles before they reach Poland. Distance from Warsaw to markets is not included in this so it would be more than 1423 miles before oranges would reach Polish plates. Emissions were calculated based on open access web based carbon and carbon dioxide emission calculator (Food Miles Calculator [8]). Results were cross compares and examined for single transport modes. Further researches are carried out for multimodal transport modes as well and the results will be presented separately.

In the last part proposals made on synthesis of findings from literature review and our own calculations were made to identify ways of how to decrease environmental impact of food.

3. CASE STUDY: THE SAME ITEM, DIFFERENT TRANSPORT MODE

As it was mentioned, food transport leaves behind itself carbon footprint. It is not always the same amount since a lot depends on transport modality, what was used to transport it and distance, that it had to travel. As we can see on Figure 1 (carbon footprint during oranges transportation) and on Figure 2 (CO_2 emission in kg during oranges transport) transporting oranges from Spain to Poland has an impact on environment. Everything depends on what was used to transport it. It could be air transport, road or railway.

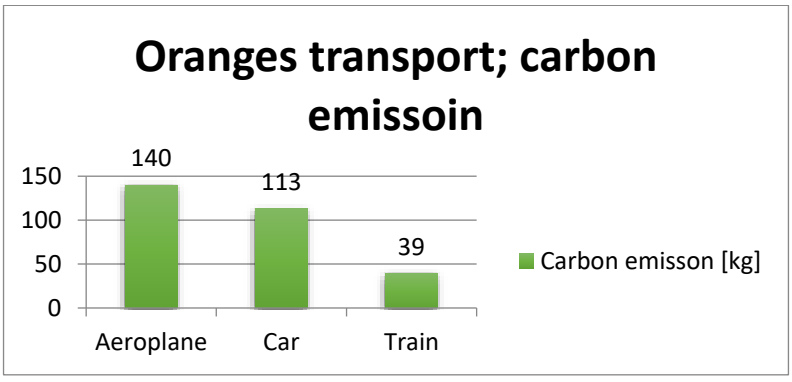


Figure 1 – Carbon footprint during oranges transporting – different transport modes
Calculation is based on data from [8].

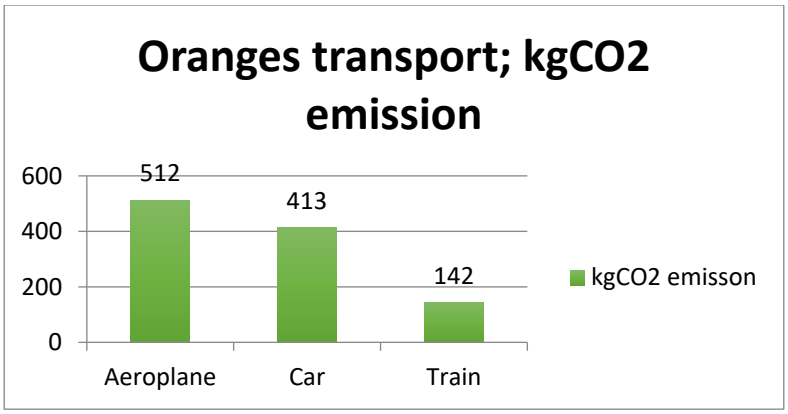


Figure 2 – CO2 emission (in kg) during oranges transport – different transport modes
Calculation is based on data from [8].

The most carbon intensive mean of transport is again proved to be the airplane. During oranges transportation from Madrid to Warsaw airplane would emit approximately 140 kg of carbon (512 kg CO2). The same load can be transported by train but then carbon emission would be over 3,5 times lower than by airplane. Comparing 39 kg of carbon emitted by train and 140kg of carbon emitted by airplane, we can see a huge difference in a different modality.

The charts clearly show, that the most unsustainable mean of transport is airplane that is responsible for the biggest amount of carbon and CO_2 (kg) related emissions. Transporting oranges from Spain to Poland can be also made by lorries but the best and the most sustainable solution is transporting them by railways, because maybe it is not the fastest way but it creates the least pollutions.

4. OUTLOOK AND POTENTIAL SOLLUTIONS

4.1 Promoting Local Food and Self-Sufficiency Along with Sustainable Consumption

Local food is for example in UK food, which was produced within 30 miles from place where final consumer lives [9]. Buying local food for sure is the best solution to limit food miles. But the question is where can we find local food? Of course Poland can not produce oranges itself since climate is not appropriate for that. However consumers can be informed and educated about environmental impacts of imported food and seasonal local food to reduce the consumption of imported food items as well as out of season fruits, vegetables etc. Can we actually say that air transportation is responsible for the biggest carbon emissions or is the responsibility on unsustainable consumers that demand imported, out of season products available at any time of the year in every corner of the world? The biggest challenge of food miles is without doubt educating people about environmental burden of some popular food items and transform food consumption, not just transportation, to become more sustainable.

Local food we can find on local markets, where farmers bring their food and gladly explain how they grow up their products. By buying locally grown food chances of being fresh and richer with minerals and vitamins increase. Simultaneously you also support local farmers. Local markets take place mainly in the morning hours. One of advantages of buying a local food is emerging lifestyle – healthy living also means that a lot of people go there on bicycle or on foot. By doing this GHG emissions can be additionally limited. You can also buy only what is available therefore you can avoid over-consumption.

Another way to find food, which was produced in sustainable way is growing seasonal food by ourselves. When we plant tomatoes or carrots in our own garden we exactly know every step of growing it up. By doing this we decrease food miles because we are at least partially self-sufficient and

do not have to go to a store every time we need one food item. In addition we also know the origin of food that we eat. When people buy food in supermarkets, very often they do not pay attention where the food which they buy comes from.

However, there are more and more people, who want to know the origin of the food. That is why they buy products directly from farmers and that is why local food production is being promoted again. It is very beneficial for both sides, farmers and consumers. For consumers, because they can observe in what condition are kept products, which they buy. For farmers, because they do not have to worry about distribution and can sell their produce directly to the end-user without someone else taking the sales margin [9].

By buying locally in general we save energy, water and decrease air pollution, which would be used to produce and transport food by conventional way. We can limit food miles by buying locally.

4.2 Comparison of Identified Measures for Reducing Food's Environmental Impact

As we can see in the Table 1 each proposal identified in the literature review has both advantages and disadvantages.

Table 1 – Advantages and disadvantages of improvements proposals

	ADVANTAGES	**DISADVANTAGES**
ENVIRONMENTALLY FRIENDLIER TRANSPORT MODE	-less environmental impact -new business opportunities -increased railway efficiency -avoid polluting air transport	-investment in cleaner technologies and infrastructure -change of habits and decreased availability of exotic food items
VERTICAL FARMS	-takes not much space -distance between farms and consumers is not long -safe from weather conditions	-expensive buildings -plots in cities are expensive -a lot of energy is needed
GROWING OWN FOOD / LOCAL FOOD SUPPLY	-known origin -local development -availability just-in-time -can be treated as exercises -limiting food miles	-requires time -necessity of buying equipment -water bill rise -space needed
SOCIETY EDUCATION	-building consumer's consciousness -building consciousness in young people -people are more sociable thanks to meetings with activists -impact on will to reduce food miles	-more advertisements on TV -more advertisements on streets -more leaflets (cut off trees)
MINIMISING MEAT CONSUMPTION	-saving money -healthier lifestyle -saving animals life -limit amount of GHG emitted in the air -less cattle rearing -decrease land use	-hard to change eating habits -hard decision about changing lifestyle (becoming vegetarian or vegan)

In our opinion multiple choices should be implemented to secure safe and reliable food supply and minimizing environmental impact simultaneously. It is very possible that vertical farms are farms of the future but at the moment, they are still to expensive. Growing own food is very profitable and a lot of people could do it. The only obstacle in most cases is time. The solution is better time management and better day planning. We have witnessed much higher interest for food self-sufficiency and heathier diets it times of lock-down in many countries around the globe since families hade more time and measures human health related preventive measures gained priority.

Society education is also very important. It is easy to say that special transport mode is guilty for the most of environmental burden, but final consumer is the one that triggers also transportation related emissions since transport only follow the demand. The earlier youth is educated about food impact on environment, the better. It is not only about education in a school but also a matter of a life-long learning. If sustainable consumption becomes a habit it will be handed over to our children.

Sustainable production and consumption is becoming increasingly important part of the EU green recovery. Companies, which will handle advertisements and campaigns should pay attention to efficient marketing of higher value added products in smaller quantities. As far as less meat consumption is considered it has a lot of advantages and the only obstacle is personal decision about changing eating habits and lifestyle due to social perception, EU tradition and lack of knowledge. It has a lot of advantages and the most important is limiting the biggest source of GHG emissions in the food supply.

5. CONSLUSION

To sum up, food miles is nowadays a big issue as globalization and transport are in advance and everyone wants every product available at any time of the year. People want to eat exotic food, which is not planted in their country. Food has to be transported over long distances and this creates a lot of air pollution and leaves behind a big carbon footprint.

Fortunately, more and more people pay attention what they eat and they try to limit food miles for example by buying fruits and vegetables on local markets or directly from farmers, by limiting consumption of e.g. water intensive food items like avocado, by limiting controversial items like palm oil etc. By doing this, they support not only environment but also local community. There are also people, who try to become partially food self sufficient.

There are numerous tools to calculate simplified food miles for free. Some organizations use tools like food miles calculators to limit their GHG emissions. They care about every stage of food life cycle and try to improve their work to make it more sustainable. They do not do it just for themselves but also for our planet. Knowledge about food miles and sustainability of food production, transport and consumption is not sufficient and should be better researched and promoted to become more popular among general and not just environmentally aware final consumers.

REFERENCES

[1] Garnett, T. The food miles debate: is shorter better? In: Mckinnon A, Browne M, Whiteing A and Piecyk M (Eds). Green Logistics. Kogan Page. 2014.
[2] Gray, G. The cost of food miles. Get your local food online. Available from: http://www.sustainablebusinesstoolkit.com/food-miles/ [06.05.2020]
[3] Wilson, L. The tricky truth about food miles. Available from: http://shrinkthatfootprint.com/food-miles [6.05.2020]. 2013.
[4] Nielsen PH and Fredriksen RH. LCA Food Database. Available from: http://www.lcafood.dk/ [10.05.2016].
[5] Poritosh R, Nei D, Orikasa T, Xu Q, Okadome H, Nakamura N, Shiina T. A review of life cycle assessment (LCA) on some food products. Journal of Food Engineering. 90(1). 1-10. 2009.
[6] Food and Agriculture Organisation (FAO). 2006. Livestock's Long Shadow, Food and Agriculture Organization, Rome
[7] Bell D. The Methane Makers. Available from: http://news.bbc.co.uk/2/hi/uk_news/magazine/8329612.stm [12.05.2020]. 2009.
[8] FoodMiles. 2020. Food Miles Calculator. available from: http://www.foodmiles.com/results.cfm [15.05.2020]
[9] Huma, M. Balanced food. Available from: http://www.ekonsument.pl/a142_zywnosc_zrownowazona.html [16.05.2020]. 2018.

VICTOR B. WILDHABER, M.A. HSG[1]
Corresponding author e-mail: victor.wildhaber@unisg.ch
[1] Institute of Supply Chain Management at the University of St.Gallen
Dufourstreet 40a, 9008 St.Gallen, Switzerland

TOWARDS A CONCEPTUAL FRAMEWORK FOR LOADSPACE SHIPMENT SHARING

ABSTRACT

The road freight transport is one of the principal generators of traffic jam costs in German-speaking countries. In these markets the road freight transport on the one hand is under high competition pressure and, at the other hand has a high rate of empty capacities. The focus needs to switch from limited efficiency potentials (mainly utilization-based) of a single fleet operator to higher efficiency potentials within the community of fleet operators. The road freight transport market, however, lacks possibilities to foster the utilization of trucks. Sharing economy concepts and their applications yet only can be found in related areas (e.g. car-sharing). Inspired by the ability and readiness of the general cargo cooperation to share shipments within the cooperation as well as already applied sharing economy concepts in related fields (e.g. car-sharing) the concept of loadspace shipment sharing builds its basis. The concept focusses on the sharing of loadspaces and shipments within a community of fleet operators. A design science research approach is applied to include theory- as well as practice-based information. A short literature review is performed, and empirical data gathered through semi-structured interviews. The paper provides a conceptual framework considering the prototype of the concept as well as insights into the concept elements, their functionalities and key tasks.

KEY WORDS

road freight transport; groupage transport; general cargo cooperation; fleet operator community; sharing economy; loadspace shipment sharing

1. INTRODUCTION

The road freight transportation is one of the principal generators of traffic jam costs in German-speaking countries (compare 1). Although fleet operators are increasingly using technologies such as transport management systems, telematics and consignment tracking to increase utilization, the fleet utilization is not optimal (2). According to the BFS (3) trucks are often empty (21%) or not fully loaded (55%). In addition, the road freight transport in German-speaking countries is under high margin pressure (due to competitive pressure) (4) on the one hand and has empty capacities (5) on the other.

The road freight transportation market in the German-speaking market consists of small, medium and large fleet operators (revenue margin of 0-3% with an average of 1.67% between 2000 and 2006) (6). Whereas large fleet operators have their own efficiency fostering logistics networks (able to optimize utilization of their fleet over several regional logistics sites) (7), small and medium-sized fleet operators (operate regionally, thus have no potential to foster their utilization) have to secure their existence through participation in a general cargo cooperation (established on markets for several decades) (8). Since medium-sized fleet operators do not have the potential to foster their utilization by themselves but within the general cargo cooperation, this research addresses medium-sized fleet operators and cargo cooperations.

A general cargo cooperation is offering its services to a larger area through connecting regional fleet operators (each offering an exclusive logistics service to its area) (8). The system partners are cooperating in order sharing through handing the shipments over to another system partner for the

main run / onward carriage and thereby levelling the general cargo cooperation network reaching a higher utilization in its main runs (9). The author hints, that the general cargo cooperation is already sharing orders (shipments), but not yet loadspaces.

While the efficiency potentials have become more and more marginal within a single fleet operator, the focus on the community becomes more important (10). The market for road freight transportation lacks possibilities to foster utilization through sharing approaches that would lower costs and enable fleet operators to achieve higher margins. The sharing economy-application can be found in various areas such as car- and warehouse-sharing (11, 12). Since the sharing economy offers various advantages such as fostering utilization of idle capacities or the reduction of the ecological footprint, these should be levered.

This research sheds light on the concept of loadspace shipment sharing that is defined as a concept through that shipment surpluses and unused loadspaces can be matched / shared with other fleet operators within a community for a fee via a digital platform (ICT platform for exchanging information on loadspaces / shipments and planning data, evaluating the information, providing transparency and matching services) (derived from 13, 14). The fleet operator community is to be understood as a closed circle of contractually bound fleet operators. The business model of loadspace shipment sharing distinguishes itself from current business models to foster capacity utilization.

The concept of loadspace shipment sharing has to be delaminated from utilization-fostering concepts such as route-optimization (fleet transparency through telematics) tools, freight exchanges and freight mediation. Freight exchanges (e.g. Timocom) are open platforms to exchange shipments among fleet operators (15, 16). Freight mediators represent open platforms that mediate shipments directly from the shipper to fleet operators. Whereas Uber Freight offers full truck load- and less than truck load-shipments to single truckers that reflects a derivate of the Uber taxi-concept (17), Pickwings spontaneously offers shipper-acquired groupage-shipments via its advanced platform (providing shipment data e.g. track & trace and controlling financials) (18) at a compensation less than production cost to fleet operators. The digital forwarding company (e.g. Instafreight) deals with the organization of transports and has no fleet to be optimized regarding its utilization (19).

This research focusses on loadspace shipment sharing in fleet operator communities shipping less than truck load and groupage with the following innovations considering the above-mentioned existing utilization-fostering options. The loadspace shipment sharing is expanding transparency over the boarders of a single fleet operator to the fleet operator community. Additionally, loadspace shipment sharing enables the exchange of shipments and loadspace in the fleet operator community during the planning process (e.g. dispatching). Through the combination of transparency and exchange of shipments and loadspace, the fleet operator community strengthens its efficiency by running trucks at higher utilization levels through network effects. Both innovations have yet not been achieved as described above.

Since community activities enable to level more efficiency potential (primarily utilization) than single fleet operators themselves, the creation of transparency in the cross-company perspective particularly on loadspace availability / shipment surpluses is required (20). As a result of loadspace shipment sharing fewer vehicle kilometers are driven for the same amount of shipments and thus fewer trucks are required. According to Mr. Einstein a reduction of 10-15% can be expected (21). These advantages foster the revenue margin by expected 0.5% or more (21). Besides the single fleet operator, the fleet operator community also benefits through achieving a higher transparency over the shipments and loadspaces (e.g. planning / forecasting).

This research seeks a conceptual framework for loadspace shipment sharing in fleet operator communities that later can be used as a foundation for further research on the concept of loadspace shipment sharing such as the elaboration of concept elements and implementation into practice.

Combining the sharing of shipments and loadspaces is expected to lead to a higher utilization and thus efficiency of the fleet operator community. Implementing the combination of sharing shipments

and loadspaces requires changes to the common business model of the general cargo cooperation (i.e. business model innovation) that among others considers the coordination of loadspace shipment sharing, governance and adjusted digital platform.

2. SHORT LITERATURE REVIEW

This chapter performs a short literature review to gain important first insights and a primary set of concept elements.

A quick key word search[1] in relevant data bases[2] resulting in 12 search results (duplicates excluded) shows how little literature is available in this field. This is why an explorative literature review is performed covering loadspace shipment sharing and similar, transferable approaches through searching relevant research streams: operations and information technology management.

Therefore, known data bases like Thomson's WEB OF SCIENCE, Ebsco's EBSCOHOST, Elsevier's SCOPUS and Microsoft's ACADEMIC were searched systematically. Key words such as "logistic* AND horizontal cooperation", "logistic* AND sharing", "road freight AND policies", "road freight AND utilization" and "logistic* AND digital platform" were applied to find full text contributions in English and German. The exemplary key words reflect the fields covered within the above-mentioned research streams. To foster relevance for this paper, the author especially selected contributions that focus on road freight transport (or logistics) and sharing.

The **horizontal logistics cooperation** is defined as "an active cooperation between two or more firms that operate on the same level of the supply chain and perform a comparable logistics function on the landside" (22). Whereas participating fleet operators are contractually bonded within a horizontal logistic cooperation, new entering fleet operators need to undergo an audit (23, 24).

Since orders are shared in the horizontal logistics cooperation, a high utilization rate of the logistics resources is achieved on the main runs. The achieved gains on the main runs need to be properly contributed to the participating fleet operators. According to Cruijssen et al. (25) this is achieved through a fair contribution management. To sustainably achieve the perceived cost reduction, the fleet operators need to work according to principles and rules. Incentives are applied to keep the fleet operators aligned.

Since the concept of the horizontal logistic cooperation and loadspace shipment sharing have congruencies in sharing and the organizational platform, the following requirements are derived:

- Community entry through an audit and bonding through contractual agreement
- Principles and incentives exist to keep the fleet operators aligned to the organization / concept
- Rules to keep the fleet operators aligned to the organizations mechanisms / processes and leadership skills / conflict management to balance the fleet operators practicing the rules
- Processes such as placement and allocation of the shipments and their coordination
- Gains shall be contributed fairly to participating fleet operators according to their performance

Horizontal logistics cooperation's coordinate logistics service creation and in parts also logistics resources. Their sharing attribute missed out almost completely, why these are discussed next.

Sharing practices in logistics refers to the shared coordination of resources and activities in logistics. The new phenomenon of the sharing economy has potential to foster utilization. Immobile (e.g. warehouses) and mobile resources (e.g. containers or trucks).

[1] "loadspace sharing", "truck sharing", "shipment sharing", "consignment sharing", "order sharing", each combined with "logistics" in titles and abstracts

[2] Ebscohost, JSTOR, Scopus, Web of Science and WISO

Warehouse sharing is already rolled out and applied in practice. An example is log-hub (11), which is applying a digital platform to coordinate the sharing of available warehouse spaces of warehouse owners with further logistics service providers. When it comes to the sharing of mobile resources such as containers the logistics resource sharing in a community remains conceptual. This probably is related to the degree of difficulty in realizing the logistics resource sharing concept, that is significantly higher than sharing immobile logistics resources (26).

Standing, Standing & Biermann (27) express, that digital platforms are required to enable logistics resource sharing. Such a concept require trust, also because fleet operators in case of loadspace shipment sharing share sensitive information and thus need to assure and protect the intended use of data (28, 29, 30). Among others the trust determinants are commitment, joint principles / purpose and incentives for alignment (29).

Since the concept of the sharing practices in logistics and loadspace shipment sharing have high congruencies, the following requirements are derived:

- Basic information sharing is required to set up a sharing / cooperation concept
- Principles and incentives to keep the fleet operators aligned to the sharing concept
- Trust is required as sensitive data is shared

Sharing practices intersect with utilization-fostering technologies that are discussed next.

Utilization-fostering technologies in logistics refers to the optimization of the planning and execution process of logistics (especially utilization through shipment-consolidation). Whereas optimization techniques address the planning process, optimization tools address the execution.

Optimization tools such as transport management systems with integrated route optimization again enhance utilization and reduce fleet kilometers. Besides that, costs due to late deliveries can be minimized and a higher service level achieved when complying to the shippers' time windows. (31, 32)

Since optimization tools focus on the execution process, they optimize real-time problems and thus require real-time data transparency. In road freight transport trucks transmit telematics data such as localization, driving and rest times. This data is brought to the transport management system through interfaces and applied to improve the execution process enriching the rather static, planning-oriented transport management systems making them dynamic decision support systems.

Since utilization-fostering technologies and the concept of loadspace shipment sharing have congruencies in the need for technology-supported methods, the following requirements are derived:

- Transparency over the loadspaces is required to dispatch the shipments
- Interfaces therefore are required to gather and display data from the fleet (loadspaces)

Utilization-fostering technologies create value (utilization) when loadpsaces and shipments are shared throughout the community. Therefore, digital platforms are necessary and discussed next.

Digital platforms in logistics refers to processing, offering and displaying of previously gathered data as value-added services. Optimization platforms offer e.g. network-optimization services, matching platforms bring together the markets supply and demand.

To be able to offer matching services, supply and demand information has to be digitally available. This means not only digital shipment data has to be available but also telematics data of the fleet operators (represent loadspaces). This refers to transparency of supply and demand. Achieving transparency further means interfaces between the participating stakeholders are required (33). These are e.g. the shippers' information technology, the fleet operators' transport management system and trucks as well as the digital platform.

Since digital platforms in road freight transport and the concept of loadspace shipment sharing have congruencies in the digital platform itself, the following requirements are derived:

- Transparency is required (to match supply and demand)
- Matching services bring together the markets' supply and demand via digital platforms
- Interfaces therefore are required to gather, process and display data

To close this short literature review, the literature streams-derived requirements are collected providing preliminary concept elements of the loadspace shipment sharing concept in Table 1.

Table 1 – Preliminary concept elements of loadspace shipment sharing

Preliminary concept elements	Theoretical requirements towards the concept elements
Mechanisms / coordination	• Processes such as placement and allocation of the shipments • Coordination of the shipments among the fleet operators
Information sharing / transparency	• Basic information sharing is required to set up the loadspace shipment sharing • Transparency is required (to match supply and demand)
Contribution management	• Gains are contributed fairly to participating fleet operators according to their performance
Incentives	• Principles and incentives to keep the fleet operators aligned to organization / concept • Trust is required as sensitive data is shared
Legal framework	• Community entry through an audit and bonding through contractual agreement • Rules to keep the fleet operators aligned to the organizations mechanisms / processes
Relationship management	• Leadership skills and conflict management
Interfaces	• Interfaces are required to gather and display data from the fleet / shipments • Interfaces are required to gather, process and display data
Transparency services	• Transparency over the fleet (in the sense of loadspaces) is required to dispatch the shipments throughout the fleet operator community
Matching services	• Matching services bring together the markets' supply and demand via digital platforms

Source: own illustration based on sources in this chapter

Based on this short literature review, the research gap regarding the conceptional framework of the loadspace shipment sharing is specified and aggregated into research questions next.

3. RESEARCH GAP AND RESEARCH QUESTIONS

As the short literature review (compare chapter 2) demonstrates, there is only little literature on loadspace shipment sharing available. Whereas there is some literature on order sharing, loadspace sharing barely provides literature. However, literature is available on general cargo cooperation but not regarding fleet operator communities. Hence, this research gathers primary information via research streams relevant to loadspace shipment sharing.

To build a conceptual foundation of loadspace shipment sharing, this paper focusses on building a conceptual framework for loadspace shipment sharing through identifying its functionalities and selecting relevant concept elements. The research questions are the following:

- *How does the loadspace shipment sharing work in fleet operator communities?*
- *What are the loadspace shipment sharings' concept elements and encompassing key tasks?*

Given these research questions a suitable methodology is chosen and explained next.

4. METHODOLOGY

Since this is one of the first research papers in the field of loadspace shipment sharing, it sheds light on yet existing literature relevant to the research. To conduct this research, the paper uses an abductive logic applying an explorative and qualitative approach. Therefore, a combined design science research- and design thinking-approach including both, empirical-to-conceptual and conceptual-to-empirical cycles are applied. Through a short literature review (chapter 2) a primary set

of concept elements is achieved. Semi-structured interviews are performed to gather data from practice. Next, the paper provides insights into the applied methods design science research, embedded design thinking and how the data from the semi-structured interviews is aggregated.

The problem identification as well as objective definition of the design science research can be found done in the chapter (1) introduction. According to Pfeffers et al. (34) these two steps as well as the three consecutive ones are part of the design science research-methodology. Third, the artefact is being developed in form of the conceptual framework for loadspace shipment sharing covering the prototype and concept elements. The concept elements are primarily set up in the short literature review (chapter 2). The prototype is developed chapter (5) cooperation prototyping for loadspace shipment sharing. Fourth, the artefact is applied in a suitable context (fleet operator communities) where it helps to solve a specific problem (increasing truck utilization) (chapter 5, 6 and 7). Fifth, the artefact ulitmately is reviewed / revised through practitioners with disciplinary knowledge applying a design thinking approach and semi-structured interviews (chapter 6 and 7). Design changes are made consecutively. The design thinking approach according to the Design School of Stanford (35) is chosen and considers the steps emphasizing, defining, ideating, prototyping and testing.

The empirical data is gathered through semi-structured interviews. Therefore, we first identify and select appropriate units: six interviews with senior management personnel of three different stakeholder groups of the loadspace shipment sharing concept (general cargo cooperation-coordinators, -dependent and -independent fleet operators) in the German-speaking area. Second, an interview guideline is crafted according to Adams (36) and considers definitions, the prototype / primary concept elements and an outlook to conduct the semi-structured, open-ended interviews. The transcripts, however, were checked and released by the interviewees. Third, a qualitative content analysis is performed according to Mayring's (37) approach considering the steps structuration dimensions, determination, formulation, material throughput, revising, recording of results, interpretation and derivation. The discussion of the prototype (chapter 5) and concept elements (chapter 6) are accompanied by a parallelly conducted literature research.

The following chapter (5) gives insight into the prototype of loadspace shipment sharing.

5. COOPERATION PROTOTYPING FOR LOADSPACE SHIPMENT SHARING

This chapter gives insight into how the concept loadspace shipment sharing works, what actors participate and what the restrictions are.

5.1 Actors and Cooperation

The actors in the loadspace shipment sharing are the general cargo cooperation, its dependent as well as independent fleet operators. Considering the cooperation within the general cargo cooperation (22, 38) and surpluses of loadspace / shipment within the fleet operator community three major cooperation types are discussed with the support of empirical data. First, the case of nearby service regions (intermediate relevance: interviewees) where logistic service providers optimize their tours through sharing loadspaces and shipments in bordering areas. Second, the case of general cargo cooperation- and branch-transports (relevant: interviewees) where the general cargo cooperation and dependent logistic service providers internally share shipment / loadspace surpluses, also of branch-transports (independent of general cargo cooperation-transports) instead of selling the surpluses (e.g. via a freight exchange). This cooperation type shows the highest relevance out of the three types. Third, the case of general cargo cooperation and independent logistic service providers (relevant: interviewees) where the general cargo cooperation and independent logistic service providers could improve their tours and utilization.

The optimization of tours in nearby service regions is already practiced selectively in Switzerland and joint main runs are as well practiced achieving a higher utilization rate (39, 40). Due to the

importance of the customer relationship for the logistic service provider and the high competition pressure (especially in Germany), the collection will not be in focus to apply the concept, but the distribution, if the trust between the logistic service providers is high (40).

5.2 Restrictions

Since the concept of loadspace shipment sharing is not free of restrictions, the paper highlights the most important restrictions that limit the previously presented cooperation types.

First, the basic conditions have to be checked, that have to be given that a loadspace shipment sharing can be realized. Empirically supported, the basic conditions consist of: spacial distance, suitable relation, timely proximity, shipment size / type (39, 40, 41, 42, 43, 44). The interviewees see the suitable relation and the shipment size / type as the higher restriction than the special distance and timely proximity, which both are flexible. However, it has to be remarked, that shippers have high and even increasing expectations to the timeliness of pick-ups and drop-offs (36). Second, there are empirically supported additional restrictions that have to be met, when sharing loadspaces and shipments: (un)loading restrictions and driving / rest times. According to the interviewees, the (un)loading restrictions have a higher impact than the driving and rest times.

5.3 Continuum Towards Added Value

Through the interviews (39, 40, 41, 42, 43, 44) the paper is able to identify the following dimensions that add up to the value of loadspace shipment sharing (improved utilization of trucks):

- The more underutilized trucks exist, the more value is added through applying loadspace shipment sharing (relevant: interviewees). The logic is that if there are more underutilized trucks (loadspace), the more available shipments can be allocated. Thereby, utilization increases.
- The less kilometers per tour driven, the more value is added through applying loadspace shipment sharing (very relevant: interviewees). The logic is that if there are less kilometers per tour driven, the more additional stops are possible on a tour. Thus, more available shipments can be allocated (increased utilization).
- The more shipment surpluses exist, the more value is added through applying loadspace shipment sharing (very relevant: interviewees). The logic is that if there are more shipment surpluses, the more shipments can be allocated to the available loadspaces (underutilized trucks). Thereby, utilization increases.
- The more logistic service providers exist in the fleet operator community, the more value is added through applying loadspace shipment sharing (relevant: interviewees). The logic is that if there are more logistic service providers within a fleet operator community, the more possibilities to match available shipments and loadspaces emerge. Through matching more underutilized truck, a higher utilization is achieved.
- The more trust between the logistic service providers in the fleet operator community exists, the more value is added through applying loadspace shipment sharing (very relevant: interviewees). The logic is that trust is an important element to foster the cooperation (also loadpsace shipment sharing), since the fleet operator community has not only to exchange shipments / loadspaces, but also sensitive data and pass on customer interaction moments to a coopetitor. Through a higher level of trust, more underutilized trucks are matched in the fleet operator community. Thus, a higher utilization is achieved.

The concept has different potentials in various transport relations. The concept of has a higher value added on main runs (4.5/5: interviewees) and lower in local transports (4.8/5: interviewees) (39, 40, 41, 42, 43, 44). Due to the differing competition pressure (lower in Switzerland) Swiss logistic service providers see a higher potential in local transports than German ones (39, 40).

Herewith, and with the primary concept elements, the third step (artefact) of Pfeffers et al.'s (34) design science research approach are set up and partially applied (fourth step).

6. ANALYSIS OF CONCEPT ELEMENTS

After the introduction into the prototype of loadspace shipment sharing concept, the concept elements are reviewed next.

6.1 Literature: Primary Concept Elements and Related Concept Element Clusters

After having extracted primary concept elements (non-cluster-allocable) in the short literature review (chapter 2) the paper aims to cluster these. Therefore, literature regarding comparable sharing practices in research fields are analyzed and searched for clusters. Table 2 provides information about literature clustering the concept elements.

Table 2 – Related research fields analyzed to gather clusters for concept elements / concept elements allocation

Research field related to loadspace shipment sharing	**Author**	**Business model as cluster of concept elements**	**Governance as cluster of concept elements**	**Digital platform as cluster of concept elements**
Mobility sharing	Beutel et al. (45)	√	-	√
Mobility sharing	Willing et al. (46)	√	-	√
Car sharing	Shaheen et al. (47)	√	√	√
Car sharing	Akyelken et al. (48)	√	√	√
Allocation of the concept elements to the clusters		• Mechanisms / coordination • Information sharing / transparency • Financial contribution • Incentives	• Legal framework • Relationship management	• Interfaces • Transparency services • Matching services

Source: own illustration considering sources in the table

Since this research emphases on the business model, the concept elements of governance and digital platform are not researched in the same detail.

Next, the clustered primary concept elements get enriched and validated through empirical data. The interview-analysis is discussed to get a holistic picture of the concept elements.

6.2 Interviews: Validating and Enhancing the Primary Concept Elements

This section highlights the interviews findings of concept elements of the loadspace shipment sharing. The evaluation after Mayring's (37) method led to six categories (concept elements of the business model depicted detailed [4] and governance / digital platform in general [2]) and is shown hereafter broken down into key components and phenomena.

Table 3 – Extract of the interview-analysis applying the method of Mayring (37)

Categories	**Key components**	**Phenomena's**
Financial contribution (very relevant: 4.6)	• Determination settlement basis • Fair allocation of workloads / benefits • Determination transfer prices	• Determination of the settlement basis • Fair allocation of the workloads • Fair allocation of the benefits • Determining transfer prices upon settlement basis, workloads and benefits *Selected remarks:* The fair contribution with respect to the fleet operator handing over the shipment and the shipment carrying fleet operator is especially important. A framework / rules how to contribute financials is important, but not as important as mechanisms that are central for running a loadspace shipment sharing concept.

Source: own illustration based on conducted interviews

The content of the above presented (Table 3) categories, key components are analyzed embedded in the road freight industry-context in the subsequent paragraphs.

According to the interviewees (39, 40, 41, 42, 43, 44), the **mechanisms / coordination** are very relevant (in average 4.8/5) to the concept and cover e.g. processes such as the placement of the shipment / loadspace surplus, allocation of the surplus (incl. prioritization according to restrictions), sharing necessary data to execute the shipment (clearing via general cargo cooperation / fleet operator community), feedback about the completion of the shipment execution and settlement of the financial contribution. Additionally, it has to be mentioned that the processes need to be digitalized / automatized to reduce workload (40). Thus, the logistic service providers can focus their resources on decision making and realize a high quality and swift service. The interviewees, however, differentiate **coordination** of the loadspaces / shipments (considered less relevant) and logistic service providers (considered more relevant). It, however, has to be highlighted that general cargo cooperations already share (and coordinate) shipments among logistic service providers (42). This shows sharing experience – vital for the concept – is pre-existent. De Lauso (40) states, that for running the concept it is highly important to take the right decisions on a loadspace / shipment- and logistic service provider / partner-level.

The interviewees assessed **information sharing / transparency** as relevant (in average 4.4/5) to the concept. They think, that the following information (selective understanding) is key to setup and re-adjust the concept on a regular basis (e.g. yearly) and thus need to be shared by the participants basis of resources and shipment that can be shared, main run plans that have to be considered and performances regarding shipments / resource (utilization) in different areas, relations and industries. It is essential to protect the shared information adequately (43). The interviewees, however, think that **transparency (operative understanding)** is required in two different dimensions: transparency over loadspaces and shipments to run the concept operatively. Transparency over shipments means sharing the sender, receiver, size, weight and other relevant shipment information like dangerous goods. Transparency over loadspaces means sharing the basic truck information such as truck-type and payload as well as telematics data such as location, utilization and driving / rest times. Two interviewees remark, that transparency is key to actively exploit the potential of the concept (44, 43). Furthermore, it has to be mentioned that for many logistic service providers and their dispatchers bringing together surpluses through a transparency requires a paradigm shift in their mindset (40).

According to the interviewees, the **contribution management** is very relevant (in average 4.6/5) to the concept and requires e.g. the determination of the settlement basis, fair allocation of the workloads / benefits and determination of transfer prices. The interviewees add, that the fair contribution with respect to the sharing logistic service providers is especially important. De Lauso (40) mentions, that a framework and rules how to contribute financials is important, but not as important as mechanisms that are key for running the concept.

Incentives are understood as relevant (in average 3.6/5) to the concept by the interviewees. They think, that the incentive alignment is achieved through the following aspects: trust, common interest / commitment, mutual support, shared customers and integrity / cooperative culture. Two interviewees (42, 40) add, that the strategic fit and mutuality are especially important. It is the general cargo cooperation- / fleet operator community-organizers' job is to attract new logistic service providers and align them through incentives (40).

According to the interviewees, the **governance** is relevant (in average 4.4/5) to the concept. It requires building blocks such as relationship management / contracts and focusses on the strategic fit, clear expectations, leadership skills and conflict management. The Interviewees consider the relationship management even more relevant than contracts. De Lauso (40) mentions, that the strategic fit and mutuality are especially important when setting up. Another interviewee (41) adds, that the mutuality needs to be given regarding the time horizon of the sharing strategy. Clear usage /

decision rules and the relationship management / dealing with possible issues is highly important when running according to De Lauso (40).

The interviewees assessed the **digital platform** as very important (in average 5/5) to the concept. They think, that the technical implementation requires the following components: data / system interfaces, data-visualization, message-based (e.g. push messages), market-based (e.g. actions to match) and collaborative planning-based systems. The digital platform has to be seamlessly integrated into the systems to achieve the active exploitation of the potentials (44). Additionally, it has to be mentioned that the digital platform keeps the participants adhering to the rules / processes and builds the interface to the general cargo cooperation- / fleet operator community-clearing and settlement of the financial contribution (40).

Herewith, the fourth (artefact application) and fifth step (artefact review) of Pfeffers et al.'s (34) design science research approach are achieved.

7. RESULTS: CONCEPTUAL FRAMEWORK

To provide the conceptual framework for loadspace shipment sharing, Table 4 aggregates the cornerstones of loadspace shipment sharing considering the theoretical primary concept elements (chapter 2) enriched by empirical data and its discussion (section 6.2) against the background of the types of cooperation (section 6.1). To round of conceptual framework of loadspace shipment sharing, concept-fostering trends and its challenges are given thereafter.

Table 4 – Clustered concept elements of the concept considering the theoretical and practical requirements

Concept element clusters	**Concept elements**	**Key components**
Business model	Mechanisms / coordination	• Placement of shipment / loadspace surplus and allocation due to restrictions • Sharing necessary data to execute the shipment • Completion feedback and settlement of the financial contribution • Coordination of the loadspaces and shipments • Coordination of the participating logistic service providers
	Information sharing / transparency	• Resources and shipment as a basis that can be shared • Main run (resp. line haul) plans that have to be considered • Performances regarding shipments / resource in different areas, relations, industries • Loadspaces: sharing truck-type, payload, location, utilization and driving / rest times • Shipments: sharing sender, receiver, size, weight and dangerous goods
	Contribution management	• Determination of the settlement basis • Fair allocation of the workloads / benefits • Determination of transfer prices upon the settlement basis, workloads and benefits
	Incentives	• Fostering trust, integrity and cooperative culture to service shared customers • Common interest / commitment and mutual support / interdependence
Governance	Legal framework	• Community entry (audit and contract) • Usage rules
	Relationship management	• Strategic fit and clear expectations • Leadership skills and conflict management
Digital platform	Interfaces	• Data- / system-interfaces
	Transparency services	• Visualizing shipment / resource data • Message-based (e.g. push messages) systems
	Matching services	• Market-based (e.g. actions to match) systems • Collaborative planning-based systems

Source: own illustration based on this paper

The concept elements are reviewed / revised and ultimately supported by general cargo cooperation-practitioners (49, 50). The in a second round interviewed managing directors represent general cargo cooperations that lead the market in terms of business innovations to foster utilization (i.e. loadspace shipment sharing). Both are developing individual concepts of loadspace shipment

sharing. Both general cargo cooperations have tested or partially implemented loadspace shipment sharing.

Herewith, the fifth step (artefact review) of Pfeffers et al.'s (34) design science research approach is achieved.

Trends underpin the demand for research and development of the concept. Based on the interviews, the subsequent trends are considered as relevant: the markets' competition and margin pressure; the market actors' increasing efficiency; increasing digitalization, automatization, transparency and platforms. The interviewees rate the trend in average as increasing.

Even though the trends are set positive for the concept, it also faces challenges. First, the mindset requires a paradigm shift at the logistic service providers (i.e. owner, CEO, head of freight forwarding, dispatcher and driver) allowing the proximation of assumptions (e.g. potential-analyses and crafted procedures / mock-ups) and reality. Second, data security has to be assured. The data has to be processed in a secure "black-box" and only necessary data shown in the front-end. The general cargo cooperation- / fleet operator community-organization would have to give their written commitment to assure data security (e.g. not leaking). Third, the transfer of the conceptual developments into practice is required to achieve improved utilization. Therefore, visualizations act as a mediator to build the loadspace shipment sharing-application – from assumptions / analyses to real applications. Fourth, the achievements such as improved utilization have to be reached continuously to stabilize the benefits of the loadspace shipment concept for the participants. (40)

8. CONCLUSION, LIMITATIONS AND OUTLOOK

The concept of loadspace shipment sharing itself is barely known in practice and literature (compare chapter 1 and 2) but intersects with some existing concepts (e.g. general cargo cooperation and warehouse sharing) and research streams (e.g. horizontal logistics cooperation and digital platform) that serve as starting points for the concept. Thus, the concept of loadspace shipment sharing could be understood as a(n incremental) business innovation of the general cargo cooperation's business model that focusses on order sharing (sharing shipments). Implementing the combination of sharing shipments and loadspaces requires changes to the common business model of the general cargo cooperation (i.e. business model innovation) that considers the coordination of loadspace shipment sharing, governance and adjusted digital platform. Combining the sharing of shipments and loadspaces is expected to lead to a higher utilization and thus efficiency of the fleet operator community.

The paper applies an abductive logic using an explorative and qualitative research approach. The methodology that includes design science research and design thinking approaches combined with semi-structured interviews for systematic data gathering.

The prototyping of the concept of loadspace shipment sharing led to three different cooperation types (nearby service areas, general cargo cooperation- / branch-transports and general cargo cooperation / independent logistic service providers). Additionally, a continuum towards value added generated through the concept is identified. The concept generates the more value (i.e. improved utilization), 1) the more underutilized trucks exist, 2) the less kilometers driven per truck tour, 3) the more shipment surpluses exist, 4) the more logistic service providers exist in the fleet operator community and 5) the more trust between the logistic service providers exists. The prototype, however, also identified restrictions such as spacial distance, suitable relation, timely proximity, shipment size / type, loading / unloading restrictions and driving / rest times that have to be considered.

The analysis of concept elements resulted in a set of concept elements and key components that frame the concept elements tasks. The concept element clusters business model, governance and digital platform host the concept elements. First, the business model hosting mechanisms, information

sharing, operative coordination, financial contribution management and transparency. Second, the governance hosting incentives, legal framework and relationship management. Third, the digital platform hosting interfaces, transparency services and matching services. The paper discusses the encompassing tasks / functionalities of each concept element.

The concept of loadspace shipment sharing is embedded in the road freight transport, that faces trends like competition pressure that foster its research. The research has to tackle challenges such as the fleet operators' mindset that requires a paradigm shift, data security to receive and process data.

Subsequent, the limitations of this paper are outlined. The design science research approach applied conceptual-to-empirical as well as empirical-to-conceptual cycles but could re-run these to refine and broaden the results. The interviews conducted cover relevant stakeholder groups but reflect a rather small number of data points. The explanatory power could be enhanced through adding interviews and thus enlarging the sample size. Since the paper only focusses on the German-speaking markets, the research results are limited to that area. The research of further areas could lead to different results in the setup, development and implementation of the concept.

Concluding, the author mentions that the further development of the concept towards implementation is a dedicated goal. This process shall be accompanied by further publications.

REFERENCES

[1] Bundesamt für Raumentwicklung (ARE). *Staukosten Schweiz 2015*. Available from: www.are.admin.ch [Accessed 31st January 2020].

[2] Mikulski J, Kwaśny A. Role of Telematics in Reducing the Negative Environmental Impact of Transport. *Proceedings of the 10th International Conference on Transport Systems Telematics*. 20-23 October 2010, Katowice, Poland. Berlin/Heidelberg, Germany: Springer; 2011. p. 11-29.

[3] Bundesamt für Statistik (BFS). *Güterverkehr in der Schweiz 2015.* Available from: www.bfs.admin.ch [Accessed 31st January 2020].

[4] Gruchmann T, Seuring S. Explaining logistics social responsibility from a dynamic capabilities perspective. *The International Journal of Logistics Management*. 2018;29(4): 1255-1278.

[5] Baier J. *Trends im Straßengüterverkehr-Aktueller Status und Meinungen der Berufskraftfahrer in Deutschland*. Furtwangen, Hochschule Furtwangen University; 2012.

[6] Meyer-Rühle O. Statistical coverage and economic analysis of the logistics sector in the EU 2008. Available from: https://ec.europa.eu/ [Accessed 10th July 2020].

[7] Waters D, Rinsler S. Global Logistics: New Directions in Supply Chain Management. London: Kogan Page Publishers; 2014.

[8] Gudehuus T, Kotzab H. Comprehensive Logistics. Berlin: Springer Science & Business Media; 2010.

[9] Kapplmüller H, Graf HC, Hoertenhuber HT, Widmann R, Stadlmann T. SmartBox – an Austrian PI solution leading to small loads mobility 4.0. *Proceedings of the 3rd International Physical Internet Conference*; 2016; Atlanta, USA.

[10] Katz JP. Strategies of supply communities. *Supply Chain Management: An International Journal*. 2003;8(4): 291-302. Available from: https://doi.org/10.1108/13598540310490053 [Accessed 31st January 2020].

[11] Log-Hub. *Supply Chain Apps & Supply Chain Analysis.* Available from: https://www.log-hub.com [Accessed 30th March 2020].

[12] Stadtmobil. *Stadtmobil.* Available from: https://www.stadtmobil.de [Accessed 31st January 2020].

[13] Botsman R. (2015). *Defining the Sharing Economy.* Available from: https://www.fastcompany.com/3046119/defining-the-sharing-economy-what-iscollaborative-consumption-and-what-isnt Accessed 31st January 2020].

[14] Zervas G, Proserpio D, Byers JW. The rise of the sharing economy: Estimating the impact of airbnb on the hotel industry. *Journal of Marketing Research.* 2016;54(5): 687–705. Available from: https://doi.org/10.1509/jmr.15.0204 [Accessed 31st January 2020].

[15] Bloos M, Kopfer H. On the Formation of Operational Transport Collaboration Systems. *Proceedings of the 4th International Conference on Dynamics in Logistics*; 2011; Berlin, Heidelberg.
[16] Timocom. *TIMOCOM.* Available from: https://www.timocom.de [Accessed 30th March 2020].
[17] Uber Freight. *Hassle-Free Load Boards and Freight Shipping*. Available from: https://www.uberfreight.com [Accessed 30th March 2020].
[18] Pickwings. *Transportportal | Innovative Transportlösungen.* Available from: https://pickwings.ch [Accessed 30th March 2020].
[19] Instafreight. *Digitale Spedition für B2B | Transporte online.* Available from: https://www.instafreight.de [Accessed 30th March 2020].
[20] Erceg A, Sekuloska, JD. E-logistics and e-SCM: how to increase competitiveness. *Logforum*. 2019;15(1): 155-169. Available from: https://doi.org/10.17270/j.Log.2019.323 [Accessed 31st January 2020].
[21] Einstein R. Robert Einstein: *Opportunities of Loadspace Shipment Sharing.* Switzerland; 2020.
[22] Cruijssen FCAM. *Horizontal cooperation in transport and logistics*. Tilburg University, School of Economics and Management; 2006.
[23] Verstrepen S, Cools M, Cruijssen FCAM, Dullaert W. A dynamic framework for managing horizontal cooperation in logistics. *International Journal of Logistics Systems and Management.* 2009;5(3-4): 228-248. Available from: https://doi.org/10.1504/IJLSM.2009.022497 Accessed 31st January 2020].
[24] Audy JF, Lehoux N, D'Amours S, Rönnqvist M. A framework for an efficient implementation of logistics collaborations. *International transactions in operational research*. 2012;19(5): 633-657.
[25] Cruijssen FCAM, Dullaert W, Fleuren H. Horizontal Cooperation in Transport and Logistics: A Literature Review. *Transportation Journal*. 2007;46(3): 22-39.
[26] Adamczak M, Domański R, Cyplik P. Sharing logistics resources as a way to physical internet - results of survey studies. *Proceedings of the 24th International Conference on Production Research*; 2017; Poznań, Poland.
[27] Standing C, Standing S, Biermann S. The implications of the sharing economy for transport. *Transport Reviews.* 2019;39(2): 226-242.
[28] Spekman RE, Davis EW. *The Extended Enterprise: Gaining Competitive Advantage Through Collaborative Supply Chains.* Upper Saddle River; NY: Financial Times/Prentice Hall; 2003.
[29] Daudi, M. *Trust in Sharing Resources in Logistics Collaboration.* PhD thesis. Bremen: University of Bremen; 2018.
[30] Islam S, Olsen T. Truck-sharing challenges for hinterland trucking companies. *Business Process Management Journal.* 2014;20(2): 290-334. Available from: http://doi.org/10.1108/BPMJ-03-2013-0042 [Accessed 31st January 2020].
[31] Vega-Mejía CA, Montoya-Torres JR, Islam SMN. Consideration of triple bottom line objectives for sustainability in the optimization of vehicle routing and loading operations: a systematic literature review. *Annals of Operations Research*, 2019;273(1/2): 311-375.
[32] Das C, Jharkharia S. Low carbon supply chain: a state-of-the-art literature review. *Journal of Manufacturing Technology Management*, 2018;29(2): 398-428. Available from: https://doi.org/10.1108/JMTM-09-2017-0188 [Accessed 31st January 2020].
[33] Hofman, W. J. (2016). Data sharing requirements of supply and logistics innovations – Towards a maturity model. *Proceedings of the 6th International Conference on Information Systems, Logistics and Supply Chain, 1-4 June 2016, Bordeaux, France.*
[34] Peffers K, Tuunanen T, Gengler CE, Rossi M, Hui W, Virtanen V, Bragge J. The Design Science Research Process: A Model for Producing and Presenting Information Systems Research. *Proceedings of 1st International Conference on Design Science Research in Information Systems and Technology, 24-25 February 2006, Claremont, California*.
[35] Tran N. *Design Thinking Playbook.* Stanford University, Design School Stanford.
[36] Adams WC. *Conducting Semi-Structured Interviews*. In: Wholey JS, Harty HP, Newcomer KE, editors. *Handbook of Practical Program Evaluation*. Jossey-Bass, SF; 2015. p. 492-505. Available from: https://doi.org/10.1002/9781119171386.ch19 [Accessed 31st January 2020].

[37] Mayring P. *Qualitative Inhaltsanalyse*. In: Mey G, Mruck K, editors. *Handbuch Qualitative Forschung in der Psychologie*. Wiesbaden, Germany: Springer VS; 2010.
[38] Verdonck L, Caris AN, Ramaekers K, Janssens, GK. Collaborative Logistics from the Perspective of Road Transportation Companies. *Transport Reviews.* 2013;33(6): 700-719. Available from: https://doi.org/10.1080/01441647.2013.853706 [Accessed 31st January 2020].
[39] Einstein R. Robert Einstein: *Conceptual Framework for Loadspace Shipment Sharing.* Switzerland; 2020.
[40] De Lauso F. Francesco De Lauso: *Conceptual Framework for Loadspace Shipment Sharing.* Germany; 2020.
[41] Anonymous. Anonymous: *Conceptual Framework for Loadspace Shipment Sharing.* Germany; 2020.
[42] Anonymous. Anonymous: *Conceptual Framework for Loadspace Shipment Sharing.* Switzerland; 2020.
[43] Anonymous. Anonymous: *Conceptual Framework for Loadspace Shipment Sharing.* Germany; 2020.
[44] Anonymous. Anonymous: *Conceptual Framework for Loadspace Shipment Sharing.* Germany; 2020.
[45] Beutel MC, Goekay S, Kluth W, Krempels KH, Terwelp C, Samsel C. Product Oriented Integration of Heterogeneous Mobility Services. *Proceedings of the 17th International Conference on Intelligent Transportation Systems.* 8-11 October 2014, Qingdao, China. Piscataway, NJ; 2014. p. 1529-1534.
[46] Willing C, Brandt T & Neumann D. Electronic mobility market platforms – a review of the current state and applications of business analytics. *Electronic Markets;* 2017;27: 267-282. Available from: https://doi.org/10.1007/s12525-017-0257-2 [Accessed 31st January 2020].
[47] Shaheen S, Mallery M, Kingsley K. Personal Vehicle Sharing Services in North America. *Research in Transportation Business & Management.* 2012;3: 71-81. Available from: https://doi.org/10.1016/j.rtbm.2012.04.005 [Accessed 31st January 2020].
[48] Akyelken N, Givoni M, Salo M, Plepys A, Judl J, Anderton K, Koskela S. The importance of institutions and policy settings for car sharing – Evidence from the UK, Israel, Sweden and Finland. *European Journal of Transport and Infrastructure Research*. 2018;18(4): 340-359.
[49] Einstein R. Robert Einstein: *Concept Elements of Loadspace Shipment Sharing.* Switzerland; 2020.
[50] De Lauso F. Francesco De Lauso: *Concept Elements of Loadspace Shipment Sharing.* Germany; 2020.